

**The Fourth China-Europe Symposium on  
Processing and Properties of Reinforced Polymers**

**ABSTRACTS**



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## Thermal Stability and Flame Retardancy of Polymer Nanocomposites

A. DASARI<sup>1</sup>, Z.-Z. YU<sup>2</sup>, G. CAI<sup>1</sup> AND Y.-W. MAI<sup>1\*</sup>

<sup>1</sup> *Center for Advanced Materials Technology (CAMT), School of Aerospace, Mechanical & Mechatronic Engineering, The University of Sydney, Sydney, NSW 2006, Australia*

<sup>2</sup> *Beijing Key Laboratory on Preparation and Processing of Novel Polymeric Materials, Department of Polymer Engineering, College of Materials Science and Engineering, Beijing University of Chemical Technology, Beijing 100029, China*

E-mail: [y.mai@usyd.edu.au](mailto:y.mai@usyd.edu.au)

Polymer/clay nanocomposites despite their considerable flame retardancy performance (delayed burning, reduced heat release/mass loss rates) are unable to satisfy the requirements of existing fire safety standards. Our efforts to understand the reasons underlying this problem will be highlighted. These include preparation and characterization of thermal and flammability properties of highly-filled polymer/organoclay nanocomposites in order to identify a critical composition that is needed to form a stable char with no apertures and to gain a thorough understanding of the mechanisms of flame retardancy [1]. Based on these results, it was derived that (a) there is no need for higher percentages of clay to reduce heat release/mass loss rates; (b) thermal stability of the nanocomposites is an important factor and must be properly tackled; (c) coupling of silicate layers upon fire should be improved; (d) a second layer of defense with another additive apart from the silicate layers can be advantageous; and (e) migration of clay layers to the burning surface upon fire should be improved. Finally, our approaches which were adopted to develop eco-friendly and superior flame retardant polymer nanocomposites will be discussed [2]. These include (a) using a thermally stable compound to modify clay nanolayers and a water-assisted processing method to eliminate completely the usage of traditional organic surfactants so as to improve the thermal stability of the resultant nanocomposites; (b) incorporating polyhedral oligomeric silsesquioxane (POSS) as an additional filler in polymer/ clay nanocomposite to enhance the coupling of silicate layers to each other upon fire and thus improve the homogeneity of the char; (c) using an intumescent agent, graphite oxide (GO), which can serve a ‘dual’ purpose because of its layered structure (‘physical’ barrier mechanism) and intumescent/blowing effect (‘chemical’ mechanism); (d) using carbon nanotubes to form a network-like structure upon burning; and (e) adding melamine in polymer/clay or polymer/ CNT or hybrid systems.

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## **Influence of Strain Path on Deformation-Induced Cavitation in Reinforced Polymers**

CHRISTIAN G'SELL

*Institut Jean Lamour, Ecole des Mines Parc de Saurupt, 54042 NANCY-cedex (France)*

E-mail: [Christian.GSell@mines.inpl-nancy.fr](mailto:Christian.GSell@mines.inpl-nancy.fr)

It has been unexpectedly shown in recent years [1] that cavitation constitutes a major mechanism in the plastic deformation of most polymers. As such, formation of crazes and voids compete with shear banding for the control of the overall strain rate. Although these mechanisms had been qualitatively observed previously, it is only after the author developed a video-controlled system for measuring volume strain during tensile testing of polymer samples that in-situ quantitative characterization of deformation damage became routinely accessible [2]. Since this system was developed, many researchers have applied it to a variety of neat amorphous and semi-crystalline polymer grades. More specifically, intensive investigation was devoted to polypropylene and polyethylene reinforced with soft or hard particles within a France-China cooperation program [3, 4]. For example, for polyethylene reinforced with 40 wt% CaCO<sub>3</sub> particles, we showed [4] that a volume strain, Log (V/V<sub>0</sub>), as high as 0.5 was attained in tension for a true axial strain, Log (L/L<sub>0</sub>) of 1.0.

Microscopic observation of polymeric samples stretched to prescribed strains revealed how and where cavitation is initiated. Unlike in glassy polymers where crazes appear at random, voids in non-homogeneous polymers are more favourably nucleated at zones of higher hydrostatic stress: in the inter-lamellar amorphous phase at the equator of spherulites in semi-crystalline polymers, at the poles of hard particles in reinforced polymers and within the rubberlike phase in toughened polymers [5]. A simple mean-field modeling was elaborated to determine the relative contribution of isochoric and cavitation mechanisms in a given polymer under uniaxial tension.

Now it is important to examine the same phenomena in more complex situations corresponding to structural parts undergoing localized plastic deformation. Particularly, the problematic of energy dissipation through shear banding and cavitation is critical in the case structural parts of automobiles subjected to crash tests. In that scope, our research protocol is to compare the kinetics of volume strain under well defined strain paths leading to contrasting states of triaxial stresses. Based on our past experience, we selected the specific cases of uniaxial tension and simple shear. In both cases, the local strain rate was carefully controlled via optimized versions of the VidéoTraction system. While in tension the volume strain could be directly measured during the test, it was necessary in shear to analyze the amplitude of cavitation post-mortem. In this work, we show that unlike neat polymers in which cavitation is very low under simple shear, significant dilatation is recorded when the microstructure includes heterogeneous particles dispersed in the polymer matrix. On the basis of experimental results, the behavior of reinforced polymers under general loading is discussed.

## Plenary Lectures

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## **The Effect of Reprocessing on the Morphology and the Properties of Polypropylene/Wood Flour Composites Compatibilized with Ethylene-Butyl Acrylate-Glycidyl Methacrylate (EBAGMA) Terpolymer**

M. KACI<sup>1\*</sup>, A. HAMMA<sup>1</sup>, I. PILLIN<sup>2</sup> AND Y. GROHENS<sup>2</sup>

<sup>1</sup> *Organic Materials Laboratory, University Abderrahmane Mira, Bejaia 06000, Algeria.*

<sup>2</sup> *Laboratoire Polymères, Propriétés aux Interfaces et Composites, Université de Bretagne Sud, Rue de Saint Maudé, 56321 Lorient Cedex, France.*

E-mail: [kacimu@yahoo.fr](mailto:kacimu@yahoo.fr)

Composites made from blend of thermoplastics and wood fillers have attracted a number of researchers and manufacturers due to the many advantages that they present [1]. Indeed, the addition of wood flour as renewable natural filler in polymer composites aims to produce an unique combination of high performance, great versatility, light weight, recyclability, biodegradability and processing advantages at favourable cost [2]. Among polymer composites, special attention has been given to polypropylene (PP) composites, due to their added advantage of recyclability [2]. Most of the polymer composites are generally subjected to a degradation of the mechanical and physical properties under the increase of temperature. It is important to understand the effects of the processing temperature, because there is constant thermal stress during the manufacturing of filler reinforced composites [2].

This article reports the effects of repetitive extrusion cycles on the morphology and the rheological and mechanical properties of PP/wood flour (20 wt-%) composites in presence of EBAGMA terpolymer used as compatibilizer.

The morphological analysis by SEM indicated that the interfacial adhesion between PP and wood flour was improved after six extrusion cycles, being much improved with the compatibilizer. However, the mechanical properties of the polymer composites, especially the Young's modulus and the stress at break were found to be less affected by reprocessing cycles when compared with PP that was strongly degraded after the first cycle. Moreover, the complex viscosity of the neat polymer decreased very rapidly compared with the composite materials.

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## Composite Recycling Based on Multilayer Cartons

COSIMO CARFAGNA, MAURIZIO AVELLA, ROBERTO AVOLIO, IRENE BONADIES, MARIA EMANUELA ERRICO\*, GENNARO GENTILE

*Istituto di Chimica e Tecnologia dei Polimeri – Consiglio Nazionale delle Ricerche*

*Via Campi Flegrei 34 – 80078 Pozzuoli (NA), Italy*

E-mail: [carfagna@unina.it](mailto:carfagna@unina.it)

Nowadays besides neat plastic resins, the use of multilayer containers is growing for food and beverage packaging.

Within this class of packaging materials, multilayer cartons (MC), mainly constituted by cellulose and low density polyethylene, are among the most used. Actually, MC recycling essentially involves the separation of paperboard from other layers, however this strategy results complicated and not convenient due to high costs. As a matter of fact, the set up of recycling strategies both of multilayer pre and post-consumer scraps is a very promising challenge also from the industrial point of view.

In this communication, mechanical recycling of multilayer carton scraps (MC), consisting in the use of MC without the physical separation of its different fractions is proposed. In particular, pre-consumer MC industrial residues constituted by cellulose (80 wt%) and LDPE (20 wt%), have been used as a source of cellulose fibers in the obtainment of HDPE based composites. In order to improve HDPE/MC interfacial adhesion and to enhance composite final properties, different amount of a proper reactive coupling agent, linear low density polyethylene characterized by maleic anhydride groups grafted on the backbone (MAPE), was added during the melt mixing. Then, composites containing up to 60 wt% of MC were prepared by reactive blending and structure/properties relationships investigated as a function of the compatibilizing agent and composition.

The compatibilization induces strong polymer/MC interactions responsible for a significant improvement of mechanical properties of composites in terms of Young's Modulus, stress at break and toughness, as well as an outstanding response of materials to water vapour permeability.

An effective and sustainable recycling of multilayer cartons has been set up, allowing to produce HDPE composites that can find applicability in different industrial sectors, ranging from automotive to packaging.

## **PVC-based Polymer Nanocomposites: Processing, Fracture and Cyclic Fatigue**

M. HOFFMAN<sup>1</sup>, I. KEMAL<sup>1</sup>, N. SAMAT<sup>1</sup>, R. BURFORD<sup>2</sup> AND A. WHITTLE<sup>3</sup>

*<sup>1</sup>School of Materials Science and Engineering and <sup>2</sup>Chemical Science and Engineering;*

*<sup>2</sup>The University of New South Wales, NSW 2052, Australia*

*<sup>3</sup>Iplex Pipelines Pty Ltd, Chipping Norton, NSW 2170, Australia*

E-mail: [Mark.Hoffman@unsw.edu.au](mailto:Mark.Hoffman@unsw.edu.au)

PVC-based polymer nanocomposites were formed by added calcium carbonate, a common PVC filler (average particle size was 60 nm), in nanoparticulate form to PVC K57 resins with Ca-Zn based thermal stabilizers and lubricants. 3, 6, 9, 12 and 20 parts per hundred of resin (phr) by weight of nanoparticle CaCO<sub>3</sub> in a dry blend. A further series was processed by adding 0.6 phr titanate coupling agent to improve particle/matrix adhesion. A monolithic sample containing no nanoparticles was also manufactured along with a reference m-PVC, which contained 6 phr of CPE rubbery particles. Dry powder blends were processed on a two roll-mill operating then granulated into flakes using a bench-top mechanical granulator. The flakes were then molded into rectangular sheets by compression molding.

Transmission electron micrographs of the samples revealed the microstructure of the samples. It was found that good particle dispersion occurred at low concentrations (<9 phr) and improved with the addition of the titanate compound with concentrations up to 20 phr showing good dispersion.

Elastic modulus increased with nanoparticulate content and followed a Kerner prediction. Strength was found to decrease with increasing nanoparticulate content and be slightly higher in samples that contained titanate. Impact energy and toughness were found, however, to increase with nanoparticulate content, with the samples containing titanate showing slightly lower values. In all cases, stiffness and strength were higher than m-PVC and toughness was lower, with the exception of the 20 phr samples. Scanning electron micrographs of the fracture surfaces revealed extensive cavitation around the nanoparticulate particles which was not present when titanates were added to the mixture during processing. Cyclic fatigue crack growth measurements revealed that fatigue behaviour was unaffected by the addition of or fraction of nanoparticulate phase. Furthermore, the addition of titanates had no influence on fatigue behaviour. Slight improvements were observed compared with m-PVC.

The addition of nanoparticulate filler appears to enhance cavitation associated with plastic deformation. This leads to an increase in toughness, especially when there is weak bonding between the nanoparticles and the filler. An improvement adhesion resulting from the addition of the titanates, improves particulate dispersion but leads to a deterioration in toughness as cavitation is reduced. Modelling reveals that this is associated with the hysteretic energy absorption processes associated with cavitation.

## Invited Lectures

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The reduced bonding between the particles and matrix, however, leads to a reduction in strength which may also be attributed to increased agglomeration in these samples. It appears that the nanoparticulate phase has no extraordinary affect upon stiffness beyond that expected from rule of mixtures influences.

## **Micro-fibrillar Blends from Recycled Plastics as Matrix for Natural Fiber Plastic Composites**

Q. WU<sup>1</sup>, Y. LEI<sup>1</sup> AND G. HAN<sup>2</sup>

<sup>1</sup>*School of Renewable Natural Resources, Louisiana State University Agricultural Center, Baton Rouge, LA 70803, USA*

<sup>2</sup>*Material Science and Engineering College, Northeast Forestry University, Harbin 150040, P. R. China*

E-mail: [wuqing@lsu.edu](mailto:wuqing@lsu.edu)

Microfibrillar blends (MFBs) with reinforcing fibrils built of bundles of flexible, organic macro-molecules are a new class of fiber reinforced composites. The manufacture of MFBs provides a promising route to enhance properties of general thermoplastics (e.g., LDPE, HDPE, and PP) using engineering thermoplastics (e.g., PET, polyamide, polycarbonates, and polybutylene terephthalate). Development of MFBs provides potential ways to make high performance wood/natural fiber reinforced composites using engineering and general plastic co-blends. To avoid thermal degradation of natural fibers, the fibers can be compounded with pre-prepared microfibrillar blends under a processing temperature usually for general plastics. Wood/natural fiber plastic composites offer enhanced bending strength, stiffness, reduced thermal expansion, and lowered cost. However, its structural properties such as creep are still lower than those of solid wood. Thus, improvement of the matrix and development of new coupling techniques between wood and plastics are needed to enhance its structural performance. The objective of the study presented in this work was to investigate the influence of compatibilization treatment and addition of wood flour to the blend on morphological, mechanical, and thermal stability properties of the HDPE/PET microfibrillar blend-based composites.

In this study, microfibrillar blends from recycled high density polyethylene (R-HDPE) and poly(ethylene terephthalate) (R-PET) were made through reactive extrusion and stretching. The optimized MFBs were then used as matrix material to produce wood fiber plastic composites through a second extrusion step at the temperature for processing HDPE. The compatibility between R-PET microfibers and R-HDPE matrix was improved through compatibilization treatment. Ethylene glycidyl methacrylate copolymer (E-GMA) provided the best treatment effect. The addition of compatibilizers did not obviously change the average diameter of R-PET fibers in MFBs. The toughness of MFB was significantly enhanced, and R-PET phase did not crystallize when 5% E-GMA was used. Addition of 25% PET microfibers obviously increased the mechanical properties of the blend. Among them, tensile modulus was increased by about 134%. The subsequent addition of 40% wood flour did not influence the size and morphology of PET microfibers, and improved the comprehensive mechanical properties of MFBs. The wood flour increased the crystallinity level of HDPE in the compatibilized MFB. The storage modulus of MFB was greatly improved by wood flour.

## Invited Lectures

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## A Novel Epoxy Resin with Thermal Remendability

Q. TIAN<sup>1</sup>, M. Z. RONG<sup>1\*</sup> AND M. Q. ZHANG<sup>2</sup>

<sup>1</sup>*Key Laboratory for Polymeric Composite and Functional Materials of Ministry of Education, OFCM Institute, School of Chemistry and Chemical Engineering,*

*Zhongshan University, Guangzhou 510275, P. R. China*

<sup>2</sup>*Materials Science Institute, Zhongshan University, Guangzhou 510275, P. R. China*

E-mail: [cesrmz@mail.sysu.edu.cn](mailto:cesrmz@mail.sysu.edu.cn)

It is believed that the recently emerging self-healing technique would guide polymers to a new era of intelligent materials and would help to reduce consumption of petroleum products as well [1,2]. Because of its excellent properties, epoxy has found wide applications in industries as surface coatings, structural adhesives, printed circuit boards, insulation materials for electronic devices, and advanced composites matrices. Nevertheless, curing reactions of epoxy with its hardeners are generally irreversible, so that cured epoxy can hardly exhibit crack remendability as a result of lack of the ability of recombination of broken molecules. In this context, it would be a reasonable starting point to develop a novel epoxy material that can heal itself during heating and cooling cycles while maintaining its integrity.

To endow epoxy resin with remendability, we synthesized a novel epoxy resin, N, N-diglycidyl-furfurylamine (DGFA), to combine epoxide with furan groups in one molecule. The epoxide groups can react with traditional curing agent like anhydride to form an epoxy network, providing the material with outstanding mechanical properties and thermal resistance as usual. Meanwhile, the furan groups can react with maleimide to introduce thermally reversible Diels-Alder (DA) bonds into the epoxy network. Eventually, the molecular networks in the cured material are comprised of two types of intermonomer linkage. Advantages of epoxy and intrinsic reworkable ability join together.

This paper discussed synthesis and characterization of DGFA and the related substances. Thermal reversibility and remendability of the resultant were also examined for having a deeper understanding of the structure-property relationship. The synthesized epoxy resin was characterized by low viscosity, high activity and good processability. The epoxy material based on DGFA resin proved to be able to offer satisfactory repair effectiveness (~74%) in addition to the similar mechanical properties and thermal stability as conventional epoxy.

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## Study of Multicomponent Compounding of Polyamide-6

A. MIMAROGLU<sup>1\*</sup>, H. UNAL<sup>2</sup>, I. KAYA<sup>1</sup>, K. I. YILMAZCOBAN<sup>1</sup> AND A. OZEL<sup>1</sup>

<sup>1</sup>*University of Sakarya, Faculty of Engineering, Esentepe Kampusu, Adapazari, Turkey*

E-mail: mimarog@sakarya.edu.tr

<sup>2</sup>*University of Sakarya, Faculty of Technical Education,, Esentepe Kampusu, Adapazari, Turkey. Fax : 90-264-3460262.*

E-mail: unal@sakarya.edu.tr

Polyamides are most important group of engineering thermoplastics due to their balanced combination of properties. Polyamides achieve high level of properties through a symbiosis with reinforcing agents-particularly glass fibres[1-3]. In the present work, two mineral fillers were selected on the basis of their shape and size. These fillers are spherical glass beads and fibrous glass fibre fillers. They were added to polyamide-6 to produce composite materials with improved mechanical properties at lower production cost. Composites of polyamide-6 reinforced with fibres were prepared by using a twin screw extruder. Heating zones were set to between 250°C to 280°C. The screw length-diameter ratio was (L/D) 40 and screw rotation rate of 270 rpm were used. The compounded extrudates were immediately quenched in water and cooled in air to ambient temperature. Then the extruded strands were chopped into granules and dried. The tensile, toughness and flexural properties of the injection moulded composites were investigated. Tensile measurements showed that the tensile strength and modulus of the composites increased with increasing filler content. The impact strength and elongation at break decreases with the increase in filler ratio. Finally the best improvement in mechanical properties is attained by the simultaneous use of two fillers.

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## **An Experimental Investigation of Free Vibrations of Curved Sandwich Composite Beams with Face/Core Debond**

BUKET OKUTAN BABA<sup>1\*</sup>, SRINIVASA THOPPUL<sup>2</sup>

<sup>1</sup> *Canakkale Vocational College, Canakkale Onsekiz Mart University, Terzioglu Campus, Canakkale 17100, Turkey*

<sup>2</sup> *Engineering Group, AAR Cargo Systems, 12633 Inkster Rd., Livonia, MI, 48150, US*  
E-mail: [deshikan@gmail.com](mailto:deshikan@gmail.com)

The aim of this research is to investigate the curvature and face/core debond influence on the vibration behavior of composite sandwich beams constituted by carbon/epoxy laminate skins over a polyurethane foam core. To be able to perform such investigation, flat and curved sandwich beams with and without debond were prepared by keeping the arc length of the sandwich beams equal to the length of the flat sandwich beams. Debond with constant length was placed at the middle of the beam length. Debonds were defined by inserting thin non-stick films at the top and bottom face/core interface of the beam prior to processing.

By performing four-point bending tests, flexural stiffness and strength were found. The natural frequencies and damping loss factors of the sandwich beams having free-free boundary conditions were also found using impulse frequency response method with a Fast Fourier Transform (FFT) spectrum analyzer. The effects of the curvature and face/core debond on stiffness and natural frequencies of sandwich beam were discussed.

The analysis of the experimental results of the four point bending tests permit to make the following conclusions: The sandwich composite stiffness decreases with increasing the curvature angle for sandwich beams with debond and presence of debond for all sandwich configurations. The load to failure decreases with increasing curvature angle and presence of debond. The maximum loads are smaller for the beams with upper debond than for the beams with lower debond.

Vibration test results indicate that face/core debond causes reduction of the natural frequencies. This is consistent with four point bending tests where stiffness decreases with debond. The damping loss factor values increase with the presence of debond. Also, it is found that the natural frequencies and stiffness are less affected by the presence of curvature and debond, whereas, the damping loss factors are significantly affected.

## WLEDs Based on the Composite of Host Polymer with Star-shaped Compounds as Red Emitter Fabricated by a Solution-Process

FENGLIAN BAI

*Institute of Chemistry, Chinese Academy of Sciences, Beijing 100190, China*

E-mail: [baifl@iccas.ac.cn](mailto:baifl@iccas.ac.cn)

Organic light-emitting diodes (OLEDs) have attracted considerable interest because of their potential applications in flat-panel displays and in solid-state lighting in recent years.

Here we report three red-emission and solution-processible organic molecules, in which Benzothiadiazole (BT) and triphenylamine (TPA) were chosen as the two basic moieties in these compounds. TPA with propeller shape and hole-transporting mobility was used as the core part. BT with high electron mobility was used to construct to the multi-branched of molecules. Vinylene bond was employed as a linkage to connect TPA and BT for constructing the conjugated push-pull branch unit. The compounds of **TPA-BT**, **b-TPA-BT** (bi-branched molecule) and **t-TPA-BT** (tri-branched molecule) were synthesized and characterized. The three molecules exhibited good solubility and high thermal properties, which make them possible to be used in fabricating OLED devices by spin coating

Based on the red emission characteristics of the TPA-BT containing compounds, white light-emitting diodes (WLEDs) were fabricated by doping the three compounds as the red emitter and PFT as green-emitter into blue PFO host material. That is the composite of synthesized compound with PFT and PFO as the active layer in WLEDs. The structure of the WLEDs is ITO/PEDOT:PSS /HTL /EML /Ca/Al. The HTL is composed of the blend of PVK and poly-TPD, and the EML is the film of blue PFO host doped with green emitter PFT and red emitter **TPA-BT**, **b-TPA-BT** or **t-TPA-BT**. The EL spectra of the three devices were shown that the emission bands of the three devices cover the whole visible range from 380 nm to 780 nm. The CIE coordinates from the devices at different voltages were investigated and the white light emission is stable and fairly close to the standard white light (CIE value of 0.33, 0.33) within the studied voltage ranges. Furthermore, the color stability of the devices with voltage depends on the molecular structures of the three red-emission compounds, and the stability is improved with the increase of the branches of molecules. For Device with the star-shaped **t-TPA-BT** as the red emitter, the CIE coordinates at different voltages were almost identical. The reason may be attributed to the special structure of the **t-TPA-BT** molecules. The WLEDs showed low turn-on voltage and high performance with the maximum luminance around 4400 cd/m<sup>2</sup> and maximum EL efficiency around 4.5 cd/A.

In conclusion, a novel series of solution-processible red-emission small molecules were designed and synthesized. High performance red-emission OLEDs and

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WOLEDs were fabricated with the compounds as the emissive layer by spin-coating technique. The results indicate that the synthesized organic compounds are promising red emitting organic materials for OLEDs.

## Study on Extraction and Properties of Feather Keratins

FANG-YING LI, RU-YAN JIA, YU-FENG HE, RONG-MIN WANG\*

*Key Laboratory of Polymer Materials of Gansu Province, College of Chemistry and Chemical Engineering, Northwest Normal University, Lanzhou 730070, China*

E-mail: [wangrm@nwnu.edu.cn](mailto:wangrm@nwnu.edu.cn)

Feathers waste, generated in large quantities from commercial poultry processing, is a kind of valuable protein source because it is the most abundant keratinous biomass in the world. Keratin can be used in lots of fields profited from its lower costs, safety and environment friendly. However, it is difficult to extract keratin from feathers because of its structural features such as tight packing of protein chains, hydrogen bonding among polypeptides, and hydrophobic interaction and stabilization of the super-coiled polypeptide chains[1]. At present, many treatments have been developed to obtain keratin. But lots of them need high temperatures and long times with low yields or molecular weights.

In this paper, a kind of simple and effective method to extract keratin from feathers had been investigated. All factors which affecting the yields and the molecular weights of extracted keratin were examined. Under the optimized conditions, the yields of the keratin can stabilize at 90%. MOLDI TOFMS, SDS-PAGE, UV-Vis Spectra, FT-IR Spectra, Elemental Analysis and Amino Acid Analysis were used to confirm the composition of feather keratins. It indicated that the total amount of C, H, O, N, S in extracted keratin exceeds 99%, the molecular weights of keratin is 16-17 KD. And the main amino acids of feather keratin are Pro, Ala, Ser, Tyr, Phe and Cys. The extracted keratin is comparatively pure. It is also noted that feather keratin includes 14-15% of cysteine residues. More cross-links by disulfide bonding resulted in  $\beta$ -sheet conformation of feather keratin.

Further more, the extracted keratin was modified by different reagent. The properties of the extracted feather keratin and the modified keratins were investigated.

### ACKNOWLEDGEMENT

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## Multi-Functionality of Conducting Polyaniline Micro/Nanostructures

MEIXIANG WAN\*

*Institute of Chemistry, Chinese Academy of Sciences, Beijing 100190, China*

E-mail : [wanmx@iccas.ac.cn](mailto:wanmx@iccas.ac.cn)

Design and synthesis of multi-functionalized micro/nanostructures of conducting polymers are necessary for realizing the practice applications of the nanostructures in nano-devices. Conducting polyaniline (PANI) nanostructures have received great attention because of their unique properties and technological applications in electrical, optical, and magnetic materials and devices [1]. By change, author found PANI micro-tubes could be synthesized by an *in-situ* doping polymerization without using any membrane as the hard-template, which was latterly called as template-free method [2]. Compared with common hard-template method, the method is simpler because of omitting membrane as the hard-template and post-process of removal template. Moreover, it has been demonstrated that the method is a universal and efficient approach to synthesis conducting polymer nanostructures including PANI micro/nanostructures. In addition, it is found that the morphology and diameter of the PANI micro/nanostructures are strongly affected by nature of dopant and oxidant as well as polymerization conditions, leading to changeful morphology including nanotubes, nanofibers, junction nanotubes and hollow microspheres. Besides, a micelle formed by dopant, dopant/aniline salt even aniline monomer itself is proposed as a soft-template for the template-free synthesized micro/nanostructures via a self-assembly process [3]. Based on deeply understanding the self-assembly mechanism of template-free method, author exposed a simple template-free method associated with some associated approaches to prepare electro-optic, electro-photoisomerization, electro-magnetic and electro-supperhydrophobic PANI micro/nanostructures.

This article will present template-free method associated with some approaches to realized multi-functionality of PANI micro/nanostructures and discussed physical properties and formation mechanism of the composite multifunctional micro/nanostructures in detail.

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## **Damage Initiation under Transverse Loading of UD-CFRP with Random Fiber Arrangement**

M. HOJO<sup>1</sup>, M. MIZUNO<sup>1</sup>, T. HOBBIEBRUNKEN<sup>1\*</sup>, T. ADACHI<sup>1</sup>, S. K. HA<sup>2</sup> AND K. K. JIN<sup>2</sup>

<sup>1</sup> *Department of Mechanical Engineering and Science, Kyoto University, Sakyo-ku, Kyoto 606-8501, Japan*

<sup>2</sup> *Department of Mechanical Engineering, Hanyang University, Ansan-shi 426-791, Korea*

*\*Present address: Airbus Deutschland, 28199 Bremen, Germany*

E-mail: [hojo\\_cm@me.kyoto-u.ac.jp](mailto:hojo_cm@me.kyoto-u.ac.jp)

A detailed numerical investigation has been carried out to investigate the distribution of microscopic interfacial normal stress for transversely-loaded unidirectional carbon fiber (CF)/epoxy composites with random fiber arrangement. Linear elastic finite element analyses were carried out for two-dimensional image-based models composed of about 70 fibers. The results of both plane strain and plane stress analyses were compared in this study. The effects of the interfiber distance and the fiber alignment angle to loading axis on the interfacial normal stresses (INSs) are investigated for all fibers in order to determine the microscopic damage initiation.

Calculations were carried out for three loading conditions: (Case A) cooling of -155K from the curing temperature; (Case B) transverse loading of 75 MPa chosen as an example of macroscopic transverse fracture strength; and (Case C) both cooling from the curing temperature and transverse loading of 75 MPa.

For Case A, high compressive INSs are observed at the location of the shortest interfiber distance. For Case B, high tensile INSs are observed at the location of the shortest interfiber distance where fibers are aligned in the loading direction. The absolute values of INSs increase with decreasing interfiber distance for both cooling and mechanical loading.

Since the high thermal residual compressive INSs and the high mechanical tensile INSs compensate each other, the INSs at a short interfiber distance for Case C are much lower than those for transverse loading only. Moreover, the INSs take a maximum of 120 MPa when the interfiber distance is about 0.5  $\mu\text{m}$ , and after that, the INSs decrease with decreasing the interfiber distance. This stress state agrees well with our former in situ experiments [1]. The interfacial failure onset was observed at the location where the interfiber distance was about 0.5-1  $\mu\text{m}$  in the loading direction, and was not necessarily observed at the location where two fibers were almost touching.

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## **Fabrication of a Stretchable, Elastic and Electrically Conductive Nanocomposite by High-Shear Processing**

YONGJIN LI\* AND HIROSHI SHIMIZU

*Nanotechnology Research Institute, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba Central 5, 1-1-1 Higashi, Tsukuba, Ibaraki 305-8565, Japan*

E-mail: [yongjin-li@aist.go.jp](mailto:yongjin-li@aist.go.jp)

Electrically conductive elastomers have been widely used in various fields including electromagnetic shielding, seals and electrostatic paintings. Recently, soft and stretchable materials with high electrical conductivity have attracted significant attention because they may be used to create stretchable electronic circuits. Carbon nanotubes (CNTs) are considered to be ideal conductive filler owing to their large aspect ratios, nanoscale diameter and very high electrical conductivity along the tube axis. The extremely low percolation threshold of polymer/CNT nanocomposites not only provides materials with electrical conductivity similar to conventional filled systems, but also maintains the performance of the matrix polymer, such as its mechanical properties, optical clarity and processibility. Therefore, CNTs are expected to be the best conductive fillers for an elastomer matrix to fabricate stretchable conductive nanocomposites because the stretchability of the matrix elastomer should be maintained upon small CNT loading. We have successfully dispersed pristine MWCNTs in poly(vinylidene fluoride) and poly(styrene-*b*-butylene-*co*-butadiene-*b*-styrene) matrixes by melt blending using a high-shear extruder. Our investigation showed that the dispersion of MWCNTs in the polymers was greatly dependent on the shear stress exerted during the melt blending, and a very strong correlations between the processing conditions, morphologies and properties were obtained for the processed nanocomposites.

In this work, a thermoplastic elastomer, poly[styrene-*b*-(ethylene-*co*-butylene)-*b*-styrene] triblock copolymer (SEBS), was compounded with MWCNTs by melt blending using a high-shear extruder with the aim of fabricating highly conductive nanocomposites with excellent stretchability and elasticity. The MWCNTs were homogeneously dispersed in the SEBS matrix, even at an MWCNT concentration of 15 wt%. The addition of MWCNTs to the elastomer significantly enhanced its electrical conductivity and mechanical properties, including increased modulus and tensile strength, with only a slightly loss of stretchability. The fabricated nanocomposites loaded with 15 wt% MWCNT showed an excellent stretchability of more than 600% and a high strain recovery under mechanical deformation. Moreover, the conductivity of fabricated conductive nanocomposites only slowly decreases with uniaxial stretching. In addition, the effect of the uniformly dispersed MWCNTs on the SEBS microphase separation behaviors was also investigated by small-angle X-ray scattering (SAXS), synchrotron SAXS and transmission electron microscopy (TEM). The results indicate that the homogeneously dispersed MWCNTs not only disturb the microphase-separated structure of SEBS, but also decrease its order-disorder transition temperature.

## **Fire Retardancy Comparison of MMT, LDH and Kaolinite on PMMA**

L. J. WANG<sup>1\*</sup> AND C. A. WILKIE<sup>2</sup>

<sup>1</sup> *Key Laboratory of New Processing Technology for Nonferrous Metals and materials, Ministry of Education, Guilin University of Technology, Guilin 541004, China*

<sup>2</sup> *Department of Chemistry and Center for Fire Retardant Research, Marquette University, PO BOX 1881, Milwaukee, WI 53201 USA*

E-mail: [wlj@glite.edu.cn](mailto:wlj@glite.edu.cn)

Polymer nanocomposites not only create enormous interest among researchers because of their unique way of preparation and properties, but also promise development of new hybrid materials for specific applications. These composites typically show astonishing effects in terms of some fire properties and tests. Among the inorganic filler materials for polymer nanocomposites, clays, such as montmorillonite (MMT), layered double hydroxide(LDH) and kaolinite, are most commonly used. In this paper, nanocomposites based on polymethyl methacrylate (PMMA) and organic modification clay fillers (MMT, LDH and kaolinite) were prepared by melt blending method. The X-ray diffraction and transmission electron microscopy were primarily used to characterize the morphology of the nanocomposites. The thermal stability and fire properties of nanocomposites have been studied by thermogravimetric analysis and cone calorimetry. The results show that LDH and MMT have relatively better dispersion in PMMA than kaolinite does, and the exfoliated MMT layers has a higher aspect ratio than LDH does. PMMA+MMT and PMMA+LDH composites have relatively higher thermal stability than PMMA+kaolinite composite does, the on-set temperature of PMMA+MMT composite and PMMA+LDH composite are 304 and 298 °C, respectively, the mid-point temperature are 398 and 393 °C, respectively. But the on-set and mid-point temperatures of kaolinite-PMMA composite are only 269 and 384 °C, respectively. The peak of heat release rate(PHRR) reduction of PMMA+MMT composite at 10% filler additive load is 55%, and 45% for PMMA+LDH composite. But the PHRR reduction of PMMA+LDH composite at 10% kaolinite additive load is only 23%.

## Polyurethane/Clay Nanocomposite Coatings

H. JIN AND S. C. KIM\*

*Department of Chemical and Biomolecular Engineering, KAIST, Daejeon 305-701,  
Korea*

E-mail: [kimsc@kaist.ac.kr](mailto:kimsc@kaist.ac.kr)

**Synthesis of Organoclay** Organifier suitable for the polyurethane coatings and elastomers was synthesized. The organifier was prepared by reacting HDI(hexamethylene diisocyanate) with NMDA(N-methyl diethanol amine) to form isocyanate terminated oligomer. This isocyanate terminated oligomer was then reacted with PEG(polyethylene glycol) or PTMG(poly(tetramethylene ether glycol)) to form PEG or PTMG terminated organifier having the amine group in the center of the chain. The molecular weight of the PEG or PTMG was varied from 200 to 3,000. Linear and three-arm organifiers having one, two and three cationic sites were synthesized to see the effect of the chemical structure of the organifier on the dispersion and the properties of the nanocomposites. The organifier thus prepared was treated with HCl to form the quarternary ammonium cation. The sodium cation in the sodium montmorillonite was exchanged with the organic cation. The organoclay having the hydroxyl end-group can react with the diisocyanate during the PU coating and elastomer synthesis and can act as the chain extender and the organifier can become part of the main PU chain, which can enhance the dispersion of the clay in PU matrix. The clay treated with the organifier having the PEG and PTMG terminal group was shown to have good dispersion stability in organic solvents used for the PU coatings such as DMF and MEK. The WAXD and SAX analysis showed that the d-spacing of the clay platelet was expanded to 2.29 nm when the PEG based organifier was used (PEG400) and to 7.18 nm when the PTMG based organifier was used (PTMG2K). It was observed that as the molecular weight of the organifier increased, the d-spacing increased. The terminal PEG chain is hydrophilic and thus can lay flat on the clay surface, but the hydrophobic PTMG terminal group is coiled inside the clay gallery and thus was more effective in expanding the gallery spacing.

**PU Nanocomposite Coatings** Typical PU coating formulation was used to test the effect of the dispersion of the clay platelets. Polyols made from the poly(ethylene adipate) (mol. wt.: 2,000), MDI, 1,4 butanediol (chain extender) and the organifier were reacted in DMF solution to form the PU nanocomposite coatings. Films were cast from 20% DMF solution. The WAXD and SAXS pattern of the PU nanocomposites having 3 wt.% of the PTMG based organoclay showed intercalated and some exfoliated structures with d-spacing ranging from 4 to 10 nm.

The TEM analysis showed that the PTMG based organoclay was more effective in dispersing the clay in PU film than the PEG based organoclay and the degree of dispersion was higher at 1% loading compared to 3 and 5% loading. However these differences in the degree of dispersion was not exactly reflected in the mechanical properties. The tensile strength of the film showed maximum at 1% loading of the organoclay (actual inorganic content is less than 1%) and the strength is about three

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times higher than the PU film without the clay. The modulus showed continued increase as the amount of the clay was increased.

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## Fracture Property of Interface between Graphite/Epoxy Laminate and MWNTs/Polymer Nanocomposites

MENG-KAO YEH\*, YUNN-YEU LAI

*Department of Power Mechanical Engineering, National Tsing Hua University,  
Hsinchu 30013, Taiwan*

E-mail: [mkyeh@pme.nthu.edu.tw](mailto:mkyeh@pme.nthu.edu.tw)

The mode II fracture property of interface between graphite/epoxy laminate and MWNTs/polymer nanocomposites was investigated. For the graphite/epoxy laminate, the fiber orientations were varied. For the MWNTs/polymer nanocomposites, the epoxy resins were used as the matrix material and the multi-walled carbon nanotubes (MWNTs) were used as the reinforcement. Different weight percentages of MWNTs were added to the MWNTs/polymer compound and the compound was mixed by the magnetic stirrer and sonicated. Then the mixed compound was placed in a vacuum oven to remove the voids and was poured into a steel mould and was hot-pressed to fabricate the MWNTs/epoxy nanocomposite beam specimen. The graphite laminate and the MWNTs/Polymer nanocomposite beam were adhered together to make specimens [1-2]. To determine the mode II fracture property, the end notch flexure (ENF) specimens were used, and the specimen was placed in a three-point bending test to evaluate the strain energy release rate ( $G_{II}$ ) [3]. In analysis, the finite element method was used to obtain the numerical values of mode II fracture property for the specimens [4-5]. According to the experimental results, the strain energy release rate ( $G_{II}$ ) at the interface was higher for the graphite/epoxy laminates with larger fiber orientations; for the MWNTs/polymer nanocomposites, the  $G_{II}$  value varied little with different wt% of MWNTs in the nanocomposites.

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## Polypropylene/Polyester Blend Fibres, Effect of Compatibilisers on Structure, Thermal and Mechanical Properties

A. MARCINČIN\*, K. MARCINČIN, M. HRICOVÁ AND A. UJHELYIOVÁ

*Department of Fibres and Textile Chemistry Institute of Polymer Materials, Slovak University of Technology in Bratislava, Radlinského 9, 813 37 Bratislava, SK*

E-mail: [anton.marcincin@stuba.sk](mailto:anton.marcincin@stuba.sk)

Polypropylene (PP)/polyethylene terephthalate (PET) blend fibres are interesting particularly from the point of view of their exhaust dyeability by disperse dyes and improved elastic properties compared with unmodified PP fibres [1]. The polybutylene terephthalate (PBT) and polytrimethylene terephthalate (PTT) have a more flexible polymer chains and some positive properties e.g. lower melting points  $T_m$ , glass temperatures  $T_g$ , and higher deformability, which are more convenient from the point of view of their application in PP/polyester (PES) blend fibres in comparison with PET. These polyesters in minority content in PET have positive effect on blend processing and improve the mechanical properties of PP/PES blend fibres [2].

In this paper the effect reactive compatibilisers based on PP-g-MA and oxasoline derivatives on phase structure and selected mechanical and thermal properties of PP – PES blend fibres was studied. Dispersed polyester phase in PP matrix is represented by PET, PBT and PTT as well as by their blends. The phase morphology of the blend fibres was investigated by microscopic method. DSC analysis was used for evaluation of the thermal properties and supermolecular structure of blend fibres. The measurements were carried out using conventional method (CM) and constant length method (CLM).

The correlations between phase structure and mechanical-physical properties of the PP/PES blend fibres are discussed in the paper. The tensile strength of the PP/PES fibres increases with length of PES microfibrils in the PP matrix. Besides the positive effect of the PBT and PTT in PES dispersed phase as well as selected reactive compatibilisers on mechanical properties of the PP/PES blend fibres was found. The tensile strength of the PP/PES blend fibres gradually increases with melting enthalpy (crystallinity) and melting temperature (orientation) of the PP matrix obtained by DSC-CLM method.

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## **Manufacturing of Conducting Polymer Based Nanotextile through Electrospinning**

S. PATRA<sup>1</sup> AND D. BHATTACHARYYA<sup>1,\*</sup>

<sup>1</sup> *Centre for Advanced Composite Materials, Faculty of Engineering, The University of Auckland, Auckland 92019, New Zealand*

E-mail: [d.bhattacharyya@auckland.ac.nz](mailto:d.bhattacharyya@auckland.ac.nz)

Nanofibres are very attractive due to their unique properties: high surface area to volume ratio, nano scale fibre diameters, porosity of structure and light weight. The distribution of pore size can vary over a wide range, so nanostructures can be considered as engineered scaffolds with broad applications in the field of tissue engineering. The main attraction of a nanostructure in biomedical applications stems from the fact that proteins, viruses, and bacteria have dimensions of this order. Among the nanostructures, multifunctionalised micro/nanostructures of conducting polymers or conducting polymer based biopolymer have received attention because of their unique properties and technological applications in electrical and biomedical devices. Conducting polymers are of special interest for tissue engineering because new technologies will require biomaterials that not only support tissue growth physically but also are electrically conductive, and thus able to stimulate specific cell functions or trigger cell responses. They are effective for carrying current in biological environments and are therefore, can be considered for delivering local electrical stimuli at the site of a damaged tissue to promote wound healing.

Electrospinning is an established way to process solutions or melts into continuous fibers with diameters in the nanometre range. In electrospinning, when the applied voltage overcomes the surface tension of a polymer solution, a polymer jet is ejected from the tip of the nozzle and fly towards the collector. This process depends on a number of parameters, including the type of polymer, solution viscosity, polarity and surface tension of the solvent, electric field strength and the distance between spinneret and collector. In this paper, the electrospinning method is utilised to engineer novel electrospun conducting polymer-based nanofibrous textiles that can be incorporated in biomedical devices for use in tissue engineering.

The present research has included polyaniline (PANi) as the conducting polymer and poly (lactic acid) (PLLA) as the biopolymer. Dodecylbenzene sulphonic acid (DBSA) doped PANi with PLLA has been dissolved in common solvent, such as chloroform, and the mixture has been successfully electrospun. Dimethyl formamide (DMF) has been used for enhanced conductivity. Fibres of PANi-PLLA nanomat exhibit circular cross section, extraordinary smooth surface and the average diameter of nanofibres is about 100 nm. Nanotextiles of almost beadfree and superfine fibres have been achieved by suitably selecting the levels of contributory parameters. The paper will also outline and review the latest developments and advances in medical textiles and biopolymers for wound management, and will discuss the generalised scope in creating novel products and superior properties.

## Development of Hybrid Injection Moldings

T. OHTA<sup>1</sup> Y. YANG<sup>1</sup> Y. W. LEONG<sup>1</sup> A. NAKAI<sup>1</sup> T. MORII<sup>2</sup> AND H. HAMADA<sup>1\*</sup>

<sup>1</sup>*Advanced Fibro Science, Kyoto Institute of Technology Matsugasaki,  
Sakyo-ku, 606-8585 Kyoto, Japan*

<sup>2</sup>*Shonan Institute of Technology Tsujido-Nishikaigan, Fujisawa, 251-8511 Kanagawa,  
Japan*

E-mail: [hhamada@kit.ac.jp](mailto:hhamada@kit.ac.jp)

Three different Hybrid material systems were examined in this paper. Jute/PP-Glass/PP, Hemp/PP-Glass/PP and Jute/Glass/PP pellet. Long natural fiber-PP pellets were prepared by using the long fiber pellet pultrusion technique, whereby the fiber bundles were continuously pulled and twisted while an extruder supplies the resin that were fed into a heated die where it impregnates into the fiber bundles. After sufficient cooling, the impregnated fiber bundles were cut into pellets according to the desired length. The length of the pellets was around 11 mm for the natural fiber/PP composites. Hybrid specimen was fabricated by both natural fiber pellet and glass fiber pellet through dry blending. In the case of Hybrid pellet both natural fiber and glass fiber were contained in the same pellet, because long fiber pellet making machine can impregnate different fibers simultaneously

Here results of weld strength were shown in Fig.1 by using Hemp fiber hybrid composites. The highest weld line strength was exhibited by the hemp/PP composites (0:100:0) while the weakest weld lines could be found in GF/PP composites (100:0:0). Normally weld strength was affected by interfacial strength between fiber and matrix, so that it is considered that Hemp/PP have higher interfacial strength. However, the hybrid specimens experienced an increase in weld line strength with the decreasing of the hemp fiber content. This is a completely different tendency from the monotonic materials system, which could be due to the difference in fiber distribution in hybrid composites as compared to monotonic composites.

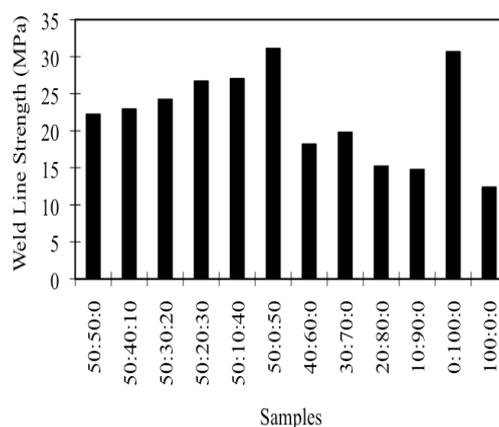


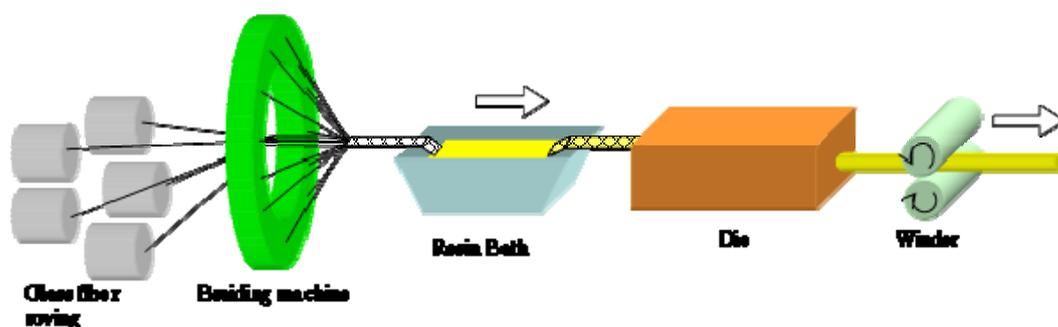
Figure 1: Weld line strength

## Braided Pultrusion Process

Y. TANAKA<sup>1</sup>, N. SHIKAMOTO<sup>1</sup>, Y. YANG<sup>1</sup>, S. MATSUBARA<sup>1</sup>, A. OHTANI<sup>1</sup>, A. NAKAI<sup>1</sup> AND H. HAMADA<sup>1\*</sup>

<sup>1</sup>*Department of Advanced fibro science, Kyoto Institute of Technology  
Gosyokaido-cho, Mastugasaki, Sakyo-ku, Kyoto, 606-8585 Japan  
E-mail:[hhamada@kit.ac.jp](mailto:hhamada@kit.ac.jp)*

In the pultrusion process, usually the unidirectional fiber reinforced composites are fabricated. One of the problems of the unidirectional fiber reinforced composites is the anisotropic of mechanical properties. In this study, the unidirectional fibers were covered with the braided yarns to reduce the anisotropic. Moreover, the new molding method which had continuity was established by combining braiding machine and pultrusion process. The impregnation states and the flexural properties of the pultrusion moldings in longitudinal and lateral directions were investigated. The fractured surfaces of the specimens after flexural tests were observed, in order to clarify the difference of the fracture mechanism between unidirectional moldings and braided one. As the result of the experiments, braided moldings with good impregnation state could be obtained in case that fiber volume fraction was enough high. It was clarified that specimens with braiding technique had high isotropic, because the braided moldings showed the much higher flexural properties in lateral directions than the only unidirectional moldings. Besides, it was found that the braiding layer restrained the development of the cracks.



## **Tensile Property of Multi-Layered Biaxial Weft Knitted (Mbwk) Fabric Composites and Delamination of Z-Pinned Mbwk Composites**

XIONG-KUI LI, SHU-LIN BAI\*

State Key Laboratory of Turbulence and Complex Systems and Department of Advanced Materials and Nanotechnology, College of Engineering, Peking University, Beijing 100871, China  
E-mail: [slbai@pku.edu.cn](mailto:slbai@pku.edu.cn)

The Multi-layered Biaxial Weft Knitted (MBWK) fabric shows superior conformability on curved surfaces and its composites may serve as alternative material to steel which can save energy and reduce emission. Tensile property of the MBWK reinforced composites was investigated in different directions. The tensile modulus and strength provide a way to estimate the mechanical behaviours of the MBWK composite structures. Both rule of mixtures and finite element analysis are applied to compare with the experimental results, e.g. [1]. Two sheets of the fabric were laminated with z-pins through the thickness, and then epoxy was infused to make MBWK/Epoxy composite plate. Mode I delamination tests were conducted to characterize the interlaminar toughness of the two-sheet z-pinned composites. Z-pins improve the interlaminar fracture toughness by more than twice over the no pins composites, e.g. [2]. Topology of the z-pins has an impact on the load–displacement curves. The z-pins standing behind the front line of z-pins near the crack tip absorb some of the suddenly released energy from the pull-out of the front z-pins, which protects the following z-pins from debonding in the composite. Finite element analysis explains quantitatively the mechanism of this phenomenon.

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## Cellulose Fibrils as Reinforcement Materials: Process and Characterization

SIQUN WANG<sup>1\*</sup> AND QINGZHENG CHENG<sup>2</sup>

<sup>1</sup>*Forest Products Center, University of Tennessee, 2506 Jacob Dr., TN 37996-4570, US*

<sup>2</sup>*Division of Forestry and Natural Resources, West Virginia University, US*

E-mail: [swang@utk.edu](mailto:swang@utk.edu)

Cellulose fibrils of micro- and nano-scale sizes have great strength and hence furnish the possibility of reinforcing polymers. Fibrils can be isolated from natural cellulose fibers by chemical or mechanical methods. However, the existing procedures either produce low yields or severely degrade the cellulose and, moreover, are not environment-friendly or energy-efficient.

In this presentation, we will present a novel process that uses high-intensity ultrasonication (HIUS) to isolate fibrils from several cellulose resources. Six factors that may affect the efficiency of fibrillation, including power, temperature, time, concentration, size, and distance, have been considered and discussed. HIUS treatment can produce very strong mechanical oscillating power; therefore, the separation of cellulose fibrils from its biomass is possible by the action of hydrodynamic forces of the ultrasound.

Then we will present characterization of cellulose fibril. The geometrical characteristics of the fibrils were investigated using polarized light microscopy, scanning electron microscopy, and atomic force microscopy. The results show that small fibrils with diameter ranging from about 30 nm to several micrometers were peeled from the fibers. The crystallinities of some cellulose fibers were evaluated by wide-angle X-ray diffraction and Fourier transform infrared spectroscopy. A nano-scale three-point bending test was performed to obtain the elastic moduli. The results indicated that the elastic moduli of cellulose fibrils were not significantly different between 30 min and 60 min of high intensity ultrasonic treatment for Lyocell fiber, between isolation methods of ultrasonic and homogenizer treatment for pure cellulose fiber, and between different cellulose sources of pulp fibers treated by homogenizer regardless the effects of sample size coupled with inherent variation in GPa. The elastic modulus of Lyocell fibrils with diameters from 150 to 180 nm was evaluated to be  $98 \pm 6$  GPa. Modulus values decreased dramatically when the diameter was more than 180 nm.

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## Cryogenic Mechanical Properties of Multi-Walled Carbon Nanotube Reinforced Epoxy Composites

SHAO-YUN FU\*, ZHEN-KUN CHEN, JIAO-PING YANG, QING-PING FENG

*Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Beijing  
100190, China*

E-mail: [syfu@mail.ipc.ac.cn](mailto:syfu@mail.ipc.ac.cn)

Epoxy resins are widely applied in cryogenic engineering and their cryogenic mechanical properties as important parameters have to be improved to meet the high requirements by cryogenic engineering applications. Recent publications from our group have reported on epoxy toughening and strengthening of epoxy resins for enhancing cryogenic mechanical properties using flexible diamines [1], thermoplastic poly(ethersulfone) [2], silica nanoparticles [3], exfoliated montmorillonite [4], hyperbranched polymer [5] and polyurethane [6]. Carbon nanotubes are regarded as exceptional reinforcements for polymers. This paper presents a study on the cryogenic mechanical properties of multi-walled carbon nanotube reinforced epoxy composites. When the temperature decreases from room temperature to liquid nitrogen temperature, the thermal contraction of epoxy matrix due to the big differences in thermal expansion coefficients of epoxy and carbon nanotubes would result in a strong interfacial bonding. As a result, the cryogenic tensile strength, Young's modulus, failure strain and impact strength at liquid nitrogen temperature are all enhanced by the addition of carbon nanotubes at appropriate contents. These results suggest that carbon nanotubes are promising reinforcements for enhancing the cryogenic mechanical properties of epoxy resins that have potential applications in cryogenic engineering areas.

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## **Influence of Different Antioxidants on Mechanical Properties of a Thermal-oxidized NBR-Matrix Nanocomposite Material**

X. COLOM<sup>\*</sup>, F. ANDREU-MATEU, F. CARRILLO AND F. J. CAÑAVATE

*Department of Chemical Engineering Chemistry, Universitat Politècnica de Catalunya,  
Terrassa 08222, Spain*

E-mail: [xavier.colom@upc.edu](mailto:xavier.colom@upc.edu)

The study considers the degrading process of a nanocomposite of NBR matrix reinforced by SiO<sub>2</sub>, when three different antioxidant agents, isopropyl paraphenylene diamine (IPPD), 1,2-dihydroquinoleine (TMQ), and Wingstay-L belonging to the phenol family, are added to it. The behaviour of each antioxidant under the thermal oxidation process was analysed by observing the performance when several SiO<sub>2</sub>-NBR matrix samples containing or not antioxidants were exposed to an oxidizing atmosphere at 140°C for different periods of time, until 240 h. The samples were characterized by using different techniques. Properties as Tensile strength, Elongation at maximum load, Young modulus, Toughness and Shore Hardness have been determined. In addition, degrees of cross-linking by means Flory-Rehner equation helped to achieve a complementary knowledge of them. The best result was using Wingstay-L, which enhanced the mechanical performance of the nanocomposite subjected to thermal oxidation. Besides, the presence of Wingstay-L extended the period of exposure during which the good mechanical properties of the nanocomposites were held-up. With respect the other two antioxidants, IPPD performed only a bit better than TMQ. In the absence of antioxidants dramatic loss in mechanical properties occurred in the nanocomposite. Cross-linking of NBR decreases in the antioxidant presence. By means the ATR-FTIR spectroscopy it was observed that the thermal oxidizing degrading process of increased the volatility of the plasticiser in all the composites studied and at the same time, several oxygen-bearing species were generated and new unsaturated sites that later became cross-linking nuclei. Disappearance of plasticizer and more cross-linked structure developed, in the long run, high stiffness levels. The DSC and above all TGA tests corroborated all results obtained.

### **ACKNOWLEDGMENT**

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## Nanostructured Interphases in Composites - Perspectives and Challenges

E. MÄDER\*, S. L. GAO, R. C. ZHUANG, J. RAUSCH, R. PLONKA

*Leibniz Institute of Polymer Research Dresden, Hohe Strasse 6, D-01069 Dresden, Germany*

E-mail: [emaeder@ipfdd.de](mailto:emaeder@ipfdd.de)

An effective utilization of exceptional high mechanical properties of nanofibres and nanoplatelets in composites is a currently challenging and unsolved issue. Thus, the potential of the nanoparticles is not fully exploited and the composites fall short of the expectations regarding their mechanical property improvement linked to dispersion homogeneity. Our approach comprises a built-up of nanostructured surfaces in an online process to 'heal' surface nanometre-scale flaws and functionalize glass fibre surfaces [1].

A hybrid sizing or coating including multiwalled carbon nanotubes (MWNTs), nanoplatelets, silane coupling agents and nanometre-scaled polymeric dispersions, as mechanical enhancement and environmental barrier layer, is applied to either E-glass fibres or alkali-resistant glass fibres. The nanostructured and functionalized traditional glass fibres with low fraction of nanotubes or nanoclay (<1 wt% in sizing) show significant improvement in both mechanical properties of fibres and composites and environmental corrosion resistance. We introduce a healing efficiency factor and conclude that the coating modulus, thickness and roughness are responsible for the mechanical improvement of fibres [1]. The most remarkable mechanical strength improvement is found for glass fibres with nanotube surface modification, corresponding to the highest aspect ratio and healing efficiency factor, respectively [2]. In case of the glass fibre coated by polymer with dispersed organoclay, the influence of moisture uptake and concentration on mechanical properties decreases. We found no apparent decay in fibre strength after the coated fibres subjected to alkaline attack. Besides, nanocomposite coatings result in higher fibre/matrix interfacial adhesion, suggesting nanotube related interfacial toughening mechanisms.

Overall, we show that the hybrid sizing or coating is essential for enhanced interfacial adhesion strength and improved mechanical properties of both the glass fibre reinforced cement and thermoplastic matrix composites.

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## Dispersion and Micro-Structure of Polymer/Silica Composites

JING-ZHI ZHENG<sup>1</sup>, CHENG-FU ZHENG<sup>1</sup>, CHEN-CHEN LV<sup>1</sup>, XING-PING ZHOU<sup>1</sup>, YIU-WING MAI<sup>2</sup>, XIAO-LIN XIE<sup>1\*</sup>

<sup>1</sup>*Hubei Key Laboratory of Materials Chemistry and Service Failure, School of Chemistry and Chemical Engineering, Huazhong University of Science and Technology, Wuhan, 430074, China*

<sup>2</sup>*Advanced Materials Technology, School of Aerospace, Mechanical and Mechatronic Engineering, J07, University of Sydney, Sydney, NSW 2006, Australia*

E-mail: [xlxie@mail.hustt.edu.cn](mailto:xlxie@mail.hustt.edu.cn)

Polymer/inorganic particle nanocomposites have attracted considerable attention owing to their excellent processability, mechanical, optical, electric, magnetic, bioactive and gas sensitive properties. Among the numerous nanocomposites, silica nanoparticles are the most commonly reported, and have been employed in a variety of applications due to their optical transparency, electrical insulation, biocompatibility, chemical and thermal resistance, mechanical stability and variable sizes, tunable surface properties and low costs [1, 2]. The greatest challenge to their large-scale production and commercialization is how to control the homogeneous dispersion of nano-silica in polymer matrix [3]. Here, the colloidal silica nanoparticles were synthesized by sol-gel process, then a series of composite particles with colloidal silica as the core and the polymer as the shell were synthesized by in-situ polymerization of vinyl monomer, whose formed polymer is miscible or compatible with the following compounding polymer matrix, such as isotactic polypropylene and acrylic resin. Compared to the colloidal silica particles, the composite particles exhibit better dispersion in polymer matrix, the received polymer/silica composites exhibit excellent thermal and mechanical properties.

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## Potential of Using Recycled PET in Comparison with Liquid Crystalline Polymer as Processing Aids, Enhancing Thermal Stability and Reinforcing Materials for In Situ Microfibrillar-Reinforced Composites

S. SAIKRASUN<sup>1\*</sup>, S. KAYAISANG<sup>1</sup>, S. SOMBATDEE<sup>1</sup> AND T. AMORNSAKCHAI<sup>2</sup>

<sup>1</sup>*Department of Chemistry and Center of Excellence for Innovation in Chemistry, Faculty of Science, Mahasarakham University, Mahasarakham 44150, Thailand*

<sup>2</sup>*Center for Alternative Energy, Department of Chemistry and Center of Excellence for Innovation in Chemistry, Faculty of Science, Mahidol University, Rama VI Road, Bangkok 10400, Thailand*

E-mail: [username@e-mailserver](mailto:username@e-mailserver)

The potential of recycled poly(ethylene terephthalate) (rPET) as well-defined processing aid, enhancing thermal stability and reinforcing material for the *in situ* microfibrillar-reinforced composite was investigated in comparison with that of liquid crystalline polymer (LCP). Each dispersed phase (LCP or rPET) was melt blended with high density polyethylene (PE) or polypropylene (PP) by using extrusion process and melt spun as continuous fibers using a single screw extrusion conducted with drawing machine. The rheological behavior, morphology, and the thermal stability of all LCP and rPET-containing blend systems were investigated. All blends and LCP exhibited shear thinning behavior, whereas Newtonian fluid behavior was observed for rPET. The incorporation of LCP or rPET into both thermoplastic matrices significantly improved the processability. A potential of rPET as a processing lubricant by bringing down the melt viscosity of the blend system was as good as LCP. The elongated LCP domains were clearly observed in as-extruded strand. Although the viscosity ratio of the rPET-containing blend was lower than that of the LCP blend, most rPET domains appeared as small droplets. An addition of LCP and rPET into the thermoplastic matrices improved the thermal resistance significantly in air but not in nitrogen. The modulus and tensile strength of the composite fibers of both composite systems increase with increasing draw ratio. Significant improvement in mechanical properties of the composite fibers was achieved with the presence of reactive compatibilizer. The obtained results suggested the high potential of rPET as a processing aid, good thermally resistant and reinforcing material similar to LCP.

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## Interface Development in All-cellulose Composites

R. K. Y. LI<sup>1\*</sup>, B. P. K. LO<sup>1</sup>, Q. ZHAO<sup>1,2</sup> AND R. C. M. YAM<sup>2</sup>

<sup>1</sup>*Department of Physics and Materials Science, City University of Hong Kong, Hong Kong, China;*

<sup>2</sup>*Department of Manufacturing Engineering and Engineering Management, City University of Hong Kong, Hong Kong, China*

E-mail: [aprkyl@cityu.edu.hk](mailto:aprkyl@cityu.edu.hk)

It has been a long history for human being to use natural fibres as the reinforcement to prepare composite materials. Our ancient ancestors began to mix straw and clay to make bricks with enhanced structural durability. The term “natural fibres” covers a broad range of vegetable, animal, and mineral fibres. However, in the composites industry, it usually refers to wood fibre and agro-based seed, bast, leaf, and stem fibres [1]. These natural fibres are made up primarily of cellulose, hemicellulose, pectin and lignin [1, 2], most of which are fully biodegradable. These chemical constituents form a complex, three-dimensional composite structure that is responsible for the good specific mechanical properties of natural fibres [2, 3]. In addition, natural fibres are derived from renewable resources and are readily available at low prices. Natural fibre reinforced polymer composites have found some industrial applications, especially in the automotive sector in Europe [4, 5].

With the increasing awareness of environmental pollution from plastic wastes, there have been active efforts to develop polymers that will degrade in the environment under actions such as microbial attack or hydrolysis. Some of the advantageous effects of using natural fibres to reinforced thermoplastics, such as polypropylene (PP) have been demonstrated in our previous studies [6- 8]. More recently, an all-cellulose eco-composite based on cellulose and rice husk has been fabricated [9]. The processing condition and composition ratio have obvious influences on the composite's mechanical properties.

In the current research, all-cellulose eco-composite based on cellulose and sisal fibre is under development. Particular emphasis on the interface development between the fibre and matrix will be monitored. The influence of the interface development on the composite properties will be characterized.

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## **On the Mechanical Behaviour of Polyethylene Based Micro- and Nanocomposites at Low Et Large Strain Levels**

A. PEGORETTI\*, A. DORIGATO AND A. PENATI

*Department of Materials Engineering and Industrial Technologies,  
University of Trento, via Mesiano 77, 38100 Trento, Italy  
E-mail: [alessandro.pegoretti@unitn.it](mailto:alessandro.pegoretti@unitn.it)*

In the present work, linear low-density polyethylene (LLDPE) based composites have been prepared by melt compounding of various silica-based fillers such as fumed silica, precipitated silica and soda-lime glass microspheres. The aim is to investigate the influence of the filler dimensions and surface area on the viscoelastic response and fracture behaviour of the resulting nano- and microcomposites.

The selected LLDPE is Flexirene® CL10, kindly supplied by Polimeri Europa (Italy), having a density of  $0.917 \text{ g/cm}^3$  and a melt flow index of  $2.6 \text{ g/10'}$  at  $190 \text{ °C}$  and  $2.16 \text{ kg}$ . Aerosil® commercial fumed silica were kindly supplied by Degussa (Germany). These nanoparticles differ for the surface area (i.e.  $90 \text{ m}^2/\text{g}$  for A90,  $200 \text{ m}^2/\text{g}$  for A200 and  $380 \text{ m}^2/\text{g}$  for A380), and for the surface treatment (Ar816 is obtained by functionalization of A200 with hexadecylsilane). Sipernat® S160 precipitated silica microparticles were also supplied by Degussa. This microfiller has a mean particles size of  $10 \text{ }\mu\text{m}$  and a specific surface area of  $165 \text{ m}^2/\text{g}$ . This elevated surface area is related to the high porosity of the resulting microparticles. Compact micrometric glass microspheres were supplied by Cores (Italy). This microfiller is mainly based on amorphous silica, with a  $\text{SiO}_2$  content of  $73 \text{ wt}\%$ . These microspheres manifest a surface area of about  $1 \text{ m}^2/\text{g}$  and a mean particle diameter of  $18 \text{ }\mu\text{m}$ .

Composites were prepared by melt compounding in a Thermo Haake® internal mixer, at  $170 \text{ °C}$  for  $15 \text{ min}$  and  $90 \text{ rpm}$ . Square sheets of about  $0.8 \text{ mm}$  in thickness were then obtained by compression molding in a Carver® laboratory press at a temperature of  $170 \text{ °C}$  and a pressure of  $0.2 \text{ kPa}$ . Four samples with a filler content of  $1, 2, 3$  and  $4 \text{ vol}\%$  were prepared with each type of filler.

A number of experimental techniques have been adopted to characterize the obtained composites, such as density evaluation by helium picnometry, parallel plates dynamic rheometry, differential scanning calorimetry, dynamic mechanical thermal analysis, tensile tests under ramp and creep conditions. Moreover, the fracture behaviour under quasi-static and impact conditions has been investigated. Marked differences in the mechanical response have been found among the investigated materials, both for as concern the low and large strain regions. A clear dependency of some mechanical parameters, such as the tensile modulus and the creep compliance, on the filler surface area has been assessed. An attempt to model rheological and elastic behaviour will be also presented.

## The Properties of NR Vulcanizate Filled with Silica-Gel Synthesized from Rice Husk Ash via Sol-Gel Process

C. THONGPIN<sup>1,2,3,\*</sup>, C. SRIPETDEE<sup>1,2</sup> AND E. WIMOLMALA<sup>3</sup>

<sup>1</sup> *Material Science and Engineering Department, Faculty of Engineering and Industrial Technology, Silpakorn University, Sanamchandra Palace Campus, Nakornpathom, 73000, Thailand*

<sup>2</sup> *Center of Excellent for Petroleum, Petrochemical, and Advanced Materials, Chulalongkorn University, Bangkok, 10330, Thailand.*

<sup>3</sup> *Polymer PProcessing and Flow Research Group (P-PROF) and CUP-NATURE Research group, School of Materials Technology, King Mongkut University of Technology Thonburi (KMUTT), Bangmod, Thungkru, 10140, Thailand.*

E-mail: [chanchai@su.ac.th](mailto:chanchai@su.ac.th)

It was found elsewhere [1] that nanoparticles (OMMT) reinforced rubber would enhance both modulus and tensile properties without suffering the elongation at break of the NR vulcanizate. This research was therefore aimed to study nano-silica reinforcing natural rubber. The nano-silica was incorporated into NR via in-situ sol-gel process together with the gelation or solidification of NR latex. The research was started with the preparation of silicate solution extracted from 10 grams of rice husk ash in 300 ml of 1 M NaOH, for 17 hours. Silicate solution was then mixed with 30 % DRC NR latex, which was previously stabilized with nonionic emulsifier, with the ratio of 1:1 by volume. 5 % H<sub>2</sub>SO<sub>4</sub> solution was added drop-wise to adjust pH of the mixture to 7, after 24 hours continuous stirring. The coagulated NR containing silica formed via in-situ sol-gel was washed with water while milling on a mini two roll mill to obtain white rubber sheet. Leached water was frequently tested with Ba(NO<sub>3</sub>)<sub>2</sub> in order to check for the SO<sub>4</sub><sup>-2</sup>. The sheet with no SO<sub>4</sub><sup>-2</sup> was then dried at 50 °C in a hot air oven for 24 hours or until dry. TGA analysis indicated that the silica content was found to be 15 phr with respect to NR. The dried NR sheet containing silica, formed in-situ, was compounded on a two roll mill with conventional vulcanization formulation and then characterized for its cure characteristic using Moving Die Rheometer (MDR) before compression molded to a rubber vulcanizate sheet at 160 °C with the cure time obtained from MDR. Neat NR and NR filled with precipitated silica, 15 phr, were also compounded and compression molded for comparison. It was elucidated from tensile and tear test results that the present of in-situ so-gel silica extracted from rice husk ash can reinforce NR better than precipitated silica due to the nano-scale silica particles present in NR matrix. SEM micrographs also show very well distribution of silica particles in NR matrix.

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## Carbon Nanotube Network on Glass Fibre as Multifunctional Sensor

S. L. GAO\*, J. ZHANG, R. C. ZHUANG, J. W. LIU, E. MÄDER

*Leibniz Institute of Polymer Research Dresden, Hohe Strasse 6, D-01069 Dresden,  
Germany*

E-mail: [gao@ipfdd.de](mailto:gao@ipfdd.de)

Carbon nanotubes on traditional glass fibres improve fibre mechanical properties and enable the in-situ monitoring of material in both processing and service environments [1,2]. We report the first electrical resistance measurements performed on multiwalled carbon nanotube networks (MWNTs) sized single glass fibre [2]. Our electrical functional glass fibres by surface nanotube networks show surface resistance values typically in the range of  $10^3$  to  $10^7$  ohm/sq, which add antistatic and electrostatic shielding features. Importantly, the electrical properties of MWNTs-glass fibre-epoxy composites have anisotropic nature, resulting in exceptionally low threshold concentrations, compared to previously reported for various carbon nanotubes in epoxy systems. In addition, we observed nonlinear and linear piezoresistivity, temperature, moisture and epoxy curing time dependences for the single glass fibre sensors and their epoxy matrix composites, respectively. The single glass fibre with MWNTs conduction properties can be well fitted with an exponential equation and associated two main mechanisms. These mechanisms of variable range hopping and tunnelling conduction are discussed.

As an effective utilization of exceptional high mechanical properties of carbon nanotubes, a nanometer-scale hybrid polymer sizing layer with MWNTs was applied to the surface of glass fibres and plates. We find remarkable improvement in fibre tensile strength which is attributed to (MWNTs) on glass fibres 'healing' surface nanometer-scale flaws [1]. We further investigate effects of MWNTs serviced as interphase adhesion reinforcements. The nanocomposite coatings with MWNTs show improved fiber/matrix interphase adhesion measured by micro-single-lap-joint, single-fibre-pull-out and fragmentation tests. The mechanical interlinking of nanotubes improves the resistance to interphase deformation/cracking.

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## Non-isothermal Crystallization Kinetics of Cyclic Butylene Terephthalate/Polycaprolactone Copolymers

CHENG-WEI HUANG AND CHANG-MOU WU\*

*Graduate Institute of Textile Engineering, Feng Chia University, Taichung 40724,  
Taiwan*

E-mail: [cmwu@fcu.edu.tw](mailto:cmwu@fcu.edu.tw)

Low viscosity cyclic butylene terephthalate (CBT) is a promising material for thermoplastic composite. However, isothermal polymerized (to pCBT) and crystallized CBT leads to big perfect crystals, which induces brittleness. Various potential toughening approaches [1-3] such as copolymerized CBT with polycaprolactone (PCL) or polyvinylbutyral (PVB), blended with organosilicate or carbon nanotubes were attempted to solve this problem. Bates [1] reported that the copolymerization of CBT/PCL hinders the crystallization of pCBT and thus explains the toughening effect of PCL addition, which leads to a much tougher material, both for unfilled material and for composites. In this study, non-isothermal crystallization kinetics, melting behaviors and crystallized morphology of CBT/PCL copolymer will be investigated and compared with pure pCBT for further understanding its toughening effect.

The pCBT/PCL samples were copolymerized with 7wt% PCL at 230°C for 30min. The crystallization behavior of pCBT/PCL copolymer were studied by differential scanning calorimetre under non-isothermal conditions. The results show the Ozawa exponent were around 2~3 for pCBT whereas the exponent ranged around 1~2 for pCBT/PCL copolymer. The result indicates strong hindrance on the crystallization dimension in pCBT/PCL copolymer. Besides, the crystallization peak temperature and the crystallization enthalpy for pCBT/PCL copolymer were around 23°C and 22% decreased respectively as compared with pure pCBT. Similar, the melting peak temperature and the melting enthalpy for pCBT/PCL copolymer were around 19°C and 21% decreased respectively as compared with pure pCBT. Under 2°C/min cooling rate, the spherulite of pCBT/PCL copolymer was smaller than that of pure pCBT. Note that the crystallization and melting behavior above in this study correspond with those properties that Bates [1] reported in unfilled copolymer and composites. Unlike the simultaneous polymerization/crystallization mechanism at 190°C in pCBT, the crystallization of pCBT/PCL copolymer occurs in the cooling process and thus a better manufacture condition for pCBT/PCL composites were revealed.

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## Viscoelastic Properties of 3D Woven Composites: A Two-Scale Theoretical Model

C. ZHOU<sup>1\*</sup>, Z. XIA<sup>2</sup> AND Q. YONG<sup>1</sup>

<sup>1</sup>*Department of Structural Engineering and Mechanics, Nanjing University of Aeronautics and Astronautics, Nanjing, Jiangsu 210016, China*

<sup>2</sup>*Department of Mechanical Engineering, University of Alberta, Edmonton, Alberta T6G2G8, Canada*

E-mail: [zcx@nuaa.edu.cn](mailto:zcx@nuaa.edu.cn)

A two-scale theoretical mechanical model was developed to predict viscoelastic properties of 3D woven composites. In micro-scale, a transverse isotropic viscoelastic model was suggested to describe time dependent deformation of resin impregnated fiber bundle. The fitting parameters in the model were calibrated by 3D FE. In meso-scale, two unit cells, representing periodic weave structures of 3D woven composite in inner and surface regions respectively, were built. They were constructed with orthogonal interlaced fiber bundles and rich resin parts. The overall viscoelasticity of 3D woven composite were obtained by combining time dependent average stresses and strains over meso unit cells with mixture law.

To verify this theoretical approach, creep and stress relaxation experiments of glass fiber/epoxy matrix 3D woven composites with various weave parameters and load levels were carried out. Model predictions are in good agreement with experiment data.

Notable deviations of both local stresses and average viscoelastic properties in meso inner and surface unit cells are found. Therefore, for a refined theoretical model surface effect should be considered.

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## Radical Initiation to Prepare Poly(Butadiene-block-Methyl Methacrylate)

A. BAJPAI\*, P. CHOUDHARY AND S. SHRIVASTAVA

*Department of Chemistry, Government Model Science College, Jabalpur- 482 001,  
India*

E-mail: [abs\\_112@rediffmail.com](mailto:abs_112@rediffmail.com)

In order to fulfil the quest of newer materials with high performance properties, there has been an increasing interest in hybrid and/or reinforced materials. Blending of two or more immiscible materials without the use of an appropriate compatibilizer does not lead to formation of a material with desirable properties. Block copolymers have been found to be very efficient compatibilizers for such materials. Block copolymers provide one of the most exciting classes of materials, both in terms of intellectual stimulation and practical utility. Use of block copolymers with blocks of two different types, such as sequences of rigid and flexible components, introduces the advantage of controlling the compositions of phases, which is otherwise difficult in mixtures of different polymers due to their limited miscibilities. Therefore, development of novel methods for preparation of block copolymers with rigid and flexible blocks is important in theory as well as in practice. Poly (methyl methacrylate) is a very important industrial polymer. Reports on block copolymers of butadiene and methyl methacrylate could not be found.

The present paper reports heterogeneous radical polymerization of MMA through generation of macroradical on hydroxyl terminated polybutadiene (HTPB) by interaction with V(V) as an oxidant in methanolic sulfuric acid medium at 35°C. The effect of various reaction parameters resembled with the characteristics of vinyl polymerization in heterogeneous media. Block copolymerization was inferred by FTIR and NMR spectral analysis. The product of polymerization was fractionated with petroleum ether and toluene. Transparent, glossy films were obtained on evaporation of solvents from petroleum ether and toluene soluble fractions. The effect of composition of sample and the solvent used for formation of films was studied. The viscosity, swelling and permeability studies were carried out along with the morphology determination by optical and scanning electron microscopic studies, which indicated the lyotropic self assembly of PBd-*b*-PMMA. Thermogravimetric analysis revealed that the block copolymer (PBd-*b*-PMMA) was sufficiently thermally stable with only 8.6% weight loss up to 200° (°C?) and degraded appreciably above 400° (°C?) only.

The adsorption of methyl orange by this block copolymer and its subsequent release in alkaline buffer exhibited pattern similar to the usual fractional release behavior of drug release observed for hydrogel systems.

Preliminary studies revealed that this material adhered to glass or metallic surface in form of a thin film from the dilute solution. The deposited film could be cured under UV irradiation which improved scratch resistance property. The deposited films were transparent, hard, scratch resistant and hydrophobic. These hydrophobic nanostructured coating with multifunctional properties can be applied on to monuments to protect the surface from dirt and rainy water. They may also protect surfaces such as tiles, wood, metal, plastic and glass.

## Transesterification of PET/PBT Blends Filled with Silica Nanoparticles During Melt Processing

FENG WANG, MINGSHU YANG\*

*Beijing National Laboratory for Molecular Sciences, CAS Key Laboratory of Engineering Plastics, Institute of Chemistry, The Chinese Academy of Sciences, Beijing 100080, China*

E-mail: [yms@iccas.ac.cn](mailto:yms@iccas.ac.cn)

The transesterification of PET/PBT has been sufficiently studied until now. Inorganic nanoparticles are commonly utilized to fill in polymer matrix to prepare PET/PBT nanocomposites which are expected to enhance their stiffness and impact properties simultaneously. Furthermore, inorganic nanoparticles are often organic modified to achieve homogeneous distribution. However, the influence of nanoparticles on transesterification of PET/PBT has been seldom studied.

In this research, the PET/PBT transesterification has been investigated in the presence of nano-fillers, including pure SiO<sub>2</sub> and silane coupling agent modified SiO<sub>2</sub>. From <sup>13</sup>C NMR quantitative analysis of PET/PBT/SiO<sub>2</sub> nanocomposites, it is evident that nanosized SiO<sub>2</sub> acts as an inhibitor of transesterification between PET and PBT during melt processing, and the inhibition effect of modified SiO<sub>2</sub> is less significant than pure SiO<sub>2</sub>.

Condensation reaction between hydroxyl end groups of polyesters and the surface hydroxyl groups of SiO<sub>2</sub> nanoparticles was confirmed by TGA, FTIR and XPS data. Therefore, the transesterification inhibition mechanism could be explained by that the amount of hydroxyl end group of polyesters decreases due to the condensation reaction, leading to the inhibition of transesterification. The modification of the SiO<sub>2</sub> nanoparticles with silane coupling agent reduces the amount of reactive hydroxyl groups of SiO<sub>2</sub> and thus inhibits less the transesterification in the corresponding nanocomposite. And hydroxyl end group of PET is less reactive than that of PBT.

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## Development of Hybrid Polymer Composites

T. CZIGANY

*Department of Polymer Engineering, Budapest University of Technology and Economics, Muegyetem rkp. 3. H-1111. Budapest, Hungary*

E-mail: [czigany@eik.bme.hu](mailto:czigany@eik.bme.hu)

Hybrid composites are complex systems in which there are more reinforcing materials in one matrix (hybrid fiber) or there is one type of reinforcement in a mixed matrix (hybrid matrix). The application of these materials is more and more common in the industry since several properties of their (e.g. toughness) are more competitive than that of conventional mono-composites.

The most common composite reinforcing material today is glass fiber, which has a good mechanical properties and properly feasible interface coupling with relatively low price. More demanding applications require carbon fibers, though these have essentially higher price and it is more difficult to assure the satisfactory interfacial adhesion. Due to the market competition and growing economic and environmental demands, many new fibers come into consideration as potential composite reinforcements. Basalt fibers are such new reinforcing materials [1]. Basalt is a common volcanic rock that can be found virtually in every country around the globe. Basalt fibers are good electric insulators, not sensitive to moisture, biologically inactive and environmentally friendly. Basalt fibers can be divided into two groups: short basalt fibers made by melt spinning (e.g. Junkers method) and continuous basalt fibers made by spinneret method [2, 3]. Basalt fibers are produced in one step, directly from crushed basalt stone. Some melt spinning technologies (e.g. the duplex and Junkers method) are suitable for producing cheap, short basalt fibers, but such fibers have relatively poor and uneven mechanical properties.

The aim of the present study is to develop a new basalt fiber reinforced hybrid polymer composites and compare their properties to the common fiber reinforced composites. Further aim is to find the positive hybrid effects between the composites.

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## Disclosed Percolation Phenomena and Mechanism in Reinforcement of Elastomeric Polymer by Nano-filler

ZHANG LIQUN<sup>1,2\*</sup>, WANG ZHENHUA<sup>1</sup>, WU YOUPIPING<sup>1,2</sup>, WU SIZHU<sup>1</sup>, LIU JIAQI<sup>1</sup>, LIU JUN<sup>1,2</sup>

<sup>1</sup>Key Laboratory of Beijing City on Preparation and Processing of Novel Polymer Materials at Beijing University of Chemical Technology, Beijing, 100029, China

<sup>2</sup>Key Laboratory of Ministry of Education on Preparation and Application of Nano materials at Beijing University of Chemical Technology, Beijing, 100029, China

E-mail: [zhanglq@mail.buct.edu.cn](mailto:zhanglq@mail.buct.edu.cn)

Nano-reinforcement by employing nanoparticles is necessary for high-efficiency reinforcement of elastomeric polymer materials, which was already proven by numerous researches and industrial applications. This report firstly disclosed the percolation phenomenon in the rubber nano-reinforcement, which is similar to the percolation behavior occurred in the rubber toughened plastics. That is, as the loading of nano-fillers (carbon black, nano sized zinc oxide) increases, the tensile strength of rubber (SBR, EPDM) first increases slowly and then increases rapidly, finally reaches the balance; meanwhile, the bigger the particle diameter is, the higher the volume fraction of reinforcement filler at the percolation point is, the lower the corresponding tensile strength of the composites is. This percolation phenomenon indicates that lower loading of nano-filler can't reinforce the rubber effectively, and in a certain loading range, the smaller the particle diameter is, the more effective the reinforcement is. Further analyzing this percolation behavior, it is suggested that the rubber reinforcement through nanoparticle was corresponding to the formation of the stretched polymer chains between the neighbor particles induced by slippage of polymer chains on the filler surface during stretching. The concept of critical particle-particle distance (CPD) is hereby put forward for the first time in rubber reinforcement. The factors to govern this critical particle-particle distance are investigated. Moreover, the concept of critical particle diameter for reinforcement is also figured out. Based on the percolation theory, some new view points for reinforcement design of rubbery materials are brought forward, including that the interfacial interaction between the nanoparticles and the rubber couldn't be the complete chemical bonding, and partial physical absorption of macromolecular chains on the filler surface is necessary, otherwise the formation of stretched chains would be seriously hindered; there should existed a optimum crosslinking density for a filler reinforce rubber composites; there should be the smallest particle diameter for reinforcement.

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## Vibration of Composite Beam with Delamination under Axial Tension

D. W. SHU\*

*School of Mechanical and Aerospace Engineering, Nanyang Technological University,  
Singapore 639798*

E-mail: [mdshu@ntu.edu.sg](mailto:mdshu@ntu.edu.sg)

Delamination is one common mode of failure of laminated composite materials. Delaminations in composites laminates may arise from either fabrication processes or impact during services. Imperfections such as air entrapment or insufficient bonding material during the fabrication processes may cause initial delaminations. Unfavourable impurities and chemical corrosion may further develop the micro-delaminations into sizeable delaminations during loading. The growth of micro-delaminations would be drastically enlarged if these delaminations encounter impact loading. Other factors that affect the growth of delaminations include the loss of adhesion between the two layers of the structure and the material discontinuities or geometries that have been developed into high stress concentration, especially edge compression. Delaminations shift the frequencies of the structure which may cause resonance if the shifted frequencies are close to the working frequencies. The mechanical properties of FRP would drop below the design limits if delaminations exist. Thus, delaminations have to be detected as early as possible before FRP fail catastrophically in the later stage. In the work to investigate buckling of the delaminated beam, Shu and Mai [1-3] successfully explored local deformation near the two fronts of delaminations. These are further expanded to investigate the effect of delamination on vibration [4-5]. Bokaian studied the natural frequencies of beams under tensile axial loads [6]. The objective of the study is to investigate the combined effect of delamination and axial tension on the vibration of laminate composites. In this research, we present an analytical solution for the free vibration of beams with a single delamination under the axial tensile loading. Both the 'free mode' and the 'constrained mode' assumptions are made. A parametric study is conducted to study the effect of the axial tensile loading on the natural frequency and the mode shapes of the delaminated beam.

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## **Role of the Intermediate Thermoplastic Phase in Improving Mechanical Properties of Polymer/Organoclay Nanocomposites**

POOYAN MOTAMEDI<sup>1</sup>, REZA BAGHERI<sup>1\*</sup>

*Polymeric Materials Research Group, Department of Material Science & Engineering, Sharif University of Technology, P.O. Box 11155-9466, Tehran, Iran*

E-mail: [rezabagh@sharif.edu](mailto:rezabagh@sharif.edu)

In search for methods to reinforce commodity thermoplastic polymers so as to replace them for more expensive alternatives, nanoclay has become a focal point of attention [1, 2]. Nanoclay, while moderately improves the elastic modulus of polypropylene, has a rather limited effect on its yield stress and impact resistance [2]. Given that, the aim of this work is finding a solution to unleash the maximum potentiality of organoclay to simultaneously improve various mechanical properties of polypropylene. In this accord, Polyamide 6 was incorporated into the polypropylene/organoclay system, as an intermediate phase. Composites of polypropylene/organoclay, polyamide/organoclay, blends of polypropylene/polyamide, and ternary nanocomposites of polypropylene/polyamide/layered silicate with and without compatibilizer were produced via melt compounding.

Nanostructure was investigated by wide-angle X-ray diffraction and transmission electron microscopy. Scanning electron microscopy was employed to study the microstructure. Modulus of elasticity and yield strength were measured by uniaxial tensile test. Results show that silicate layers can only be observed inside polyamide particles. Moreover, polypropylene was unable to intercalate the selected grade of organoclay. While polyamide/organoclay system exhibited an exfoliated structure, the nanostructure of ternary nanocomposites was chiefly intercalated, due to the high concentration of silicate layers inside polyamide particles. Incorporation of organoclay into the polypropylene/polyamide system was observed to have a noticeable effect on the shape and size of polyamide particles. Finally, it was found that simultaneous incorporation of nanoclay and a second thermoplastic phase would affect different mechanical properties and generally have a synergistic effect. Clay mostly improves elastic modulus, while nylon affects yield stress and impact resistance.

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## All-PP Composites Based on $\beta$ and $\alpha$ Polymorphic Forms

J. KARGER-KOCSIS\*, T. BÁRÁNY

*Department of Polymer Engineering, Faculty of Mechanical Engineering, Budapest  
University of Technology and Economics, H-1111 Budapest, Hungary*

E-mail: [karger@pt.bme.hu](mailto:karger@pt.bme.hu)

Nowadays considerable efforts are being made to improve the properties of poly(propylene) (PP) (versatile thermoplastic) matrices by reinforcing it with fibres. Although excellent mechanical properties have been achieved in this way, life cycle assessment does not yield favourable results for PP composites when they are “traditionally” reinforced with glass fibres. Self-reinforced composites represent an effective alternative to the traditional fibre reinforced composites where the matrix and the reinforcement are from the same polymer, thereby supporting the ease of recyclability. This topic has gained interest since Porter et al. (mid 70s) showed the production of “single polymer composite” from polyethylene fibres and polyethylene matrix [1]. Later on the group of Ward [2] succeeded to convert a part of such fibres into matrix in which the residual fibres were embedded via “hot compaction”. This material is nowadays commercially available as Curv®. The creation of highly oriented, co-extruded PP tapes allows the production of recyclable “all-polypropylene” (all-PP) composites, with a large temperature processing window (20-40°C) and a high volume fraction of highly oriented PP. This concept explored by researchers in the last years and was commercialised under the trade name Pure® [3]. The most recent development with all-PP composites is to exploit the polymorphism-related difference in the melting range of beta( $\beta$ )-(matrix) and alpha( $\alpha$ )-phase (reinforcement) PPs carried out in our laboratory [4,5]. Note that the  $\beta$ -PP has a markedly lower melting point than the alpha version [6].

In this work, all polypropylene (all-PP) composites were manufactured from  $\alpha$ -PP tapes and  $\beta$ -PP matrix. The mechanical performance of the composite was investigated in a range of frequencies and temperatures using dynamic mechanical thermal analysis (DMTA). The volume fractions of matrix and reinforcement were estimated using optical microscope images. Both the DMTA and the static flexural bending tests revealed that the  $\alpha$ -PP tapes act as an effective reinforcement for the  $\beta$ -PP matrix.

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## Fracture Mechanisms of Halloysite-Epoxy Nanocomposites

L. YE<sup>1,2\*</sup>, J. ZHANG<sup>1</sup>, L. ZHOU<sup>1</sup>, S. DENG<sup>2</sup>, J. S. WU<sup>3</sup>

<sup>1</sup> *Dept of Mechanical Engineering, Hong Kong Polytechnic University  
Hung Hom, Kowloon, Hong Kong, China (SAR)*

<sup>2</sup> *School of Aerospace, Mechanical & Mechatronic Engineering  
The University of Sydney, NSW 2006, Australia*

<sup>3</sup> *Dept of Mechanical Engineering, Hong Kong University of Science & Technology  
University, Clear Water Bay, Kowloon, Hong Kong, China (SAR)*

E-mail: [l.ye@usyd.edu.au](mailto:l.ye@usyd.edu.au)

As a naturally existing clay mineral, consisting of unique tubular particles in nano-sizes, halloysite has recently attracted some research attentions, as a new type of additive for strengthening and toughening epoxies [1-3]. The recent results have demonstrated that blending epoxies with a certain amount of halloysite nanoparticles can noticeably increase their mechanical performance, such as fracture toughness, strength and modulus, without scarifying their thermal mechanical properties, such as glass transition temperature ( $T_g$ ) [2, 3]. The present study aimed to present strengthening and toughening mechanisms in halloysite-epoxy nanocomposites, characterized by the high-resolution TEM and SEM following tensile and compact tension (CT) tests. Various mechanisms such as, nanotube pull-out, nanoparticle pinning and bridging, etc., are observed after intensive TEM and SEM examination.

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## Electrospinning of Poly(vinylidene difluoride) and Polyimide Containing Carbon Nanotubes

T. X. LIU<sup>1\*</sup>, D. CHEN<sup>1</sup>, S. HUANG<sup>1</sup> AND X. H. LU<sup>2</sup>

<sup>1</sup> *Key Laboratory of Molecular Engineering of Polymers of Ministry of Education, Department of Macromolecular Science, Fudan University, Shanghai 200433, China*

<sup>2</sup> *School of Materials Science and Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 639798*

E-mail: [txliu@fudan.edu.cn](mailto:txliu@fudan.edu.cn)

Electrospinning is a simple technique used to produce fibers with diameters ranging from micrometers down to tens of nanometers. In this work, poly(vinylidene difluoride) (PVDF) solutions containing a very low concentration of single-walled carbon nanotubes (SWNT) and multiwalled carbon nanotubes (MWNT) of similar surface chemistry, respectively, were electrospun. The polymorphic behavior and crystal orientation of the electrospun nanofibers were studied using X-ray diffraction and infrared spectroscopy, while the nanotube alignment and interfacial interactions in the nanofibers were probed by transmission electron microscopy and Raman spectroscopy. It is shown that the interfacial interaction between the SWNT and PVDF and the extensional force experienced by the nanofibers in the electrospinning and collection processes can work synergistically to induce highly oriented  $\beta$ -form crystallites extensively. In contrast, the MWNT could not be well aligned along the nanofiber axis, which leads to a lower degree of crystal orientation.

Neat polyimide (PI) and high performance PI nanocomposite fibers containing different concentrations of MWNT were also produced by electrospinning. Membranes consist of highly aligned nanofibers were fabricated by collecting the electrospun nanofibers using a high speed rotating collector. The dispersion and alignment morphologies of MWNT as well as the mechanical and thermal properties of the membranes were systematically investigated.

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## Thermoplastics Reinforced by Scaffold-Like Filaments

GUOZHANG WU\*, JIAKUN SONG, BINGPENG LI

*School of Materials Science & Engineering, East China University of Science & Technology, Shanghai 200237, China*

E-mail: [wgz@ecust.edu.cn](mailto:wgz@ecust.edu.cn)

Short-Fiber Reinforced Plastics (SFRPs) are still under developing for better processability, good appearance and multi-functionalization. Except for the mechanical strength, many fibers, especially carbon fiber, endow themselves very high heat resistance as well as electrical and thermal conductivity. However, these characteristics are greatly weakened since the fibers are generally randomly dispersed and separated by the polymer matrix.

The research strategy of this work was to develop a series of SFRPs in which the short fibers are self-welded and built a three-dimensional continuous scaffold in the polymer matrix. By adding a small amount of the third component as “fastener”, the randomly dispersed short fibers could be fused together preferentially at their crossover points during the compounding and/or injection molding. We have already reported [1,2] a self-assembled carbon nano-fiber (CNF)/HDPE network throughout the PMMA matrix where the HDPE domains are preferentially absorbed at the ends of the CNF filaments. With addition of 1-5 wt% HDPE, the percolation concentration of CNF/PMMA composites was reduced remarkably from 8.0 phr to 1.5 phr due to the architecture of the conductive scaffold.

The research work was recently further extended to the glass fiber and metal fiber reinforced systems. Owing to the mechanical or electrical scaffold, we observed that the heat distortion temperature of glass fiber/ABS composites increases from 87°C to about 220°C, and the electrical resistivity of metal fiber/ABS mixtures could be reduced to  $10^{-4}\Omega\cdot\text{cm}$  by addition of only 5% metal fiber. Studies on influencing factors, processing conditions and structure characterization of the self-welded scaffold-like structure will be demonstrated in details on the presentation.

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## Alignment and Construction of Electrospun Nanofibers and Cables

H. YAN, L. Q. LIU AND Z. ZHANG\*

*National Center for Nanoscience and Technology, China, Beijing 100190, China*

E-mail: [zhong.zhang@nanoctr.cn](mailto:zhong.zhang@nanoctr.cn)

Morphology control of electrospun nanofibers is a major task to facilitate their wide applications. In this work, various dielectric materials were employed as collectors to prepare electrospun fiber mesh based on polyvinyl alcohol (PVA) and polyvinyl pyrrolidone (PVP) polymers. Experimental showed the nanofiber alignment is strongly depended on the collectors' relative static permittivity. Theoretical simulations revealed that the electric field can be tuned by different dielectric collectors. The horizontal electric field strength is the major factor to stretch electrospinning jet across the gap, and to eventually achieve the aligned fiber-mesh. Moreover, new methodology for constructing twist cables using electrospun nanofibers has been further developed. The length of the cable could reach up to several meters and the diameter about 20 to 50 microns constructed by single fibers with the diameter of several hundred nanometers. Mechanical properties of nanofiber twist cables were systemically investigated. This work is believed to be of help to the design of more complicate structures based on the electrospinning technique.

This work was jointly supported by National Natural Science Foundation of China (Grant No. 50753003), National Key Basic Research Program of China (Grant No. 2007CB936803), and a key item of the Knowledge Innovation Project of the Chinese Academy of Science (KJCX2-YW-M01).

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## **The Interfacial Engineering for the Fabrication of Epoxy Microfluidic-photonic-integrated Devices on Glass Substrates**

THOMAS KOWPAK<sup>1</sup>, BENJAMIN R. WATTS<sup>2</sup>, SHIPING ZHU<sup>1</sup>, CHANG-QING XU<sup>2</sup> AND ZHIYI ZHANG<sup>3\*</sup>

<sup>1</sup>*Department of Chemical Engineering,* <sup>2</sup>*Department of Engineering Physics, McMaster University, Hamilton, ON, Canada,* <sup>3</sup>*Institute for Microstructural Sciences, National Research Council Canada, Ottawa, ON, Canada*

E-mail: [zhiyi.zhang@nrcnrc.gc.ca](mailto:zhiyi.zhang@nrcnrc.gc.ca)

Fabricating epoxy SU-8-based microfluidic and photonic devices on glass substrates, such as pyrex wafers, has proven to be very difficult. The reason is that it is hard to completely remove residual material between patterned structures while obtaining sufficient bonding of the structures to the pyrex surface. The crosslinking reaction of epoxy photoresist SU-8, which is dictated by light exposure and post expose bake [1], unfortunately, affects both the removal of residual materials and the bonding in a conflict behavior. Although low exposure doses was found in favor of the elimination of residual material between structures while slow heating and cooling in favor of the bonding, the processing window allowing for low residual material and sufficient bonding is very narrow or does not exist by manipulating processing parameters alone. Consequently, we have tried to engineer the SU-8-pyrex interface to open the processing window and thus simultaneously eliminate the residual materials and achieve strong bonding.

Our first approach was to modify pyrex surface from hydrophilic to hydrophobic nature using hexamethyldisilazane (HMDS) coating and Omnicoat and even to introduce interfacial chemical reaction between SU-8 and pyrex using 3-glycidoxypropyltrimethoxysilane (GTMP) as a coupling agent, to improve the interface strength, which resulted in some limited improvements. The second approach included both the interfacial-strength improvement and interfacial-stress management because the coefficient of thermal expansion of SU-8 (CTE at 52ppm/°C) is substantially different from that of pyrex (CTE at 3.25ppm/°C), and the required high post baking temperature of SU-8 (90°C) can make the situation even worse. To achieve the both goals, we introduced an intermediate layer using a specialty epoxy photoresist. The material is known to have a good adhesion with glass and is compatible with the epoxy photoresist SU-8 used in device fabrication. It was pre-coated on pyrex and fully cured before SU-8 was processed. A 180 nm thick layer of such a material was determined to be the minimum intermediate layer thickness required to provide low to no residual material and sufficient bonding that can withstand the post dicing procedures. With this intermediate layer, the processing window is wide enough to allow the simultaneous elimination of the residual materials between the pattern structures and achievement of strong bonding, and thus the fabrication of quality SU-8microfluidic-photonic-integrated devices on glass wafers.

## Invited Lectures

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## Dielectric and Dynamic Relaxations in Polypropylene Organoclay Nanocomposites

YEH WANG\*, SYH-W. HUANG AND JIANG-Y. GUO

*Department of Chemical Engineering, Tunghai University  
Taichung, Taiwan*

E-mail: [yehwang@thu.edu.tw](mailto:yehwang@thu.edu.tw)

The dynamic mechanical and dielectric relaxation properties of maleic anhydride grafted polypropylene (PPgMA) and its clay filled nanocomposites with different degree of clay exfoliation have been investigated. Fully and partially exfoliated samples were prepared through powered sonication and melt blend, respectively. Our results indicated that both mechanical and relaxations can be identified. The glass transition of the nanocomposites shifted to slightly lower temperatures for nearly all formulations due to reduced chain cooperative motion. However, the broad transition became more distinct with increasing clay loading for sonicated nanocomposites, and shifted to higher temperatures due to chain confinement of amorphous polymer chains in the crystalline region. The reinforcement in the glassy storage modulus  $E'$  of PPgMA was examined by the Halpin-Tsai theory. The smaller thickness of clay stacks in the fully exfoliated nanocomposites led to significant increase in reinforcing efficiency. Only a single high-temperature process due to interfacial polarization was observed in broadband dielectric measurements because of nonpolar polypropylene backbone in PPgMA with very low MA content. Dielectric dispersion parameters were identified that appear sensitive to clay loading and degree of exfoliation. Specific to clay content is that the Maxwell–Wagner strength of dispersion, increases with increasing clay weight fraction. The nanomorphology is primarily reflected in the Maxwell–Wagner characteristic relaxation frequency value,  $f_{\max}$ , where samples with higher degree of exfoliation showed lower relaxation rate. The relaxation time constant, which is the reciprocal of  $2 f_{\max}$ , can be correlated with mean distance of clay layer separation in the nanocomposites and therefore provides additional information on exfoliation of clay platelets. Furthermore, we have found significance difference in the dc conductivity,  $\sigma_{dc}$ , of the nanocomposites. For fully exfoliated samples,  $\sigma_{dc}$  is much larger than that of partially exfoliated ones. In addition a percolation-like dependence of  $\sigma_{dc}$  with clay loading was also seen in both nanocomposites, and again fully exfoliated samples showed sharper increase of  $\sigma_{dc}$  around percolation threshold.

### ACKNOWLEDGEMENT

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## Invited Lectures

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## Ultrasonic Measurement for High Frequency Viscoelastic Behavior of Composites

QING-QING NI<sup>1\*</sup>, TETSUYA KUNIZAWA<sup>2</sup>, YINHUA ZHAO<sup>3</sup>

<sup>1</sup>*Dept of Functional Machinery & Mechanics, Shinshu University, 3-15-1 Tokida, Ueda, 386-8567, Japan*

E-mail: [niqq@shinshu-u.ac.jp](mailto:niqq@shinshu-u.ac.jp)

<sup>2</sup>*Sumitomo Rubber Industries, LTD., Kobe, Japan*

<sup>3</sup>*Dalian Maritime University, # Linghai Road, Ganjingzi Dist, Dalian, China*

In this paper, a viscoelastic measuring method by using the ultrasonic device at a high frequency range was proposed for rubber compounds. The measurable frequency is usually lower than  $10^2$  Hz by the conventional dynamic viscoelasticity method because of the limit of machinery, while it is possible to measure the viscoelasticity at high frequency of  $10^6$  Hz level or more in case of using the ultrasonic device. The viscoelastic properties by the dynamic mechanical analysis (DMA) and ultrasonic method were compared using several rubber samples. As a result, some differences are observed between these two methods. In addition, the maximum friction coefficient (Max- $\mu$ ) at wet condition was investigated for several rubber samples and the relationship between Max- $\mu$  and  $\tan\delta$  was made clear. It is shown that ultrasonic viscoelasticity is very beneficial one for estimating frictional characteristics and physical properties in a high frequency region for rubber compounds.

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## **Bistable Electrical Switching and Electronic Memory Effects in Electroactive Polymer Nanocomposites**

G. LIU<sup>1</sup>, C. X. ZHU<sup>2</sup>, K. G. NEOH<sup>1</sup> AND E. T. KANG<sup>1\*</sup>

<sup>1</sup>*Department of Chemical & Biomolecular Engineering, National University of Singapore, Kent Ridge, Singapore 119260*

<sup>2</sup>*Department of Electrical & Computer Engineering, National University of Singapore, Kent Ridge, Singapore 119260*

E-mail: [cheket@nus.edu.sg](mailto:cheket@nus.edu.sg)

Electrical switching and memory phenomena in polymers have emerged as an active research topic in organic electronics in recent years. Polymer electronic memories are potentially an alternative or a supplementary technology to the conventional memory technology facing challenges in miniaturizing from micro- to nano-scale. With an understanding of the current state of memory technology and the basic concepts of electronic memories, the historical development of polymer electronic memories can be classified into three categories by drawing the mechanistic analog between the polymer memory element and one of the three primary circuit elements, *viz.*, capacitor, transistor and resistor. Resistive random access memories (RRAM) based on electroactive polymer nanocomposites have been great interest and have been widely studied [1]. In this work, it is illustrated that by merely varying the carbon nanotube (CNT) content in the composite thin films, the electrical conductance switching of the indium-tin oxide/poly(*N*-vinylcarbazole)-CNT/aluminium (ITO/PVK-CNT/Al) sandwich structures can be tuned in a controlled manner. Four types of distinctly different electrical behaviors, *viz.*, insulator, write-once read-many-times (WORM) memory, rewritable memory and conductor are discernible from the current density-voltage characteristics. The turn-on voltage of the two bistable conductance switching devices decreases and the ON/OFF state current ratio of the WORM device increases, with the increase in CNT content of the composite films. Both the WORM and rewritable devices are stable under a constant voltage stress or a continuous pulse stress, with an ON/OFF state current ratio in excess of  $10^3$ . The conductance switching has been attributed to electric field-induced charge carrier tunnelling between CNTs in the PVK matrix.

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## Deformation and Fracture Behaviour of PP-MWNT Nanocomposites

MARTIN GANß<sup>1</sup>, BHABANI K. SATAPATHY<sup>2</sup>, MAHENDRA THUNGA<sup>1,3</sup>,  
ROLAND WEIDISCH<sup>1,3\*</sup>, PETRA PÖTSCHKE<sup>3</sup>, ANDREAS JANKE<sup>3</sup>, DIETER  
JEHNICHEN<sup>3</sup>,

<sup>1</sup>*Institute of Materials Science and Technology (IMT), Friedrich-Schiller-University  
Jena, Löbdergraben 32, D-07743 Jena, Germany*

<sup>2</sup>*Centre for Polymer Science and Engineering, Indian Institute of Technology Delhi,  
Hauz Khas, 110016 New Delhi, India*

<sup>3</sup>*Leibniz Institute of Polymer Research Dresden, Hohe Strasse 6, D-01069 Dresden,  
Germany*

E-mail: [roland.weidisch@uni-jena.de](mailto:roland.weidisch@uni-jena.de)

Recently, polymer-nanocomposites reinforced with carbon nanotubes (CNT) have attracted steadily growing interest in science and engineering because of the excellent properties as well as several functional applications. In this work we investigate the deformation and fracture behaviour of polypropylene-multi-walled carbon nanotube (MWNT) composites with uniaxial tensile test and essential work of fracture approach (EWF) based on post yield fracture mechanics. In addition to an increase of the Young's modulus and the yield stress with increasing MWNT-content, we observed a transition from ductile-to-semiductile transition in the crack resistance behaviour. The possible interrelation between deformation and fracture behaviour to the morphology is discussed on the basis of TEM, AFM, WAXD and polarisation microscopy studies. A maximum in the non-essential work of fracture was observed at 0.5 wt.-% MWNT demonstrating enhanced resistance to crack propagation compared to pure PP, followed by a sharp decline with the increase in MWNT content to 1.5 wt.-% revealing a ductile-to-semiductile transition, affirmed with SEM investigation of the fracture surfaces. Fracture kinetics studies presents a qualitative picture of the nature of such a transition in terms of (a) switch over from non-steady (in pure PP) to steady state crack tip opening displacement (CTOD) rate (in nanocomposites) and (b) ductile-to-semiductile transition; largely due to delayed-yielding of the nanocomposites.

## Microstructure-Property Relations in Polymer/Carbon Nanotube Materials

ARAVIND DASARI<sup>1</sup>, ZHONG-ZHEN YU<sup>2\*</sup> AND YIU-WING MAI<sup>1</sup>

<sup>1</sup> *Centre for Advanced Materials Technology (CAMT), School of Aerospace, Mechanical and Mechatronic Engineering J07, The University of Sydney, Sydney, NSW 2006, Australia*

<sup>2</sup> *Beijing Key Laboratory on Preparation and Processing of Novel Polymeric Materials, Department of Polymer Engineering, College of Materials Science and Engineering, Beijing University of Chemical Technology, Beijing 100029, China*

E-mail: [yuzz@mail.buct.edu.cn](mailto:yuzz@mail.buct.edu.cn)

It is well known that incorporation of conducting fillers such as carbon black, graphite, metal particles, carbon fibers and carbon nanotubes can make insulating polymers electrically conductive [1]. But mechanical properties (particularly, toughness and ductility) of these materials, in general, are negatively affected as higher loadings are required to achieve the electrical percolation threshold in thermoplastic polymers. ‘Volume exclusion’ concept has been successfully used in the past to reduce the percolation threshold loading of conductive fillers [2]. Here, immiscible polymer blends are used and the fillers are selectively located in either of the polymer phases or along the interface. However, immiscible blends tend to form a co-continuous morphology or a sea-island microstructure with very large domains, which are again not beneficial for mechanical properties of the conductive blend. Therefore, the fundamental objective of this work is to improve both electrical conductivity and toughness of polyamide. For this purpose, a ‘ternary nanocomposites’ approach [3] is adopted where carbon nanotubes are used as a nano-reinforcement to achieve conductivity (and improve elastic modulus and strength of the nanocomposite) and grafted maleic anhydride polyethylene-octene copolymer (POE-g-MA) as a toughening agent. The results show the importance of obtaining the correct and controlled microstructure in hybrid ternary polymer nanocomposite, which possesses better properties than either of the constituent binary polymer nanocomposites. The absence of nanotubes inside the rubber particles and their presence in the continuous matrix enhanced the electrical conductivity due to ‘volume exclusion’ effect; whereas the dispersed rubber particles were able to participate in the toughening processes similar to binary polymer/rubber blends increasing the notched impact energy of the nanocomposites.

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## **Tribological Behaviour of Selected Engineering Polymers under Rolling Contact**

M. HARRASS<sup>1</sup>, K. FRIEDRICH<sup>2\*</sup> AND A. A. ALMAJID<sup>3</sup>

<sup>1</sup>*Vossloh Fastening Systems GmbH, 58791 Werdohl, Germany*

<sup>2</sup>*Institut für Verbundwerkstoffe GmbH (Institute for Composite Materials), Technical University of Kaiserslautern, 67663 Kaiserslautern, Germany, and King Saud University, Riyadh, Saudi Arabia*

<sup>3</sup>*College of Engineering, King Saud University, Riyadh, Saudi Arabia*

E-mail: [klaus.friedrich@ivw.uni-kl.de](mailto:klaus.friedrich@ivw.uni-kl.de)

The motion and power transmission in machines occurs often by components like gears or rolls which ensure the operating of technical units and therefore guarantee the functioning of the total system. Because of the surface geometries of these power transmission components, the mainly kind of driving is a rolling motion – often accompanied by a sliding motion. Frequently, components working under these conditions are manufactured out of polymers though their behavior is insufficient accurately known by now.

Therefore, this article deals with the tribological behavior of mainly commercially available polyamide 6 (PA 6), polyoxymethylene (POM) and polyetheretherketone (PEEK) materials under stress in rolling-/sliding contact. A further material examined under these conditions is a novel PA 6 material, filled with special ceramic particles.

For the experimental investigations of the polymer materials, mostly tested as plates, different rolling wear testing rigs were used. These machines are working according the ball-on-plate principle, i.e. a steel ball (as counterpart) rolls on a polymer plate specimen in rotational or linear motions. The construction of these new types of wear machines with their specific testing configuration as well as an analytical approach for the necessary determination of the rolling wear amount is described in a detailed manner.

The basis of the investigations represents the appropriateness of different unfilled polymer materials following their resistance against rolling wear. Then, the ability of various fillers and reinforcements, added to the polymers, shall be identified to optimize the behaviour against rolling stress.

The results are shown under different stress parameters which vary by load (100 N up to maximal 2000 N) and testing time (up to 50 hours). As a major result, all reinforced polymer materials show an insufficient suitability in rolling-sliding contact, as compared with the unfilled materials. Only the PA 6 filled with ceramic particles demonstrates an increasing in the resistance against rolling wear. The reasons for the fitness or the failure of the materials are shown on the basis of the wear mechanisms, and they are discussed in a detailed manner.

## Introducing Reactive Groups into Polymer Chains by Radiation Induce Grafting Technique

MING YU, BO DENG, LINFAN LI, LEIDONG XIE, ZHENGCHI HOU,

XIAOFENG LU AND JINGYE LI\*

*Department of Radiation Chemistry and Processing, Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai 201800, China*

E-mail: [jingyeli@sinap.ac.cn](mailto:jingyeli@sinap.ac.cn)

Reactive groups such as acid groups, epoxy groups can be introduced into polymer chains by radiation induced graft polymerization technique. The general procedure of pre-irradiation induced grafting technique can be divided into two steps. Firstly, the base polymers are irradiated by  $\gamma$ -ray from  $^{60}\text{Co}$  source or electron-beam to form macromolecular radicals or peroxides. Then, the irradiated polymers are put into monomer solutions or emulsions to initiate the graft polymerization.

In the present work, an epoxy-group-containing monomer, glycidyl methacrylate, (GMA) was grafted onto poly(vinylidene fluoride) (PVDF) powder by pre-irradiation induced emulsion graft polymerization. The existing of graft chains was proved by FTIR spectroscopy study. The grafting kinetic was studied and the degree of grafting can be controlled in a very large scale from 10% to 90%.

The epoxy groups on the graft chains have relative high reactivity. In mixture solution of NaOH and ethanol, PVDG-g-PGMA reacted with 1.6M taurine for 48hours, the conversion ratio of the epoxy groups can reach 61.97%.

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## **An Alternative Route for Designing Functional Nanocomposites from the Synthesis of Nanostructured Hybrid Organic-Inorganic Polymers Based on Metal-Oxo Clusters**

JEAN-FRANÇOIS GERARD<sup>1\*</sup>, JOCELYNE GALY<sup>1</sup>, N. ZAFEIROPOULOS<sup>2</sup>, M. STAMM<sup>2</sup>, CLÉMENT SANCHEZ<sup>3</sup>, LAURENCE ROZES<sup>3</sup> AND GIULA FORNASIERI<sup>3</sup>

<sup>1</sup>*Université de Lyon – UMR CNRS #5223 Ingénierie des Matériaux Polymères  
INSA Lyon– 69621 Villeurbanne Cedex, France*

<sup>2</sup>*Leibniz Institute für Polymerforschung Dresden e.V. - 01069 Dresden, Germany*

<sup>3</sup>*Laboratoire Chimie Matière Condensée UMR CNRS #7574 - LCMC Université  
Pierre & Marie Curie - 75252 PARIS Cedex 05, France*

E-mail: [jean-francois.gerard@insa-lyon.fr](mailto:jean-francois.gerard@insa-lyon.fr)

Hybrid nanocomposite materials, denoted I/O hybrids, based on an inorganic phase and an organic phase that can be physically mixed (Type I I/O hybrids) or covalently connected at a nanometer level (Type II I/O hybrids) are of a large interest to combine the properties of the organic and inorganic moieties and nanostructured materials. In fact, a large variety of architectures and morphologies can be designed. Thus, such materials could be considered as innovative advanced materials and promising application are expected in many fields, such as optics, electronic, mechanics, membranes, protective coating, catalysis, sensors, etc.

The conventional route for processing such materials involves the well-known sol-gel chemistry that allows to synthesize the final material starting from molecular metal precursors combined with monomers, oligomers, or polymers. The synthesis is based on the hydrolysis and condensation of organically-modified metal alkoxides i/ in the presence of a polymer or ii/ organic monomers as well as iii/ grafted groups on an organic oligomer. Such a route, which can be done in soft conditions, implies a precise control of the different steps and reaction conditions such as pH, temperature, stoichiometric ratio, rate for solvent and volatile moieties, etc. A better definition on the organic-inorganic interface can be achieved by use of defined organic-inorganic bricks, i.e. nanobuilding blocks such as metal-oxo clusters which can be assembled from their homopolymerization or copolymerization with organic precursors, i.e. monomers or functional oligomers. The well-known POSS, polyoligomeric silsesquioxanes, are one type of such metal-oxo clusters. In fact, the introduction of an inorganic nanophase having a controlled reactivity with the surrounding polymer chains could allow to i/ design nanostructured linear polymers or networks ii/ understand the proper length scale at which the design of an inorganic phase needs to be done or the architecture of the I/O nano-object. The purpose for choosing to use I/O nanoclusters instead of preformed inorganic nano-objects such as fumed silica is related to the fact that they are smaller than those conventional inorganic objects and one can consider them as a molecule or as a nanofiller particle. As a consequence, the final question is: Are such nanobuilding blocks efficient nanofillers? What type or combination of properties can be achieved from the use of such I/O nanoclusters?

In this lecture, different synthesis routes for designing new nanostructured polymer

## Invited Lectures

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materials, i.e. nanocomposites or hybrid organic-inorganic nanomaterials, are described with a special emphasis of that one based on the introduction and assembling of organic-inorganic nanobuilding blocks, methacrylate-polyoligomeric silsesquioxanes, POSS, (mono and multifunctional) or titanium based nanoclusters, methacrylate-functionalized  $Ti_{16}O_{16}(OEt)_{32}$ . The different routes are reviewed for a given type of polymer chemistry, i.e. free radical polymerization of methacrylate or dimethacrylate monomers leading to nanostructured thermosets or thermoplastics. These syntheses used for processing hybrid organic-inorganic materials from neat organic polymer (TP or TS) to organic/inorganic materials based up to 15 wt. % of inorganic phase will be used to compare the achieved properties of the resulting O/I nanomaterials.

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## **Influence of Surface Modification of Fibre on Wettability and Mechanical Properties of Banana Fibre / Phenol Formaldehyde Resin Composites Fabricated by Resin Transfer Molding**

K. N. INDIRA<sup>1</sup>, Y. GROHENS<sup>2</sup>, C. BALEY<sup>2</sup>, S. THOMAS<sup>3</sup>, K. JOSEPH<sup>4</sup>, L. A. POTHEN<sup>5</sup>

<sup>1</sup>*TKMM College, Nangiarkulangara, Alappuzha, Kerala, India*

<sup>2</sup>*Labaratoire Polymers, L2PIC, Universite de Bretagne Sud, Lorient Cedex, France*

<sup>3</sup>*School of Chemical Sciences, Mahatma Gandhi University, Kottayam, Kerala, India*

<sup>4</sup>*Indian Institute of Space Technology, Thiruvananthapuram, Kerala, India*

<sup>5</sup>*Bishop Moore College, Mavelikkara, Alappuzha Kerala, India*

E-mail: [sabut@sancharnet.in](mailto:sabut@sancharnet.in)

This paper describes the influence of various chemical treatments on the fibre/matrix compatibility in terms of surface energy and mechanical properties of composites. Composites were prepared by Resin Transfer Moulding (RTM) technique. The modifications done in the present case are alkali treatment, silanation, benzoylation, potassium permanganate treatment, formylation and acetylation. The effects of treatments on the fibres have been characterized by Fourier Transform Infra Red Spectroscopy (FTIR). Dynamic contact angle method has been used to determine the surface energy values. Of all the modifications, the relative surface energy was found to be maximum for alkali treated fibre and minimum for benzoylated fibre. The experimental results show that mechanical properties of the mercerized fibre are better than other treated fibres. The chemical modification with vinyl trimethoxy silane, benzoyl chloride and acetic anhydride results hydrophobic nature to the fibre.

## **Effects of Modifiers on the Thermal, Dynamic Mechanical and Frictional Properties of Sisal Fiber/Phenolic Resin Composites**

MING ZENG, CHUN WEI \*

*Department of Material and Chemical Engineering, Guilin University of Technology,  
Guilin 541004, China*

*Key Laboratory of New Processing Technology for Nonferrous Metals , Ministry of  
Education, Guilin University of Technology, Guilin 541004, China*

E-mail: [glweichun@glite.edu.cn](mailto:glweichun@glite.edu.cn)

Different surface modifiers (alkali, coupling agent and borax[1] ) were used to treat sisal fiber. The phenolic resin modified by nanoparticles was used to prepared the composites through compression molding . The thermal properties of the composites had been studied by Thermo gravimetric analysis (TG) and Dynamic mechanical analysis (DMA).The frictional properties was investigated on M-2000 wear tester in dry friction condition. The abrasion surfaces of composites were observed by scanning electron microscope (SEM). Results indicated that different treatments on sisal fiber can improve the thermal stability of the fiber composites. The initial decomposition temperature of composites modified by alkali was 399.71°C, which increased by 28°C, compared to the untreated fiber composites. Dynamic mechanic analysis revealed that the storage modulus and glass transition temperature of treated fiber composites were all higher than the untreated fiber composites. This was due to the greater interfacial bond strength between the matrix resin and the fiber [2-3].The frictional test revealed that the surface treatment of sisal fiber had little effect on the friction coefficient but improved the anti-wear properties of the composites. The wear volume treated by the borax decreased by 73.3%, compared to the untreated fiber composites.

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## **Dynamic and Static Fatigue of Unidirectional Carbon Nanotube Rope Reinforced Polymer Composites**

Z. R. ZHOU<sup>1</sup>, H. M. CHENG<sup>2</sup> AND K. LIAO<sup>1\*</sup>

<sup>1</sup>*School of Chemical and Biomedical Engineering, Nanyang Technological University, Singapore 639798*

<sup>2</sup>*Shenyang National Laboratory for Materials Science, Institute of Metal Research, Chinese Academy of Sciences, Shenyang 110016, PRC*

E-mail: [askliao@ntu.edu.sg](mailto:askliao@ntu.edu.sg)

Although the mechanical properties of carbon nanotubes (CNTs) have been extensively studied in recent years, the question that how long these nanometer-sized tubes can last when subjected to prolonged static or cyclic mechanical loading remains unanswered. Here we report a study on the long-term behavior of unidirectional, aligned single-walled carbon nanotube (SWCNT) ropes and their composites, wherein the dynamics and static fatigue behavior of SWCNT ropes embedded in polymer matrix were studied. It is found that SWCNT ropes do fatigue under sustained mechanical load. Bench marking against the behavior of graphite fiber, it is found that the static fatigue strength of SWCNT ropes is at least twice that of graphite fiber within  $10^4$  s and similar to that of graphite fiber at longer times, while their dynamic fatigue strength is twice that of the graphite fiber, to  $10^7$  cycles. Similar to conventional engineering materials, fatigue limits seem to exist for SWCNT ropes within the time scale of the investigation. We will also highlight a molecular life prediction scheme and compare the SWCNT fatigue data to theoretical predictions. Combining with a recent study in defect-defect interaction in SWCNTs, we will examine the effect of interacting defects on fatigue behavior of SWCNTs. Based on microscopy observations and results of the molecular life prediction model, it is suggested that the fatigue behavior of SWCNT ropes may be controlled by preexisting defects.

## Interfacial Studies of Natural Fiber Reinforced Composites

Y. LI<sup>1,2\*</sup>, X. CHEN<sup>1</sup>, F. LV<sup>2</sup> AND Y. LUO<sup>1</sup>

<sup>1</sup>*School of Aerospace Engineering and Applied Mechanics*

<sup>2</sup>*Key Laboratory of Advanced Civil Engineering Materials, Ministry of Education*

*Tongji University, Shanghai 200092, China*

E-mail: [liyana@tongji.edu.cn](mailto:liyana@tongji.edu.cn)

Natural fibers are promising reinforcements for use in composite materials due to the low cost, high specific strength and modulus, easy availability, especially the renewability and environmental friendly characteristics. Natural fiber reinforced polymers (NFRPs) have raised great attentions and interests among material scientists and engineers in recent years. However, the poor interfacial bonding between the hydrophilic natural fibers and the hydrophobic polymers is a major obstacle for the application of this material. Many researches related to the interfacial properties of NFRPs have been conducted [1]. Among those studies, the unique structures of natural fibers have seldom been considered. Conventional methods which are normally used for studying the regular and uniform man-made fiber reinforced composites were borrowed directly. These would definitely lead to the discrepancy from the true values.

In this paper, the multi-scale structures of two kinds of natural fibers (ramie and sisal) which were extracted from different plant sources were clearly revealed with the aid of scanning electronic microscopy (SEM). Interfacial parameters, such as the interfacial fracture toughness,  $G_{ic}$ , coefficient of friction,  $\mu$ , and the residual fibre clamping stress,  $q_0$  were obtained based on the single fiber pull out tests and Gao-Mai-Cotterel model[2]. Effects of fiber surface treatments on the interfacial properties of NFRPs were explained by the quantitative parameters. It showed that fiber surface treatments can improve the interfacial bonding of NFRPs effectively. However, moisture absorption led to a decreased interfacial property. A modification on the Gao-Mai-Cotterel model with the consideration of the complicated structures of natural fibers was attempted. The validity of the model was examined by the experimental results. It showed that the pull-out forces for a single natural fiber from the polymer matrix calculated by the modified model had good agreement with the experimental values. The very close results obtained by both Gao-Mai-Cotterel model and the modified one may also indicate that the irregularity of the diameter of natural fiber along its length may be neglected for the study of the interfacial properties of NFRPs.

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## Mechanical Properties of Ramie Fiber Reinforced Automobile Interior

LI-PING HE\*, DIAN-WU ZHOU, ZHIHUA ZHONG AND TIAN YONG

*State Key Laboratory of Advanced Design and Manufacture for Vehicle Body (Hunan University), College of Mechanical & Vehicle Engineering, Hunan University, Changsha, Hunan 410082, P.R. China*

E-mail: [elisahk\\_2003@yahoo.com](mailto:elisahk_2003@yahoo.com)

For many years, glass and carbon fiber have been the accepted traditional reinforcements to polymers. But now many people have recognized that glass fiber is difficult to be disposed and carbon fiber is too expensive. Natural fibers are realistic alternative reinforcement because of the advantages of their low cost, relatively high toughness, good thermal properties and excellent environmental performance, and their reinforced polymer composites have attracted a lot of attention in automobile industry as environmental friendly and recycleable materials. This work has successfully fabricated ramie fiber reinforced polypropylene composites (RF/PP) with injection moulding method, which is more economic than press moulding method. RF/PP is fabricated by blending treated RF with PP using a twin-screw extruder and then making them as blended pellets. The blended pellets were subsequently injection molded to obtain the ramie fiber reinforced polymer composites. The effects of fiber length, fiber content and fiber treatment method on the mechanical properties of the fabricated RF/PP composites being applied as automobile interior were investigated using an Instron computer-controlled testing machine at room temperature. The morphologies of the RF/PP composites were investigated by a scanning electron microscope (JSM-5610). It is found that the increases of fiber length and fiber addition can improve the tensile strength, flexural strength and compression strength apparently with slight decrease of the impact strength. The treatment of ramie fiber can not only clean the fiber surface, but also modify its microstructure. This is good to get better mechanical properties of RF/PP composites.

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## **Kinetic of Poly(ethylene glycol) Monomethacrylate (PEGMA) Grafted from Silicon(100) Surface to Form Polymer Brush**

PENG JIN-WEN\*, DENG WEI-XING

*Key Laboratory of New Processing Technology for Nonferrous Metals and Materials,  
Ministry of Education; Department of Materials and Chemical Engineering, Guilin  
University of Technology, Guilin 541004, China*

E-mail: [jwpeng@glite.edu.cn](mailto:jwpeng@glite.edu.cn)

ATRP can cater for the requirements which are essential to bind well-defined polymer brushes covalently to the surface of a silicon solid surface <sup>[1-2]</sup>. In this paper the kinetics of poly(ethylene glycol) monomethacrylate grafted from silicon (100) surface to form poly(poly(ethylene glycol) monomethacrylate) (P(PEGMA)) polymer brush was investigated. A covalently bonded, (Si-C bonded), VBC monolayer (the Si-VBC surface) was formed via UV induced coupling of the vinyl group of VBC with the Si-H surface <sup>[3]</sup>. The monolayer VBC was employed for the surface-initiated ATRP. Then PEGMA was grafted from silicon(100) surface to form polymer brush via surface-initiated ATRP. The modified silicon surfaces were characterized by X-ray photoelectron spectroscopy (XPS), ellipsometry and telescopic goniometer. The presence of grafted P(PEGMA) from the Si-VBC surface was confirmed by XPS and ellipsometry measurement. The thickness of the grafted P(PEGMA) (from the Si-VBC surfaces) brushes, obtained after 2 h of ATRP, is about 11 nm. Their corresponding surface graft density was estimated to be 63 equivalent monomer units/nm<sup>2</sup>. The static water contact angle of the Si-VBC surface was about 83°. In the presence of grafted P(PEGMA) brushes, the surface still maintains hydrophilic and the static water contact angle is 55°. This data is the same as P(PEGMA) with bulk polymerization. The thickness of the grafted P(PEGMA) brushes on the initiator surfaces increases approximately linearly with polymerization time. These results suggest that the chain growth from Si-VBC surface is consistent with a “controlled” or “living” process.

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## **Dispersibility and Surface Functionality of CNTs for Polymer Nanocomposites**

PENG-CHENG MA, NAVEED A. SIDDIQUI, MIAO XU, RUI WANG AND  
JANG-KYO KIM\*

*Department of Mechanical Engineering, Hong Kong University of Science and  
Technology, Clear Water Bay, Kowloon, Hong Kong, China.*

E-mail: [mejkkim@ust.hk](mailto:mejkkim@ust.hk)

CNT/polymer nanocomposites hold the promise of delivering exceptional mechanical properties and multi-functional characteristics. The potential of employing CNTs as reinforcements has, however, been limited because of the difficulties associated with dispersion of CNTs during processing and poor interfacial interactions between CNTs and polymer. For effective reinforcement of CNTs in a composite, proper dispersion and interfacial adhesion have to be guaranteed.

For proper dispersion, a technique based on pre-dispersion of CNTs in a solvent, followed by mixing with a monomer or a polymer has been proven to be effective. However, the evaluation of CNT dispersion in a solvent is not a trivial matter due to the non-transparency even at a very low CNT concentration and no proven method to rate the dispersion quality. Observation of the fraction of CNTs remaining after dispersion with naked eyes or using a digital photograph has been most widely used to provide qualitative CNT dispersibility.

This paper proposes the correlation between the electrokinetic potential and the degree of CNT functionalization in terms of surface energy and oxygen content. Multi-walled carbon nanotubes (CNTs) with two different surface conditions, i. e. as-produced (AP) and ethanol treated (ET), were subjected to UV/ozone treatments of varying durations, resulting in changes in oxygen content and surface energy. Zeta potentials of several different colloidal systems consisting of CNTs dispersed in different solvents, such as water, ethanol and hexane, were measured to evaluate quantitatively CNT dispersion in these liquids.

The absolute zeta potential values increased consistently with increasing the duration of prior UV/O<sub>3</sub> treatment, the increase being most pronounced in a hydrophilic liquid such as water. This is attributed to the attachment of functional groups on the CNT surface after treatment, which was further confirmed by the elemental composition of CNT surface. The O/C ratio of CNT surface increased by more than 10 times after 60 min of UV/ozone treatment. The surface energies of the CNTs after functionalization were determined from the contact angles of CNT films. There was approximately a linear correlation between the surface energy and the O/C ratio. It is seen that the CNT dispersibility in a liquid is affected by the hydrophilicity of CNT surface, which is reflected by the potential value because the surface functionality promoted by UV/O<sub>3</sub> treatment could resist aggregation. Judging from these observations, 25 mV can be regarded as the threshold zeta potential value, above which the CNT dispersion is stable.

## Direct Formation of Nanohybrid Shish-kebab in The Injection Molded Bar of Polyethylene/Multi-walled Carbon Nanotubes Composite

QIANG FU\*, KE WANG, CAOYU WANG

*Department of Polymer Science and Materials, State Key Laboratory of Polymer Materials Engineering, Sichuan University, Chengdu 610065, People's Republic of China*

E-mail: [qiangfu@scu.edu.cn](mailto:qiangfu@scu.edu.cn)

The formation of nanohybrid shish-kebab (NHSK) superstructure, in which fibrillous carbon nanotubes (CNTs) act as shish while polymer lamellae as kebab, is a novel way to bond polymer and CNTs together and was first observed in the solution crystallization of polyethylene in the presence of CNTs<sup>[1-3]</sup>. However, NHSK superstructure formed directly in the processing product has rarely been reported<sup>[4]</sup>. In our study, a so-called dynamic packing injection molding technology (DPIM) was adopted to achieve fine nanohybrid shish-kebab (NHSK) superstructure directly in the injection-molded bar of high-density polyethylene (HDPE)/multi-walled carbon nanotubes (MWCNTs) composite. Interestingly, whatever the long axis of CNTs is perpendicular to or parallel to the shear flow direction, the lamellae of PE is always perpendicular to long axis of CNTs, as shown in Figure 1. Importantly, the NHSK structure can bring significant mechanical reinforcement in the HDPE/MWCNTs composite. For the oriented composites containing 5% MWCNTs, its tensile strength is increased by 150% and 270%, compared to the oriented pure HDPE and the isotropic composites containing 5% CNTs, respectively; meanwhile, its Young's modulus is enhanced by 130% and 180%, compared to the oriented pure HDPE and the isotropic composites containing 5% CNTs, respectively. This work is the first to enlarge the theoretical value and application potential of NHSK structure in the crystallizable polymer/CNTs composite.

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## Viscoelasticity of Multi-component Polymer Systems

QIANG ZHENG\*

*Key Laboratory of Macromolecular Synthesis and Functionalization, Ministry of Education,*

*Department of Polymer Science and Engineering, Zhejiang University, Hangzhou 310027, China*

E-mail: [zhengqiang@zju.edu.cn](mailto:zhengqiang@zju.edu.cn)

Rheological measurement has been an effective method to characterize the structure and properties for multiphase/multi-component polymers, owing to its sensitivity to the structure change of heterogeneous systems<sup>1,2</sup>. In this article, recent progress in the studies on the morphology/structure and rheological properties of heterogeneous systems is summarized, mainly reporting the findings of the authors and their collaborators, involving the correlation between the morphology and viscoelastic relaxation of LCST-type polymer blends, the microstructure and linear/nonlinear viscoelastic behavior of block copolymers, time scaling of shear-induced crystallization and rheological response of polyolefins, and the relationship between the structure/properties and rheological behavior of filled polymer blends. It is suggested that a thorough understanding of the characteristic rheological response to the morphology/structure evolution of multiphase/multi-component polymers facilitates researchers' optimizing the morphology/structure and ultimate mechanical properties of polymer materials.

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## On the Durability Test of an Ionic Polymer-Metal Composite Actuator Based on PSMI-Incorporated PVDF

IL-KWON OH<sup>1</sup>, SANG-GYUN KIM<sup>2</sup>, SUNWOO LEE<sup>3</sup> AND JUN LU<sup>4\*</sup>

<sup>1</sup>*School of Mechanical Systems Engineering, Chonnam National University, 300 Yongbong-dong, Buk-gu, Gwang-Ju, 500-757, Republic of Korea*

<sup>2</sup>*Membranes & Separation Research Center, Korea Research Institute of Chemical Technology, P.O. Box 107, Yuseong, Daejeon 305-600, Republic of Korea*

<sup>3</sup>*Department of Chemistry, Chonnam National University, 300 Yongbong-dong, Buk-gu, Gwang-Ju, 500-757, Republic of Korea*

<sup>4</sup>*Key Laboratory of Advanced Technologies of Materials, Ministry of Education, School of Materials Science and Engineering, Southwest Jiaotong University, Chengdu 610031, Sichuan, P. R. China*

E-mail: [junluprc@hotmail.com](mailto:junluprc@hotmail.com)

To improve the electrical and mechanical performance of the artificial muscles, a novel ionic polymer-metal composite (IPMC) actuator was developed by employing the ionic networking membrane of poly (styrene-*alt*-maleimide) (PSMI)-incorporated poly (vinylidene fluoride) (PVDF) [1, 2]. However, the tip displacement of the as-prepared actuators was found to decrease along with the increase of the test time at high frequency [1, 2]. In this study, more durability test was conducted so as to elucidate the performance degradation of such IPMC actuators. The results showed that the actuation performance of the actuator based on PSMI-incorporated PVDF was mostly recovered after the ion exchange in the 1.5N lithium chloride solution for 1h, but could not be recovered after the immersion into deionized water for the same applied duration. Also, the fabricated IPMC actuator displayed much better electromechanical response in the lithium chloride solution of higher concentration. The durability test indicated that the leakage of mobile cations such as Li<sup>+</sup> and Na<sup>+</sup> during the actuation could possibly be the main reason for the function deterioration of the actuators of PSMI-incorporated PVDF. The study presented here may be instructive for the design and fabrication of diversified functional self-healing artificial muscles so as to materialize the action of natural muscles.

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## Continuous Carbon Nanotube Network Reinforced High Strength Composite Fibers

LUQI LIU<sup>1\*</sup>, WENJUN MA<sup>2</sup>, ZHONG ZHANG<sup>1</sup>, SISHEN XIE<sup>2</sup>

<sup>1</sup> National Center for Nanoscience and Nanotechnology, Beijing 100190, P.R. China

<sup>2</sup> Beijing National Laboratory of Condensed Matter, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, P.R. China

E-mail: [liulq@nanoctr.cn](mailto:liulq@nanoctr.cn)

During the past decade, great efforts have been applied to improve the mechanical performance of carbon nanotubes based polymer composites.<sup>[1,2]</sup> The main factors influencing the mechanical behavior of CNTs based polymer composites, including nanotubes dispersion, the interfacial adhesion, alignment as well as the volume fraction of nanotubes have been fully considered. Unfortunately, in most cases, the mechanical performance of CNTs based composites is still beyond our expectation as a consequence of various uncertainties.

Here we fabricate the continuous carbon nanotubes network based polymer composite micro-fiber by liquid submersion method, in which nanotubes acting as continuous reinforcing filler rather than discontinuous one. Polymer type influence on the mechanical properties of CNTs composite fiber is also investigated. Furthermore, on the basis our recent work regarding mechanical behavior of pure SWNTs fiber,<sup>[3]</sup> the micromechanical mechanism of composite fiber is revealed with the help of in-site Tensile Raman test. The key parameter dominating the mechanical performance of CNTs composites fiber is highly illustrated, which would guide the future design for high performance of CNTs based composite fiber.

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## **Eco-Friendly Composites: Properties and Applications**

**P. PERSICO<sup>1,2,\*</sup>, D. ACIERNO<sup>1</sup>, C. CARFAGNA<sup>1,2</sup>, F. CIMINO<sup>2</sup>, R. CIOFFI<sup>3</sup>**

<sup>1</sup>*Department of Materials and Production Engineering, University of Naples  
“Federico II”, Naples 80125, Italy*

<sup>2</sup>*Institute of Chemistry and Technology of Polymers (ICTP)-CNR, 80078 Pozzuoli  
(NA), Italy*

<sup>3</sup>*Engineering Department for Technologies, University of Naples “Parthenope”,  
Naples 80143, Italy*

E-mail: [paopersi@unina.it](mailto:paopersi@unina.it)

Environment friendly “green” materials are increasingly being explored as alternatives to conventional plastics to improve the environmental sustainability [1]. In the building and construction industry, many government regulations are in place to encourage the use of eco-friendly alternative materials.

This communication deals with the fabrication of fiber-reinforced green composites from three different matrices: one is poly(3-hydroxybutyrate-co-3-hydroxyvalerate) PHBV derived from corn, an annual renewable resource, the second is Ecoflex<sup>®</sup> from petrochemical raw materials, both are completely biodegradable polyester, and the third is defatted soy flour (SF), a plant-based biopolymer.

The efficiency of the fiber-reinforced composites depends on the fiber-matrix interface and the ability to transfer stress from the matrix to the fiber. In order to improve the interfacial bonding between fibers and matrix two chemical treatments have been carried out to get fibers surface modification [2], one involving caustic soda because it is inexpensive and effective, the other one using 3-aminopropyltriethoxysilane (APS) coupling agent.

Effect of fiber weight contents and fiber treatments on the mechanical and thermal properties of composites was investigated by means of morphological and thermo-gravimetric analysis, flexural and impact tests. According to their characteristics, composites resulted useful in secondary structures for indoor applications.

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## **Dynamic Visco-elasticity of Polycarbonate(PC) Composites under Different Pre-load/Dynamic Load**

YIN SHUIPING\*

*Institute of Rheological Mechanics & Material Engineering,  
Central South University of Forestry and Technology, Changsha, 410004, China  
E-mail: [ysp8293@sina.com](mailto:ysp8293@sina.com)*

As polymeric composites find greater use in aerospace and other applications, the need to understand their mechanics behavior is also increased. The Eplexor 500N of Germany GABO company was used to determine the dynamic mechanical properties of polycarbonate(PC) composite, which can offer a maximal load of 500N compared to other DMA equipment. All experiments were carried out in the uniaxial tensile mode, at room temperature and frequency of 0.1Hz, 1Hz, 5Hz and 10Hz. The effects of experiment parameters, such as pre-load, dynamic load were investigated. The result shows that the storage modulus increases with the pre-load, but decreases with the dynamic load.

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## Use of Poly( $\epsilon$ -caprolactone)-Grafted Carbon Nanotubes (CNT-g-PCL) for High Performance Nanocomposites

SOPHIE PEETERBROECK<sup>1\*</sup>, BENOIT RUELLE<sup>2</sup>, THOMAS GODFROID<sup>3</sup>,  
MICHEL HECQ<sup>2</sup>, RONY SNYDERS<sup>2</sup>, CARLA BITTENCOURT<sup>2</sup> AND PHILIPPE  
DUBOIS<sup>4</sup>

<sup>1</sup>Laboratory of Polymeric and Composite Materials, Center of Innovation and Research in Materials & Polymers, Materia Nova, Avenue N. Copernic 1, B-7000 MONS, Belgium

<sup>2</sup>LCIA, University of Mons, Place du Parc 20, B-7000 MONS, Belgium

<sup>3</sup>LCIA, Materia Nova, Avenue N. Copernic 1, B-7000 MONS, Belgium

<sup>4</sup>Laboratory of Polymeric and Composite Materials, Center of Innovation and Research in Materials & Polymers, Materia Nova & University of Mons, Avenue N. Copernic 1, B-7000 MONS, Belgium

E-mail: [sophie.peeterbroeck@materianova.be](mailto:sophie.peeterbroeck@materianova.be)

Polymers filled with carbon nanotubes (CNTs) are credited with good mechanical and thermal properties. But the dispersion of this kind of anisotropic nanofillers is not straightforward.

The functionalization of nanotube sidewalls represents a solution in order to improve the interactions between CNTs and the polymer matrix and accordingly to increase their dispersion ability.

There are two main approaches for the surface modification of CNTs. One is the *noncovalent functionalization* used in several processes, such as ultrasonication, addition of surfactants, polymer wrapping and polymerization-filling technique (PFT) [1]. One advantage of the noncovalent approach is that the structure of nanotubes remains unaltered, thus their mechanical properties should not change but the forces between the wrapping molecules and the nanotubes surface might be weak and the efficiency of the load transfer might be low. Another approach relies on the *covalent grafting* of functional groups along the CNTs sidewalls. These functions are interesting to improve the interactions with the polymer matrix [2] and can be useful as anchoring sites for polymer chains. The covalent bonding between CNTs and the polymer matrix allows to get an optimal interfacial strength and thus a perfect load transfer to the CNTs. However, in the majority of so far reported processes such as chemical functionalization performed in solvent [3-5] or by reactive ball milling [6], only a very tiny fraction of the carbon atoms in the nanotubes get functionalized and some targeted reactive functions, like amines, most often require time-consuming and costly multistep reactions. Interestingly, a microwave-generated N<sub>2</sub> plasma has been very recently used as a source for incorporating nitrogen functional groups into SWNTs via sidewall attachment [7]. However the reported production of atomic nitrogen was not highly efficient limiting the extent of surface-functionalization.

This work aims to finding an original process to readily functionalize in one step the surface of multi-walled carbon nanotubes (MWNTs) with nitrogenated functions, and

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particularly with (reactive) amines obtained via Ar+N<sub>2</sub> microwave plasma in the post-discharge chamber avoiding any structural alteration and polluting substances. These functions can further initiate the polymerization of lactone monomers to produce highly filled masterbatches. These pre-dispersed CNTs can be mixed in the molten state with several polymer matrices (miscible to the studied polyester chains or not) to obtain nanocomposites with interesting mechanical and electrical properties.

In summary, this three-step strategy combines a highly efficient microwave plasma functionalization, the covalent grafting reaction of *in situ* grown polyester chains and melt compounding techniques.

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## **The Masterbatch Approach: An Efficient Tool to Elaborate Nanocomposites with Enhanced Properties**

L. BONNAUD, S. BENALI, S. BREDEAU, S. PEETERBROECK,  
O. PERSENAIRE AND PH. DUBOIS\*

*Dep Center of Innovation and Research in Materials & Polymers (CIRMAP),  
Laboratory of Polymeric and Composite Materials (SMPC), University of Mons  
(UMons) & MATERIA NOVA Research Center, Place du Parc 20, 7000 MONS,  
BELGIUM*

E-mail: [Leila.bonnaud@umh.ac.be](mailto:Leila.bonnaud@umh.ac.be)

With the recent developments in nanoscience and nanotechnology, nanoparticles such as clay nanoplatelets and carbon nanotubes have attracted much interest among scientists and industrials due to their remarkable intrinsic properties (i.e. mechanical and barrier properties for clay nanoplatelets and mechanical, electrical and thermal properties for carbon nanotubes).

These nanoparticles are considered to be very promising candidates for the elaboration of a new class of polymeric materials, also called nanocomposites, which are composed of a single polymer or a polymer blend matrix containing a very small amount of nanoparticles individually and uniformly dispersed and organized in the organic phases. At a macroscopic scale, such a nano-material exhibits improved mechanical, barrier and flame resistance properties. Nevertheless, manufacturing true polymer-based nanocomposites is a challenging area because nanoparticles usually tend to form aggregates that are difficult to break under classical melt blending processing conditions. More precisely, clay nanoplatelets are connected to each other by ionic interactions and carbon nanotubes are stuck by  $\Pi$ - $\Pi$  electronic interactions and entanglements.

The present work focuses on an original and efficient nanocomposite preparation technique that does not alter the nanoparticles (clay nanoplatelets and carbon nanotubes) surface thus does not modify their intrinsic properties. The approach selected consists in embedding and coating the nanoparticles individually by *in-situ* polymerisation leading to the manufacture of pre-structured highly filled masterbatches, which can then be readily diluted and dispersed in polymer or polymer blend matrices using classical melt blending tools and processing conditions to produce true nanocomposite materials. This method also gives a way to avoid the use of “volatile” nanoparticle powder, which can be of great interest for the industry.

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## Microencapsulation of Isocyanates for Self-healing Coating

J.L. YANG

*School of Mechanical and Aerospace Engineering, Nanyang Technological University,  
639798 Singapore*

E-mail: [mjlyang@ntu.edu.sg](mailto:mjlyang@ntu.edu.sg)

Structural polymers are very susceptible to damage in the form of cracks, which are normally induced deeply within the structure where detection is difficult and repair is almost impossible. In protective coatings it can lead to serious corrosion and thus great threat to substrates. Many approaches have been developed for healing cracks in polymers, glasses, and concretes for several decades. In these methods, however, human intervention including manual detection of damage location is always necessary. Recent self-healing materials [1] proposed by White group in UIUC realized autonomic healing. Self-healing polymers have become one of the most promising directions in materials science in the very recent years. In this study, we developed a novel encapsulation recipe for reactive chemical as healing agent [2] and applied in anti-corrosion coatings.

Microcapsules containing reactive diisocyanate were synthesized based on interfacial polymerization of polyurethane (PU) prepolymer for development of future self-healing polyurethane coating materials. The isocyanate has potential for healing in humid or wet environments without catalyst. The preparation of PU prepolymer and microencapsulation of isophorone diisocyanate (IPDI) are presented. Microcapsules of 40-400  $\mu\text{m}$  in diameter were synthesized by changing agitation rate in the range of 500-1500 rpm. A power relation exists between average diameter of capsules and agitation rate. Smooth outer surface morphology and variable shell wall thickness were investigated by optical and scanning electron microscopy. Shell wall thickness is linearly increased with increasing capsule diameter. High yields ( $\sim 70\%$ ) of a free flowing powder of spherical microcapsules were produced with a liquid core content of 70 wt% as determined by TGA analysis. After manufacturing, microcapsules showed long shelf life of 6 months with only 10 wt% loss of IPDI. Brittle behavior of microcapsules was illustrated by direct compression test, and the normalized strength of capsules presented a power relation with capsule diameter. Preliminary application of microcapsules in a polyurethane coating showed self-healing functionality to retard corrosion process.

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## Structure and Properties of Unidirectional Nano-silica/ PP Composites

W. H. RUAN<sup>1\*</sup>, M. Q. ZHANG<sup>1</sup>, M. H. WANG<sup>2</sup>, M. Z. RONG<sup>1</sup>

<sup>1</sup> *Materials Science Institute, Zhongshan University, Guangzhou 510275, China*

<sup>2</sup> *Key Laboratory for Polymeric Composite and Functional Materials of Ministry of Education, Zhongshan University, Guangzhou 510275, China*

E-mail: [cesrwh@mail.sysu.edu.cn](mailto:cesrwh@mail.sysu.edu.cn)

Polymer based nanocomposites, in which inorganic nanoparticles are dispersed in organic polymer matrices, have formed an interesting field of materials research because considerable performance improvement can be achieved by the addition of trace amount of the nano-scale fillers [1]. Our early investigation revealed that when tension is applied, the grafted nanoparticle agglomerates in composites could be extended and broken up along the tensile direction, thus the dispersion of nanoparticles can be improved [2]. On the basis of the above considerations, a new route, that the nano-silica filled polypropylene (PP) sheets were unidirectional stretched under a temperature slightly lower than the melt point of PP, was developed in this work. The mechanical properties and crystalline characteristics of the unidirectional nano-silica/PP composites prepared under different drawing ratio were investigated. The fractured specimens were observed with scanning electron microscope (SEM). Orientation structure of the PP crystals and the amorphous part of unidirectional PP and composites were studied by wide angle X-ray diffractometer and fluorescence depolarization. The results show that nano-silica filled unidirectional nanocomposites are much stronger and stiffer than the unfilled PP. The crystallinity of nanocomposites is little higher than that of pure PP, but drawing process has no influence on the crystallinity of materials. Crystal orientation of PP is unchanged during hot-drawing, while degree of orientation of amorphous part of nanocomposites is increased with the increase of drawing ratio. Micrograph observations show that nanoparticles could induce the structure change of polymer matrix. The reinforcing mechanism of nanoparticles should be further explored. The resultant unidirectional nanocomposites are potential candidates for manufacturing self-reinforced composites.

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## **Production of Nanocomposites of Barium Sulfate with Polyoxymethylene**

I. ROMERO, A. SÁNCHEZ-SOLÍS AND O. MANERO\*

*Instituto de Investigaciones en Materiales. Universidad Nacional Autónoma de México. México, D. F. 04510. Mexico*

E-mail: [manero@unam.mx](mailto:manero@unam.mx)

Polymer nanocomposites made of nanoparticles of barium sulfate and polyacetal (polyoxymethylene, POM) were produced in the melt. The barium sulfate was synthesized to produce particles of various shapes, namely, spheres, fibers and toroidal or donut-like aggregates. The particles were dispersed in the polymer using a twin-screw extruder and thereafter they were injection-molded to obtain samples for morphological, X-ray, mechanical, impact and rheological tests. Shear viscosity as a function of the shear rate depends on the particular shape and size of the dispersed phase. Morphological features were observed by scanning electron microscopy (SEM) to assess the degree of dispersion and X-ray tests provided information on the radio-opacity of the samples. Results show that for particle concentrations in the range of 1-3 phr (parts per hundred of resin), most of the samples are transparent and maintained the mechanical properties of the matrix (although in some samples strain at break increased 37 % with respect to the matrix) showing a level of radio-opacity, suggesting potential applications in the bio-medical sector.

## Synthesis and Characterization of Polyindane Synthesized by Cationic Polymerization of Indene Using Maghnite as Catalyst

MARREF MOHAMED<sup>1\*</sup>, MEGHABAR RACHID<sup>2</sup>, BELBACHIR MOHAMED<sup>2</sup>

<sup>1</sup>*Département de Chimie Industrielle, faculté des sciences, Université des Sciences Et de la Technologie d'Oran, BP1505, Bir El Djir, Oran – Algérie.*

<sup>2</sup>*Département de Chimie, Faculté des Sciences, Université d'Oran Es-sénia – Algérie*

E-mail: [marrefdz@yahoo.fr](mailto:marrefdz@yahoo.fr)

In the present work the synthesis of polyindane by cationic polymerization of indene using Maghnite (Mag-H) as catalyst, montmorillonite sheet silicate clay exchanged with protons, is reported. Indene monomer, which is polymerized by a cationic process, was used to elucidate the polymerisation cationic character. The influences of reaction temperature, reaction time on the conversion of monomer, the amount of Ma-H and the molecular weight are investigated.

Furthermore, the cationic initiators used to make polymers are expensive. They may be poisoned by products of the reaction or impurities present in the monomer feed, and contain heavy metals such as chromium, mercury, antimony, etc. that present environmental disposal problems for the user. Frequently, these initiators require the use of very high or very low temperature and high pressures during the polymerization reaction, thus the yield is often poor. The separation of the initiators from the polymer is not always possible.

The purpose of this paper is to study the cationic polymerization of indene by a montmorillonitic clay called Maghnite-H (Mag-H), a new non-toxic cationic catalyst for vinyl and heterocyclic monomers[1,2,3]. Mag-H can be easily separated from the polymer product and regenerated by heating to a temperature above 100 °C [4].

We have shown that Maghnite-H 0.25 M treated in acid medium catalyses the polymerisation of indene. The catalytic activity as measured by the conversion rate and the molecular weight of formed polymers depend on the catalyst proportion in the reaction medium and the reaction temperature. NMR <sup>1</sup>H of the polymer obtained, show with comparison with those of the monomer, that polymerization had very place. Polyindanes were produced by a very simple procedure. Through simple filtering the clay can be separated form the reaction mixtures. Moreover this acid clay is inexpensive, stable and non corrosive

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## Geometry Design of Braided Composites Tubes as Energy Absorption Element

Y. YANG, A. NAKAI AND H. HAMADA

*Advanced Fibro Science, Kyoto Institute of Technology Matsugasaki,  
Sakyo-ku, 606-8585 Kyoto, Japan  
E-mail: [d6851014@edu.kit.ac.jp](mailto:d6851014@edu.kit.ac.jp)*

Until now, most researches of the energy absorption capability of FRPs concentrated on the circular cross-sectional tubes. However, square cross-sectional tubes are geometrically more practical as they can be assembled easily with other components during automotive manufacturing, although square tubes were found to be less effective at energy absorption than comparable circular tubes according to the previous researches. Therefore, the geometry of the FRP tube is studied in this research. An attempt to enhance the energy absorption capability of the FRP tubes as energy absorption component by combining circular and square cross section together was carried out. The mandrel was designed to have three parts i.e. circular, cone and square parts. The cone part is used to combine the circular and square parts smoothly.

Carbon fibers as reinforcement and Epoxy resin as the matrix were used to fabricate braided FRP tubes with VARTM process. According to the braiding architecture, three kinds of specimens are made i.e. Type 15-15 Type 15-60 and Type 60-60. In Type 15-15 and Type 60-60 specimens, there is the same braiding angle i.e. 15 or 60 degree on three parts. However, In Type 15-60, there 15 degree of braiding angle in circular part but about 60 degree in cone and square parts. The axial quasi-static compression tests were carried out to identify their crushing performance.

The braided FRP specimensof Type 15-15 and Type 15-60 were all crushed into splaying pieces in a stable crushing mode which had a relative crushing load. Progressive crushing illustrate that this geometric design is successful for FRP tubes with proper braiding structures design.

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## **The Effects of the Injection Parameters on Flow Length in Molding of the Pa 6 Reinforced Glass Fibre**

ABDULMECIT GÜLDAŞ<sup>1</sup>, RESUL TÜRK<sup>2</sup>, HAKAN DİLİPAK<sup>3</sup>

<sup>1</sup>*Gazi University, Technical Education Faculty, Machine Edu. Dep., Ankara, Turkey*

<sup>2</sup>*Gazi University, Institute of Science and Technology, Machine Edu. Dep., Ankara, Turkey*

<sup>3</sup>*Gazi University, Technical Education Faculty, Machine Edu. Dep., Ankara, Turkey*

E-mail: [aguldas@gazi.edu.tr](mailto:aguldas@gazi.edu.tr)

It is very important to know flow properties of plastics when the mold is designing for the thermoplastics. Flow length of the plastic in the mold gives the information about the flow properties of molten plastic. Yield length depends on injection parameters. To determine how to change yield properties according to injection parameters, the mold containing spiral channels were used according to ASTM 1321 standard. In this study, flow length of Pa 6 reinforced glass fibre in the ratio of 10%, 20% and 30% respectively were determined experimentally. According to this study, the values of flow length decreased with increasing proportion of glass reinforced. On the contrary, the values of flow length increased when the injection temperature, injection pressure and injection flow rate increased.

## **The Effects of Surface Roughness on Flow Length in Injection Molding**

R. TÜRK<sup>1</sup>, A. GÜLLÜ<sup>2\*</sup>

<sup>1</sup>*Gazi University, Institute of Science and Technology, Machine Edu. Dep. Ankara, Turkey*

<sup>2</sup>*Gazi University, Technical Education Faculty, Machine Edu. Dep. Ankara, Turkey*  
E-mail: [agullu@gazi.edu.tr](mailto:agullu@gazi.edu.tr)

Approximately 1/3 of thermoplastics are manufactured via by injection molding. The mold determines physical properties such as geometric structure, appearance, strength and aesthetic of the plastics. While a mold designing, it is very important to know flow properties of molten plastic. One of the parameters affecting the flow in cavity is also surface roughness. The effects of surface roughness on the flow length have been examined in this experimental study. According to the results obtained, it was determined that the flow length decreased when the surface roughness increased. The most important reason is not surface roughness that obstructs the flow, but it was thought that contact surface area between molten plastic and mold wall was increased because of surface roughness. In fact, the amount of heat transfer have also increased by the increasing the contact surface area.

## **Dynamic Damping Properties of Thermoplastic Elastomers Based on EVA and Recycled Ground Tire Rubber**

N. ROCHE<sup>\*</sup>, A. CHETTAH, M. ICHCHOU AND M. SALVIA

*Laboratoire de Tribologie et Dynamique des Systèmes, Ecole Centrale de Lyon,  
69134 Ecully, France*

E-mail: [nicolas.roche@ec-lyon.fr](mailto:nicolas.roche@ec-lyon.fr)

Recycling waste tires being important for both economical and environmental reasons, ground tire rubber can be blended to other polymers, modifying their properties [1]. In order to characterize and explain these modifications, an experimental study was carried out concerning the improvement on the dynamic damping properties when adding recycled ground tire rubber (GTR) fillers to an elastomeric matrix (Ethylene Vinyl Acetate EVA).

To evaluate the influence of both the ground tire rubber and the porosity in a GTR/EVA composite, three samples have been elaborated by injection: the EVA matrix alone, a GTR/EVA composite and a GTR/EVA porous composite. Dynamic measurements of the samples were performed using Dynamic Mechanical Thermal Analysis 'DMTA'. The Young's modulus and loss factor of these materials are estimated by using the frequency-temperature equivalence introduced by Williams-Landel-Ferry (WLF) expanding the measurement of the dynamic properties over a wider range of frequencies.

The studied GTR filled thermoplastics are to be applied in the conception of structures submitted to vibrations in the 1-2 KHz bandwidth, for example in the automotive industry. This method showed that in this frequency bandwidth the loss factor has been improved by the addition of GTR to the EVA matrix. Chains friction being a major factor in the vibration energy dissipation by a viscoelastic material [2], chains mobility was studied. The  $\alpha$ -relaxation activation energy, determined using the WLF parameters, showed lower activation energy for both of the GTR filled composites leading to the conclusion that the mobility of the polymer chains has been improved by addition of GTR.

The impact behavior study carried out using a weight drop-test experiment also concluded to better impact energy absorption for the GTR filled composites at the expense of a larger maximum strain.

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## Transport in the Biodegradable Systems on the Base of Poly(3-Hydroxybutyrate). From Barrier Composite Membranes via Polymer-Inorganic Hybrids to Microparticles for Drug Delivery

A. L. IORDANSKII<sup>1,2</sup>, A. P. BONARTSEV<sup>2</sup>, S. Z. ROGOVINA<sup>1</sup>, E. L. IVANTSOVA<sup>1</sup>, G. A. BONARTSEVA<sup>3</sup>, E. V. PRUT<sup>1</sup>

1 - N.N. Semenov's Institute of Chemical Physics, Moscow, Russia; 2 - M.I. Lomonosov's Moscow state university, Moscow, Russia; 3 - A.N. Bach's Institute of Biochemistry, Moscow, Russia.

E-mail: [aljordan08@gmail.com](mailto:aljordan08@gmail.com)

Over last two decades increasing environmental perceptions as well as medical challenges have stimulated academic and industrial interest in biodegradable plastics. As a family of biodegradable polymers, poly(3-hydroxybutyrate) [BPHB] and its derivatives (polyhydroxyalkanoates: PHAs) have performance characteristics sufficient to replace a significant portion of petroleum-based plastics used currently in biomedicine, packaging and food-service industry. We have unified the academic research and the bench-scale testing of composites based on BPHB synthesized in Russia. The composites were prepared by solvent casting or melt/solid extrusion (two-screw extruder) and they included as the second component the biopolymers from renewable resources (chitosan, cellulose, natural rubber) as well as a special medical mineral (shungit) for reinforcing polymer matrix and a drug capacity enhancement. The BPHB microspheres were obtained by oil-in-water emulsification and their diameters ranged between 4 and 92  $\mu$ . Variation of second component polarity regulates composite morphologies and, hence, both water and drug transport as well as thermophysical and mechanical behavior. Analysis of extreme points for "transport coefficient - composite content" relationships combined with the morphology features (controlled by FTIR, XRD, SEM and AFM) and thermophysical testing (DSC, TGA) enable us to elucidate the impact of crystallinity and second component nature upon mechanism of (bio)degradation. The structure transitions range in BPHB composites with shungit or partly miscible blends with natural polymers shifted along the second component concentration scale as *natural rubber* (at 25 wt%) < *cellulose* (30 %) < *chitosan* (40 %). The kinetic profiles of drug release from microspheres into phosphate buffer reflect the superposition of diffusion and zero-order process of PHB degradation. Coupling the transport coefficients and macromolecule degradation constants as functions of composite morphology (crystallinity) we propose that blending of the parent biodegradable polymer with above biopolymers is a perspective tool to design novel reinforced biomaterials with advanced characteristics such as regulated rate of (bio)degradation, controlled drug release profiles, improved mechanic behavior and with economic advantages for material performance.

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## Synthesis of PE-Cu-C Nano-Crystalline Composite by Mechanochemical Technique

T. EBRAHIMI SADRABADI\*, S. M. ZEBARJAD AND J. VAHDATI KHAKI

*Department of Materials Science and Metallurgical Engineering, Engineering Faculty,  
Ferdowsi University of Mashhad, Mashhad, Iran, P.O. Box 91775-1111*

E-mail: [Ebrahimi.Tahere@yahoo.com](mailto:Ebrahimi.Tahere@yahoo.com)

Polymer–metal composite materials are increasingly important due to their remarkable properties based on the combination of two different materials, and due to easy machinability of polymers [1]. Planetary ball milling technique is a high energy ball milling process for preparation of alloyed powders or composites in powder form. This technique has been used to synthesize many materials, such as nanocrystalline materials [2].

To the best of our knowledge and in spite of the importance of in situ synthesis of polymer nanocomposite, it has not been under more attention. This study tries to fill the literature gap in this issue. Thus the main goal of the current research is to find out whether ball milling can be a new method to produce Nano-Crystalline Composite reinforced with metallic particles by reducing of the corresponded oxide particle simultaneously or Not?

In this study in situ Synthesis of PE-Cu-C nano-crystalline composite by mechanochemical technique has been studied. The exact reason of using graphite powder can be attributed to facilitate the solid state reduction of CuO. High energy planetary ball milling was used to synthesis of PE-Cu-C nano-crystalline composite. Polyethylene, CuO and graphite powders were used in synthesis of final composite. The mixture of powders was examined in various milling condition to synthesis of final nano-crystalline composite. In order to clarify the formation of nano-crystalline particles during milling, the as-milled powder was characterized by X-ray diffraction (XRD). Thermal behavior of all samples including PE and its composite was done using differential scanning calorimetry analysis (DSC) and thermogravimetry analysis (TGA). Scanning electron microscopy (SEM) was performed to investigate the dispersion of Cu particles in the matrix.

The SEM micrographs illustrate the good dispersion of copper particles inside the matrix. Also the results of XRD prove that the formation of nano-crystalline PE-Cu-C depends strongly on milling condition. In fact an increase in milling time leads to form nano-crystalline composite. The DSC graph show that thermodynamic parameters such as melting point, crystallization temperature and latent heat of polyethylene matrix composite change as milling time increases. In the following of the current research it will be tried to elucidate the role of milling condition on degradation behavior of polyethylene matrix composite using TGA method.

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## Vibration Damping Characteristics of CFRP Laminates Containing Carbon Nanotubes

CHI YIN LI, NAVEED A. SIDDIQUI, JANG-KYO KIM\*

*Department of Mechanical Engineering, Hong Kong University of Science &  
Technology, Clear Water Bay, Hong Kong*

E-mail: [mechiyin@ust.hk](mailto:mechiyin@ust.hk)

Epoxy based carbon fiber reinforced composites (CFRP) are widely used in aerospace, automotive and other high performance structural applications due to their high stiffness and strength to weight ratio. Vibration damping is also an important dynamic mechanical property of CFRP as it affects system performance, safety and reliability. Recent studies indicate that the vibration damping capabilities of polymer resins could be improved with the incorporation of carbon nanotubes (CNTs) [1]. It is well expected that use of a CNT-modified epoxy matrix may also improve the damping property of CFRPs. We hereby report an experiment study in which the effects of CNT content on damping characteristics of CNT-CFRP hybrid composites are specifically evaluated.

The multi-walled CNTs were subjected to a combination of UV/Ozone and surfactant treatments before dispersion in an epoxy resin. The CNT-epoxy nanocomposite was used to produce carbon fiber reinforced prepreg via a solventless prepregging process. Unidirectional CNT-CFRP hybrid composites laminates were fabricated by hand lay-up, from which specimens were prepared for testing according to the ASTM standard E756. The CNT-epoxy nanocomposites were also tested to establish a correlation between the damping properties of the matrix materials and hybrid composites.

The forced vibration tests indicate that the presence of CNT enhanced the damping characteristics of CFRPs in terms of both damping ratio and natural frequency. The damping ratio increased by about 70% and 48%, respectively, for neat epoxy and neat CFRP composites due to the addition of 0.5wt% of CNT. Meanwhile, the corresponding improvement in natural frequency was less than 5% for both the resin and CFRP samples. Increase in CNT content to 1.0wt % resulted in further increase of these properties. The enhancement in damping capabilities is attributed to the increase in interfacial contact area of CNTs with the epoxy as well as the inherently excellent damping property of CNTs, which helps dissipation of energy upon vibratory loading of composite structure.

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## Investigation of Thermal Behavior of Cyanoacrylate in the Presence of Nano-sized SiO<sub>2</sub>

A. YAGHMAEI, M. KASHEFI AND S.M. ZEBARJAD

*Department of Materials Science and Metallurgical Engineering, Faculty of Engineering, Ferdowsi University of Mashhad, Mashhad, Iran*

E-mail: [amiryaghmaei@yahoo.com](mailto:amiryaghmaei@yahoo.com)

Nowadays, solvent-free, one-part cyanoacrylate adhesive widely used in a range of industries including the automotive, beauty aid, electrical, electronic, machinery, medical, and plumbing [1-3]. According to literature survey done by the authors, there are a few papers concentrated on role of nano-sized particles on thermal behavior of cyanoacrylate glue. Thus the main goal of current research has been focused on clarifying the role of nano-sized SiO<sub>2</sub> on thermal behavior of cyanoacrylate. For this purpose, 1 Vol% of para-toluene sulfonic acid was dissolved in cyanoacrylate as polymerization inhibitor [2] and various amounts of nano-sized SiO<sub>2</sub> powders were added to the cyanoacrylate base composite. Moreover, caffeine was used as a polymerization initiator to cure cyanoacrylate in an appropriate time [3]. It is worth noting that without such initiator, polymerization will be postponed for several days.

Transmission electron microscopy (TEM) was used to observe the dispersion of nano-sized SiO<sub>2</sub> inside the matrix (i.e. cyanoacrylate). Thermal behavior of all materials including cyanoacrylate and its nanocomposites was studied using DSC and TGA methods.

TEM micrographs prove that nano-sized SiO<sub>2</sub> disperse in cyanoacrylate adequately. The results of DSC show that increase in amount of nano-sized SiO<sub>2</sub>, results in decrease in duration of cyanoacrylate curing, energy release during polymerization and starting time of polymerization. Furthermore, the results of TGA test illustrate that the weight loss of cyanoacrylate strongly depends on both caffeine and SiO<sub>2</sub> content. In fact, an increase in nano-sized SiO<sub>2</sub> content promotes degradation temperature of cyanoacrylate.

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## Preparation and Characterization of Epoxy/Carbon Nanotube Composites

W. S. CHOW\*, P. L. TAN

<sup>1</sup>*School of Materials and Mineral Resources Engineering, Engineering Campus,  
Universiti Sains Malaysia, Nibong Tebal 14300 Penang, Malaysia*  
E-mail: [shyang@eng.usm.my](mailto:shyang@eng.usm.my)

Carbon nanotube (CNT) filled polymer composites could exhibit higher stiffness, strength and better electrical conductivity compare to unfilled polymer. The efficiency of CNT in improvement of material performance is generally controlled by the degree of dispersion and polymer-CNT interfacial adhesion [1]. The potential applications of polymer/CNT nanocomposites are numerous, i.e. aerospace and automotive components, optical switches, EMI shielding, photovoltaic devices, adhesives and coatings [2]. The objective of this research is to investigate the mechanical, thermal and morphological properties of epoxy/carbon nanotube composites. The epoxy/multi-walled carbon nanotube (MWCNT) nanocomposites were prepared using in-situ polymerization. Different concentrations of MWCNT were incorporated into the epoxy. The mechanical properties of the epoxy/MWCNT nanocomposites were characterized using 3-point bending and impact fractured toughness tests. The morphology of the epoxy nanocomposites was investigated using field-emission scanning electron microscopy (FESEM). Differential scanning calorimetry (DSC) and dynamic mechanical thermal analysis (DMTA) was used to examine the thermal properties of the epoxy/MWCNT nanocomposites. It was found that the mechanical (e.g. flexural modulus and strength, fracture toughness properties,  $K_{IC}$ ) and thermal properties (e.g. glass transition temperature, storage modulus, loss modulus) of the epoxy nanocomposites were controlled by different concentration of MWCNT, condition of dispersion technique, polymerization and curing. The enhancement of modulus and stiffness of the epoxy could be associated to the good dispersion and reinforcing efficiency of the MWCNT. It is believed that the cross-linking of epoxy was influenced by the addition of MWCNT. The relationship between the mechanical properties and morphology (e.g. dispersibility of CNT) of epoxy/CNT composites was established.

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## **Biomimetic Self-healing Glass Fibre Reinforced Epoxy Composites Using Hollow Glass Fibres**

J. LEE<sup>1</sup>, D. BHATTACHARYYA<sup>1\*</sup>, R. J. T. LIN<sup>1</sup>, P. S. TAN<sup>1</sup>, S. W. KAVERMANN<sup>1</sup>, A. J. EASTEAL<sup>2</sup>, M. Q. ZHANG<sup>3</sup>

<sup>1</sup> *Centre for Advanced Composite Materials and Department of Mechanical Engineering* <sup>2</sup>*Department of Chemistry The University of Auckland, Private Bag 92019, Auckland, New Zealand*

<sup>3</sup> *Materials Science Institute, Zhongshan University, Guangzhou 510275, PR China*  
E-mail: [jim.lee@auckland.ac.nz](mailto:jim.lee@auckland.ac.nz)

Self-healing composites have an increasing amount of worldwide interest as a method to enhance the performance and applications of composite materials. The objective of this study is to develop a novel fibre reinforced composite which employs a biomimetic approach to undertake self-repair from filled hollow fibres when encountering damage during service. The use of functional repair components stored inside hollow glass fibres (HGF) is a method of extrinsic (inbuilt) healing 1,2. It considers the placement of self-healing HGF plies within glass fibre/epoxy laminates to mitigate damage occurrence and restore mechanical strength. Two perpendicular layers of hollow glass fibres were put into a glass-epoxy composite. Samples were filled with epoxy resin and novel hardener using vacuum. The HGF samples had damage done to them using a novel ball indentation method. Through the effective observation on the damaged specimens by means of optical microscopy and other imaging techniques, it was evident that the damage had led to successful mixing of the healant components and subsequent curing of epoxy resin. Mechanical tensile tests also showed that the performance of the material was partially recovered by the presence of the healant-containing HGF. Further study will be carried out to maximise the healing efficiency by investigating different healant combinations.

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## Antibacterial Surface Modification of Cotton Fabrics by Sol-Gel Coating with Zinc Oxide

W. SRICHARUSSIN<sup>1,2\*</sup>, A. GITCHAIWAT, N. PROMMEE AND U. PANTIPSAK

<sup>1</sup>*Department of Materials Science and Engineering, Faculty of Engineering and Industrial Technology, Silpakorn University, Nakorn Pathom, Thailand 73000*

<sup>2</sup>*Center of Excellence for Petroleum, Petrochemicals, and Advanced Materials, Chulalongkorn University, Bangkok 10330, Thailand*

E-mail: [shebolite@yahoo.co.uk](mailto:shebolite@yahoo.co.uk)

ZnO nanoparticles were synthesized by the sol-gel process. The ZnO nanoparticles were characterized by XRD and SEM. The as-prepared sol was applied onto cotton fabrics via the pad-dry-cure process at various temperatures. The characteristics of the coating were investigated by FTIR, SEM, Atomic absorption spectroscopy (AAS) and tensile strength tests. Antibacterial activity was determined using the disc diffusion method. The antibacterial activity was measured by the diameter of the inhibition zone formed around the disc. The results of XRD on the powders show that ZnO can be produced starting at a temperature of 150°C. The investigation by FTIR and SEM clearly revealed that ZnO was effectively deposited on the cotton surface and that the adhesion was retained after many washing cycles. The curing temperature shows no considerable effect on the tensile strength of the sample. Antibacterial properties against *Staphylococcus aureus* and *Staphylococcus epidermidis* of treated samples are excellent.

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## Reactive Blends of Biodegradable Poly(lactic acid) and Poly(butylene adipate-co-terephthalate)

S. SUTTIRUENGWONG<sup>1,2\*</sup>, R. KANKRUA<sup>1</sup> AND M. SAEDAN<sup>3</sup>

<sup>1</sup>*Department of Materials Science and Engineering, Faculty of Engineering and Industrial Technology, Silpakorn University, Nakorn Pathom 73000, Thailand.*

<sup>2</sup>*Center of Excellence for Petroleum, Petrochemicals, and Advanced Materials, Chulalongkorn University, Bangkok, 10330, Thailand.*

<sup>3</sup>*Department of Physics, Faculty of Science, Silpakorn University, Nakorn Pathom 73000, Thailand.*

E-mail: [supakij@su.ac.th](mailto:supakij@su.ac.th)

The biodegradable polymers research has gained considerable interest in the last two decades due to the availability of renewable resources and the ease of environmental problems. Among these, polylactide (PLA), bio-based polymer, and poly(butylene adipate-co-terephthalate) (PBAT), petroleum-based polymers, are often used to obtain the desired products. PLA and PBAT are semicrystalline aliphatic polyesters, which can be processed by most conventional methods. PLA possesses high strength and modulus, but brittle. An addition of PBAT, tough and flexible, into PLA matrix, leading to the increased ductility as PBAT content increases [1], would give interesting blend materials for industrial packaging applications. However, both polymers are immiscible in nature [2]. In this work, the reactive melt blending between PLA and PBAT with various ratios were investigated through free radical and condensation reactions. The PLA/PBAT blends were melt-blended at 180 °C using an internal mixer with an addition of 0-1 %wt reactive agents (maleic anhydride (MA), peroxide and glycidyl methacrylate (GMA)). The morphology and mechanical properties of both homopolymers and PLA/PBAT blends were compared. From the analysis of PLA/PBAT/peroxide/MA blends, the SEM micrographs illustrated good interface adhesion and finer morphology when compared to the blends without reactive agents, but poorer mechanical property. In case of PLA/PBAT/peroxide/GMA blend, interface adhesion between PLA and PBAT was improved as shown by SEM, as well as the increased elongation and impact strength significantly. Even by addition of peroxide alone in PLA/PBAT blends, both strain at break and impact strength could extensively increase.

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## Effect of Both Nano-sized Alumina Particles and Severe Deformation on Polyethylene Crystallinity Index

GH. TADAYYON, S.M. ZEBARJAD<sup>1\*</sup> AND S. A. SAJJADI

*Department of Materials Science and Metallurgical Engineering, Faculty of Engineering, Ferdowsi University of Mashhad, 91775-1111, Mashhad, Iran*

E-mail: [Zebarjad@um.ac.ir](mailto:Zebarjad@um.ac.ir)

Based on the literature survey, there is no any evidence of study concentrated on polyethylene-alumina nanocomposites. Thus, the main goal of this study is to fabricate polyethylene-alumina nanocomposites by high energy ball milling as a new method. Also it is tried to elucidate the role of both ball milling and alumina nanoparticles on crystallinity index of medium density polyethylene.

For this purpose PE/Al<sub>2</sub>O<sub>3</sub> nano-composite was prepared by dry high energy ball milling from polyethylene and Alumina nanoparticles. The materials were characterized using scanning electron microscopy (SEM), transmission electron microscopy (TEM), and X-ray diffraction (XRD). The results show that during mechanical milling of PE/Al<sub>2</sub>O<sub>3</sub> powders, the morphology and structure of the particles undergo continuous changes. Plastic deformation, chain scissions of materials are dominant mechanism which influence the characteristics of milled powders. The results show that the addition of nano-scaled alumina particles accelerated milling process of polyethylene powder. In other word, the small hard particles may act as small milling agent. Therefore, the fracture process in ball milling of polyethylene nanocomposite powders is started earlier. Another parameter that influences the ball milling process of nanocomposite powder and degree of crystallinity is the volume fraction of the reinforcement. With increasing the volume fraction of alumina particles, crystallinity percent decreases. During the early stage of milling the degree of crystallinity decreases rapidly and slows down afterwards.

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## **Experimental Characterization of the Correlation between Water-absorb-squeeze and Mechanical Properties of Textile Structures and Sheet-Like Materials**

I. RIKU<sup>1\*</sup>, S. IGA AND K. MIMURA

*Division of Mechanical Engineering, Osaka Prefecture University, Osaka 5998231,  
Japan*

E-mail: [riku@me.osakafu-u.ac.jp](mailto:riku@me.osakafu-u.ac.jp)

Compression and recovery properties of textile structures and sheet-like materials that pass through a set of press rolls are found to be the controlling factor in determining the pressure schedule within the nip region, the loading of the rolls and the minimum separation of the roll surfaces of the press[1].

In this study, factors affecting the mechanical deformation behavior of felts (napped textile structures[2]) that are used to carry a wet sheet of paper through the press section of a paper machine are examined to clarify the correlation between water-absorb-squeeze and mechanical properties of felts. The stress-strain curves at the compression and recovery process are obtained separately using the drop weigh type impact testing device (TS2000, Saginomiya Seisakusho, Inc.) and a developed laser displacement measurement system. For the compression process, the new, dry felt is immersed in water for one day to saturation level and the specimens are cut out from the saturated felt with the hollow punch. The specimens are subjected to load cycles and the squeezed water is wiped off after each cycle. For the recovery process, the specimens are cut out from the worn, dry felt and are put on laminate Aluminum sheets, which are perforated with holes along a set pattern (called punching metal) and are filled with water.

To give the data that are applicable to the analysis for felts, three factors such as wear history, water content, the content of impregnated urethane and strain rate are considered. The results show that worn felts require more force to achieve a given level of compression than new, napped felts. Under the quasistatic compression (strain rate is about 2.5/s), the water within the felt has plenty of time to leave the felt and thus offers no resistance to compression. In reverse, under such condition, due to the lubrication effect of water between fibers, the felt offers less resistance to compression as its water content is increased.

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## Estimation of Transition of Chitosan into Liquid-Crystalline and Oriented States in Solutions

A.A. KHOLMUMINOV\*, S.SH. RASHIDOVA

*Institute of Polymer Chemistry and Physics of Academy Sciences of Republic of Uzbekistan, Tashkent 100128, Uzbekistan,*

E-mail: [Kholmuminov@rambler.ru](mailto:Kholmuminov@rambler.ru)

Nanostructural fibrous and film materials based on chitosan can be obtained in solutions with conformational transformation of molecular chains into liquid crystal and oriented states. In the present work the possibility of transition in LC- and oriented condition of chitosan, obtained from chitin of chrysalis of silkworm *Bombyx mori* have been investigated. Chitosan solutions were prepared in 2 % CH<sub>3</sub>COOH-water. Molecular mass of chitosan ( $M_{sn} \approx 100000$ ) was determined according to data of high-speed sedimentation and viscometry. Since the weight of the elementary chitosan is  $M_0 \approx 161$ , number of links in the chain amounts  $s \approx 600$ . The elementary link in polysaccharides has an average length  $\lambda \approx 0.5$  nm and accordingly the contoured length of chitosan is  $L \approx 300$  nm. Taking into account that a length of segment of Kuhn in polysaccharides is about  $A = 20-30$  nm, their number in a chitosan chain is  $N = 8 - 10$ . A diameter of chitosan molecules is approximately  $d \approx 1$  nm, which explains that axial ratio of a chain is  $p \approx L/d \approx 300$ . On the basis of the obtained data and based on the calculations following the Flory criteria a possibility of transition of chitosan into LC state with was estimated [1]: - the ratio of mobile flexible and static rigid bonds ( $f$ ) in a chain of chitosan makes below  $2/3$  and for such polymers pertinently transition in a LC-condition with increase of a volumetric share of polymer ( $\varphi_2$ ) in a solution; - critical data  $\varphi_2^* \approx (8/p)[1-(2/p)] \geq 0.03$ , according to this chitosan to be in a LC-condition at concentration  $C \geq 5$  %.

By criteria of S. Frenkel the transition of chitosan into oriented state was estimated as function of a degree uncoiled chains  $\beta \approx (3/2N)^{-0.5}$ . Since for chitosan  $N < 13$  the conditions  $\beta > 0.25$  is ensured, i.e. chains are in the uncoiled state at  $\varphi_2^* < 0.03$ .

For orientation of the uncoiled chains on the certain direction shift or longitudinal flow of the solution should be ensured. The given assumption was investigated for the 3 % chitosan solution. The shift stream was generated at the device "Rheotest-2". It was found that effective viscosity reduces from 0,37 up to 0,016 Pa.c when the speed gradient increases up to  $g \approx 80$  c<sup>-1</sup>; after that point the viscosity did not change. It proves transition of chains into oriented state as a result of the deformational ordering. The longitudinal stream of a solution was provided at the "Rheodynamooptimeter" of Frank-Keller device. The sharp transition of chains into the uncoiled oriented state was found at the speed gradient  $g \geq 90$  c<sup>-1</sup>. The maximal uncoiled degree of oriented chains  $\beta \approx 0.8$  is reached at  $g \geq 200$  c<sup>-1</sup>. After shutting off the longitudinal field chains disorient within one hour. Presence of a hysteresis in the given case is caused by increase of interactions between oriented chitosan molecules in the stream.

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## **Continuous Processing and Modifications of Unidirectional Carbon Fibre Reinforced PVDF: Impact of Atmospheric Plasma on Composite Performance**

KINGSLEY KC HO\*, SITI SHAMSUDDIN AND ALEXANDER BISMARCK

*Polymer and Composite Engineering Group PaCE, Department of Chemical Engineering, Imperial College London. SW7 2AZ. UK*

E-mail: [kin.ho@imperial.ac.uk](mailto:kin.ho@imperial.ac.uk); [a.bismarck@imperial.ac.uk](mailto:a.bismarck@imperial.ac.uk)

Carbon fibre reinforced polymers continue to find applications in the offshore oil and gas industry due to the extreme conditions encountered during operations which require superior material performance and durability. Polyvinylidene fluoride (PVDF) matrix exhibits excellent toughness and corrosion resistance and offers great potential as a matrix for the development of ultra-inert fibre reinforced composites. However, due to the inertness of PVDF and the lack of reactive groups, development of carbon fibre reinforced PVDF is limited by the lack of interfacial compatibility between PVDF and carbon fibres.

This paper presents the successful development of a continuous process with integrated surface modification technology to manufacture unidirectional carbon fibre reinforced PVDF composites. The primary function of a fibre surface modification is to improve the fibre wettability by the matrix and to create optimum adhesion at the fibre matrix interface. The introduction of fluorine functional groups to the fibre surface has been proven to enhance interfacial compatibility [1] via atmospheric plasma fluorination [2]. Unidirectional unsized PAN based carbon fibre reinforced PVDF tape was manufactured using a home build modular laboratory scale composite production line based on the powder impregnation technique. As produced carbon fibre/ PVDF composite tape ( $12.5 \times 0.1$ mm) with fibre volume content of 60% were processed into composite laminates via compression moulding. Short beam shear, flexural and interlaminar fracture toughness tests were conducted on the laminated composites and results show significant improvement in interface dominated properties (by up to 200%) as a result of the introduction of fluorine functionalities to the surface of the reinforcing fibre.

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## Transparent TV Screens on Polymer Hydrogel Base

I. E. SULEIMENOV<sup>1</sup>, G. A. MUN<sup>2</sup>, K. PROSKURA<sup>2</sup>, A. LAZAREV<sup>1</sup>, O. KHVAN<sup>1</sup>,  
N. SEMENYAKIN<sup>2</sup>

<sup>1</sup>*Almaty Institute of Power Engineering and Telecommunications, Baitursynova 126  
Str., 050013, Almaty, Kazakstan*

<sup>2</sup>*Kazakh National University, Chemical Faculty, Karasai Batyr Str. 95a, 050012,  
Almaty, Kazakstan*

E-mail: [Esenych@yandex.ru](mailto:Esenych@yandex.ru)

Development of transparent TV screens may be considered as a first step to the full-scale 3-dimensional TV, while such screen may be designed as a set of layers, each of them is optically transparent in initial state and form concrete elements of an image under the influence of input signal. It is shown, that suitable approach to development of transparent screen is based on using of polymer hydrogels, which are sensitive to heating or electric field application. A wide spectrum of hydrogels, which are thermosensitive ones, is described in current literature [1]. A phase transition from swollen to deswollen state takes place in such hydrogels due to increasing of temperature, and this transition corresponds to sharp increasing of gel's ability to scatter optical irradiation. Multi-component thermosensitive hydrogel (copolymer of vinyl ether of ethyleneglycol, polyacrylic acid and vinylbutyl ether) having phase transition temperature close to 35°C was used in present report. Initially this gel was fully transparent for optical irradiation; it obtains ability to scatter light after heating on 2-3°C. A matrix formed by two sets of perpendicular electrodes was used for synthesis of image, which appear due to scattering of light from external source. Experimental model of proposed device includes 64 vertical and 64 horizontal 1-mm optically transparent electrodes placed just on the glass walls of the volume filled by hydrogel. The heating of hydrogel takes place just by electric currents, which were managed by two sets of electronic keys connected directly with correspondent electrodes. Hydrogel plate 70×70×4 mm was used.

Experimental model of proposed device describing in this report show that velocity of heating by electric current with water coloring of gel is enough to realize frequency of image changing equal to 24 Hz and 64×64 pixel image without additional modification of using hydrogel. Such screen (image is decomposed on 64×64 pixel fragments) may be directly used, for example, for large-scale displays and screens placed at windows of buildings. Such screens may be used freely in nighttime while in daytime the window stays transparent. Further increasing of frequency of managing signal needs in using of nano-structured hydrogels [1] as it is shown in present report.

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## **Effect of Gelatin and Carboxymethyl Cellulose Concentration and Relative Humidity on Cassava Starch Based Film Properties**

W. TONGDEESOONTORN<sup>1\*</sup>, L. MAUER<sup>2</sup>, S. WONGRUONG<sup>3</sup> AND P. RACHTANAPUN<sup>4</sup>

<sup>1</sup>*Department of Biotechnology, Chiang Mai University, Thailand*

<sup>2</sup>*Whistler Center for Carbohydrate Research, Department of Food Science, Purdue University, IN, USA*

<sup>3</sup>*Department of Biotechnology, Chiang Mai University, Thailand*

<sup>4</sup>*Department of Packaging Technology, Chiang Mai University, Thailand.*

E-mail: [wtongdee@hotmail.com](mailto:wtongdee@hotmail.com)

Cassava starch (5% w/v) based films containing glycerol (30g/100g starch) as a plasticizer were characterized with respect to the effect of gelatin and carboxy methylcellulose (CMC) concentrations (0, 10, 20, 30 and 40% w/w total solid) on mechanical properties and solubility of the films. Films were stored at 33% RH (23 °C, 24 hrs) before determining their tensile strength and % elongation. Increasing concentration of gelatin and CMC increased tensile strength and reduced % elongation of the film blends. CMC-starch blended films showed higher tensile strength than gelatin-starch films. Nevertheless, gelatin-starch film was more flexible than CMC-starch film. Film containing 30% CMC showed the highest tensile strength. Effect of relative humidities (33% and 54% RH) on mechanical properties of the film blends was also investigated. All films stored at 54% RH gave higher elongation but lower tensile strength than films at 33% RH condition. Effect of gelatin and CMC concentrations on water solubilities of film blends was observed. Increasing of gelatin and CMC concentrations in cassava starch film decreased water solubility of the film blends.

## Effect of Filler Type on Electrospun Natural Rubber Non-woven Mats

P. THREEPOP NATKUL<sup>1,2\*</sup>, C. KULSETTHANCHALEE<sup>3</sup>, C. THONGPIN<sup>1</sup>,  
N. NOICHAM<sup>1</sup>, P. KIMCHIANG<sup>1</sup> AND R. JONGARIYAGUL<sup>1</sup>

<sup>1</sup>*Department of Materials Science and Engineering, Faculty of Engineering and Industrial Technology, Silpakorn University, Nakorn-pathom 73000, Thailand*

<sup>2</sup>*Center of Excellence for Petroleum, Petrochemicals, and Advanced Materials, Chulalongkorn University, Bangkok 10330, Thailand*

<sup>3</sup>*Faculty of Science and Technology, Suan Dusit Rajabhat University, Bangkok 10300, Thailand*

E-mail: [poonsubt@yahoo.com](mailto:poonsubt@yahoo.com)

Natural rubber (NR) has been known to exhibit a number of outstanding properties. In this work, the preparation of NR nonwoven mats was made with electrospinning technique provided. Electrospun NR nonwoven mats provided the fibrous membranes with controlled porosity. Numerous types of fillers have been used to obtain more appropriate properties for specific applications. Addition of fillers into NR during compounding process could help improving stability of spinned fiber along the fiber length. Subsequently, it led to a good morphology (the fine fiber structure and no beads on surface) of electrospun NR nonwoven mats. Electrospun NR nonwoven mats were investigated using varieties of particulate fillers such as carbon black, zeolite and fly ash at the amount of 20, 30 and 40 parts per hundred rubber (phr). Tetrahydrofuran (THF) was employed as a solvent for preparation compounded NR solution. The morphology of electrospun filled natural rubber nonwoven mats was studied by means of scanning electron microscopy (SEM). The result showed the addition of carbon black to NR resulted in better ability of the electrospun fiber to maintain its shape. This could be explained from its effects in term of electrical conductivity properties of carbon black so that it could control fibrous stability of filled elastomeric nonwoven mats during electrospinning process.

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## Effect of Co-monomer Content on Mechanical Properties on Sawdust/Wood Composites

P. THREEPOP NATKUL<sup>1,2\*</sup>, W. TEPPINTA<sup>1,2</sup> AND N. SOMBATSOMPOP<sup>3</sup>

<sup>1</sup>*Department of Materials Science and Engineering, Faculty of Engineering and Industrial Technology, Silpakorn University, Nakorn-pathom 73000, Thailand*

<sup>2</sup>*Center of Excellence for Petroleum, Petrochemicals, and Advanced Materials, Chulalongkorn University, Bangkok 10330, Thailand*

<sup>3</sup>*Polymer Processing and Flow (P-PROF) Group, School of Energy, Environment and Materials, King Mongkut's University of Technology Thonburi (KMUTT), Thongkru, Bangmod, Bangkok, 10140, Thailand*

E-mail: [poonsubt@yahoo.com](mailto:poonsubt@yahoo.com)

The mechanical properties of Acrylonitrile-Butadiene-Styrene (ABS) copolymer/wood sawdust composites with different co-monomer contents in ABS were investigated. Two grades of commercial ABS resin (Super high impact, SHI and medium impact, MHI grade of ABS) were characterized using Nuclear Magnetic Resonance (NMR) and CHN elemental analyzer for determination of co-monomer content. The surfaces of wood sawdust were treated with N-2(aminoethyl) 3-aminopropyl trimethoxysilane as coupling agent to improve the interfacial adhesion in the composites formed by wood sawdust and ABS. The composites of wood sawdust and ABS were prepared by varying wood sawdust contents of 10 and 40 part per hundred (phr). Blends of wood sawdust filled ABS were compounded using a twin screw extruder and specimens formed by injection molding machine. The mechanical properties namely tensile strength, tensile modulus, flexural strength, flexural modulus, and impact strength of composites were tested. The NMR and CHN elemental analyzer results indicated that SHI-ABS contains higher amount of butadiene but less amount of styrene than MHI-ABS. The impact strength of SHI-ABS/wood sawdust composites was higher than MHI-ABS/wood sawdust composites. This could be explained with the influence of butadiene content. Whereas the styrene content in ABS/wood composites plays an important role in both tensile and flexural properties. Tensile strength, tensile modulus, flexural strength and flexural modulus of SHI-ABS/wood sawdust composites were lower than MHI-ABS/wood sawdust composites.

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## **Compression after Impact of Stitched Composite Material Fabricated by Resin Film Infusion (RFI) Process**

PEI-CHI CHEN<sup>1\*</sup>, CHANG-HSUAN CHIU<sup>1</sup>, MAO-CHIAO (JOE) SHIH<sup>2</sup>

<sup>1</sup> *Department of Fiber and Composite Materials, Feng Chia University, 100, Wenhwa RD., Seatwen, Taichung 40724, Taiwan*

<sup>2</sup> *Epotech Composite Cororation, No 22-1, Tung Kuan St, Tung Shih Town, Taichung, Taiwan*

E-mail: [pay0821@hotmail.com](mailto:pay0821@hotmail.com)

Through-the-thickness stitching followed by resin film infusion (RFI) process is one of the liquid moulding techniques that has become attractive to composite manufactures. For the resin film, DGEBA liquid epoxy was modified by isocyanate and Epolec<sup>®</sup> resins with 4,4'-diaminodiphenyl sulfone (DDS) as the curing agent. In order to improve the thermal properties of the film, different concentrations of bismaleimide (BMI) were added. The composite specimens were made by resin film infusion process with Kevlar<sup>®</sup> yarn stitched carbon woven fabric. The influences of the stitched parameters such as stitch spacing and stitch density on the mechanical properties were investigated and which were compared with the unstitched structure.

## Synthesis and Characterization of Semi-IPNs of Polyurethane Based Nanocomposites

D. L. MERLIN<sup>1</sup>, B. SIVASANKAR<sup>\*2</sup>

<sup>1</sup>*Department of Chemistry, Anna University, Chennai, Tamil Nadu, India*

<sup>2</sup>*Department of Chemistry, Anna University, Chennai, Tamil Nadu, India*

E-mail: [linde\\_merlin2002@yahoo.co.in](mailto:linde_merlin2002@yahoo.co.in)

Semi-IPNs of Polyurethane based clay nanocomposites were synthesized using modified and unmodified clay respectively. The montmorillonite (MMT) clay was modified with cetyl trimethylammonium bromide (CTAB) salt. One natural (K10 clay) and one organically modified (CTAB) montmorillonites have been used as clays for preparing polyurethane (PU) nanocomposites. The dispersion of nanofillers in PU matrix was confirmed by X-ray diffraction patterns and scanning electron microscopy. The thermal stability enhanced by the incorporation of nanofillers into the polyurethane matrix. The DSC analysis showed a single glass transition temperature ( $T_g$ ) for both modified and unmodified PU nanocomposites. Mechanical and swelling properties of these nanocomposites were also studied. The tensile strength increases with the increase in the filler content. The percentage elongation decreases with the increase in the clay content. The swelling ratio increases with the increase in the amount of clay content. The modified polyurethane nanocomposites showed better properties when compared to the unmodified polyurethane nanocomposites.

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## Thermal and Mechanical Properties of PET/LDPE Blends

C. THONGPIN<sup>1,2,3\*</sup>, K. JANROD<sup>1</sup>, C. PANIAME<sup>1</sup>, P. PLONGTHONG<sup>1</sup> AND N. SOMBATSOMPOP<sup>3</sup>

<sup>1</sup>Materials Science and Engineering Department, Faculty of Engineering and Industrial Technology, Silpakorn University, Sanamchandra Palace Campus, Nakorn Pathom, 73000, Thailand; <sup>2</sup>Center of Excellent for Petroleum, Petrochemical, and Advanced Materials, Chulalongkorn University, Bangkok, 10330, Thailand; <sup>3</sup>Polymer Processing and Flow Research Group (P-PROF) and CUP-NATURE Research group, School of Materials Technology, King Mongkut University of Technology Thonburi (KMUTT), Bangmod, Thungkru, 10140, Thailand.

E-mail: [chanchai@su.ac.th](mailto:chanchai@su.ac.th), [cmaterials@hotmail.com](mailto:cmaterials@hotmail.com)

This study is aimed to evaluate the effect of PE on PET properties, both thermal and mechanical properties, in PET and LDPE blends. The various contents of LDPE in PET/LDPE blends, with and without compatibilizer, 10 % by weight of MA-g-HDPE added with respect to the blend composition, were studied. PET and LDPE, with the formulations of 90:10, 80:20, 70:30 and 60:40, were blended in a co-rotating Twin Screw Extruder. The blends of PE/LDPE/MA-g-HDPE with formulation of: 81:9:10, 72:18:10, 63:27:10 and 54:36:10 were also blended in the extruder. The palletized extrudate were then characterized using DSC and TGA techniques to evaluate crystallinity, melting temperature and degradation temperature of the blends. The palletized extrudate were also injection molded for tensile, impact and hardness testing. The morphology of the blends was also examined using SEM technique.

The DSC results revealed that, without compatibilizer, the present of LDPE effected crystallization of PET, by showing 2 melting peaks, around 230-260°C, on the thermograms. In term of thermal stability, the high content of LDPE would be able to thermally stabilize the blend, especially with the blend system containing compatibilizer. Considering tensile properties, it was found that Young's Modulus and Tensile strength of the blends decreased whereas elongation at break increased with the contents of LDPE. However, the present of compatibilizer brought tensile strength and elongation up to the higher values than without it. Meanwhile, Young's modulus was suffered by the present of the compatibilizer. Undoubtedly, the impact energy needed for fracture the blend specimens was increased with the contents of LDPE and even more pronounced with the present of compatibilizer. LDPE clearly lowered the hardness of the blends. It was found from SEM micrographs that the blends were clearly miscible using compatibilizer up to the high ratio of 63/27/10. At the high content of 54/36/10, the phase separation was found to be very clear in the micrograph due to the limited amount of compatibilizer used in this blend composition.

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## Thermal Behavior and Non-Isothermal Crystallization of Thermotropic Liquid Crystalline Polymer/Polypropylene In-situ Composite Films

SAYANT SAENGSUWAN\* AND PONGSATHORN TONGKASEE

*Advanced Organics Materials and Devices Laboratory, Department of Chemistry, Faculty of Science, Ubon Ratchathani University, Ubon Ratchathani 34190, Thailand.*

E-mail: [sayant@sci.ubu.ac.th](mailto:sayant@sci.ubu.ac.th)

In this study, in-situ composite films were prepared by two-step method. First, polypropylene (PP) and thermotropic liquid crystalline polymer (TLCP), Rodrun LC5000 were melt blended in a twin-screw extruder and then fabricated by extrusion through a miniextruder as cast film. Effect of TLCP contents on thermal behavior and non-isothermal crystallization kinetics of PP in the composite films was investigated using differential scanning calorimetry. Various kinetic models [1-2] were employed to describe non-isothermal crystallization kinetics of the samples. It was found that no effect of TLCP contents on the melting temperature of PP component. However, the crystallinity of composite films was slightly increased with increasing TLCP contents, owing to the nucleating effect of TLCP fibrils. The Ozawa analysis failed to provide an adequate description of the crystallization process; however, the method developed by Mo was successful in describing the non-isothermal crystallization of composite film. Different kinetic parameters such as Avrami exponent  $n$ , kinetic crystallization rate constant  $k_c$ , another kinetic parameter  $F(T)$ , half life of crystallization  $t_{1/2}$  etc. were evaluated at various cooling rates. The values of  $t_{1/2}$ , and  $F(T)$  showed that in all composite films crystallization rate increased with increase in cooling rate. Finally, the activation energy calculated by the Kissinger method of the composite films containing 5wt%, 10wt% and 15wt% TLCP were 256, 210 and 216  $\text{kJmol}^{-1}$ , respectively, which were slightly higher than that of the pure PP film (202  $\text{kJmol}^{-1}$ ).

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## Preparation and Properties of Poly(lactic acid) – based Nanocellulose Biocomposites

D. Y. LIU<sup>1</sup>, X. W. YUAN<sup>1\*</sup>, D. BHATTACHARYYA<sup>1</sup> AND A. J. EASTEAL<sup>2</sup>

<sup>1</sup>*Department of Mechanical Engineering, University of Auckland, Auckland, New Zealand*

<sup>2</sup>*Department of Chemistry, University of Auckland, Auckland, New Zealand*

E-mail: [xw.yuan@auckland.ac.nz](mailto:xw.yuan@auckland.ac.nz)

The preparation and characterization of fully biodegradable Poly(lactic acid) (PLA)-based nanocellulose biopolymer composites is discussed. Polylactide polymers are been attracting enormous attention as a replacement for conventional synthetic packaging materials because they are biodegradable, compostable and recyclable. PLA, as a versatile biopolymer made from renewable agricultural raw materials, provides an opportunity for the packaging market because of the combination of high clarity and stiffness, and excellent printability and conventionally available production technology[1]. It has high potential in packaging of respiring food due to its high O<sub>2</sub> and CO<sub>2</sub> permeability ratio. However, high water vapour permeability and low thermal stability limit its application in packaging. Nanocellulose is also a naturally renewable and biodegradable material with good mechanical properties (modulus of 138GPa), which makes it a better candidate for reinforcement of biopolymer matrices to improve the water vapour permeability, mechanical properties and thermal stability without affecting the transparency of the matrix[2].

In our experiment, the nanocellulose whiskers were produced by sulphuric acid (65 wt.%) hydrolysis of bleached flax yarn at 55 °C for 60 min. Composite films with different thickness were prepared by mixing cellulose aqueous with PLA/1, 4 dioxane solution using solution casting technology. The microstructure and chemical state of the composites were studied by Transmission Electron Microscopy (TEM) and Attenuated Total Reflectance Fourier Transform Infrared (ATR/FTIR) analysis. The mechanical performance was evaluated using conventional tensile testing and dynamic mechanical thermal analysis (DMTA). The transparency and barrier properties of the films were investigated using UV-Vis spectroscopy and an oxygen permeability chamber. Differential Scanning Calorimetry (DSC) and Differential Thermal Analysis (DTA) were also performed to investigate the thermal properties..

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## **Experimental Design on Engineered Wood: Laminated Veneer Lumbers(LVL) Reinforced Composites**

Y. MINGMONGKOL<sup>1,2</sup> AND U. MEEKUM<sup>1,2</sup>

<sup>1</sup>*School of Polymer Engineering, Institute of Engineering, Suranaree University of Technology, Nakorn Ratchasima 30000, Thailand*

<sup>2</sup>*Center for Petroleum, Petrochemical, and Advanced Materials, Chulalongkorn University, Bangkok 10330, Thailand*

E-mail: [yumatorn\\_nk@hotmail.com](mailto:yumatorn_nk@hotmail.com)

Engineered woods for outdoor furniture and construction materials for hazards environmental condition is the prime concern for this study. The laminated veneer lumber(LVL) derived from rubber wood and eucalyptus peeled sheet and teak veneer was prepared. All of the wood obtained from economic farm forest. The glass and carbon woven fiber reinforcement and in house room temperature and prepreg epoxy matrix were employed. 2<sup>k</sup> factorial experimental design were used to analyze the significant effect of those constituent of the mechanical property by mean of flexural strength of the engineered wood obtained. The main experimental factors for the design include fiber, adhesive and peeled wood types. The treatment of the laminated wood such as smoking and anti termite application is also investigated. Quantity silane addition to curing agent will also evaluated. According to the preliminary experimental design results, based on the statistical analyses, it was found that adhesive types had significantly effected on flexural strength of LVL vice versa the fiber types.

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## Plasma Oxidation Effect on MWCNT for Electrophoretic Deposition

BYUNG SUN KIM<sup>1</sup>, OYOUNG CHOI<sup>1</sup>, JOON HYUNG BYUN<sup>1</sup>, JIN BONG KIM<sup>1</sup>  
DONG LYUN CHO<sup>2</sup>, KYUNG SEOK KIM<sup>2</sup>, WOO IL LEE<sup>3</sup>

<sup>1</sup>*Composites Mat'ls Lab, Korea Institute of Materials Science, Changwon, Korea  
641-010*

<sup>2</sup>*Faculty of Applied Chem. Eng., Chonnam National University, Gwanju, Korea  
500-757*

<sup>3</sup>*Dept. of Mech. Eng., Seoul National University, Seoul, Korea 151-742  
E-mail: [kbs@kims.re.kr](mailto:kbs@kims.re.kr)*

CNTs were reinforced into the carbon fabric composites by the electrophoretic deposition (EPD) which is one of efficient methods to disperse and deposit nano particles. In EPD, the charged particles in suitable suspension move toward an electrode under an applied electric field between anode and cathode, and finally deposited onto opposite electrode. In order to charge the CNTs in aqueous suspension under an electric field, CNT needs surface treatment. When carboxylic acid functional group COOH introduced to CNT, it could be charged negative (COO<sup>-</sup>) in aqueous suspension by losing hydrogen (H<sup>+</sup>). Plasma oxidation which is well known for CNT dispersion method was chosen in order to provide efficient CNT dispersion and deposition. In addition to (1) COOH carboxylic functional group, (2) CH<sub>2</sub>=CHCOOH acrylic acid group (unsaturated carboxylic acid with a vinyl group) and (3) COO-Na sodium carboxylate which is modified COOH (H<sup>+</sup> replaced by Na<sup>+</sup>) were introduced by plasma treatment, respectively. Plasma oxidation introduces the functional group without damage of CNT surface, while oxidation using acid solution which breaks the C-C covalent bonding. The surface of CNT deposited carbon fabric was observed with scanning electron microscope (SEM) and CNT depositions were evaluated. The qualified ones were fabricated as composites for the characterization. Plasma treated CNT were dispersed homogeneously in distilled water suspension, which corresponds to CNT's uniform deposition on carbon fabric. Plasma treated CNTs reinforced carbon fabric composites have improved mechanical properties, short beam strength, comparing with plain carbon fabric composites. Also, electrical conductivities were improved with CNT contents.

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## Overall Characterization of Cellulose Fiber Reinforced PLA

J. G. KOVÁCS<sup>1\*</sup>, J. SOULESTIN<sup>2</sup>, T. TÁBI<sup>1</sup>, R. RAMY-RATIARISON<sup>2</sup>, E. LAFRANCHE<sup>2</sup>, M.-F. LACRAMPE<sup>2</sup>, T. CZIGÁNY<sup>1</sup>, P. KRAWCZAK<sup>2</sup>

<sup>1</sup>*Budapest University of Technology and Economics,*

*Department of Polymer Engineering, Budapest, Muegyetem rkp 3, H-1111, Hungary*

<sup>2</sup>*Ecole des Mines de Douai Polymers and Composites Technology & Mechanical Engineering Department 941, rue Charles Bourseul, BP 838, 59508 DOUAI Cedex, France*

E-mail: [kovacs@pt.bme.hu](mailto:kovacs@pt.bme.hu)

Due to the environmental protection there is an increment in the applications of degradable matrix composites and several of these products are reinforced with natural fibers to keep their biodegradability. The aim of our project was to develop these kinds of biologically degradable biopolymer composites and to fully determine their mechanical and other characteristics. From several biodegradable polymers, poly(lactic-acid), PLA was chosen as the matrix material [1, 2], and cellulose fibers as reinforcement.

Our main goal was to describe not only the basic mechanical properties but the shrinkage, orientation and degradation properties of these materials in a complex way. To fulfill the research a special 2 mm thick and 80×80 mm wide plate specimen was used. The shrinkage and warpage data were measured and also the orientation measurements were carried out, because it has a huge influence on the uneven shrinkage, hence on the warpage as well. The optimization of the different manufacturing parameters is essential for the manufacturability of these products. For this reason the material was fully characterized (viscosity, pvT, etc.) to be able to use the data in the injection molding simulations (Moldflow Plastics Insight 6.2) [3, 4].

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## **Micromechanical Analysis of Randomly Distributed Fiber Reinforced Composites under Off-axis Loading**

M. J. MAHMOODI<sup>\*</sup>, M. M. AGHDAM AND M. SHAKERI

*Department of Mechanical Engineering, Amirkabir University of Technology, Hafez Avenue, Tehran, Iran*

E-mail: [mjmahmoodi@aut.ac.ir](mailto:mjmahmoodi@aut.ac.ir)

A three-dimensional micromechanical model is presented to predict the elastoplastic behavior of a randomly distributed unidirectional fiber reinforced composites subjected to off-axis loading. By extending the geometry of the RVE of the Simplified Unit Cell (SUC) model [1,2] for square array to an  $r \times c$  sub-cell domain achieve an RVE to model mixed materials that inclusions are distributed randomly in some sub-cells depending on relevant volume fraction. Under general off-axis loading, after transforming the overall load to material coordinate system, applied normal and shear load on the RVE are obtained, depending on the off-axis angle. Using theory of elasticity regulations and substitution of thermo-elasticoplastic constitutive equations for isotropic constituents' sub-cells and satisfaction equilibrium conditions between various sub-cells into compatibility equations in conjunction with equilibrium equations on the boundary of the RVE, governing equations can be obtained which includes a system of  $m=r \times c+r+2 \times c$  equations for the RVE with the same number of unknown normal and shear stress component. For solving this iterative system of equations, successive approximation method together with Von-Mises yield criterion for local yielding of matrix sub-cells is used. Results for random fiber arrangement are obtained using average values of 5–7 analyses with  $10 \times 10$  and  $50 \times 50$  sub-sells for two composite system including SiC/Ti and B/Al. Effects of different parameters such as manufacturing process thermal residual stresses, fiber packing including square, hexagonal and random arrangement, fiber volume fraction and loading direction are investigated. Comparison between results of the presented model shows very good agreement with the other analytical and finite element micromechanical analysis for more realistic randomly distributed fiber reinforced composites in various off-axis angles.

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## Compatibility and Toughness of PA6 Modified with MAH Grafted POE

WANG LIXIAN<sup>1</sup>, GUO QIANG<sup>1\*</sup>, PAN GUOLIANG<sup>1</sup>, WANG XIAOMING<sup>2</sup>, XU CHENG<sup>1</sup>

<sup>1</sup>*School of Materials Science and Engineering, Shanghai University, Shanghai 201800, China*

<sup>2</sup>*Shanghai Electric Cable Research Institute, Shanghai 200093, China*

E-mail: [guoq@shu.edu.cn](mailto:guoq@shu.edu.cn)

To improve the compatibility of POE in PA6 blends, Maleic anhydride (MAH) grafted ethylene-1-octene copolymer (POE) was prepared by reactive extrusion in twin-screw extruder. The effects of MAH, dicumyl peroxide (DCP) and EDS on grafting product were studied. The results showed that melt index (*MI*) decreased while grafting degree increased with increasing MAH and DCP contents. However, EDS would deteriorate properties of products when using extruder with strong shear and short residence time [1]. POE-g-MAH and/or POE were also blended with PA6 by twin-screw extruder under 150~200°C. For the PA6 blends with different composition, the notched impact strength tested under RH60% was always higher than that tested under dry air. But the curves of mechanical properties vs. POE-g-MAH content under different testing conditions exhibited similar trends. The notched impact strength of blends increased with the increase of the relative content of POE-g-MAH. There was a jump between 10 and 15phr during the curve of notched impact strength vs. POE-g-MAH content. When the content of POE-g-MAH was 20phr the notched impact strength was about fifteen times that of pure PA6. However, the tensile strength of blends decreased with the increase of the content of POE-g-MAH as well as flexural strength and flexural modulus. In addition, the water absorption rate of blends decreased with the increase of the content of POE-g-MAH. As blends of PA6/POE+POE-g-MAH (80/20) were concerned, when the content of POE-g-MAH was less than 4phr, the toughness increased rapidly with increasing content of POE-g-MAH, and then almost kept this value after. The micrographs of SEM showed that the break of materials transfer from brittle break to tough break when the graft degree was 0.14-0.28%. It should be noted that graft degree had little influence on tensile strength and flexural strength under different testing condition. If PP was filled into the blends above, the notched impact strength would decrease with the content of PP, but the tensile strength and flexural strength increased slightly. In comparison with blends of PA6/EPDM-g-MAH, both the notched impact strength and tensile strength of PA6/POE-g-MAH were higher than that of PA6/EPDM-g-MAH.

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## Composite Fibers Containing Carbon Nanotubes: Effects of Aspect Ratio on the Physical Properties

D. ACIERNO, P. RUSSO\* AND P. SPENA

*Department of Materials and Production Engineering, University of Naples*

*“Federico II”, Naples 80125, Italy*

E-mail: [pietro.russo@unina.it](mailto:pietro.russo@unina.it)

During the last decades, carbon nanotubes (CNTs) have gained an increasing attention from scientist and industrial researchers because of their outstanding properties [1]. This peculiarity, mainly due to their typical morphology with high aspect ratio and anisotropic structure, is widely shown in terms of high modulus and electrical/thermal conductivity.

Several evidences are available about the use of CNTs to enhance the modulus and the strength of neat fibers based on many largely used polymers such as PP, PC, PMMA, PET and so on.

However, although this scenario is surely verified on the size scale of both single (SWCNTs) and multi walled carbon nanotubes (MWCNT), it is worth to say that performances of derived polymer based composites usually depend upon many variables. At this regard, as well established in the literature [2], processing conditions, presence of any functionalization at the interphase with the hosting matrix and geometrical features of the nano reinforcement (aspect ratio, diameter) play key roles.

In light of this latter consideration, main aim of this research is to analyze effects of MWCNTs aspect ratio on the physical properties of melt-spun fibers based on poly(butylene terephthalate) PBT.

In particular, dynamic-mechanical, tensile and thermal measurements were carried out on fibers containing 0.2, 0.5 and 1.0 % by weight of not functionalised MWCNTs considering three different aspect ratios.

Preliminary results show that expected improvements of elastic behaviour, stiffness and tensile strength of PBT based fibers, consequent to the inclusion of nanotubes, are significantly enhanced by increasing their aspect ratio.

Moreover, a slight increase of the matrix melting point is revealed by increasing both nanotubes content and aspect ratio as a sign of an enhancement of the composites thermal stability.

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## **Tensile Properties and Durability of Kenaf Fiber-Poly(lactic acid) Biocomposites**

R. M. TAIB<sup>1\*</sup>, S. RAMARAD<sup>1</sup>, Z. A. MOHD ISHAK<sup>1</sup> AND M. TODO<sup>2</sup>

<sup>1</sup>*Department of Material and School of Material and Mineral Resources Engineering, Universiti Sains Malaysia, 14300 Nibong Tebal, Penang, Malaysia*

<sup>2</sup>*Key Research Institute of Applied Mechanics, Kyushu University, Fukuoka 816-8580, Japan*

E-mail: [razaina@eng.usm.my](mailto:razaina@eng.usm.my)

Increasing awareness on the environmental safety has forced manufacturers to consider biodegradable materials for their products. The aim of this work was to investigate tensile properties and durability of biocomposites from kenaf fiber (KF) and poly(lactic acid) (PLA). The composites were prepared by an internal mixer and compression molding. Polyethylene glycol (10 wt.%) was used as plasticizer for PLA. Fiber loadings were up to 40 wt%. Reinforcing effect of KF was observed when the fiber loading exceeded 10 wt%. This was observed in spite of the inferior interfacial adhesion between KF and PLA matrix as observed via scanning electron microscopy (SEM). Un-plasticized PLA/KF composite with 40 wt% KF showed better tensile properties than the plasticized composite counterpart. In contrast, heavily coated pulled-out fibers by the PLA matrix as well as fiber breakage were observed on the composite fracture surface. These observations suggest that PLA is compatible and can interact with KF and that PEG might have interrupted the interaction between KF and PLA in the plasticized composites. Water absorption behavior of PLA/KF composites was studied by immersion in distilled water at room temperature for 60 days. All composites were found to exhibit non-Fickian diffusion process. This was attributed to the development of micro-cracks on the surface and inside the materials. In addition to micro-cracks that occurred along the fiber length, water absorption too caused fiber-matrix debonding. Both were revealed via SEM examination on the surfaces of the composites. PLA/KF composites were buried in soil and also exposed to natural weathering for 3 months. In both experiments, composites exhibited some weight losses, fragmentation of the composite surfaces, formation of micro-cracks and discoloration. Examination via FTIR showed increased intensities of absorption peaks associated to C=O, C-O and -OH groups suggesting degradation of PLA. Results suggested that KF is a potential reinforcement for plasticized poly(lactic acid) composites. The possible applications, however, should avoid high humidity environments and outdoor exposure.

## **The Structure and Properties of Mineral Clay Reinforced Blend PVA/Corn Starch**

N. OTHMAN\*, S. H. MOHD

*School of Materials & Mineral Resources Engineering, Universiti Sains Malaysia,  
Nibong Tebal, 14300 Penang, Malaysia*

E-mail: [snadras@eng.usm.my](mailto:snadras@eng.usm.my)

Several PVA/ corn starch blended films were prepared by solution casting method and reinforced with mineral clay to improve the properties of the films. Two different types of mineral clay namely; bentonite and kaolinite were used in this research. The amount of mineral clay was varied and the effects to the structure and properties of the film were studied. The objective of this study is to determine the optimum clay loading that will give superior combination of properties. The physical, mechanical and biodegradable properties were studied. The structure of the films was characterized by Fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), tensile testing, water absorption, and scanning electron microscopy (SEM). The FTIR result shows clearly the active group present in the PVA, starch and also in the mineral clay. The highest crystallinity of the kaolinite reinforced blend film was shown by the XRD results. From the tensile results, the blend with 0.4 g of kaolinite was found to have the highest tensile strength about 14MPa and its elongation at break was 210%. While the blend with 0.4g bentonite shows lower tensile strength and elongation at break than kaolinite reinforced blend PVA/ starch film. Moreover, water absorption of bentonite filled PVA/starch blend film shows higher value than kaolinite filled film and the water absorption increases as the clay content increases. On the other hand, the distributions of clay in the blend were revealed through SEM. It is shows that kaolinite filled film has uniform distribution than bentonite filled film. The soil burial degradation test showed that bentonite filled film is more susceptible to degrade than kaolinite filled films.

## Structure and Properties of SPEEK Proton Exchange Membrane Doped with CeO<sub>2</sub> and Treated with High Magnetic Field

TONG JUYING<sup>1,2</sup>, GUO QIANG<sup>1,\*</sup>, YANG LINGLING<sup>1</sup>, WANG XIANXIAN<sup>1</sup>, DONG YUNFENG<sup>1</sup>

<sup>1</sup>*School of Materials Science and Engineering, Shanghai University, Shanghai, 201800, China*

<sup>2</sup>*School of Wenling, Zhejiang TV University, Wenling, 317500, China*

E-mail: [guoq@shu.edu.cn](mailto:guoq@shu.edu.cn) or [ktong607@yahoo.cn](mailto:ktong607@yahoo.cn)

To improve the competitive comprehensive properties, the proton exchange membrane of sulfonated polyetheretherketone(SPEEK) doped with CeO<sub>2</sub> for direct methanol fuel cell application were prepared with 48.3% sulfonation degree, and then they were treated with high magnetic field either parallelly or perpendicularly against the surface of membrane. The spectra of samples, which were collected by a FT-IR spectrometer, illustrate certain coordination between oxygen anion of sulfonic groups and cerium cation of CeO<sub>2</sub> which dispersed evenly in the membranes, demonstrated by a SEM. The XRD patterns of samples prove the crystal structure of CeO<sub>2</sub> without change in composite membranes.

The water uptake of samples decreased drastically initially, but slightly with further increasing CeO<sub>2</sub> contents, and they were almost the same under the different treatments. The methanol permeability of SPEEK/CeO<sub>2</sub> composite membranes decreased generally with increasing CeO<sub>2</sub> contents using a diaphragm diffusion cell [1]. As for the methanol permeability, perpendicularly treated membrane exhibited lower leakage, while parallelly treated one without obvious improvement. The conductivities of the all samples decreased with increasing CeO<sub>2</sub> contents, but increased with elevating temperature. Compared to the membrane without magnetic field treatment, parallelly treated one performed higher conductivity, but lower than that via perpendicular high magnetic field treatment. There were two mechanisms of proton transportation [2], vehicle mechanism, in which proton transports by the phase separation channels in the form of H<sub>3</sub>O<sup>+</sup> or H<sub>5</sub>O<sub>2</sub><sup>+</sup>, or Grotthuss mechanism, by hopping between sulfonic groups with the coordination of cerium cation of CeO<sub>2</sub> and oxygen anion of sulfonic groups.

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## Process Induced Residual Stress and Deformation in a Ring-Stiffened Composite Launching Tube

XU CHAO<sup>1\*</sup>, LIN SONG<sup>1</sup> AND LI RUIJIE<sup>2</sup>

<sup>1</sup>*College of Astronautics, Northwestern Polytechnical University, Xi'an 710072, China*

<sup>2</sup>*Aerospace Research Institute of Material and Processing Technology, Beijing 100076, China*

E-mail: [chao\\_xu@nwpu.edu.cn](mailto:chao_xu@nwpu.edu.cn)

Composite materials are being used to fabricate launching tubes for strategic missiles due to their excellent specific strength and stiffness over traditional metal materials. The favoured method of manufacture is filament winding. Depending on lay-up and cure cycle, large localized residual stresses can be generated during processing which could cause defects such as layer separation, micro-cracking and poor dimensional fidelity.

In this paper, the residual stress field and deformation in a ring-stiffened composite launching tube are studied. Two process-induced sources of residual stress and strain are considered. They are curing and winding tension. Three-dimensional composite hexahedral elements in Marc are applied to model a 9000 mm long, 750 mm inner radius launching tube. Cyclic symmetry analysis is used to reduce computation cost. Using lamina material properties and assuming that the curing temperature is stress free, the elastic residual stress and deformation during curing are predicted. The influence of different fillet transition geometry between ring stiffeners and cylinder shell as well as winding tension on residual stresses are examined detailed.

It is concluded that residual stress formation in stiffened composite shells has a non-monotonic character determined by the structure geometry and by the processing parameters. Residual stresses and deformation are chiefly caused by the thermal expansion incompatibility between the ring stiffener and cylindrical shell. For a giving curing regime, a residual stress distribution with respect to strength can be obtained by choose rational fillet transition, lay-up and winding tension parameters.

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## Structural Variations and Transcrystallinity in Polymer Nanocomposites

A. DASARI<sup>1,2\*</sup>, Z.-Z. YU<sup>3</sup> AND Y.-W. MAI<sup>1</sup>

<sup>1</sup> *Center for Advanced Materials Technology (CAMT), School of Aerospace, Mechanical & Mechatronic Engineering, The University of Sydney, Sydney, NSW 2006, Australia*

<sup>2</sup> *Madrid Institute for Advanced Studies of Materials (IMDEA-Materials), E. T. S. de Ingenieros de Caminos, 28040 Madrid, Spain*

<sup>3</sup> *Beijing Key Laboratory on Preparation and Processing of Novel Polymeric Materials, Department of Polymer Engineering, College of Materials Science and Engineering, Beijing University of Chemical Technology, Beijing 100029, China*

E-mail: [adasari@usyd.edu.au](mailto:adasari@usyd.edu.au); [aravind.dasari@imdea.org](mailto:aravind.dasari@imdea.org)

There are many questions surrounding the occurrence of preferential orientation of lamellae (transcrystalline regions) in the vicinity of fillers and their influence on interface and ultimate mechanical properties in polymer composites [1]. More significantly, preferential oriented growth due to epitaxy *versus* geometric confinement effect (offered in particular by nano-fillers) during crystallization, size range and dimension of fillers, differences in thermal conductivities of fillers (and polymers), and the toughness of the resultant nanocomposites. In this talk, we will discuss the polymer lamellae orientations in the vicinity of different nano-fillers (carbon nanofiber, organoclay, calcium carbonate and carbon black) and more importantly, their role during the deformation processes. Further, correlations and comparisons will be made with the recently introduced 'mobility' concept [2, 3] concerning the enhanced ductility in polymer nanocomposites. Briefly, it was revealed that the ductility of polymer nanocomposites is system dependent and that the presence (due to lattice matching) or absence of transcrystalline regions does not have a significant bearing. Besides, mobility of nanoparticles is also only one of the mechanisms and not exclusively responsible for ductility.

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## **Influence of Surface Modification of RTM Fabricated Composites**

K. N. INDIRA<sup>1\*</sup>, Y. GROHENS<sup>2</sup>, S. THOMAS<sup>3</sup>, K. JOSEPH<sup>4</sup>, L. A. POTHAN<sup>5</sup>

<sup>1</sup>*TKMM College, Nangiarkulangara, Alappuzha, Kerala, India*

<sup>2</sup>*Labaratoire Polymers, L2PIC, Universite de Bretagne Sud, Lorient Cedex, France*

<sup>3</sup>*School of Chemical Sciences, Mahatma Gandhi University, Kottayam, Kerala, India*

<sup>4</sup>*Indian Institute of Space Technology, Thiruvananthapuram, Kerala, India*

<sup>5</sup>*Bishop Moore College, Mavelikkara, Alappuzha Kerala, India*

E-mail: [indiraelamon@yahoo.com](mailto:indiraelamon@yahoo.com)

The aim of this investigation is to relate the mechanical properties of the composites with the surface energy values of chemically treated banana fibres.

### **Introduction:**

Banana fibre obtained from the pseudo stem of *Musa Sapientum* is found to have a good reinforcement capacity. Here these fibers are utilized as effective reinforcement in PF resin. Observations of Alexis et al [1] Garcia [2] support this work.

### **Experimental:**

Morphological analysis of the fibers and developed composites were done using FTIR and SEM. Surface polarity of the embedded fibers were measured using contact angle. Strain withstanding properties of the fabricated composites were measured.

### **Results and Discussion:**

In our studies lower contact angle is observed for hydrophilic surface using polar probe liquid and higher for hydrophobic surface. The same trend is shown for mechanical properties.

### **Conclusion:**

The contact angle of raw banana fiber is more with polar glycerol and less with non polar 1-bromonaphthalene. Wettability increases with increasing cellulose content and is improved by various treatments. The fibre matrix adhesion is higher in the case of NaOH treated fibre composite. Mechanical properties are found to be maximum in the case of NaOH treated fibre composites.

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## **Fabrication and Characterization of Locally Woven Polyester Fiber Reinforced Polyester Composites**

M. T. ISA\*, P. A. P. MAMZA<sup>1</sup>, T. K. BELLO AND A. U. NDANUSA

*Department of Chemical Engineering Department, Ahmadu Bello University, Zaria*

*<sup>1</sup>Department of Chemistry, Ahmadu Bello University, Zaria*

E-mail: [mtisa@abu.edu.ng](mailto:mtisa@abu.edu.ng) or [mtisaz@yahoo.com](mailto:mtisaz@yahoo.com)

Properties of composite Moulded using locally woven polyester fiber were studied in this work. The results showed that though properties of polyester resin were improved upon, but were far lower than composites obtained using fiber such as glass. The density of the composite was found to be low compared with that of glass fiber reinforced composite. The composite moulded at pressure of 388.132kN/m<sup>2</sup> was found to have the best properties, tensile strength 85MN/m<sup>2</sup>, modulus of elasticity 1.846GN/m<sup>2</sup>, impact strength 609.496kJ/m<sup>2</sup> and modulus of rupture of 9.910GN/m<sup>2</sup>.

## **Synthesis and Characterization of TiO<sub>2</sub> Structured PI Nano-Composite Thin Films for Use in Modern Technology Applications**

ANAND KUMAR GUPTA\*<sup>1,2</sup>, A. TIWARI<sup>2,3</sup>, J. M. KELLER<sup>1,2</sup> AND RAKESH BAJPAI<sup>2</sup>

<sup>1</sup>*Macromolecular Research Center, Rani Durgawati University, Jabalpur, (M.P), India*

<sup>2</sup>*Department of Physics, Rani Durgawati University, Jabalpur, (M.P), India*

<sup>3</sup>*Mata Gujri Mahila Mahavidyalaya, Jabalpur, (M.P), India*

E-mail: [anandlug2005@rediffmail.com](mailto:anandlug2005@rediffmail.com)

A break through in organic nano-composite material would be of tremendous scientific and practical signification in the area of information technology, communication, hardware and other frontier areas. The concept of structuring inorganic material within organic matrix is to obtain new materials with synergistic and additive properties. The importance of polyimide in 'state of the art' microelectronics due to its excellent properties and versatility in converting in to numerous end products has led to extend the new concept of development. Nanoscopically structured Titanium oxide (TiO<sub>2</sub>)/polyimide (PI) nano-composite films were prepared using solution cast technique with the help of In-situ Generated Nano-Phase Structure (IGNPS) approach. A systematic nanoscale structured TiO<sub>2</sub> nano-composite films posses desired organizational features between the size of single molecules and about 100 nm. The TiO<sub>2</sub>/PI nano-composite thin films are likely to exhibit superior and unique macroscopic and micromechanical properties because of the size of the reinforcing material. These novel properties could be attributed to a very high surface/volume ratio of the nano-particle and as well very different inter-phase between TiO<sub>2</sub> nano-particle and the PI matrix. Titanium oxide (TiO<sub>2</sub>) incorporated polyimide (PI) nano-composite films were synthesis and analyses using FT-IR, Optical and AFM characterization. Thereafter, micromechanical performances were evaluated using tensile strength, tensile modulus and elongation. Thermal stability of TiO<sub>2</sub>/PI nano-composite film was studied using TGA technique. Value of hardness (H<sub>v</sub>) was calculated using Vickers indenter. Optical and AFM topographic image clearly shows the incorporation of TiO<sub>2</sub> within the PI matrix in nano domain. Value of hardness H<sub>v</sub> for TiO<sub>2</sub>/PI composite films were found to be greater than pure PI film which shows the hardening behavior of the composite films. The presence of TiO<sub>2</sub> within PI matrix reinforced the PI as a whole, increasing the micromechanical properties and thermal stability up to 370°C. The resultant product has exhibited the functional characteristic either that of the TiO<sub>2</sub> nano-particles itself or special structure of TiO<sub>2</sub> nano-particles within the PI matrix and assigning to be use in modern microelectronics and engineering application.

## Strength and Damage Assessment on Bonded-Joint of GFRP Composite under Tensile Loading

P. K. DASH<sup>1</sup>, R. ASOKAN<sup>1</sup> AND A. J. STANLEY<sup>2\*</sup>

<sup>1</sup>*Dept. of Aeronautical Engineering, Hindustan University,  
Padur, Chennai-603103, Tamilnadu, India*

<sup>2</sup>*Department of Aerospace Engineering, M.I.T., Chromepet, Chennai - 600 044,  
Tamilnadu, India*

E-mail: [drpdash@gmail.com](mailto:drpdash@gmail.com)

Dramatic development of new structural materials in form of composite (either metal, or non-metal, or metal and non-metal combinations) has catapulted for substituting only metals in various industries such as aviation, shipbuilding, civil engineering, transport, locomotive and chemical-petroleum industries. Though it is filled with lot of virtues, still one of the avenue leading to the safety and durability of infrastructure systems built by these composite materials are rear challenge for industries. One of the problem areas is application of joints of these materials for full assembly into a required configuration.

In this paper, an extensive research on strength measurement and failure mechanism of various types of joints practiced on composite in design process were studied. Selected numbers of specimens were fabricated using bi-directional woven glass fiber and epoxy resins, and homogeneity was checked. All the specimens were shaped according to ASTM Standard and have tested under tensile loading condition. The results are analyzed for single lap adhesive joint of composite, riveted joint of composite and bolted joint of composite. The pre-failure evaluation was carried out and was monitored by application of acoustic emission technique (AET). This was assessed by amount of strain energy release during failure of the specimens.

It has been observed that the influence of adhesive joint on composite material provides significant strength in compare to other two joints and peel type of failure was accounted at higher value of tensile load with respect to adhesive failure. The failures of the jointed specimens were portrayed through strain energy release rate, density distribution of strain energy and acoustic emission recorded. The results are enduring positive outcome of the failure at point of joint.

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## **Copolymerisation Cationique of 1,3,5-trioxane with 1,3-dioxolane Catalyzed by Maghnite-H<sup>+</sup>**

K. BELOUFA, N. SAHLI, M. BELBACHIR

*Laboratory of Polymer Chemistry, Department of Chemistry, Faculty of Science*

*University of Oran Es-Senia, BP 1524, EL M'NAOUR 31000 Oran*

E-mail: [trioxane13@yahoo.fr](mailto:trioxane13@yahoo.fr)

Polyacetal is a hard thermoplastic which is synthesized by polymerization of 1,3,5-trioxane or by cationic polymerization of 1,3,5-trioxane with cyclic ethers. This material is widely used in automotive industry. During our work, we are interested in studying the copolymerization of 1,3,5-trioxane with 1,3-dioxolane catalyzed by a new catalyst-based clay, which is the Maghnite-H<sup>+</sup>. And a kinetic study was done on the synthesis by varying parameters such as: The amount of Maghnite, the effect of the solvent, the effect of 1,3-dioxolane and the effect of temperature. The products obtained were characterized by <sup>1</sup>H-NMR, <sup>13</sup>C-NMR, IR and Viscometry.

## **New Electrostatic Discharge Protection and Electromagnetic Wave Shielding Effectiveness from Poly (vinyl chloride)/Graphite/Nickel Nanoconducting Composites**

A. A. AL-GHAMDI<sup>1</sup>, FARID EL-TANTAWY<sup>2\*</sup>, NADIA ABDEL AAL<sup>3</sup>,

W. E. MAHMOUD<sup>1</sup> E. H. EL-MOSSALAMY<sup>4</sup>

<sup>1</sup>*Department of Physics, Faculty of Science, King Abdulaziz University, Jeddah, P.O. 80203, Jeddah 21569, Kingdom of Saudi Arabia*

<sup>2</sup>*Department of Physics, Faculty of Science, Suez Canal University, Ismailia, Egypt*

<sup>3</sup>*Department of Chemistry, Faculty of Science, Suez Canal University, Ismailia, Egypt*

<sup>4</sup>*Department of Chemistry, Faculty of Science, King Abdulaziz University, Jeddah, P.O. 80203, Jeddah 21569, Kingdom of Saudi Arabia*

E-mail: [faridtantawy@yahoo.com](mailto:faridtantawy@yahoo.com)

Poly(vinyl Chloride)/graphite nanosheet/nickel (PVC/GN) nanocomposites are new alternative candidates for electrostatic charge dissipation and electromagnetic interference shielding applications due to their light weight, ease processing and tunable conductivities. The structures of the nanocomposites were examined by means of scanning electron microscopy (SEM) and x-ray analysis. The mechanical properties such as hardness, modulus of elasticity and elongation at break as a function of GN content were examined. The applicability of the nanocomposites as electrostatic charge dissipation was tested in terms of displaying the variation of decay voltage with time. In addition, the dielectric properties such as real and imaginary permittivity of composites as functions of frequency were investigated. Finally, the electromagnetic properties were measured in the frequency range from 1 to 12 GHz and compared with theoretical modeling. The highest shielding effectiveness at microwave frequency of these nanocomposites was 47 dB which is realistic for defense applications like radar evasion.

## **New Nano Conducting Composites from Polyvinyl Chloride Reinforced Graphite Nanosheets/Nickel Nanoparticles for Self Heating and Piezoresistive Application**

A. A. AL-GHAMDI<sup>1</sup> AND FARID EL-TANTAWY<sup>2,3\*</sup>

<sup>1</sup> *Department of Physics, Faculty of Science, King Abdulaziz University, Jeddah, P.O. 80203, Jeddah 21569, Kingdom of Saudi Arabia*

<sup>2</sup> *Department of Physics, Faculty of Science, Suez Canal University, Ismailia, Egypt*

<sup>3</sup> *College of Education for Girls at Balgarn, Department of Physics, King Khalid University, Balgarn, Sabt Alalaya, Kingdom of Saudi Arabia*

E-mail: [faridtantawy@yahoo.com](mailto:faridtantawy@yahoo.com)

Polyvinyl Chloride-graphite-nickel (PVC/GN) nanocomposites are new alternative candidates for PTCR thermistors, self heating element and pressure sensor applications due to their light weight, ease processing and tunable conductivities. The microstructure of the nanocomposites was examined by means of scanning electron microscopy. Mechanical properties like hardness, elongation at break, modulus of elasticity of composites were examined. The effect of GN concentration on the electrical conductivity, mobility carriers and concentration of charge carriers of the composites was studied. In addition, the conductivity as a function on temperature was investigated. Finally, the resistivity dependence on applied pressure was tested. It is believed that PVC/GN nanocomposite is one of the most promising candidate materials for PTCR thermistors, self heating element and pressure sensor applications.

## Crystallinity Behavior of MDPE-Clay Nanocomposites Fabricated Using Ball Milling Method

M. ABARESHI<sup>1</sup>, S. M. ZEBARJAD<sup>2\*</sup> AND E. K. GOHARSHADI<sup>1</sup>

<sup>1</sup> *Department of Chemistry, Faculty of Sciences, Ferdowsi University of Mashhad, 91779, Mashhad, Iran*

<sup>2</sup> *Department of Materials Science and Metallurgical Engineering, Faculty of Engineering, Ferdowsi University of Mashhad, 91775-1111, Mashhad, Iran*

E-mail: [Zebarjad@um.ac.ir](mailto:Zebarjad@um.ac.ir)

The high energy ball milling (HEBM) technique has emerged as a non-expensive route to produce nonequilibrium phases in several varied forms, such as nanostructured, amorphous materials, nanocomposites, and extended solid solutions [1]. It has many advantages, e.g. low cost, simple operation, high efficiency [2]. To the best of our knowledge, and in spite of simplicity of ball milling method, it has not been under more attention to produce polyethylene-clay nanocomposites. Thus, the goal of this study is to fabricate polyethylene-clay nanocomposites by high energy ball milling. To do so polymer-clay nanocomposites were fabricated using the planetary ball milling as a new method from medium density polyethylene (MDPE) and clay. The materials were characterized using scanning electron microscopy (SEM), transmission electron microscopy (TEM), and X-ray diffraction (XRD). The crystalline size of polyethylene filled with clay was studied by X-ray diffraction. These studies indicate that the addition of clay decreases the crystalline size of the polymer. Moreover, the degree of crystallinity of both ball-milled and un-milled polyethylene and polyethylene clay nanocomposites was measured by applying the X-ray diffraction technique. The results show that both milling time and clay content decrease the degree of crystallinity of polyethylene.

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## **Molecular Model of Plastic Deformation of an Oriented Linear Flexible Chain Crystalline Polymer**

ULMAS GAFUROV

*Institute of Nuclear Physics, Tashkent, Uzbekistan*

E-mail: [ulmas3@mail.ccc.uz](mailto:ulmas3@mail.ccc.uz)

Modelling of molecular processes in plastic deformation of an oriented linear partly crystalline polymer was carried out. Simple cosine periodic potential as in Frenkel-Kontorova's dislocation model was used for intermolecular interaction and condition of balance of loaded chain in polymer crystallite.

The dislocation formation is accompanied molecular chains slippage and local loads relaxation on their amorphous sections as well as by conformation regroupings of these sections in some conditions. In dependence on external load and amorphous region length different cases are realized. The first case takes place when the load is moderate. In this case the load on the amorphous section of a slipped out chain are completely relaxed and this section could change its conformation state. In the another case slipped out amorphous section of a macromolecule is in strained state but its strain is less than one of the macromolecule before its slipping out.

The load relaxation value influences on dislocation behaviour. This behaviour depends except for of macromolecular chain parameters and geometrical configuration mainly from sizes of stressed amorphous section and of initial load on it. Beside of its deformation molecular processes are complexly dependent concentration of chain ends, entanglements and cross –links.

According to of the model in polymer deformation the leading elementary process is mechanically stimulation of thermo-fluctuation slippage of passage macromolecules. It is valid at least for flexible chain polymers.

## **Effect of Filler Surface Modification on the Processing and Properties of PP/BaSO<sub>4</sub> Composites**

I. GHAMARIAN<sup>\*</sup>, N. YOUSEFI, R. BAGHERI AND S. ZOKAEI

*Polymeric Materials Research Group, Department of Materials Science and Engineering, Sharif University of Technology, Tehran, Iran*

E-mail: [imanghamarian@yahoo.com](mailto:imanghamarian@yahoo.com)

Filler/matrix interaction has an important role on the physical and mechanical properties of particulate-filled polymer composites. The interaction can be modified by using different filler surface modification agents. Modification of the filler surface can enhance filler dispersion and filler loading level. Barium sulfate is a high density filler which is mostly used for increasing the density of polymer composites. Loading the matrix with extensive amounts of barium sulfate can promise a high density composite, but it severely deteriorates the impact strength of them. In this study, the effect of filler dry coating by stearic acid and wet coating by sodium stearate has been investigated. Besides, the optimum amount of coating has been determined and the effect of excessive filler coating has been discussed. At last, a new method for diminishing the negative effects of excessive coating has been proposed.

Dry and wet methods were used for coating the barium sulfate particles. Coated powders containing 1, 3 and 5 percent by weight of coat were prepared and melt blended with co-polypropylene in a co-rotating twin screw extruder. Mechanical testing (Tensile and Impact), DSC, SEM and Brabender® internal batch mixer were used to study the processing and properties of the composites.

Use of coated filler has increased the impact strength of the composites dramatically. The modulus and tensile strength, on the other hand, have decreased. Study of the fracture surface of the samples by SEM has proved that use of proper amounts of surface treatment has improved the impact strength through securing a better filler dispersion and providing a mean for timely debonding and cavitation of filler particles in the course of the fracture. Dry and wet coating methods generally provide similar results, but processing of the composites containing wet coated fillers is easier due to the existence of free sodium stearate molecules which act as lubricating agent. The lubricating effect of free sodium stearate also increases the crystallinity of the samples by increasing the mobility of polymer chains and enhancing their transport to the crystallites. Excessive coating has deteriorating effects on the impact strength due to filler agglomeration. Use of a low molecular weight processing aid such as polypropylene wax aids deagglomeration and through this, enhances the impact strength of composites containing excessively coated fillers.

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## Nanofillers in Fire Retarded Polymer Composites

B. BODZAY\*, B. MAROSFOI, P. ANNA, GY. MAROSI

*Budapest University of Technology and Economics, Department of Organic Chemistry and Technology, Budapest, 1527 Hungary*

E-mail: [bbodzay@mail.bme.hu](mailto:bbodzay@mail.bme.hu)

The possibility for combining the effects of reinforcement and fire retardancy was investigated using various thermoplastic and thermoset matrices. Beyond the known positive influences of nanofillers on the fire retardancy (FR) polymers the degradation initiating effect of certain nanofillers is also known (1). The influences of the nanofillers can be enhanced or reduced by modifying their surfaces. It has been investigated using thermal analytical and rheological methods. Various methods for formation and analysis of thin surface layers have been published (2-5). In this paper the formation and analysis of modified interfacial layers around CNT, MMT and sepiolite and their influence on the fire retardancy are discussed. Polymer matrix: ethylene-vinyl acetate copolymer, nanofillers: Sepiolite; multi wall carbon nanotubes and montmorillonite. The polymer and filler (5% w/w) were mixed in a Brabender internal mixer PL2000 at a temperature of 140°C, 250 rpm for 10 min. The composites were then compressed at 120°C and 100 bar for 2 min to obtain 4 mm thick samples. The samples were characterized by XPS, SEM, micro-Raman and FTIR-ATR methods. Laser Pyrolysis treatments were performed using CO<sub>2</sub> laser (10.6 μm, SYNRAD 48-1 equipped with Universal Laser and Gate Controller).

Characteristic chemical changes in the first stage of degradation are the scission of acetate groups and formation of double bonds. It is quite clear that the progress of degradation of MMT-containing system is larger, due to the access of catalytic Fe atoms. Cone calorimetry studies confirmed the advantages of the use of surface modified fibrous nanofillers in FR systems

A network of reinforcing fibrous nanofillers can be formed in the polymer matrix. Under the influence of fire it helps to keep the coherence of the char residue. The char formation, in turn, can be promoted by metal activation of the nanofillers.

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## Flame Retardant Epoxy Resin Based Composites

P. ANNA\*, A. TOLDY, B. BODZAY, B. SZOLNOKI, GY. MAROSI

*Budapest University of Technology and Economics, Department of Organic Chemistry and Technology, Budapest, 1527 Hungary*

E-mail: [panna@mail.bme.hu](mailto:panna@mail.bme.hu)

In this study the flame retardant performance and mechanism of a recently synthesized phosphorus-containing reactive amine (TEDAP) (1), which can be used in epoxy resins both as crosslinking agent and as flame retardant, was investigated. The mode of action and degradation pathway was compared in an aliphatic and aromatic epoxy resin system and in their combination. The thermal stability and flame retardant performance was characterized by thermogravimetry, limiting oxygen index (LOI) and UL-94 measurements, mass loss type cone calorimeter tests and by laser pyrolysis method (2).

It was observed that the main difference in the degradation of the reference and the flame retardant systems is that the degradation of the latter begins at lower temperature mainly with the emission of degradation products of phosphorous amine, which act as radical flame retardant in the gas phase delaying the further degradation steps. At the high temperature degradation stage the solid phase effect of the phosphorus compound prevails resulting in formation of phosphorocarbonaceous intumescent char and increase in mass residue. The ratio of phosphorus acting in gas phase and solid phase, respectively, was determined on the basis of thermogravimetric and XPS measurements.

In case of the aromatic system the ignition time did not increase, however the initial level of heat release rate decreased significantly and an elongated burning process was observed with moderately increasing heat release rate. In case of the aliphatic system, the ignition time increased and after ignition the peak of heat release rate was immediately reached and after that its value constantly decreased. The difference between these two systems could be explained by investigating the intumescent char structure formed during the burning: It could be concluded that in the aliphatic resin the average bubble diameter is smaller and the char is more flexible, while the aromatic resin forms a more rigid and inhomogeneous char. By combining the two epoxy resin components the solid phase effect of phosphorus could be enhanced and thus the heat release rate could be decreased at high temperature degradation, compared to the aromatic resin. By applying clay nanoparticles further decrease could be reached, due to their bubble nucleating effect, resulting in smaller average bubble diameter.

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## Synthesis of a Novel Hydrophobically Modified Polyacrylamide

MONA MARKAM AND ANJALI BAJPAI\*

*Department of Chemistry, Government Model Science College,  
Jabalpur 482001, India*

E-mail: [abs\\_112@rediffmail.com](mailto:abs_112@rediffmail.com)

Hydrophobically modified water soluble polymers are an important class of smart polymers which attract wide spread attention. Water soluble polymers modified with a few mole percentage of hydrophobic comonomer exhibit polymolecular association in aqueous solution. Consequently the viscosity and thickening property is higher by several orders of magnitude than the solutions of unmodified polymers of same molecular mass and at the same concentration. Further, it is possible to avoid the irreversible mechanical degradation. The solution behaves as physical gel, above a threshold concentration corresponding to the formation of three dimensional reversible network.

Hydrophobically modified polyacrylamide is a comparatively new class of polyacrylamide (PAAm) which has been extensively studied in recent years. The present communication reports a novel redox system comprising of potassium permanganate and dimer acid (DA) for polymerization of acrylamide (AAm). DA is the dimer of ricinoleic acid, a constituent of castor oil. DA not only served as the reductant for the radical initiator redox system but also provided the hydrophobic component in the resulting polymer. The polymerization was investigated in aqueous acetone acidified with sulphuric or nitric acid. Better yields were obtained on use of nitric acid. The product was characterized by FTIR spectroscopy, viscosity and swelling measurement. The product swelled significantly in water and the resulting hydrogel had sufficient strength to avoid irreversible mechanical degradation. Moreover, because of non polyelectrolytic nature of this polymer aqueous solutions were less salt-sensitive.

The swelling kinetics was investigated in water and buffer solutions in pH 4.0 and 9.2. The equilibrium swelling was attained in 24 hours. In alkaline buffer the swollen sample remained mechanically stable but degraded in the acidic buffer. The hydrogel shrank within few seconds on pouring the organic solvent, viz. acetone, methanol and chloroform. The shrank hydrogels re-swelled in water to a greater extent than before. This smart behaviour could be attributed to the strong conformational changes in response to the environmental changes. This material can be used to develop surfaces which switchable hydrophobic-hydrophilic properties.

This polymer was found to be very efficient for metal ion extraction from dilute solutions of metal ion.

## Reactive Compounding as Tool for Compound Development: Study on Rheology, Morphology and Mechanics

C. GREIN, T. SCHEDENIG, C. KNIESEL, D. GLOGER AND T. PHAM\*

*Borealis Polyolefine GmbH, 4021 Linz, Austria*

E-mail: [tung.pham@borealisgroup.com](mailto:tung.pham@borealisgroup.com)

Over the last decades, different methods have been developed to improve mechanical performance of polymer compounds and blends by controlling the interfacial strength and stabilizing the phase morphology. One of the proactive approaches in compatibilizing multiphase polymer systems is the reactive modification which utilizes different chemistries in order to form copolymers directly during the compounding process [1-5]. In the last years we have developed and commercialized an efficient technology for post reactor modification of polypropylene materials based on the peroxide-initiated free radical reactions as tool for compound development.

In this study, we have investigated the effect of peroxide-initiated reactive modification on rheology, morphology and mechanical performance of blends and compounds based on different heterophasic polypropylene systems with different chemical compositions (e.g.ethylene/propylene ratio).

The rheological investigation was carried out on plate/plate rheometer. The effect of reactive modification on the polymer chain structure and, thus rheology could be visualized by applying the time-temperature superposition concept by van Gurp-Palmen [6].

Morphological investigation was carried out using scanning electron microscope and transmission electron microscope, respectively. It can be observed that the reactive modification leads, not only to a finer, but also to a much more stable phase morphology. The reason for this effect is believed to be the formation of ethylene-propylene copolymer grafted to polypropylene by free-radical reactions.

Mechanical investigations (e.g. tensile, bending, impact tests) confirmed the positive influence of phase compatibilization on the mechanical properties of PP compounds

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## The Influence of a Constant Magnetic Field on Structure, Specific Density and Electrical Conduction of Modified Epoxy Resins

V. DEMCHENKO, V. VILENSKY

*Institute of Macromolecular Chemistry, NAS of Ukraine, 48, Kharkivske Shausse, Kyiv, 02160, Ukraine*

E-mail: [dvaleriyl@ukr.net](mailto:dvaleriyl@ukr.net)

Physical modification of polymers and polymer composites is an effective remedy of the regulation of their structure and properties.

Therefore, it is important, both with scientific and practical points of view to investigate influence of external factors, in particular an external constant magnetic field on the structurization mechanism in composites and their properties <sup>[1]</sup>.

So, the purpose of the work was the researching of the influence of the value of the intensity external (ECMF)  $H=2\div 8$  A/m on structure, specific density and electrical conductivity of composites, received on the base of the polymer of a net structure – epoxy resins and fine-dispersed powders oxides of diamagnetic or ferromagnetic metals  $Al_2O_3$  and  $Fe_2O_3$ . The filler's concentration was changed in a range of 0,2-19,0 vol. %. Composites were investigated in the form of the films, received on a flat teflon plate, the which hardening lasted during 10 hours between poles to an electromagnet (a plane of the sample was perpendicular to a plane of poles) at  $T=295\pm 2$  K.

As a result of action ECMF there is reduction of the crystallites sizes of the iron oxide in structure to a composite from size  $L = 18,0$  to  $5,4$  nanometers, which was established by the method of X-ray analysis of polymers.

As a result of measurements of density by a method of hydrostatic weighing, it was shown, that composites on a base of epoxy resins and oxides of metals ( $Fe_2O_3$ ,  $Al_2O_3$ ) was generated in ECMF tend to density increase.

The researches of electrical conductivity on a constant current have shown the essential increase of this value under the influence of ECMF for composites of epoxy resin-3 vol. % of  $Fe_2O_3$  (on five usages) and epoxy resin - 3 vol. % of  $Al_2O_3$  (on six usages). This result, on our opinion, was caused by that oxide aluminium less capable to the formation of complexes with participation donor-acceptor groups of a polymeric matrix because complexes of  $Al_2O_3$  are not such deep traps, as ligand complexes with participation of  $Fe_2O_3$ .

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## **Functionalization and Engineering of Carbon Nanotubes with Ion Beam Irradiation**

ZHIWEI XU<sup>\*</sup>, LIANGSEN LIU, XIAOQING WU, YANAN JIAO, LI CHEN,  
JIALU LI

*Key Laboratory of Advanced Braided Composites, Ministry of Education, Tianjin  
Polytechnic University, Tianjin 300160, China*

E-mail: [xuzhiwei@tjpu.edu.cn](mailto:xuzhiwei@tjpu.edu.cn)

The paper reviews the basic effects of ion beam irradiation on carbon nanotubes (CNTs), as well as how this could be potentially useful for modification and functionalization of nanotubes. The production of irradiation-induced defects and their migration in CNTs are introduced and the influence of irradiation on the structural transformation, dimension, mechanical property, electrical property and magnetic property of CNTs is discussed. Several examples are given with particular emphasis on the structure tailoring, shaping, welding and molecular junctions of CNTs by the ion beam. It is shown that the change of irradiation conditions will lead to the different irradiation results. It is expected that ion irradiation studies will continue to play an important role in the research on CNTs.

## Prediction of Tensile and Morphological Properties of SBR Nanocomposites Using Constitutive Models

MOHAMMAD KARRABI\*, ISMAEIL GHASEMI, MIR HAMID REZA GHOREISHY

*Department of Rubber, Iran Polymer and Petrochemical Institute,*

*P.O.Box:14965/115, Tehran, Iran*

E-mail: [M.Karabi@ippi.ac.ir](mailto:M.Karabi@ippi.ac.ir)

SBR nanocomposites have been prepared containing 3, 6 and 9 Phr nanoclay contents at different mixing times (4, 8, 12 min). The effects of mixing time and concentration of nanoclay were studied on the tensile and morphological properties of nanocomposites, using tensile and XRD tests. The main purpose of this work was to investigate the applicability of four different constitutive models for a SBR rubber compound reinforced by nanoclay. The stress–strain behaviours of different morphologies (intercalated and exfoliated) were determined and then compared with the predicted data from the different constitutive models. It was shown that the mixing condition not only has a great effect on the morphology of the prepared compound but also the degree of fit between the experimental data and the predicted stress–strain behaviour is extensively influenced.<sup>[1-3]</sup>

It was found that the Ogden model could be used for all rubber/clay nanocomposite structures at various nanoclay loadings and mixing times while the Arruda–Boyce equation should be used with care since it cannot predict the true behaviour of all structures and morphologies. It can be concluded that an intercalated and/or exfoliated structure changes the dynamics of the macromolecular motions in compounds resulting in the requirement for some new theoretical study to be done to develop new models for the description of the mechanical behaviour of SBR nanocomposites.<sup>[4-5]</sup>

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## **Polypropylene/ Wood Flour/Organo Clay Hybrid Nanocomposite: The Effect of Nano Filler on the Long-term Water Absorption Behavior**

ISMAEIL GHASEMI\*<sup>1</sup>, BEHZAD KORD<sup>2</sup>

<sup>1</sup>*Iran Polymer and Petrochemical Institute, P.O. Box 14965/115, Tehran, Iran.*

<sup>2</sup>*Islamic Azad University, Chalous Branch, Iran*

E-mail: [I.Ghasemi@ippi.ac.ir](mailto:I.Ghasemi@ippi.ac.ir)

Using submicron-size fillers in wood plastic composites (WPCs) has been of great interest to improve of mechanical properties of the composite and compensate the negative effect of wood fiber incorporation into polymeric matrix.<sup>[1-3]</sup>

Polypropylene/wood flour composites with different nanoclay and maleated polypropylene (MAPP) contents were fabricated by melt compounding and then injection molding. The long-term water absorption of the composites was evaluated by immersing them in water at room temperature for several weeks (up to 3000 hours). Water diffusion coefficients were also calculated by evaluating the water absorption isotherms. Results indicated that water absorption decreased with increase of clay loading, and also the effect of compatibilizer was positive in terms of enhancing the dimensional stability of the composites. The maximum water absorption and diffusion coefficients decreased by increasing the proportion of clay and MAPP contents. Water absorption of the studied composites was proved to follow the kinetics of a Fickian diffusion process. The X-ray diffraction (XRD) and TEM micrographs confirmed the intercalation morphology in nano composite samples.

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## Study of Thermal and Mechanical Properties of Poly(Vinylchloride)/Alfa Fibers Composites

A. BOUKERROU\*, H. DJIDJELLI AND M. A. RAHMOUN

*Laboratoire des Matériaux Organiques, Université A.MIRA Bejaia 06000 Algeria*

E-mail: [aboukerrou@yahoo.fr](mailto:aboukerrou@yahoo.fr)

The present research investigates the thermal and mechanical properties of poly(vinyl chloride)/alfa flour composites prepared by melt blending in a high-speed twin steel-wall mixer at various loadings, i.e. 5, 10 and 15 wt. % , coded as F<sub>5</sub>; F<sub>10</sub> and F<sub>15</sub>, respectively), taking into account the effect of chemical treatment of the alfa flour. The study showed that composite samples prepared with the untreated fibers exhibited higher tensile modulus and hardness compared with the neat resin, whereas elongation and tensile strength were observed to decline. On the other hand, the PVC hardness was found to increase with addition of the untreated alfa flour, however the composite samples prepared with the treated fibers exhibited lower hardness and tensile strength than those prepared with untreated fibers <sup>[1]</sup>. Moreover, the amount of absorbed water depends on the amount of filler in the composite. The comparison of the results obtained from the samples of F<sub>5</sub>; F<sub>10</sub> and F<sub>15</sub>, formulations between the untreated and treated alfa flour indicated a reduction in absorbed water for the composite samples containing treated fibers. As a result, the thermal stability of the different samples carried out by thermogravimetric analysis revealed an increase in the onset temperatures of decomposition for the treated composites <sup>[2]</sup>.

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## TiO<sub>2</sub> Reinforced PI Nano-Composite Thin Films: Structural, Morphological and Mechanical Characterization

A. K. GUPTA<sup>1,2\*</sup>, A. TIWARI<sup>3</sup>, J. M. KELLER<sup>1,2</sup>, R. BAJPAI<sup>2</sup> AND S. TIWARY<sup>4</sup>

<sup>1</sup>Macromolecular Research Center, Rani Durgawati University, Jabalpur 482001, India; <sup>2</sup>Department of Physics, Rani Durgawati University, Jabalpur 482001, India  
<sup>3</sup>Department of Physics, Mata Gujari Mahila Mahavidyalaya, Jabalpur 482001, India  
<sup>4</sup>Department of Applied Physics, Jabalpur Engenerring College, Jabalpur 482001, India

E-mail: [anandlug225@rediffmail.com](mailto:anandlug225@rediffmail.com)

Conventional multifunctional materials such as fiber-reinforced or filled polymers require a trade-off between various mechanical and physical properties, cost and processability. However, combinations of properties derived at the nano-scale provide opportunity to circumvent these traditional trade-offs. The transition from micro-particles to nano particles leads to a number of changes in physical properties [1, 2]. Reinforced polymer using metalloid/oxides are widely studied in recent years due to the unique combination of advantageous properties from each component. The concept of combining inorganic material within organic matrix in nano meter regime is to obtain new materials with synergistic or additive properties.

The Tin Oxide (TiO<sub>2</sub>) from bulk to nano-particles was structured within polyimide (PI) matrix by subsequent thermal imidization using Molecular Root Incorporation approach (MRI) in variable concentrations at its precursor stage i.e. polyamic acid (PAA) to PI. There after, FT-IR, AFM, XRD, optical microscopy, TGA, Hydraulic, Microhardness and micromechanical characterization was carried out to study structural, morphological and mechanical relationship. The FT-IR spectrum confirms the presence of TiO<sub>2</sub> within PI matrix. Morphology shows the uniform films formation and pin hole free. The average size of the particle is about 50 nm, using XRD.

On the basis of the observed results it is concluded that the TiO<sub>2</sub>/PI nano-composite films exhibit excellent thermal, microscopic and micromechanical properties along with less water absorption. Since the possibility of nano structures of the incorporated TiO<sub>2</sub>, a part of continuous PI backbone, constitute by the insitu generation providing reinforcement to the PI matrix in comparison to unmodified PI film. Moreover, modified composite films show the increment in thermal stability i.e. 400°C, retaining all the improved properties. The created new polymeric films may be use as membrane for the separation technology, microelectronics, coating and other high temperature engineering applications.

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## Synthesis of 5V Cathode Material $\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$ via Co-precipitation Process

QIAOLI ZHAO<sup>1,2</sup>, NAIQING YE<sup>1,2\*</sup>, FEIHUA LING<sup>2</sup>, DAN LIU<sup>1,2</sup> AND LONG LI<sup>1,2</sup>

<sup>1</sup>Key Laboratory of New Processing Technology for Nonferrous Metals, Ministry of Education, Guilin University of Technology, Guilin 541004, China

<sup>2</sup>Department of Material and Chemical Engineering Chemistry, Guilin University of Technology, Guilin 541004, China

E-mail: [zqldouzi@163.com](mailto:zqldouzi@163.com)

The spinel compound  $\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$  will become a promising cathode material for lithium ion batteries because of its high voltage and good stable cyclability. In synthesizing  $\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$ , secondary phases such as NiO and  $\text{Li}_x\text{Ni}_{1-x}\text{O}$  usually exist in the products, which can deteriorate their electrochemical behaviors. In this investigation, a co-precipitation method was employed to synthesize  $\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$ . The product that almost did not contain impurities of nickel oxide was obtained when the appropriate synthesizing conditions. At first,  $\text{Mn}(\text{CH}_3\text{COO})_2 \cdot 4\text{H}_2\text{O}$  and  $\text{Ni}(\text{CH}_3\text{COO})_2 \cdot 4\text{H}_2\text{O}$  reacted with  $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$  to produce a precursor, then the precursor reacted with  $\text{LiOH} \cdot 2\text{H}_2\text{O}$  to synthesize product  $\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$ .

The samples were characterized by XRD, SEM, TG, DSC and Cyclic Voltammetry. XRD and SEM indicated that  $\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$  has cubic spinel structure with small and homogeneous particles.  $\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$  synthesized via co-precipitation method exhibits almost one discharge voltage plateau at around 4.7V. A stable electrochemical performance and low capacity fading were found upon cycling of  $\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$  electrodes. The discharge capacity for the  $\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$  at C/10 is 133 mAh/g and the capacity retains above 128.2 mAh/g after 50 cycles.

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## Surface Modification of Nano-SiO<sub>2</sub> by Emulsion Polymerization

JIAN-SHU KANG, FA-AI ZHANG\*

*Key Laboratory of Nonferrous Materials and New Processing Technology, Ministry of Education; Department of Material and Chemical Engineering, Guilin University of Technology, Guilin 541004, P. R. China*

E-mail:[zhangfaai@163.com](mailto:zhangfaai@163.com)

Nano-SiO<sub>2</sub> particles are widely used in the fields of rubbers, plastics, coatings, printings and cosmetics, etc. However, the strong hydrophilicity and the high surface energy cause the nanoparticles easily to agglomerate and difficult to disperse in polymer matrix. Chemical modification of the surface can enhance the dispersibility of SiO<sub>2</sub> particles in various continuous phases, change the surface activity of the SiO<sub>2</sub> particles, and bring about new surface physical and chemical characteristics. Much effort has been devoted to the surface modification of nano-SiO<sub>2</sub> in recent years<sup>[1-4]</sup>.

In this paper, nano-silica was modified by means of emulsion polymerization with styrene(St), methyl methacrylate(MMA), methyl methacrylate-hydroxyethyl methacrylate (MMA-HEMA) as monomers, respectively. The effects of the level of silica, the variety of monomer on the surface property of nanoparticles were studied. The structure, thermal behavior, size and polydispersity of nanocomposites were characterized by FT-IR, DSC, TG and laser particle analysis, respectively. The IR spectrum of modified nanoparticles indicated that polymers grafted onto the surface of the nano-SiO<sub>2</sub> particles. The nano-SiO<sub>2</sub> particles modified by St emulsion polymerization have a relative larger mean size but the smallest particle distribution index (PDI). Thermal analysis indicated that the thermal stability of nano-SiO<sub>2</sub> particles modified with styrene is better than MMA. Settling tests showed that after modified by the emulsion graft polymerization, the surface of the nano-SiO<sub>2</sub> particles changed from hydrophilic to hydrophobic.

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## Chitosan Cobalt-Phthalocyanine Membrane for Photo-Catalytic Photodegradation

ER-XIA HAO, RONG-MIN WANG\* AND YU-FENG HE

*Key Laboratory of Polymer Materials of Gansu Province, Institute of Polymer, Northwest Normal University, Lanzhou 730070, China.*

E-mail: [wangrm@nwnu.edu.cn](mailto:wangrm@nwnu.edu.cn)

During the past decades, porphyrin, phthalocyanines (Pc) and their polymer supported derivatives have been received much attention in the field of catalytic reaction, dyestuffs, plastics, and pollution control etc<sup>[1,2]</sup>. Chitosan is a kind of important supporter<sup>[3]</sup>. The advantages of membrane reactor are its integration catalytic conversion, product separation and catalyst recovery into a single operation. In this paper, the cobalt phthalocyanine complex(CoPc) was immobilized on chitosan (CTS). The photocatalytic activity of chitosan-phthalocyanines membrane (CTS/CoPc) for the photodegradation of Rhodamine B (RB) has been investigated.

The CTS/CoPc membrane was prepared as following: CTS/CoPc(SO<sub>2</sub>Cl)<sub>4</sub> multilayers were deposited on glass slide substrates by dipping the substrates alternately into the CTS, CoPc(SO<sub>2</sub>Cl)<sub>4</sub> solutions for 15 min. Then the membrane was air-dried.

In order to investigate the photocatalytic activity of the CTS/CoPc membrane, the degradation of RB was investigated in the presence of CTS/CoPc at r. t. The reactants were irradiated by a 250W high pressure Hg lamp with a major emission at about 365 nm. The change in RB concentration was monitored by UV-Vis spectra.

It was found that at the present of CTS/CoPc, the color of aqueous RB solutions changed to colorless in short irradiation time. The CTS/CoPc showed high catalytic activity and stability for the degradation of RB. The degradation of RB was up to 99% when the catalyst amount is 0.50 g/L in neutral medium. The effects of catalyst amount and pH of RB on the photodegradation of RB by the polymer membrane (CTS/CoPc) were also investigated.

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## Pyrolysis Kinetics of Casein-Montmorillonite Hybrid Materials

JIAN-FANG GE

*Department of Chemistry, Zhongkai University of Agriculture and Technology,  
Guangzhou 510225, China*

E-mail: [ge650704@163.com](mailto:ge650704@163.com)

As a main film-forming additive for leather coating, casein plays an important role in leather making industry. Owing to its poor moisture scratches resistant, inferior mechanical performance and easy deterioration under bacterial action, further application is limited. By incorporating of layered montmorillonite (MMT), the water resistance of casein may be enhanced effectively<sup>[1-2]</sup>. Some papers focused on the thermal degradation processes of the natural polymer, but any information relevant thermal degradation of casein hybrid has hitherto not been reported. Casein was swelled and dissolved in distilled water in the presence of triethanolamine. A given amounts of  $[(\text{CH}_3)_3\text{N}(\text{CH}_2)_{15}\text{CH}_3]^+$ -MMT was added into the above mixture with continuous stirring, after that it was raised and retained at about 60°C for 240min, then dried at 40°C vacuum oven for 24h to obtain the casein-MMT hybrid sample. The hybrid sample was sheeted with KBr and scanned from 4000  $\text{cm}^{-1}$  to 400  $\text{cm}^{-1}$  with a Perkin Elmer Spectrum GX FTIR. X-ray diffraction (XRD) were performed on a Rigaku D/max-III X-ray diffractometer with CuK as a radiation source, operated at 40 kV and 30 mA. The pyrolysis kinetics analysis was conducted by a Perkin-Elmer Pyris TGA 7 under  $\text{N}_2$  (50mL/min) with a series of heating rate such as 10, 15, 20 and 25°C/min, respectively. FTIR spectra all showed characteristic absorption bands of casein at 3300 $\text{cm}^{-1}$ , 1665 and 1060 $\text{cm}^{-1}$ . Compared with pure casein, the IR spectra transmittance of its hybrids was improved significantly according to the following sequence: casein-organic MMT hybrid > casein-inorganic MMT hybrid > casein, probably due to crystallinity diminution and the hybrid granule change. The HO content of casein decreased which was indication of the weakening of the hydrogen bond association effects of the hybrid. XRD analysis results showed intercalation or delamination of the casein-MMT hybrid. The peak temperature at different heating rate of casein and casein-MMT hybrid was obtained from the DTA curves. From this data the kinetic analysis was calculated according to Flynn-Wall-Ozawa model<sup>[3]</sup>, the apparent pyrolysis energy of casein and casein-MMT are 15.86 and 14.32 kJ/mol, respectively. The presence of the MMT may act as the active center for casein's decomposition.

In conclusion, the casein-clay hybrid can be prepared by the intercalation of casein into MMT layers. In comparison with casein, the pyrolysis temperature of the hybrid was slightly elevated, while the apparent pyrolysis energy  $E_d$  decreased.

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## The Effect of HEMA Amount on Poly(St-HEMA)/MMT/SiO<sub>2</sub> Nanocomposites Prepared by Emulsion Polymerization

JIQUAN MA, CAILI-YU, FA-AI ZHANG\*

*Key Laboratory of Nonferrous Materials and New Processing Technology, Ministry of Education; Department of Material and Chemical Engineering, Guilin University of Technology, Guilin 541004, China*  
E-mail: zhangfaai@163.com

To the polymer/MMT nanocomposite, the dispersed state of MMT and the binding force of the contact surface with polymer matrix are the most important factors to improve the properties of the nanocomposite materials. It is hard for MMT with laminated structure, which has strong polarity, to be dispersed into the low polarity polymer matrix, such as common used poly(methyl acrylate) (PMMA) and polystyrene (PS). If some high polar monomers, like 2-hydroxyethyl methacrylate (HEMA) or acrylic acid (AA), are added to the polymerization system to copolymerize with MMA or St, it is easy for the polymer chain to be inserted into the MMT layers, which will make the MMT layer exfoliated and thus improve the properties of the nanocomposite.

In this paper the MMT was modified with cetyltrimethyl ammonium bromide(CTAB) (designated as OMMT). Poly(St-HEMA)/OMMT/Nano-SiO<sub>2</sub> nanocomposites were prepared by emulsion polymerization. The effects of HEMA amount on the thermal properties of the nanocomposites were studied. The nanocomposites were characterized by fourier transform infrared spectroscopy(FTIR), differential scanning calorimetry(DSC), thermogravimetry(TG) and X-ray diffraction(XRD). It was found that the OMMT layers were exfoliated and dispersed in the polymer matrix randomly. When the amount of the HEMA was appropriate, the thermal properties of the nanocomposite were improved.

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## Synthesis of Hyperbranched Poly(butyl acrylate) by the Batch Emulsion Polymerization

LIE ZHAO<sup>1</sup>, FA-AI ZHANG<sup>1\*</sup>, JIANFANG GE<sup>2</sup>

<sup>1</sup>*Key Laboratory of Nonferrous Materials and New Processing Technology, Ministry of Education; Department of Material and Chemical Engineering, Guilin University of Technology, Guilin 541004, China*

<sup>2</sup>*Department of chemistry, Zhongkai University of Agriculture and Technology, Guangzhou 510225, China*

E-mail:[zhangfaai@163.com](mailto:zhangfaai@163.com)

In recent years, hyperbranched polymers have received much attention due to their unique chemical and physical properties as well as their potential applications in drug, additives, coatings, nanotechnology, supramolecular science and so on. Butyl acrylate (BA) as a classical “soft monomer” was applied to many areas. Hyperbranching brought it more excellent properties due to its special structure<sup>[1-3]</sup>, such as various new end groups. Very few papers were reported to synthesize hyperbranched polymer applying the emulsion polymerization method.

In our study, branched Poly(butyl acrylate) was prepared via facile, batch emulsion polymerization with high conversion. BA was copolymerized with a branching divinyl monomer, divinylbenzene (DVB), an appropriate amount of n-dodecanethiol (C<sub>12</sub>SH) as chain transfer agent to inhibit gelation. The structure of copolymer, branch degree, size and polydispersity of the latex particles, molecular weight and molecular weight distribution were characterized by FT-IR, <sup>1</sup>H NMR, laser particle analysis and GPC, respectively. The IR and <sup>1</sup>H NMR spectrums indicate the product obtained is a copolymer of BA and DVB. With the increase of DVB and C<sub>12</sub>SH contents, the branched degree (BD) increases at the mole feed ratio of DVB/ C<sub>12</sub>SH 1/2; with the increases of C<sub>12</sub>SH content the BD increases at mole feed ratio of BA/DVB 100/10. The latex has a relative smaller mean size and particle distribution index (PDI). The result of GPC shows that branched polymers have an ordinary molecular weight and relative wide molecular weight distribution.

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## **Nanotechnology and its Applications in Lignocellulosic Composites, a Mini Review**

S. KAMEL

*University of Malakand, Pharmacy Department, Chakdara Dir, N.W.F.P., Pakistan*  
*Permanent address; National Research Center, Cellulose & Paper Department,*  
*El-Tahrir St. Dokki, Cairo, P.O. 12622, Egypt*  
E-mail: [samirki@yahoo.com](mailto:samirki@yahoo.com)

Nanotechnology has applications across most economic sectors and allows the development of new enabling science. The ability to see materials down to nanoscale dimensions and to control how materials are constructed at the nanoscale is providing the opportunity to develop new materials and products in previously unimagined ways.

This review covers the academic and industrial aspects of the preparation, characterization, material properties, crystallization behavior, melt rheology, and processing of polymer/cellulose or cellulose/cellulose nanocomposites. Cellulosic materials have a great potential as nanomaterials because they are abundant, renewable, have a nanofibrillar structure, can be made multifunctional, and self-assemble into well-defined architectures. The fibrillation of pulp fiber to obtain nano-orderunit web-like network structure, called microfibrillated cellulose, is obtained through a mechanical treatment of pulp fibers, consisting of refining and high pressure homogenizing processes. Also, nano-whisker can be used as novel reinforcement in nanocomposites; it can be obtained by acid hydrolysis from various sources such as wood, tunicin, ramie, cotton, wheat straw, bacterial cellulose, and sugar beet. The properties of nanocomposite materials depend not only on the properties of their individual parents, but also on their morphology and interfacial characteristics. Compared with plant cellulose, bacterial cellulose has found many applications in the biomedical field as tissue engineering materials due to their good biocompatibility, mechanical properties similar to those of hard and soft tissue and easy fabrication into a variety of shapes with adjustable interconnected porosity. One of the drawbacks of cellulose whiskers with polar surfaces is poor dispersibility/compatibility with nonpolar solvents or resins. Thus, their incorporation as reinforcing materials for nanocomposites has so far been largely limited to aqueous or polar systems. To overcome this problem and broaden the type of possible polymer matrices, efforts of surface modification have been made. These attempts include surfactant coating or graft copolymerization.

## **Mechanical and Dynamic Rheological Properties of Single and Hybrid Filler/Polypropylene Composites Based on Talc and Calcium Carbonate**

HAMED AZIZI, JALAL FAGHIHI

*Plastics Department, Iran polymer & petrochemical Institute (IPPI)*

*P.O.Box. 14965/115, Tehran, Iran*

E-mail: [h.azizi@ippi.ac.ir](mailto:h.azizi@ippi.ac.ir)

Some results of experiments on the mechanical and rheological properties of mineral filled polypropylene were presented. Single filler and hybrid filler composites of talc and calcium carbonate ( $\text{CaCO}_3$ ) were prepared in a co-rotating twin-screw extruder. The effect of filler type, filler content and coupling agent on the mechanical and rheological properties of the polypropylene were studied. The coupling agent was maleic anhydride – grafted polypropylene (PP-g-MA). It was found that the mechanical properties are affected by filler type, filler concentration and the interaction between filler and matrix. The tensile strength of the composite is more affected by the talc while the impact strength is influenced mostly by  $\text{CaCO}_3$  content. The elongation at break of PP/  $\text{CaCO}_3$  composites was higher than that of PP/talc composites. The incorporation of coupling agent into PP/mineral filler composites increased the mechanical properties. Rheological properties indicated that the complex viscosity and storage modulus of talc filled samples were higher than those of calcium carbonate filled samples while the  $\tan\delta$  was lower. The rheological properties of hybrid-filler filled sample were more affected by the talc than calcium carbonate. The PP-g-MA increased the complex viscosity and storage modulus of both single and hybrid composites.

## PAA/Bentonite Composites for Removing Pb(II) from the Wastewater

DE-ZHEN YAN, YU-FENG HE\*, XIA ZHANG, ZHENG-HUA ZHANG,  
RONG-MIN WANG

*Key Laboratory of Polymer Materials of Gansu Province, College of Chemistry and  
Chemical Engineering, Northwest Normal University, Lanzhou 730070, China*

E-mail: [heyufeng@nwnu.edu.cn](mailto:heyufeng@nwnu.edu.cn)

Heavy-metal pollution is, and will continue to be, a public health problem. Lead is a kind of metal that is harmful to the environment and mankind's health which produces several diseases<sup>[1-2]</sup>. Most traditional methods for treatment of wastewaters containing lead were ineffective, extremely expensive, generation of secondary pollution<sup>[3]</sup>. In order to find a kind of effective and economical adsorbents for removing heavy metal from wastewater, in this paper, a new kind of polymer and inorganic composites adsorbent, the poly(acrylic acid)/bentonite composites (PAA/Bent), was prepared as following: acrylic acid was intercalated into activated bentonite with mechanically agitated at room temperature. Then the mixture was partially neutralized and acrylic acid was polymerized in interlayer of bentonite with initiation. In process of the reaction,  $m(\text{AA}): m(\text{Bent}) / 2: 1$ , initiation temperature is 70°C, initiation time is 40 min. The raw product was washed and dried. The yield got to 90.0%.

The PAA/Bent adsorbent showed excellent activity for removing lead ion. Some factors for absorbing  $\text{Pb}^{2+}$  were examined, such as the amounts of original materials, polyacrylic acid and PAA/Bent, the concentration of  $\text{Pb}^{2+}$ , the pH values of wastewater, temperatures. The removal efficiency of PAA/Bent reached 99.0% if treating  $1000 \text{ mg}\cdot\text{L}^{-1}$   $\text{Pb}^{2+}$  wastewater under 20°C and pH=5.0 by  $1 \text{ g}\cdot\text{L}^{-1}$  of PAA/Bent. The adsorption capacity for  $\text{Pb}^{2+}$  got to 990 mg/g. Adsorption mechanism was also discussed.

It is concluded that poly(acrylic acid)/ bentonite composites is a kind of important candidate for the removal of the pollutant of lead (II) ions from aqueous solutions.

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## Synthesis of Core-shell Nano- SiO<sub>2</sub>/Poly (Diacetone Acrylamide-Hexafluorobutyl Methacrylate) Emulsion

JUN-FENG GUO, YU-FENG HE, JUN-FENG WANG, WEI-HUA LV, RONG-MIN WANG\*

*Key Laboratory of Polymer Materials of Gansu Province, Institute of Polymer,  
Northwest Normal University, Lanzhou 730070, China*

E-mail: [wangrm@nwnu.edu.cn](mailto:wangrm@nwnu.edu.cn)

Fluorinated polyacrylate emulsion have attracted increasing attention of many investigators, due to their special surface property, good adhesion to matrices and environmental protection value<sup>[1]</sup>. They have been used to a progressively greater extent in a wide-range of applications, especially as surface coatings for textile, paper and leather<sup>[2]</sup>. However, the prices of fluorine-containing acrylic monomers are very high. In this paper, a kind of fluorine-containing polyacrylate emulsion was successfully synthesized by a seed emulsion polymerization method, which contain nano-SiO<sub>2</sub> nanoparticles in core and diacetone acrylamide, hexafluorobutyl methacrylate(HFMA) in shell. The effects of nano-SiO<sub>2</sub>, emulsifier, and the composition of core monomers on the particle size have been investigated. The structure and properties were characterized by FT-IR and particle size analysis. It showed that HFMA was effectively involved in the latex copolymerization. It was also found that the particles had a core-shell structure and a narrow particle size distribution.

The keto-carbonyl of diacetone acrylamide was fixed on the surface of fluorine-containing polyacrylate emulsion and it can reacted with adipic dihydrazides to form a film with a cross-linked network structure. The fluorine-containing polyacrylate emulsion could be used as room temperature curable waterborne coating. Based on the water resistance experiment, it showed that water resistance property of fluorine-containing polyacrylate emulsion with cross-linker was better than those of emulsion without cross-linker.

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## Study on Curing Reaction Kinetics and Properties of Epoxy Molding Compounds with Different Curing Systems

LV JIAN<sup>1\*</sup>, CHENG PENG<sup>2</sup>, WANG JIAN, HAN JUNHUA

<sup>1</sup>*Department of Material and Chemical Engineering Chemistry, Guilin University of Technology, Guilin 541004, China*

<sup>2</sup>*Key Laboratory of New Processing Technology for Nonferrous Metals, Ministry of Education, Guilin University of Technology, Guilin 541004, China*

E-mail: [gllvjian@yahoo.com.cn](mailto:gllvjian@yahoo.com.cn)

Taking o-cresol novolac epoxy resins (ECN) as matrix, DDS, DICY and PF as three kinds of different curing agent, 2,4-EMI as curing accelerator, silicon powder and glass fiber as fillers, epoxy molding compound (EMC) was prepared in this paper. The curing reaction kinetics of the three kinds of EMC was studied by differential scanning calorimetry (DSC). Several phenomenological models (including simple models by Ozawa and Kissinger and the Kissinger–Akahira–Sunose isoconversional method) have been used to compare the cure kinetics of EMC with three different curing systems. The curing reaction kinetic parameter was obtained and the reaction mechanism was discussed. Mechanical properties, electrical insulation properties, dynamic mechanical properties and stability properties of EMC were studied. The results show that, different curing systems affect on the processing property, dynamic mechanical property and stability property so great, the glass transition temperature ( $T_g$ ) of the EMC with PF curing system ( $T_g=216^\circ\text{C}$ ) is higher than DDS system ( $T_g=206^\circ\text{C}$ ) and DICY system ( $T_g=192^\circ\text{C}$ ), but have little influence on the impact strength ( $5.2\sim 5.5\text{KJ/M}^2$ ) and electrical insulation property (surface resistance  $0.93\sim 1.59\times 10^{15}\Omega$ , volume resistance  $5.50\sim 6.14\times 10^{14}\Omega\cdot\text{m}$ ).

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## **Effect of Curing Agent Content on the Properties of Electrical Composites of Phenolic Aldehyde(FA) Reinforced with Glass Fiber**

WANG JIAN<sup>1</sup>, LV JIAN<sup>2\*</sup>, XIAO-WEI XU, CHENG PENG

<sup>1</sup>*Department of Material and Chemical Engineering Chemistry, Guilin University of Technology, Guilin 541004, China*

<sup>2</sup>*Key Laboratory of New Processing Technology for Nonferrous Metals, Ministry of Education, Guilin University of Technology, Guilin 541004, China*

E-mail: [gllvjian@yahoo.com.cn](mailto:gllvjian@yahoo.com.cn)

Electrical composites of phenolic aldehyde (FA) reinforced with glass fiber were prepared with different content of curing agent taking phenolic resin as matrix, hexamethylenetetramine (HMT) as the curing agent in this paper. The effect of content of curing agent on the properties of plastic made by this method was investigated by means of Differential Scanning Calorimetry (DSC), Dynamic mechanical Analysis and analysis of mechanical and electrical properties. The results show that the plastic has increased with the increasing content of curing agent in storage modulus, loss of machine peak narrowed and peak value decreased. When the content of curing agent was 14%, the plastic has increased by 25.18°C and 38.8 °C in the value of glass transition temperature and the heat distortion temperature respectively, and up to 225.35°C and 209.8°C. The plastic electric property was improved with the increasing content of curing agent, but the impact strength, dimensional stability and water resistance decrease.

## Preparation of Waterborne Coatings with Modified Composite Nano-TiO<sub>2</sub> and its Antimicrobial and Self-cleaning Behaviors

BO-YUN WANG, YU-FENG HE, JUN-FENG GUO, JUN-FENG WANG,  
RONG-MIN WANG\*

*Key Laboratory of Polymer Materials of Gansu Province, Institute of Polymer,  
Northwest Normal University, Lanzhou 730070, China*

E-mail: [wangrm@nwnu.edu.cn](mailto:wangrm@nwnu.edu.cn)

The photocatalytic antimicrobial coatings have been attracted more attention in recent years. Nano-TiO<sub>2</sub> is a kind of distinguished photocatalyst and widely utilized as self-disinfecting and self-cleaning materials due to its excellent photo-chemical stability, low cost and non-toxicity<sup>[1-2]</sup>. In this paper, the composite nano-TiO<sub>2</sub> with doping Fe<sup>3+</sup> and Ag was prepared. It was further modified by 3-Methacryloxypropyltrimethoxysilane. They were characterized by Zetasizer Nano ZS Particle and Zeta Potential Analyzer, X-ray diffraction, UV-Vis Spectrophotometer, FT-IR spectra and Transmission electron microscopy. The modified composite nano-TiO<sub>2</sub> was applied to prepare multifunctional fluorocarbon coatings. Antibacterial activity of multifunctional fluorocarbon coatings containing modified composite nano-TiO<sub>2</sub> was investigated. Its photocatalytic antibacterial activity reached 92%. The influence of doping ingredients, amount of composite nano-TiO<sub>2</sub>, different light houses or surface modification was discussed. Coating surface can't be easily smirched by oiliness, dust, and water for hydrophobic fluorocarbon resin. It would be an available modern interior building coating for its remarkable photocatalytic antibacterial property as well as self-cleaning function<sup>[1-3]</sup>.

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## **Synthesis of p-Toluenesulfonate-Pillared Hydrotalcites and its Flame Retardance Study for Unsaturated Polyester Resin**

G. W. ZHANG<sup>1</sup>, L. J. WANG<sup>2\*</sup> AND X. L. XIE<sup>1</sup>

<sup>1</sup> *Department of Materials and Chemical Engineering, Guilin University of Technology, Guilin 541004, China*

<sup>2</sup> *Key Laboratory of New Processing Technology for Nonferrous Metals and materials, Ministry of Education, Guilin University of Technology, Guilin 541004, China*

E-mail: [wlj@qlite.edu.cn](mailto:wlj@qlite.edu.cn)

p-Toluenesulfonate-pillared layered double hydroxides(LDH-PTS) were synthesized by coprecipitation method. Unsaturated polyester resin / LDH composites was prepared by blending with LDH-PTS. The X-ray diffraction and transmission electron microscopy were primarily used to characterize the morphology of the nanocomposites. The thermal stability and fire properties of nanocomposites have been studied by thermogravimetric analysis and limit oxygen index and UL94 burning test. The results show that the pillared layered double hydroxides have good layered structure, and the interlayer spaces of LDH-PTS are expanded to 1.73nm for LDH-PTS and 2.077 nm for composites from 0.775nm for the LDH. Compared with unsaturated polyester resin, the use of 3% (mass fraction) of LDH-PTS improved the flame retardancy remarkably. For example, LOI was up to 23.30 % of composite from 21% of the pure resin, the char residue rate increased by 3.7% and the speed of horizontal burning was decreased by 20.24%.

## Theoretical Investigations on the Geometric and Electronic Structures of Polyacetylene Molecules under the Influence of External Electric Field

YANWEI LI<sup>1\*</sup>, JINHUAN YAO<sup>1</sup> AND YAN LI<sup>2</sup>

<sup>1</sup>Department of Material and Chemical Engineering Chemistry, Guilin University of Technology, Guilin 541004, China

<sup>2</sup>Civil Engineering Department, Guilin University of Technology, Guilin 541004, China

E-mail: [lywhit@126.com](mailto:lywhit@126.com)

The geometric and electronic structures of all-trans polyacetylene (PA) molecule in neutral, cationic, and anionic states have been studied theoretically by density functional theory method at the B3LYP level. The results show that both the geometric and electronic structures of the PA molecule are sensitive to the external electric field. For neutral PA molecule, with the increase of external electric field, the carbon-carbon single bonds are shortened and the carbon-carbon double bonds are elongated. The energy gap between the highest occupied molecular orbital and the lowest unoccupied molecular orbital (HOMO-LUMO gap) decreases with the electric field increasing. For cationic PA molecule, the carbon-carbon single bonds and carbon-carbon double bonds on the low potential side are elongated and shortened, respectively. While, the carbon-carbon single bonds and carbon-carbon double bonds on the low potential side are shortened and elongated, respectively. Similar to the neutral PA case, with the increase of electric field the HOMO-LUMO gap decreases. Contrast to the case of cationic PA, the evolution of carbon-carbon bond length of the anionic PA molecule under the external electric field reverses. The evolution of the HOMO-LUMO gap of the anionic PA molecule also decreases with the increase of the external electric field. In addition, the spatial distribution of the HOMO and LUMO are also shifted under the influence of external electric field for the PA molecule in neutral, cationic, and anionic states.

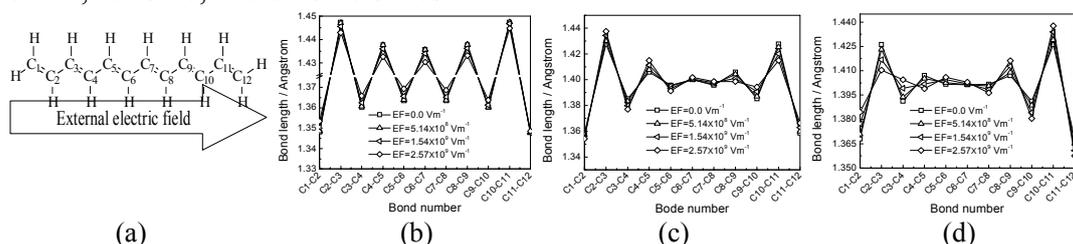


Figure 1. (a) Molecular model. (b) Bond length evolution of PA in neutral state. (c) Bond length evolution of PA in cationic state. (d) Bond length evolution of PA in anionic state.

### ACKNOWLEDGEMENT

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## **Synergistic Flame Retardancy of ABS/Montmorillonite Nanocomposites**

X.J.HE<sup>1</sup>, X. L. XIE<sup>1</sup>, L. J. WANG<sup>2\*</sup>, K. ZHANG<sup>1</sup>

<sup>1</sup> *Department of Material and Chemical Engineering, Guilin University of Technology, Guilin 541004, China*

<sup>2</sup> *Key Laboratory of New Processing Technology for Nonferrous Metals, Ministry of Education, Guilin University of Technology, Guilin 541004, China*

E-mail: [wlj@glite.edu.cn](mailto:wlj@glite.edu.cn)

The ABS/MMT nanocomposite was prepared by melt blending ABS containing Cetyltrimethyl Ammonium Bromide (CTAB) modified montmorillonite. The XRD, TEM and FT-IR were primarily used to characterize the morphology of the nanocomposites. The thermal stability and fire properties of nanocomposites have been studied by thermogravimetric analysis, limit oxygen, vertical burning test and cone calorimetry.

The basal spacing of MMT increases from 1.46nm of original MMT to 2.71nm of CTAB modified MMT. ABS intercalated into the OMMT's layers and MMT was exfoliated in ABS. The tensile strength of composite at 4% OMMT additive increased 15% than pure ABS. The largest peak reduction in the heat release rate for the polymer nanocomposites is 57.3% at 4% OMMT content. Compared to pristine ABS, the total heat released and values of smoke rate for the polymer nanocomposites is decreased. The LOI of nanocomposite increased to 28% from 18% of pristine ABS. The vertical burning test (UL94) results indicated that the materials achieved V-0 grade.

## Investigation of Tension Strength of the Laminate with Ply Splicing

LI LIANG<sup>1\*</sup>, JIA PURONG<sup>1</sup>, JIAO GUIQIONG<sup>1</sup>, WANG WENGUI<sup>2</sup>, DAI DI<sup>2</sup>

<sup>1</sup>Department of Engineering Mechanics, Northwestern Polytechnical University, Xian 710129, China;

<sup>2</sup>Beijing Aeronautical Manufacturing Technology Research Institute, Beijing 100024, China

E-mail: [liliangxm@yahoo.cn](mailto:liliangxm@yahoo.cn)

Fiber reinforced composites have been widely applied to weight saving in many different constructions. When the composites are manufactured for special shell, some splice plies in laminates are usually to be used. In order to investigate the influence of the ply splicing on the laminate properties, composite specimens with carbon/epoxy laminates have been designed including different ply splicing form. The splicing types are shown in Fig.1, the specimen size is marked out in Fig.2.

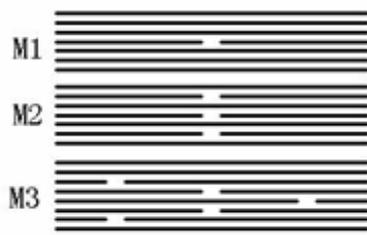


Fig.1 Splicing form of specimens

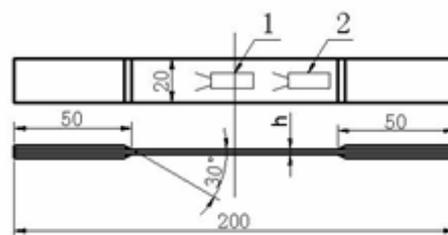


Fig.2 Type and size of the specimen

The tension experiments of the specimens have been performed on a test machine. The curves of loading to extension are shown in the Fig.3. It can be seen that ply splicing specimen have clear decrease in load when the ply damage occurs and the crack propagates. The 2D FEA model has been established for three ply splice laminates to calculate the interlaminar shear stress and simulate the ply failure process by mean of the numerical computation. The stress concentration in the splicing area is clearly shown in Fig.4. Thus, the delamination at the ply splice area happens easily when the load is large enough.

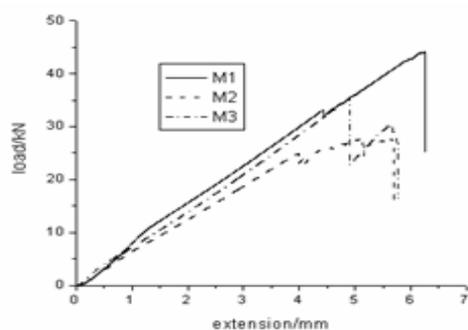


Fig.3 Curves of load to extension

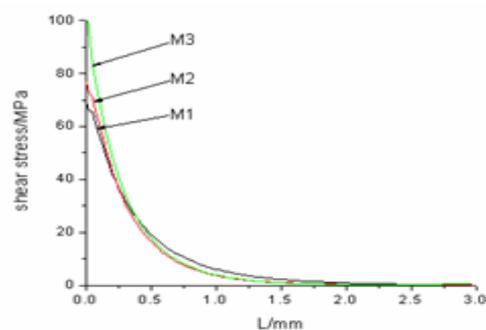


Fig.4 Interlaminar shear stress

## Investigation in Shear Strength of the Splice Laminate

WANG LING<sup>1,2\*</sup>, JIA PURONG<sup>1</sup>, JIAO GUIQIONG<sup>1</sup>, WANG WENGUI<sup>3</sup>,  
DAI DI<sup>3</sup>

<sup>1</sup>Department of Engineering Mechanics, Northwestern Polytechnical University, Xian 710129, China; <sup>2</sup>Department of Mathematics and Mechanics, Xi'an Polytechnical University, Xian 710048, China; <sup>3</sup> Beijing Aeronautical Manufacturing Technology Research Institute, Beijing 100024, China

E-mail: [wl42148@163.com](mailto:wl42148@163.com)

The shear strength of the splice laminate of carbon fiber reinforced resin matrix composites was studied in order to analysis the effect of the splice ply angle on the shear strength. The laminate, having a total of 17-ply, is continuous in odd number ply and splice in even number ply. The splice ply angle  $\theta$  was  $15^\circ$ ,  $30^\circ$  and  $45^\circ$  respectively in the splice ply. The specimen has the shape of a rectangular beam of small dimension, with symmetric V-notches at its centre, as shown in figure 1. A suitable fixture is used in order to transform the applied load into a shear loading, acting at the specimen minimum cross-section area, between the V-notches. The geometry of the V-notches is such that a quasi-uniform shear-stress distribution is produced at the centre of the specimen. The force and strain outputs were recorded on a personal computer. Typical loading-displacement curves of all three laminates with different ply splice angle were gotten. Then the shear strength was calculated. Results show that change of the ply angle almost has no effect on the shear strength.

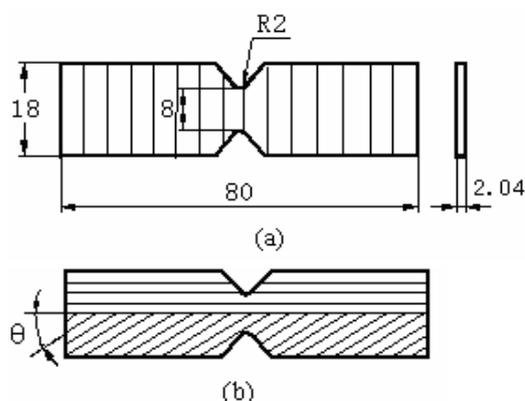


Fig.1 Dimension and shape of the splice ply

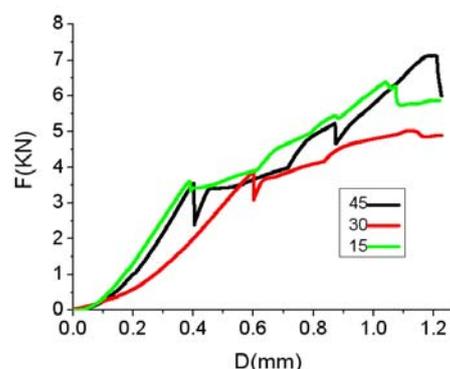


Fig.2 Loading-displacement curves

Furthermore the finite element analysis using the software package ABAQUS6.5 is also used to predict the response of the splice laminate. The dimensions of model are similar to the specimens. The steel rails and composite specimen were modeled as three-dimensional solids. Results show that the shear stress concentrations are present in the joint region in all three laminates, with the most severe stress concentrations observed in the  $45^\circ$  laminate. But the average of the shear stress along the bottom of V-notches had no change. That is to say change of the splice  $\theta$  almost has no affect on the shear strength of splice laminates. The numerical solution is almost agreement with the experimental result.

## Study of Recycling of Poly(vinylchloride)/Treated Olive Husk Composites

H. DJIDJELLI\*, A. BOUKERROU, M. KACI AND N. MAOUCHE

<sup>1</sup>Laboratory of Organics Materials, University of Béjaia 06000, Algeria

E-mail: [hocdjidi@yahoo.fr](mailto:hocdjidi@yahoo.fr)

Polymer composites are a special group of composite materials produced by combining organic polymer resins with different kinds of filler materials. Natural composites have gained significant popularity in the last decade.

However, the primary disadvantages are (a) poor interfacial adhesion and dispersion in olefin thermoplastic matrix materials due to hydrophilic character of cellulose, (b) high moisture absorption leading to dimensional instability, and (c) low permissible temperatures of processing and use due to their limited thermal stability. The hydrophilic groups present in unmodified cellulose are detrimental to the performance of the cellulose based composites if the fibers are exposed to the outside atmosphere. Water, in liquid or vapour form, can diffuse into the composite, and the properties are hampered due to hydration.

During the past two decades, several methods have been reported in the literature for improvement of the adhesion between the filler and thermoplastic matrices. Many papers have been published about the effect of chemical treatments on composite properties<sup>[1]</sup>.

In North Africa countries, every year, during the season of transformation of olive to oil, thousands tons of olive residue are rejected to nature or incinerated causing environmental pollution. The recovery of this renewable waste may have a double positives impact, economic, and ecological.

This study is aimed to investigate the recycling of PVC/modified olive husk composites. The olive husk was chemically with benzoic acid chloride to improve the interface between the PVC matrix and the cellulosic fillers.

Samples of PVC and composites were recycled eight times by calendering and compression and were characterized by the mechanical and thermal tests.

Results showed that the composite can undergo several cycles of processing without significant loss of thermal and mechanical properties.

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## Effect of Orientation on Thermal and Mechanical Properties of Metallocene Polypropylene Fibres

A. MARCINCIN\*, M. HRICOVA, K. MARCINCIN, A. HOFERIKOVA

*Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Department of Fibres and Textile Chemistry, Bratislava, SK*

E-mail: [anton.marcincin@stuba.sk](mailto:anton.marcincin@stuba.sk)

In this paper, the rheological properties of polymer melt, spinning and selected properties of PP fibres, such as mechanical and thermal, were studied. Two kinds of the selected equivalents of commercial miPP and conventional-based zniPP were used in experimental work. The first PPs were with melt flow rate (MFR) about 11 g/10 min and second ones with MFR 25 g/10 min. The results reveal that the melt viscosity of miPP is higher in average in comparison with zniPP equivalent. The difference is higher for higher MFR of PP. In spite of higher viscosity, miPP exhibited lower deviation from the Newtonian behaviour expressed by exponent of power law equation.

Both kinds of PP were spun at the same spinning conditions within the spinning temperatures 190-290°C. The fibres were drawn at 120°C and annealed under tension at 100°C.

The mechanical and thermal properties of fibres were evaluated. Experimental results reveal, that mechanical properties of miPP fibres depend mainly on molecular weight of polymer and orientation of fibres and less on spinning and drawing temperatures. The miPP fibres exhibited higher deformability in drawing and lower elongation in comparison with their conventional-based equivalent zniPP.

The DSC measurements were carried out using conventional method (CM) and constant length method (CLM) at which the constant length of fibres during measurement was assured. The average orientation of fibres has been evaluated by method of sonic velocity. The parameters of the thermal properties and supermolecular structure of fibres were correlated with the basic mechanical properties of fibres. It was found straight-line dependence between factor of orientation and melting temperature of fibres obtained by DSC-CLM method. On the basis of experimental results it was found that melting temperature and melting enthalpy correspond with tenacity and Young's modulus of PP fibres.

Both spinning and drawing conditions as well as thermal properties of miPP fibres are discussed from the point of view of higher mechanical properties of fibres for technical textiles in the paper, as well.

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## **PET-HDPE Blends from Recycled Materials by Reactive Extrusion, a Static-Mixer-Head and Sonication**

A. SANCHEZ-SOLIS\*, J. A. ESQUIVEL AND O. MANERO

*Instituto de Investigaciones en Materiales. Universidad Nacional Autónoma de México. Apartado postal 70-360, DF. México.*

E-mail: [sancheza@servidor.unam.mx](mailto:sancheza@servidor.unam.mx)

Polyethylene terephthalate (PET) and high density polyethylene (HDPE) are two polymers mostly used in package and packing industry. From recycled PET almost only fibers are produced because the lost of melt viscosity due to thermal, physical and chemical degradation which takes place into injection-blow molding process, when bottles for carbonated drinks are being manufactured. On the other hand, processing of recycled HDPE has practically not problems. Nevertheless, joining of both polymers for producing plastic profiles like pipes, windows and laminates is causing of a great setback on processing by have not affinity between phases and diminishing of melt strength. The objectives of this work were: to determine the effects on PET-HDPE blend compatibilization by grafting maleic anhydride onto polyethylene (HDPE-g-MAH), the use of a static mixer-extrusion process, application of sonication on melting mixtures and addition of chemically modified clay-nanoparticles with L-Lysine aminoacid in blends. Tensile mechanical properties, rheological measurements (viscosity versus shear rate) and fracture morphology (scanning electron microscopy) were evaluated. Mixtures were processed in a mono-screw extruder with a static mixer device at the end of the extruder which has four piezoelectric elements for sonication (20 kHz). It was found that compatibilization of PET-HDPE mixtures by grafting of maleic anhydride onto HDPE have positively repercussions on tensile mechanical properties and Izod impact notched test, because interfacial tension was diminished until disappearance of interface between both polymers. On weight, the best proportions of PET-HDPE were 70-30 and 60-40. The use of static-mixer-head with sonication diminished size and dispersion of clay nanoparticles considerably. Shear viscosity of the mixtures showed an important increment to low shear rate and displayed shear thinning phenomena. PET-HDPE-g-MAH blends were utilized to yield tubular profiles.

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## Mechanical Properties of LDPE, EVA/Clay Nanocomposite Foams

MARZIEH RIAHI NEZHAD<sup>\*1</sup>, ISMAEIL GHASEMI, MOHAMMAD KARRABI,  
HAMED AZIZI

*1- Iran Polymer and Petrochemical Institute, P.O. Box 14965/115, Tehran, Iran*

E-mail: [m.riahi@ippi.ac.ir](mailto:m.riahi@ippi.ac.ir)

Polymer nanocomposite foams have received increasingly attention in both scientific and industrial communities. The combination of functional nanoparticles and foaming technology has a high potential to generate a new class of materials. As the demand for highly functional polymeric materials grows, nanocomposite foams are likely to play a vital role in the future foam industry<sup>[1-2]</sup>.

In this research work, nanocomposite foams of low-density polyethylene (LDPE) and poly ethylene-co-vinyl acetate (EVA) were prepared. Nanocomposites based on LDPE, EVA and their blends (with blending ratio of LDPE/EVA: 75/25 and 25/75) and various amounts of organically modified montmorillonite (OMMT) as filler and also nucleating agent have been prepared by melt mixing in an internal mixer. Different amounts of clay were selected as 0, 1, 3 and 5 wt%. Single stage batch foaming is carried out by using azodicarbonamide (ADC) as foaming agent and zinc oxide (ZnO) as ADC activator or kicker in a hot-plate press. In order to stabilize the cells during cell growth and also limit the escaping of gas, a certain crosslinking degree has achieved during chemical crosslinking by means of dicumylperoxide (DCP). Polyethylene grafted with maleic anhydride was used as compatibilizer to improve the clay dispersion.

Mechanical properties of nanocomposite foams were studied. The results indicated that the tensile modulus and tensile strength of nanocomposite foams are depend on nanoclay content and its dispersion and blending ratio, as the tensile modulus of LDPE and EVA nanocomposite foams were the highest and the lowest respectively, due to the high and low modulus of LDPE and EVA. The results showed, tensile properties of nanocomposite foams have been increased with increasing foam density. Moreover it was found that the presence of compatibilizer (PE-g-MA) has improved the mechanical properties.

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## Achievement of a Transparent Polycarbonate (Pc)/Poly(Methel Methacrylate) (Pmma) Nanoblend by High-Shear Processing

HIROSHI SHIMIZU\* AND YONGJIN LI

*Nanotechnology Research Institute, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba Central 5, 1-1-1 Higashi, Tsukuba, Ibaraki 305-8565, Japan*

E-mail: [shimizu-hiro@aist.go.jp](mailto:shimizu-hiro@aist.go.jp)

Transparent heterogeneous polymeric material attracted significant attention recently because the material may combine the excellent physical properties of different phases in addition to the optical clearance. According to Rayleigh scattering law, the scattering loss in a heterogeneous system depends on the relative size of the dispersed phase and the relative refractive index. Therefore, the size of the dispersed phase is of critical importance to reduce the scattering loss if the refractive indexes are different for different phases. In general, it is necessary to achieve a homogeneous dispersion of less than 100 nm to obtain a transparent heterogenous material. The blending of two immiscible polymers with different reflective index using conventional mixing machines can not be adapted to make a transparent blend because the phase size of the obtained blend is usually larger than 500 nm, which is obviously too big to satisfy the requirement for the transparency. We have recently established a new high shear extruder, which can reach a maximum screw rotation speed of 3000 rpm, corresponding to the shear rat of about  $4400 \text{ sec}^{-1}$ . Previous investigations showed that the established high shear processing technique was not only effective for decreasing the phase size for polymer blend systems, but also helpful for the nanofiller dispersions in polymer matrix. <sup>[1-3]</sup> Here we present the results of PC/PMMA blend processing using the high-shear processing technique with the aims of fabricating transparent polymeric materials. The high-shear processed blend has a phase structure with the domains size of less than 50nm, while the low-shear processed blend gives a micro- to submicro- dispersed structure (Fig. 1). The high-shear processed PC/PMMA blend shows very high transmittance in the visible region, in contrast to the opaque appearance of the low-shear processed one (Fig.2).

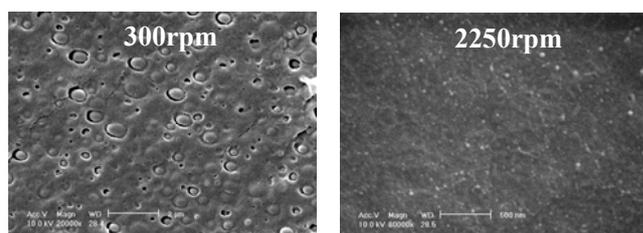


Fig. 1 Morphology of low and high-shear processed PC/PMMA



Fig. 2 Photos of low- (left) and high-shear (right) processed

## Poster Presentations

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## Dielectric Properties of Ground Rubber Tire Composites

R. MUJAL<sup>1\*</sup>, J. ORRIT<sup>2</sup> AND X. COLOM<sup>3</sup>

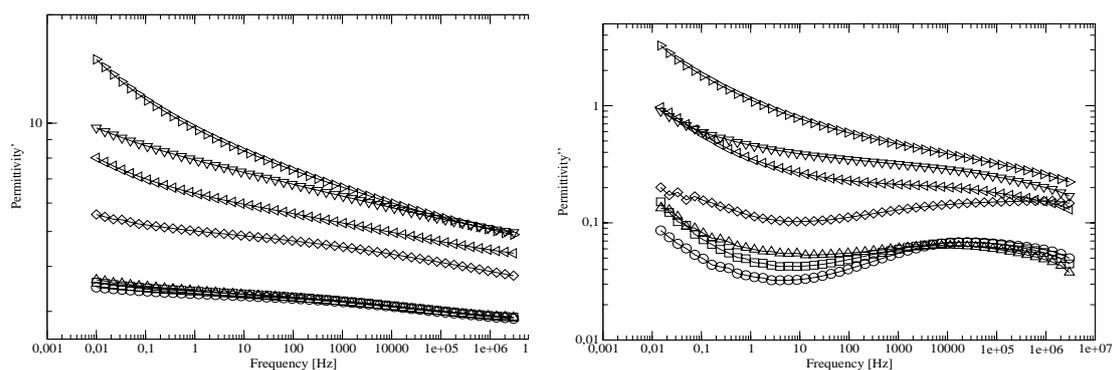
<sup>1</sup>*Department of Electrical Engineering, EUETIT, Universitat Politècnica de Catalunya, Spain*

<sup>2</sup>*Department of Applied Physics, ETSEIAT, Universitat Politècnica de Catalunya, Spain*

<sup>3</sup>*Department of Chemical Engineering, EUETIT, Universitat Politècnica de Catalunya, Spain*

E-mail: [mujal@ee.upc.edu](mailto:mujal@ee.upc.edu)

Recycling of waste materials is growing importance for all the industries in the world. Rubber wastes are generated from both the products of the manufacturing process and post consumer products, mainly consisting in scrap tires. It has been estimated that around one billion tyres are withdrawn from use in the world every year. In Europe, this figure is approximately 250 million tyres. In order to help to reduce the amount of ground rubber tire (GTR) new approaches has been investigated. In this work, we have studied the dielectric properties of GTR composite using PVC as a matrix.



○ PVC; □ PVC+5%GTR; ◇ PVC+10%GTR; △ PVC+20%GTR; ◁ PVC+40%GTR;  
▽ PVC+50%GTR; ▷ PVC+70%GTR.

Dielectric permittivity ( $\epsilon'$ ) and loss factor ( $\epsilon''$ ) versus frequency at 30°C are shown in figures attached. The presence of GTR particles increase the conductivity of the composite and consequently the permittivity acquires higher values than those of the pure PVC matrix as predicted by other authors<sup>[1]</sup>. At elevated temperatures permittivities are higher because of the increased segmental mobility of the matrix. The frequency dependence of  $\epsilon'$  in composites the decrease in permittivity with increasing frequency is clearer at elevated temperatures and low frequencies.

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## **Cure Monitoring of Epoxy/MWNT Composites via Ultrasonic Wave**

JIN-CHAO ZHAO<sup>1</sup>, Z. H. LUO<sup>2</sup>, WEI CUI<sup>1</sup>, XING-PING ZHOU<sup>1</sup>,  
HONG-MAO ZHU<sup>2\*</sup>, XIAO-LIN XIE<sup>1\*</sup>

<sup>1</sup>*School of Chemistry and Chemical Engineering, Huazhong University of Science and Technology, Wuhan 430074, China*

<sup>2</sup>*School of Civil Engineering and Mechanics, Huazhong University of Science and Technology, Wuhan 430074, China*

E-mail: [xlxie@mail.hustt.edu.cn](mailto:xlxie@mail.hustt.edu.cn)

A non-instructive ultrasonic transmission method was applied to on-line monitor the cure behaviors of epoxy/multi-walled carbon nanotube (MWNT) composites. Their ultrasound velocity values and attenuation coefficients of longitudinal and transverse waves were measured following the whole cure cycle. The effects of MWNT content on the cure behavior of the composites were discussed. The results showed that the increase of velocity is attributed to the evolution of the mechanical properties of composites during cure, such as Young's moduli, and Poisson's ratio. The variation of sound attenuation is sensitive to the viscosity and filler content of composites. A correspondence between the ultrasonic data and the cure state (cure rate, gel time and vitrification) could be observed. Furthermore, the addition of MWNT could decrease the gel time. The wave velocity and attenuation coefficient increase with MWNT content.

## Characterization of High-Property ABS/PA6 Compatibilized Blend

SOMAYYEH MOHAMMADIAN\*, ISMAEIL GHASEMI, ABDOLRASOUL OROMIEHIE

*Iran Polymer and Petrochemical Institute, P.O. Box 14965/115, Tehran, Iran.*

E-mail: [s.mohammadian@gmail.com](mailto:s.mohammadian@gmail.com)

Using melt blending techniques, blends of PA6 and ABS can display the desirable properties of both materials without their deficiencies. An effective method for compatibilizing ABS/PA6 blends is the reactive extrusion process involving addition of a compatibilizer miscible with ABS phase, which has functional groups like anhydride<sup>[1-3]</sup>, acid<sup>[2]</sup>, epoxide<sup>[4]</sup> and oxazoline<sup>[5]</sup>, capable of reacting with the amine or carboxylic acid end groups of PA6.

This paper addresses some key issues related to the SMA-compatibilized blends of ABS and PA6. Using experimental design, blends with variety in the composition and compatibilizer content have been prepared at various screw speeds in a co-rotating twin screw extruder. Compatibilizing has been proved by detecting the SMA-PA6 graft copolymer in the solvent extraction and FTIR spectroscopy. The morphological and rheological properties of blends have been discussed in detail.

In all compositions, with presence of SMA, the average particle size decreased dramatically, phase inversion concentration ( $\phi_{PA6}$ ) decreased and the asymmetry trend in dispersed particle size under and above the phase inversion point changed. Without SMA, particle size was larger in the state of ABS dispersing and the reverse trend occurred at the presence of SMA. Lower screw speed resulted in the finer particle size and the higher screw speed shifted the phase inversion point up to the higher PA6 content.

The rheological tests confirmed the role of SMA as the compatibilizer.  $Tan\delta$  of compatibilized blends was less than that of the uncompatibilized blends, indicating more elastic nature. Also, the complex viscosity of samples containing SMA was very high compared with the net ABS and PA6, while the uncompatibilized blends had the less complex viscosity.

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## Nanocomposites Based on Linear Polyethylene and Montmorillonite

R. ASHUROV\*, V. DOLGOV, SH. SADYKOV, M. USMANOVA

*The Institute of Chemistry and physics of polymers of Academy of Sciences of the Republic of Uzbekistan. 7b, Abdulla Kadyri Street, Tashkent, 700128, Uzbekistan  
Tel. (+99871) 241 79 82; Fax: (+99871) 244 26 61*

E-mail: [ashurov@globalnet.uz](mailto:ashurov@globalnet.uz)

Introduction of the layered silicate (LC) into a polymeric matrix and ensuring of conditions for intercalation of macromolecules into space between LC layers and further exfoliation of these macromolecules till nanoparticle sizes provides essential strengthening of physical and mechanical and barrier properties of polymeric materials. These conditions can be easily ensured for polar polymers whereas for nonpolar polymers such as polyolefines they should be functionalized.

In the present work we have carried out investigation of the preliminary functionalization of polyethylene by the maleic anhydride and functionalized by the latter in process of blending of components in a melt under variation of polyethylene density, LC concentration and conditions of blending. As a polyethylene we used copolymer of ethylene with the butene-1 of low, moderate and high density and the modified montmorillonite (MMT) (Closite 30B, Closite 20A, abbreviation: 30B, 20A) supplied by Southern Clay Products. Composites have been obtained at mini-max blender under the temperature 180° C, shear rate 100 s<sup>-1</sup> and using balls with diameter of 3.8 mm. The MMT concentration was varied within ranges of 1-7% of the weight.

The X-Ray examination of structure of the obtained composites by the position of the reflex  $d_{001}$  typical for MMT (30B  $2\theta=4.7^\circ$ , 20A  $2\theta=3.8^\circ$ ) revealed the following. In case of absence of balls in the blending process no changes have been detected in the MMT reflex  $d_{001}$  position and intensity of this peak was proportional to concentration of the 30B. On the contrary, creation of more efficient blending conditions with use of balls (3 pieces) leads to formation of exfoliated nanocomposites with up to 3% of the 30B weight, and in case of higher concentrations of the 30B partly exfoliated and intercalated composite structures are forming. Varying of the polymeric matrix composition by introduction of functionalized polyethylene (25, 50 and 75% of the weight) at the same concentration of the 30B (3% of the weight) strengthens as it was expected polarity of polyethylene (PE) and causes essential decrease of the intensity and widening of the  $d_{001}$  peak which supposedly takes place due to the partly intercalation and exfoliation of the MMT. In this connection the similar efficiency of the polyethylene functionalization by direct introduction of the maleic anhydride in the process of blending of PE with the MMT in the melt. Comparison of the modifier types in the 30B and 20A proved that the organophilic 20A one creates more favorable conditions for formation of exfoliated structures. Structural analysis of the obtained nanocomposites by the

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scanning electron microscopy confirms X-Ray diffractions data.

Preliminary estimation of the obtained nanocomposites by elasticity module shows notable increase of this parameter for exfoliated structures of the composite with concentration of the MMT up to 3% of the weight.

## **Kinetics for Thermal Degradation of Isotactic Polypropylene in Presence and Absence of Anti-oxidant B<sub>215</sub> ( Irganox 1010/ Irgaphos 168 (1:2))**

M. T. TAGHIZADEH, A. BAHADORI\*, P. SEIFI-AGHJEKOHAL, M. RANJI

*Department of Physical Chemistry, Faculty of Chemistry, University of Tabriz, Tabriz, Iran.*

E-mail: [mttaghizadeh@tabrizu.ac.ir](mailto:mttaghizadeh@tabrizu.ac.ir).

The thermal degradation of isotactic polypropylene (I-pp) was carried out in the absence and presence of concentrations of B<sub>215</sub> at different temperatures. A method of viscometry was used to study the degradation behavior and Kinetics model was developed to estimate the degradation rate constant. The thermal degradation properties of polymer have been studied by differential scanning calorimetry (DSC) and melt flow index (MFI). Experimental data indicated that the presence of B<sub>215</sub> greatly decreased the rate of degradation of PP. We indicated that the temperature in the presence of oxygen has direct effect on polymer degradation and rate of degradation was much minor at N<sub>2</sub> environment.

The activation energies, determined from the temperature dependence of the rate coefficients for pure PP and PP/B<sub>215</sub> were 13.38 and 24.5 kJ/mol, respectively.

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## **Interface Modification with Styrene-co-Maleic Anhydride Oligomers on the Mechanical Properties of Recycle EPS-Lignocellulosic Fiber Composites**

MATHEUS POLETTO, JULIANE DETTENBORN, MARA ZENI,  
ADEMIR J. ZATTERA\*

*Caxias do Sul University (UCS), Chemical Engineering Department, 95070-560  
Caxias do Sul/RS, Brazil  
E-mail: [ajzatter@ucs.br](mailto:ajzatter@ucs.br)*

This work has the aim to study techniques of green composites manufacturing. Industrial region of Caxias do Sul generates a big amount of industrial and urban wastes. The furniture industry generates wastes of sawdust of *Pinus elliotti* and nowadays there is a large amount of EPS (expanded polystyrene) being deposited in the city landfill. The first phase of the work was the manufacturing of the composites sawdust /EPS in a twin-screw extruder with temperature below 200°C using 20 wt% of sawdust. The effect of the addition of three styrene-co-maleic anhydride oligomers with different content of maleic anhydride, 30%, 25% and 20% (w/w), as interfacial modification agent on sawdust /EPS composite properties was studied. Were incorporated 1, 2 and 4% in weight of coupling agents (SMA 2000, SMA 3000 and SMA EF40) in the composites. Mechanical properties, such as tensile strength, flexural strength, impact strength, tensile and flexural modulus were analyzed. This interface modification improves the compatibility of hydrophilic sawdust with hydrophobic polystyrene. It has been observed that the addition of oligomers improves the mechanical properties of the composites with the incorporation of 2% in weight of coupling agents. The mechanical properties showed to be dependent on content of maleic anhydride in the coupling agent. Scanning electron microscopy (SEM) was used to investigate the fiber surfaces of lignocellulosic material and the fiber-matrix interfaces.

## Chemical Modification of Poly(Epichlorohydrin) Using Montmorillonite Clay

FATIMA BEKKAR\* AND MOHAMED BELBACHIR

*Laboratoire de Chimie des Polymères, Faculté des Sciences, Université d'Oran  
Es-Senia, BP 1524, Al M'Naouer, Oran 31000, Algérie*

E-mail: [fbekkar@yahoo.fr](mailto:fbekkar@yahoo.fr)

Chemical modification of polymers has been widely used to prepare novel polymers for new applications <sup>[1-3]</sup>. Poly (epichlorohydrin) (PECH) (1) is an interesting commercially available polymer due to the presence of labile chlorines on the polymer backbone. This facilitates the nucleophilic substitution for side chain modification, absence of phenyl groups that would have stiffened the polymer chains in case of styrene polymers <sup>[4]</sup> in addition to the presence of a flexible backbone <sup>[5]</sup>.

Much attention has been paid to the modification of PECH (1) with a large number of nucleophiles such as azides <sup>[6]</sup> carbazole <sup>[7]</sup>, carboxylates <sup>[8]</sup> and phenolates <sup>[9]</sup>, either under conventional conditions or under phase transfer catalyzed (PTC) conditions <sup>[10]</sup>.

On this basis, the present work deals with the preparation of PECH (1) through cationic ring opening polymerization followed by nucleophilic displacement of chlorine functionality with heterocyclic amines morpholine (2), piperidine (3) and pyrrolidine (4) using Mghnite-H<sup>+</sup> catalyst, a new non-toxic cationic initiator.[11] P1 was chemically modified with morpholine (2), piperidine (3) and pyrrolidine (4) into the corresponding new functional poly (epichlorohydrin)s (P2-P4) in a moderate reaction conversion %.

The conversion of P1 into P2-P4 was confirmed by using FTIR and NMR spectroscopy and the yield % was calculated from the elemental analysis data according to the mole fraction concept.

The obtained functional polymers were further characterized by thermal analysis which showed a substantial increase of the glass transition temperature (T<sub>g</sub>). Thus, the chemical modification of PECH using Mag-H<sup>+</sup> offers a simple method for obtaining functional polymers. Mag-H<sup>+</sup> is a montmorillonite sheet silicate clay exchanged with proton.

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## **Influence of Gamma-Irradiation on of Crystalline Structure of Recycled Polypropylene Composites**

ULMAS GAFUROV\*, NINA MUKHTAROVA

*Institute of Nuclear Physics, Tashkent, Uzbekistan*

E-mail: [ulmas3@mail.ccc.uz](mailto:ulmas3@mail.ccc.uz)

Influence of  $\gamma$ -irradiation on crystalline structure (morphology) of thermoplastic composites on recycled polypropylene bases has been investigated. The composite samples were  $\gamma$ -irradiated at different dose of the irradiation ( $\gamma$ - source Co60 with energy of 1.25 MeV).

It was investigated follows thermoplastic composites 1 - PPR/EPDM- (40/35 wt, % ) and 2- PP<sup>R</sup>/EPDM/GTR – (40/35/25 wt,%). EPDM(ethylene-propylene diamine)

X-Ray diffraction patterns (diffractograms) were obtained using X-ray diffractometer DRON-3M with usual focusing by Bragg-Brentano procedure (CuK $\alpha$  -radiation).

At the first stage the samples from all groups were irradiated up to doses of 100, 500 and 1000 kGy. But X-ray analysis has shown that all changes of the structure parameters were within experimental error. Thereby doses (and doses step) were increased.

The lattice parameters  $a$  and  $b$  of the polypropylene lattice of the polymeric composite TDV irradiated with various doses of *gamma* radiation has been defined.

Calculation was carried out on usual algorithm: on the measured values of angles of reflection  $2\theta$  with the help of Woolf – Bragg's formula.

It was shown different character of influence of gamma-irradiation on structure (lattice parameters  $a$  and  $b$ ) of the samples with various composition.

The dose dependence of crystallinity degree both of composite and polypropylene are analogous; it means that character of these changes is similar. So gamma radiation-induced change of crystallinity degree of the vulcanizates is defined mainly by the recycled polypropylene basis. Some initial increase in crystallinity with a dose is the result both of forming of cross-links and radiation-induced annealing of structure defects.

For vulcanizates on the basis of the recycled polypropylene more apparent reduction of crystallinity degree and expansion of a lattice occurs at smaller radiation doses. At doses higher than 2000 kGy polypropylene vulcanizate amorphization was accompanied by decomposition processes (gas outlet).

## **Prospects of the Usage Ceramic-Polymeric Composite Slim in Heliumtechnics and the Agriculture**

R. RAKHIMOV, V. ERMAKOV, P. JOHN

*Physical-Technical Institute, Physics-Sun, Tashkent, Uzbekistan*

E-mail: username@e-mailserver

Technical-power parameters of working agricultural heated constructions and various hothouse drying, helium technical drying devices with light transparent barrier remains at a level of achievements of 70th. For last years the important results on substantial improvement of their parameters also are not received.

In this connection, improvement of optical thermo-physical characteristics and the fall of price on agricultural heated objects helium power plants with glass, especially with slim light transparent barriers concerns as on of actual questions of the use of a sunlight and energy saving.

New approaches and the ideas promoting creation of cheap slim materials with optimum optical properties are necessary for break in researches and development in this direction, allowing to achieve the peak of efficiency of use solar and other kinds of energy.

Our approach to the decision of a problem instead of the idea of drawing on a surface of transparent protections thermo illumination selective coverings in particular SnO<sub>2</sub> will consist in creation composite a slim on a basis energy, light transforming powder components and polymeric materials.

At the same time, at low streams and adverse corners of falling of a light stream, the slim with ceramics has shown high efficiency in comparison with a slim without ceramics. Comparative tests of efficiency ceramic containing slims are carried out in Germany by doctor P.Jonom.

Conditions of experiment: An angle of falling of a sunlight about 30 degrees, Temperature of air 8°C, Weather clear, windless.

Table 1

Operation	Without ceramics	With ceramics
Heating of a film gr. °C(2 min)	12	35
Heating of a dark paper directly under a film °C(2 min) 20		35

As follows from the resulted data, 1 weight of % ceramics in a slim allows to strengthen essentially efficiency of use of a solar energy at adverse corners of falling of a light stream.

Doctor P.Jonom carried out an estimation of economic efficiency of application of a ceramic-slim composite during cultivation of plants for the countries of the European Community at the rate of 100 million people. Application of a slim-ceramic composite allows to increase productivity up to 35 % or up to 21 tons on hectare, to lower a time of recovery of outlay under the income more than 3 times, to lower a power consumption by equal manufacture up to 288000 euros on hectare or as a

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whole on 3556 - 4800 euros, to receive the additional income plus economy of energy of euro on hectare 298500. A time of recovery of outlay under the income plus the economy of energy makes up 0.0101 – 0.0109 a year.

Thus, the total estimation of efficiency of usage a slim-ceramic composite, shows perspectivity of this direction in the solution of economical, ecological, social and other essential problems.

## **The Electrical Influences of Various Multiwalled Carbon Nanotubes with Plasma Modification and Chemical Oxidation in the Polymer Matrix**

WAN-JUNG CHOU, CHUH-YUNG CHEN\*

*Department of Chemical Engineering, National Cheng-Kung University, Tainan  
70101, Taiwan*

E-mail: [ccy7@ccmail.ncku.edu.tw](mailto:ccy7@ccmail.ncku.edu.tw)

The dispersion behaviors of fillers in the polymer matrix determine the reinforcement for composites. For multiwalled carbon nanotube, it is difficult to obtain homogeneously dispersed multiwalled carbon nanotube (MWCNT) nanocomposites because of the non-reactive nature of the MWCNT surface and the unavoidable bundle formation due to van der Waals' forces during synthesis. Therefore, we prepared a series of multiwalled carbon nanotube/polymer nanocomposites with two types of tube. One was plasma-modified with maleic anhydride and the other was modified with acid and the same plasma treatment. After plasma modified, the MWCNT have good dispersion in the polymer matrix [1-2]. Moreover, it has been reported that the size of filler can influence its dispersion behavior in the polymer matrix [3-4]. To combine these concepts, our aim was adjust the ration of this two different MWCNT to control the electrical properties of the nanocomposites. The optimum conductivity of multiwalled carbon nanotube /polymer nanocomposites with specific ratios was of the order of  $10^{-3}$  S/cm for a total MWCNT content of 2.0 and 3.0 wt.%.

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## **Fiber-detouring-hole Microstructure of Rutelidae Cuticle and Biomimetic Application**

B. CHEN<sup>\*</sup>, J. LUO, Q. YUAN AND X. PENG

*College of Resource and Environment Science, Chongqing University, Chongqing  
400044, China*

E-mail: [bchen@cqu.edu.cn](mailto:bchen@cqu.edu.cn)

The observation of scanning electron microscope on the microstructures of the cuticle of Rutelidae (a kind of insect) showed that the cuticle is a kind of fiber-reinforced biocomposite consisting of chitin fibers and protein matrix with particular laminated microstructures. The observation also showed that there are many micro-holes in the cuticle. These holes are used for transferring nourishment matters by the insect. More careful observation showed that the chitin fibers at the brims of these holes detour the holes continuously forming a kind of fiber-detouring-hole reinforced microstructure, which improves the strength at the brim of the holes. The fiber-detouring-hole microstructure was analyzed based on its representative model. The analytical result showed that the larger volume fraction and the rational distribution of the chitin fibers at the brims of the holes are the main mechanisms of the higher strength of the microstructure. The fiber-detouring-hole microstructure was also used for the biomimetic design of the composite with hole using glass fibers and epoxy resin. The strength of the biomimetic composite was experimentally compared with that of the composite with drilled hole. The results showed that the strength of the biomimetic composite with the fiber-detouring-hole structure gains a remarkable increase compared with that of the conventional composite with drilled hole.

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## Investigation of the Helical Microstructure of the Aragonite Sheets in Rufescens Shell

B. CHEN\*, Q. YUAN, J. LUO AND X. PENG

*College of Resource and Environment Science, Chongqing University, Chongqing  
400044, China*

E-mail: [bchen@cqu.edu.cn](mailto:bchen@cqu.edu.cn)

Molluscan shell is a kind of bioceramic composite. Despite the material contains over 95% CaCO<sub>3</sub> in the form of aragonite combined with 5% collagen, the fracture work it can bear can be up to 3000 times that of pure aragonite. Such high fracture toughness can be attributed to the optimized microstructure of the shell. In this paper, a scanning electron microscope was used for observation of the microstructures of Rufescens shell. The observation showed that the shell is a kind of hierarchical bioceramic composite consisting of laminated aragonite and collagen protein. The observation also showed that the aragonite layers are furthermore composed with long and thin aragonite sheets. The diameter of the aragonite sheets are about several dozen nanometers. There are different microstructures of the aragonite sheets in their different locations. A kind of helical microstructure was found at the center of the shell. The maximal pullout force of the aragonite sheets with the helical microstructure, which is closely related to the fracture toughness of the shell, was investigated based on its representative model. The results showed that the helical microstructure could markedly improve the fracture toughness of the shell. At last, the advantage of the helical microstructure in improving the fracture toughness of the shell was experimentally verified.

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## Recycling of PC and HIPS from Electronics Waste by Mean of Compatibilized Blending

U. MEEKUM<sup>1,2</sup>

1. *School of Polymer Engineering, Institute of Engineering, Susranaree University of Technology, Nakron Ratsasima, 3000, Thailand*

2. *Center for Petroleum, Petrochemical, and Advanced Materials, Chulalongkorn University, Bangkok 10330, Thailand*

*Email: umsut@g.sut.ac.th*

Electronics waste especially mobile phone set and computer caste are mainly manufactured from polycarbonate(PC) and high impact polystyrene(HIPS). Sorting these two polymeric materials from the municipal waste is costing. Recycling of the polymers by blending is attractive alternative. In this research work, blending of virgin PC and HIPS was the main focus. Epoxy system, solid epoxy and DDS curing agent, were used as compatibilizer. The blending was performed in twin screw extruder at temperature ranging from 230 – 280°C and screw speed of 10 rpm. The output rate of approximately 30 g/min was obtained. The test samples were prepared by injection molding and also compression molding. Accordance with ASTM standards, the MFI, HDT, impact strength, tensile strength and flexural strength were tested. Rule of mixture together with SEM were used to reveal the compatibility of those two polymer. The mechanical properties by mean of tensile, impact and flexural strength had elucidated that they are slightly increase at PC/HIPS blending composition less than 100:20. Higher ratio gave rise to brittle compound. Adding epoxy compatibilizer at 1 phr had also improved those properties. By applying rule of mixture to the MFI result and using Fox's equation for the HDT of the blends, they revealed that there was some degree of miscibility of the compatibilized blends. SEM was also strengthen this observation. From the study, it was believed that there is a potential for blending PC and HIPS from electronic waste using epoxy as compatilizer. This process will would reduce the sorting step in the solid waste management and hence reducing the cost.

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## **The Effect of Different Dispersion Methods on the Mechanical Properties of MWCNT/Carbon Fiber/Epoxy Hybrid Composites**

**G. SZEBÉNYI<sup>1\*</sup>, G. ROMHÁNY<sup>1</sup>**

*<sup>1</sup>Department of Polymer Engineering, Budapest University of Technology and Economics, Budapest, Hungary*  
E-mail: [szebenyi@pt.bme.hu](mailto:szebenyi@pt.bme.hu)

After their discovery carbon nanotubes came into the focus of many fields of research. Their outstanding mechanical properties and high self surface area make them ideal reinforcement materials for polymer matrix composites. Up to date they can not yet compete with conventional micro-sized reinforcing materials, like carbon or glass fiber widely used by the industry, but they can be successfully used besides them as secondary reinforcement materials in hybrid composites. In such hybrid systems the toughening effect of carbon nanotube filled matrices can be successfully utilized in mainly matrix-dominated properties like delamination resistance and other interlaminar properties. In our former research [1] we have characterized some improvements in the field of MWCNT/carbon fiber/epoxy composites and faced the viscosity increasing effect of nanotube filling, which had a negative impact on the quality of the specimens prepared. One way to avoid these problems is to use low viscosity epoxy resins instead of the conventional resins widely used for laminating and injection.

The goal of our research was to develop alternative nanotube mixing and specimen preparation methods for use with low viscosity epoxy resins and compare them through the mechanical properties of the composites. A one-step direct mixing and a multi-step masterbatch technique has been used to prepare carbon nanotube filled resins for the preparation of MWCNT/carbon fiber/epoxy laminates with different carbon nanotube contents. Three point bending, interlaminar shear strength and instrumented falling weight impact tests have been run on the specimens to characterize the effect of the different nanotube dispersion methods on the properties of the hybrid composites.

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## Friction Stir Welding of Fiber Reinforced Polymer Sheets

Z. KISS<sup>1\*</sup>, T. CZIGÁNY

*Department of Polymer Engineering, Budapest University of Technology and Economics, Budapest, Hungary*

E-mail: [kiss@pt.bme.hu](mailto:kiss@pt.bme.hu)

The explosive development of industrial technologies requires the application of novel structural materials. The innovation of materials that belong to the family of metals, ceramics and polymers often involves the formation of new processing technologies. Environmental friendliness and productivity are obvious requirements of new processes. Innovations are also born in case of metal welding that has significant past and has already provided a lot of experience. Nowadays, the excessive use of fiber reinforced polymer matrix composites calls for joining techniques suitable for such materials. Welding is superior to mechanical fastening or other joining methods in means of cost effectiveness, productivity and mechanical properties of the produced joints. Friction stir welding (FSW) has been recently applied for aluminum and other light metals as well as their alloys for the first time <sup>[1]</sup>.

A welding process, with the help of which the feeding and speed parameters of welding can be controlled well, developed for the preparation of butt seams on short fiber reinforced PP sheets is presented. The process makes exact reproduction of seams possible, hence the long series of experiments necessary for the total mapping of this welding method can be started.

The authors detail the strength and structural properties of specimens prepared with different tool types, revealing the crucial role of tool geometry in the quality of the welding. The results of light and scanning electron microscopic images taken of the seam and the zone of the heat effect of welding are presented.

The aim of this study is to give a short overview of the current state of the art of friction stir welding method of fiber reinforced polymer sheets.

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**Nanocomposites Based on Polyesters and Carbon Nanotubes**

M. KWIATKOWSKA<sup>1\*</sup>, G. BROZA<sup>2</sup>, J.J. HERNANDEZ<sup>3</sup> AND Z. ROSLANIEC<sup>1</sup>

<sup>1</sup>*Institute of Materials Science and Engineering, West Pomeranian University of Technology,*

*70 – 310 Szczecin, Poland*

<sup>2</sup>*Polymer Composites Group, Technical University Hamburg – Harburg, D-21073 Hamburg, Germany*

<sup>3</sup>*Instituto de Estructura de la Materia, CSIC, 28006 Madrid, Spain*

E-mail: [magdalena.kwiatkowska@zut.edu.pl](mailto:magdalena.kwiatkowska@zut.edu.pl)

Polymer nanocomposites, as a new class of materials, make a challenge for scientists to understand and create new quality of polymer systems. An incorporation of carbon nanotubes (CNT) within a polymer matrix aims to exploit their extremely high mechanical, electrical, and thermal properties and gives a promise for preparation of composite materials with improved / novel physical properties. However changes in material's performance result not only from CNT intrinsic features, but also from the changes of crystalline structure and phase transitions in the presence of nanostructures.

The objective of this study was to investigate and compare the physical properties of poly(ethylene terephthalate) (PET) and poly(buthylene terephthalate) (PBT) filled with carbon nanotubes. In order to ensure a homogenous distribution of nanofillers nanocomposites were obtained by *in situ* method, i.e. CNT were first mechanically dispersed in glycol and then a synthesis of polymer matrix in the presence of nanofillers was carried out. The synthesis proceeded in two stages: transesterification of dimethyl terephthalate and glycol, and polycondensation reaction. Composite materials, containing different concentrations (but not higher than 0.5 wt%) of SWCNT or MWCNT, were next granulated, dried and injection moulded to prepare bulk samples. Characterization of materials included the analysis of microstructure (SEM) and crystalline structure (DSC, WAXS, SAXS), phase transitions (DSC), mechanical and electrical properties.

Both PET and PBT based nanocomposites retained small density and processability. It was proved that the addition of CNT in content not higher than 0.5 wt% accelerated the crystallization process (mainly MWCNT), increased the thermal stability, mechanical strength, and electrical behavior of nanocomposites. Although the chemical structures of PET and PBT are similar, poly(ethylene terephthalate) exhibited higher sensitivity for the presence of nanostructures in polymer system.

The present results were partially generated within the confines of the research project no. DFG/83/2006 financed by the Polish Ministry of Science and Higher Education.

## The Improvement of Mechanical Properties of Nano-TiO<sub>2</sub>/Poly(vinyl alcohol) Composites by Enhanced Interaction Between Nanofiller and Matrix

YUANHUA LOU, MEIHONG LIU, XIAOWEI MIAO, LI ZHANG,  
XINPING WANG\*

*Department of Chemistry, Key Laboratory of Advanced Textile Materials and Manufacturing Technology of Education Ministry, Zhejiang Sci-Tech University, XiaSha Higher Education Zone, Hangzhou 310018, China*

E-mail: [wxinping@yahoo.com](mailto:wxinping@yahoo.com)

A new composite material with properties that differ greatly from those of conventional materials can be obtained by introducing nano-size inorganic particles into polymer matrices. Organic–inorganic nanocomposite materials have been extensively studied in the past few years.<sup>1,2</sup> However, during the preparation process of nanocomposites, it is very difficult to retain homogenous dispersions of nanosized particles, since there is a strong tendency for them to agglomerate. To improve the fundamental understanding of inorganic-organic nanocomposite materials and to extend the application of these materials, it is crucial to improve nanoparticle dispersity in matrices.

In order to improve dispersity of nano-TiO<sub>2</sub> particles in poly (vinyl alcohol) (PVA) and enhance the interaction between nanofiller and matrix, surface-carboxylated nano-TiO<sub>2</sub> was used to prepare PVA nanocomposites. The effects of the extents of carboxylation and carboxylated nano-TiO<sub>2</sub> loading on mechanical properties of the nanocomposites were investigated. The results show that the tensile strength of the composites were greatly improved by increasing the carboxylated nano-TiO<sub>2</sub> loading or the extent of carboxylation of the nanoparticles, as compared with unmodified nano-TiO<sub>2</sub>. The storage modulus within the rubbery state increased and the loss tangent decreased with increasing –COOH content on the TiO<sub>2</sub> surface and increasing carboxylated nano-TiO<sub>2</sub> loading. These observations are attributed to a high dispersion of modified nano-TiO<sub>2</sub> in the PVA matrix and to crosslinking between –OH groups in PVA chains and –COOH moieties on inorganic nano-particle surfaces.

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## A Quantum Chemistry Study on the Structure of Electronic Properties of Paraphenyleneacetylene Macrocycles

JINHUAN YAO<sup>1\*</sup>, YAN LI<sup>2</sup> AND YANWEI LI<sup>1</sup>

<sup>1</sup>Department of Material and Chemical Engineering Chemistry, Guilin University of Technology, Guilin 541004, China

<sup>2</sup>Civil Engineering Department, Guilin University of Technology, Guilin 541004, China

E-mail: [lywhit@126.com](mailto:lywhit@126.com)

Due to the well-defined geometry and potential application in organometallic chemistry and supramolecular science [1], the paraphenyleneacetylene macrocycles (PAM) have received much attention in recent years. In the present work, the geometric structure, the electronic structure, and the ring strain energy characters of the PAM with different size are investigated by B3LYP/6-311+G\*\*//HF/6-31G\* method. The results show that the carbon-carbon bond length and bond angle are seriously dependent on the macrocycle size, which correlates to the ring strain energy. Electronic structure analysis demonstrates an odd-even difference behavior of the frontier molecular orbitals and the HOMO-LUMO gap. In addition, a quantitative relationship between the ring strain energy and the macrocycle size has been given.

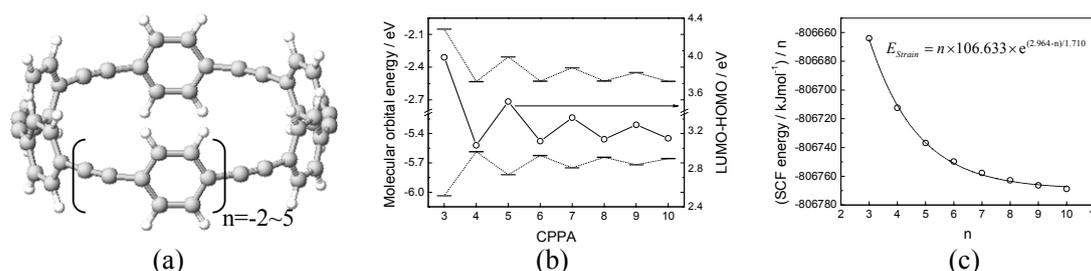


Figure 1. (a) Chemical structures of paraphenyleneacetylene macrocycles (PAM) studied in this work (b) HOMO and LUMO energy levels as well as the LUMO–HOMO gaps for the series of PAMs calculated by B3LYP/6-311+G\*\*//HF/6-31G\* method. (c) Ring strain energy evolution with the increase of PAM size

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## **Study on Friction Behavior of HDPP Modified with French Talc in the Condition of Dry Friction**

CHEN NANCHUN<sup>1,2</sup>, CHENG PENG<sup>2</sup>

*1. Key Laboratory of Nonferrous and new Materials Processing Technology ,ministry of Education, Guilin 541004,China*

*2.Department of Materials and Chemistry Engineering Guilin Institute of Technology, Guilin 541004,China*

E-mail: [cnc@glite.edu.cn](mailto:cnc@glite.edu.cn)

Taking the high density HDPP as the matrix, superfining powder of French talc as the reinforcing material, coordinated suitably with coupler to improve the French talc volume an average size of 5.35  $\mu\text{m}$ . The composition was injection molded with 1.7% coupling agent, 4%~14% different mass talc mixed with HDPP were added. Surface alternative nature feature was analysed by means of SEM, and the friction behavior of stainless steel during the inter-friction in the dry friction condition with was appraised by M-2000 type of abrasion and wear tester. The results showed that , when the talc use level as well as 8%,the composite of compare friction rate is  $1.909 \times 10^{-5}$ . The abrasion proof rate is lower, and the friction factor is 0.147. Such fine behaviour of friction resisting that is offer constrasting data to the material in light and so on in another field application.

## Microstructures of Spruce Wood and Research of Biomimetic Sandwich Composite

B. CHEN<sup>\*</sup>, J. LUO, X. PENG, Q. YUAN

*College of Resource and Environment Science, Chongqing University, Chongqing  
400044, China*

E-mail: [bchen@cqu.edu.cn](mailto:bchen@cqu.edu.cn)

Through the evolution of many centuries wood achieve higher stiffness, strength, fracture toughness and keep its lightweight at the same times. The eminent mechanical and physical properties of wood are closely related to the excellent microstructures of wood. In this paper, a scanning electron microscope (SEM) was used to carefully observe the microstructure of spruce, a kind of lightwood. The observation results showed that the wood possess a kind of typical sandwich structures, which consists of countless wood cells. The wood cells are arranged with interphase form and parallel to the surface of the wood. More careful observation showed that the each wood cell consist of wood-fiber plies and organic matrix. The fiber plies in different locations of the wood have different directions which compose a kind of helicoidal microstructure. Based on the observation, the buckling strength of the sandwich structure of the wood was analyzed based on its represented model. The function of the helicoidal-fiber arrangement in improving the fracture toughness of the wood was analyzed based on the idea of fiber-pullout energy. The analytical results showed that the helicoidal fiber arrangement could markedly increase the fracture toughness of the wood, which was verified with a special experiment.

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## Swelling Behavior and Mechanical Properties of Composite Materials Derived from Poly(acrylamide) Hydrogel and Kaolin

S. E. KUDAIBERGENOV<sup>1,2\*</sup>, D. S. SVETLICHNYY<sup>2,3</sup>, N. A. DOLYA<sup>2</sup>,  
ZH. E. IBRAYEVA<sup>1,2</sup>

<sup>1</sup>Laboratory of Engineering Profile, K.I. Satpaev Kazakh National Technical University, Almaty, 050013, Republic of Kazakhstan

<sup>2</sup>Institute of Polymer Materials and Technology, Almaty, 050004, Republic of Kazakhstan

<sup>3</sup>Research & Development Center of “KazTransOil”, Almaty, 050004, Republic of Kazakhstan

E-mail: [ipmt-kau@usa.net](mailto:ipmt-kau@usa.net)

The objective of this paper is to describe the influence of immobilized kaolin particles on swelling, thermodynamic and mechanical properties of poly(acrylamide) hydrogel (PAAH) in order to clarify the interaction between polymer and clay components.

Kaolin microparticles with average size of 1  $\mu\text{m}$  were embedded within the network of PAAH by *in situ* radical polymerization. Mechanical experiments were carried out on PSM-2 (Williams type) and RMI-60 instruments. Typical duration of a stress-strain measurement was around 2 min. Thickness and width of each sample was measured at room temperature using a digital caliper. The crosshead speed was 10 mm/min. All samples were tested in triplicate and the results were averaged.

Dynamic swelling behavior of PAAH/Kaolin composites reveals that the swelling process follows by non Fickian law and the swelling degree of composite hydrogels decreases with increasing of clay content. The increase of kaolin concentration in PAAH matrix results in increase of volume fraction of polymer ( $\phi_2$ ). The enthalpy of polymer-water mixing ( $\Delta H_m$ ) was calculated according to Gibbs-Helmholtz equation. The positive values of  $\Delta H_m$  indicate that the swelling process is endothermic. The increase of kaolin quantity in PAAH volume leads to reinforcing of mechanical properties of composite materials.

It is concluded that PAAH/Kaolin composites can potentially be used as “pigs” for the cleaning of the internal surface of main pipes from debris, sand and asphaltene-resin-paraffin deposits.

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## Preparation of Silica/Polystyrene Composite Films at Liquid/Liquid Interfaces

WENJUN LIU<sup>1</sup>, KUN LUO<sup>1,2\*</sup> AND JIANPING LI<sup>1,2</sup>

<sup>1</sup>Department of Material and Chemical Engineering Chemistry, Guilin University of Technology, Guilin 541004, China

<sup>2</sup> Key Laboratory of New Processing Technology for Nonferrous Metals, Ministry of Education, Guilin University of Technology, Guilin 541004, China

E-mail: [luokun998@gmail.com](mailto:luokun998@gmail.com)

Silica nanoparticles were reported to be able to apparently improve the mechanical properties of polymers and polymer matrix composites when the particles were mixed into the polymer matrix [1]. However, it is normally difficult to disperse the particles into the polymeric matrix without aggregation. Herein, we present a novel approach where monodispersive silica colloids with variant sizes were synthesized by a surfactant-templated method [2].

Liquid/liquid interfaces between immiscible liquids offer the possibility of assembling silica colloid particles into monolayers due to its discontinuity of physical chemistry. It was noticed that silica particles were able to maintain stable distance from each other at liquid/liquid interface owing to the repellant from the surface charge [3], and closely compacted silica particle monolayers were also available when more silica particles were introduced at the liquid/liquid interface, where the structure could be further solidified by the reduction of  $Ag^+$  in the aqueous solution by the ferrocene in toluene in our lab.

A similar approach was employed in our present work, where *in situ* interfacial polymerization of styrene was initiated after variant amounts of silica particles were introduced at the toluene/water interface. The composite films of silica/polystyrene were prepared, which led to a bulk composite material with controllable content and distribution of silica particles in polystyrene matrix.

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## Synthesis and Improved Electrochemical Performance of LiVPO<sub>4</sub>F/C Composite Material

SHENGLUI ZHONG<sup>1\*</sup>, LETONG LIU<sup>1</sup>, JIAN WANG<sup>1</sup>, LIU JIE-QUN<sup>2,1</sup>,  
YANHONG LI<sup>3</sup>

<sup>1</sup>*Department of Material and Chemical Engineering, Guilin University of Technology, Guilin, 541004, China*

<sup>2</sup>*Key Laboratory of New Processing Technology for Nonferrous Metals and Materials, Ministry of Education, Guilin University of Technology, Guilin, 541004, China*

<sup>3</sup>*a. Guangxi Key Laboratory of Environmental Engineering, Protection and Assessment; b. Department of Resources and Environmental Engineering, Guilin University of Technology, Guilin 541004, China*

E-mail: [zhongshk@qlite.edu.cn](mailto:zhongshk@qlite.edu.cn)

LiVPO<sub>4</sub>F/C composite material obtained with carbon gel as carbon sources was prepared by carbothermal reduction (CTR) process. The crystalline structure, morphology of particles, carbon contents were analyzed by X-ray diffraction (XRD), SEM and carbon/sulfur determinator. The results of X-ray diffraction showed that the LiVPO<sub>4</sub>F/C is pure triclinic structure. SEM results indicated that the addition of the carbon reduced the particle size of LiVPO<sub>4</sub>F. The carbon was dispersed between the grains, ensuring a good electrotronic contact. Electrochemical tests showed that the material obtained by adding carbon gave enhanced performance in term of improved practical capacity and cycleability. It was suggested that the addition of the carbon gel obtained pure triclinic LiVPO<sub>4</sub>F/C with good electrochemical performance, and LiVPO<sub>4</sub>F/C can be used as candidate cathode materials for lithium ion batteries.

## Synthesis and Improved Electrochemical Performance of $\text{Li}_3\text{V}_2(\text{PO}_4)_3/\text{C}$ Composite Material

JIEQUN LIU<sup>1\*</sup>, QIAN ZHANG<sup>2</sup>, YANHONG LI<sup>3</sup>, XINHE XIAO<sup>4</sup>

<sup>1</sup>*Key Laboratory of New Processing Technology for Nonferrous Metals and Materials, Ministry of Education, 541004, China*

*Guilin University of Technology, Guilin, 541004, China*

<sup>2</sup>*Department of Biological and Chemical Engineering; Guangxi University of Technology; Liuzhou 545006, China*

<sup>3</sup>*a. Guangxi Key Laboratory of Environmental Engineering, Protection and Assessment; b. Department of Resources and Environmental Engineering, Guilin University of Technology, Guilin 541004, China*

<sup>4</sup>*Hunan Institute of Humanities, Science and Technology, Loudi, 417000, China*

E-mail: [Liujiequn@glite.edu.cn](mailto:Liujiequn@glite.edu.cn)

$\text{Li}_3\text{V}_2(\text{PO}_4)_3/\text{C}$  composite material obtained with carbon gel as carbon sources was prepared by carbothermal reduction (CTR) process. The crystalline structure, morphology of particles, carbon contents were analyzed by X-ray diffraction (XRD), SEM and carbon/sulfur determinator. The results of X-ray diffraction showed that the  $\text{Li}_3\text{V}_2(\text{PO}_4)_3/\text{C}$  is pure monoclinic structure. SEM results indicated that the addition of the carbon reduced the particle size of  $\text{Li}_3\text{V}_2(\text{PO}_4)_3$ . The carbon was dispersed between the grains, ensuring a good electrotonic contact. Electrochemical tests showed that the material obtained by adding carbon gave enhanced performance in term of improved practical capacity and cycleability. It was suggested that the addition of the carbon gel obtained pure triclinic  $\text{Li}_3\text{V}_2(\text{PO}_4)_3/\text{C}$  with good electrochemical performance, and  $\text{Li}_3\text{V}_2(\text{PO}_4)_3/\text{C}$  can be used as candidate cathode materials for lithium ion batteries.

## First-principles Studies of Electron Transportation of Functionalized Polyacetylene Molecular Wires

JIQIONG JIANG\* AND YANWEI LI

*Department of Material and Chemical Engineering Chemistry, Guilin University of Technology, Guilin 541004, China*

E-mail: [jjq0618@163.com](mailto:jjq0618@163.com)

With the continuous miniaturization of conventional silicon-based electronics, molecular electronics have been considered as one of the most promising alternatives for the future nanoscaled electronic devices <sup>[1-3]</sup>. Most of these molecular devices consist of the conjugated molecular units, which contain alternating single and double (or triple) bonds facilitating the electron transport from one end to the other under the applied voltage. All-trans polyacetylene (PA) is the prototype of the conjugated structure, and many other conjugated molecules can, in principle, be derived by the structure modification of PA. Therefore, it provides a good theoretical model for investigating the electronic transport through single organic molecules. In this work, the nonequilibrium Green's function technique and density functional theory were used to perform ab initio quantum-mechanical calculations of electronic transport of single polyacetylene (PA) molecular wire sandwiched between two gold electrodes. To inspect the substituents effect on the electronic transport properties, both the electron-donating ( $-NH_2$ ) and electron-withdrawing ( $-NO_2$ ) groups were asymmetrically introduced into the conjugated PA molecular wire, resembling the semiconductor p-n junction. The results demonstrated the rectification behavior of the substituted PA. The asymmetric evolutions of the energy levels and spatial distributions of the frontier molecular orbitals with the applied voltage are found to be essential in generating this current-voltage asymmetry.

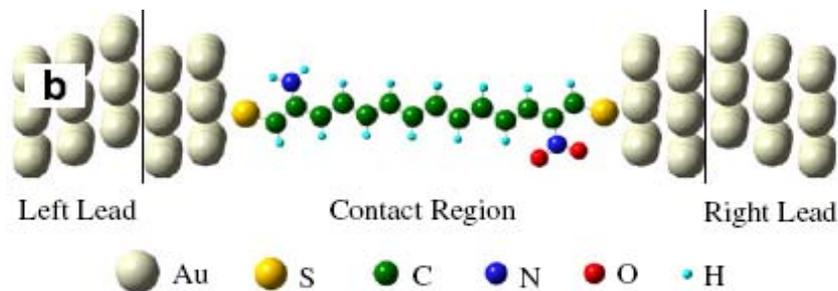


Fig. 1. Schematic illustration of the molecular junctions: (a) bare PA and (b) sub-PA.

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## Toward Nanocomputer on Polyelectrolyte Molecular Base

I. E. SULEIMENOV<sup>1</sup>, G. A. MUN<sup>2</sup>, S. PANCHENKO<sup>1</sup>

<sup>1</sup>*Almaty Institute of Power Engineering and Telecommunications, Baitursynova 126 Str., 050013, Almaty, Kazakstan*

<sup>2</sup>*Kazakh National University, Chemical Faculty, Karasai Batyr Str. 95a, 050012, Almaty, Kazakstan*

E-mail: [Esenych@yandex.ru](mailto:Esenych@yandex.ru)

A number of different approaches to development of nano-scale elements, which are able to carry out logical operations, are proposed <sup>[1]</sup>. Nevertheless, the problem is quite far from solution, in particular, due to difficulties of managing of currents of very low magnitude.

It is shown, that using of electrostatic charges, which are comparable with elementary one, is suitable for carrying out logical operation in this report. It is of importance that non-compensated charges appear due to natural reasons (electrolyte dissociation) when polyelectrolyte molecules are used. Moreover, non-compensated charge actually demonstrates its properties at the distances about Debye's length, which has namely nano-scale order.

It is shown that reactions of dissociation and association of low-molecular ions with polyions may be considered as motion of separate elementary charge along macromolecule skeleton in present report. Consequently, a set of cells may be formed inside separate macromolecule, and each such cell is connected with zero (logical 0) and non-zero (logical 1) electrostatic charge. Repulsion of charges placed in such cells corresponds to carrying out logical operations. Concrete type of logical operation is determined by geometry and chemical composition of concrete fragment of polyion. In particular, 8-byte adder may be realized directly on the base of polyion charges repulsion, as it is shown in present report.

One of the most difficult problems connecting with computation with the help of such method is information recording inside n-byte nanoadder. This difficulty may be solved with the help of analogy between separate polyion and neural network. Namely, the action of average field forming by all charges belong to definite polyion on given functional group may be considered as a set of connections inside of neural network <sup>[1]</sup>. The concrete theoretical model, showing the validity of mentioned analogy is build up in present report too.

Proposed model shows, in particular, that the action on the network as whole by an electric field, which have quite definite dependence of magnitude on time, gives possibility to form given distribution of charges along macromolecule skeleton, i.e. mentioned above analogy is a base for recording of information in nano-scale computing elements.

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## Micromechanics of Randomly Distributed Fiber Reinforced Polymer Matrix Composites with Transversely Isotropic Constituents

M. J. MAHMOODI\*, M. M. AGHDAM AND M. SHAKERI

*Department of Mechanical Engineering, Amirkabir University of Technology, Hafez Avenue, Tehran, Iran*

E-mail: [mjmahmoodi@aut.ac.ir](mailto:mjmahmoodi@aut.ac.ir)

Many inclusions in polymer matrix composite (PMC) materials are not isotropic. For example, carbon and graphite fibers are transversely isotropic. By extending the geometry of the RVE of the Simplified Unit Cell (SUC) model for square array<sup>[1]</sup> to an  $r \times c$  sub-cell domain achieve an RVE to model mixed materials that inclusions are distributed randomly in some sub-cells depending on relevant volume fraction. In order to obtain governing equations, it is assumed that all micro-stress and micro-strain components in sub-cells are constants. Furthermore, it is assumed that the applied normal stress on the RVE does not introduce any shear stress inside the sub-cells and vice-versa. Using theory of elasticity regulations and substitution of thermo-elastic constitutive equations including transversely isotropic behaviour for fibre sub-cells and isotropic behaviour for matrix sub-cells and satisfaction equilibrium conditions between various sub-cells into compatibility equations in conjunction with equilibrium equations on the boundary of the RVE, governing equations can be obtained which includes a system of  $m=r \times c+r+c$  equations for the RVE with the same number of unknown normal stress component. For applied shear force, it is possible to obtain the governing equations using the same procedure as normal loading. By applying the definition of any effective properties, overall axial and transverse young's modulus, overall axial and transverse shear modulus and coefficient of thermal expansion can be obtained from unknown stresses. For the presented model, results were obtained using average values of 5–7 analyses with random  $20 \times 20$  arrangements of the fibre sub-cells within the matrix. The chosen composite system for comparison of presented model with experimental data and kown's micromechanical model<sup>[2]</sup> is graphite/epoxy composite with relevant material properties for each constituent. The results show good agreement with kown's micromechanical theory and experimental data. Also the model provides closed form solutions for overall shear moduli of the heterogeneous media. It can be shown that the shear modulus only depends on the shear properties of the constituents and their volume fraction but not their shape.

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## Micromechanical Analysis of Initial Yielding of Fiber Reinforced Composites Subjected to Various Loading Conditions

M. J. MAHMOODI\*, M. M. AGHDAM AND M. SHAKERI

*Department of Mechanical Engineering, Amirkabir University of Technology, Hafez Avenue, Tehran, Iran*

E-mail: [mjmahmoodi@aut.ac.ir](mailto:mjmahmoodi@aut.ac.ir)

A micromechanical model is developed to study initial yielding behavior of unidirectional fiber reinforced composite subjected to various combined loading conditions including off-axis loading. By extending the geometry of the RVE of the Simplified Unit Cell (SUC) model for square array <sup>[1]</sup> to an  $r \times c$  sub-cell domain achieve an RVE to model mixed materials that inclusions are distributed randomly in some sub-cells depending on relevant volume fraction. Under general off-axis loading, after transforming the overall load to material coordinate system, applied normal and shear load on the RVE are obtained, depending on the off-axis angle. Using theory of elasticity regulations and substitution of thermo-elastic constitutive equations for isotropic constituents' sub-cells and satisfaction equilibrium conditions between various sub-cells into compatibility equations in conjunction with equilibrium equations on the boundary of the RVE, governing equations can be obtained which includes a system of  $m=r \times c+r+2 \times c$  equations for the RVE with the same number of unknown normal and shear stress component. The overall initial yield surface of the composite can be determined provided that overall load stresses can be related to the local stress components of individual sub-cell, and satisfaction of Von-Mises yield criterion at least, in one of the matrix sub-cells as the overall loading on the composite is increased. Results for random fiber arrangement are obtained using average values of 5–7 analyses with  $10 \times 10$  and  $50 \times 50$  sub-cells for two composite system including SiC/Ti and B/Al. Initial yielding surface in Transverse/Transverse plane and Transverse/Longitudinal plane are constructed. Effects of different parameters such as manufacturing process thermal residual stresses, fiber volume fraction and fiber packing are investigated. Results revealed that prediction of initial yield stress occurs at lower stress states for more realistic random fiber arrangement. Initial yielding stress in off-axis loading is also presented for various off-axis angles. In this way, one can distinguish the damage modes of the composite, depending on the off-axis angle.

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## Investigation into Impact Processes of Polycarbonate Projectile and Application in Penetration Experiments

HU WEN-JUN<sup>1</sup>, CHEN YU-ZE<sup>1</sup>, HUANG XI-CHENG<sup>1\*</sup>, LIU ZHAN-FANG<sup>2</sup>

<sup>1</sup>*Institute of Structural Mechanics, China Academy of Engineering Physics, Mianyang 621900, PR China*

<sup>2</sup>*Dept of Engineering Mechanics, Chongqing University, PR China*

E-mail: [huangxc@caep.ac.cn](mailto:huangxc@caep.ac.cn)

The impact experiments of polycarbonate (PC) projectiles with various head were carried out at velocity of 150m/s ~ 250m/s on Hopkinson bar system. The impact processes were recorded by high speed camera and the interface pressure history was measured. The targets were made from pure aluminium and A3 steel. The perforation mechanisms were studied through experiment analysis. The experiment results are as following.

1. The measured pressure by PVDF in our experiments was consistent with the recorded data through internal storage of project by Goldsmith. The project-target interface pressure history can be used in calculation of load history in project.
2. The impulse width depends on project length, and shape on project head.
3. The correlative equation about stress amplitude in head and impact velocity were obtained. The head shape affects greatly on deformation of project. Engineering design should consider about this.
4. The project-target interaction duration was derived from strain history. Then, the average acceleration and overloading were obtained by law of conservation of momentum. Analysis shows the similarity of parameters variation in impact experiments between PV project and metal project.
5. The residual deformation of targets under half-through perforation is greater than that under whole perforation at the same impact velocity.

PC projects can be used in penetration mechanics. PC penetration tests have many advantages duo to the material transparency. Deformation and failure in PC projects after impact testing can be observed clearly. This is important when the micro-damage occur in projects. The failure information in PC projects can be analogized to metal projects, and can provide designing advice for engineers.

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## Synthesis and Electrochemical Performance of Highly Defected Nickel Hydroxide

CHANGJIU LIU<sup>1,2\*</sup>, MEIRONG QI<sup>1</sup>, CHUNXIAO XING

<sup>1</sup>Department of Material and Chemical Engineering Chemistry, Guilin University of Technology, Guilin 541004, China

<sup>2</sup>Key Laboratory of New Processing Technology for Nonferrous Metals, Ministry of Education, Guilin University of Technology, Guilin 541004, China

E-mail: [Liuchj\\_1229@163.com](mailto:Liuchj_1229@163.com)

Highly defected nanosized nickel hydroxide (see Figure 1) was successfully synthesized by rapid freezing micro-emulsion precipitation method. The structure and electrochemical performance of the highly defected nanosized nickel hydroxide were characterized by XRD, TEM, IR, Raman spectra, and thermal gravity testing. The results of IR spectroscopy and thermal gravity analysis indicate that the highly defected nanosized nickel hydroxide contains water molecules and anions. Raman spectrum displays more peaks, indicating the high disordered feature of the highly defected nanosized nickel hydroxide. Cyclic voltammogram and charge/discharge test show that the highly defected nanosized nickel hydroxide in alkaline media has a relatively high discharge capacity ( $350 \text{ mAh g}^{-1}$ , see Figure 2) and good structural stability, which indicates its potential application as an electrode material for secondary alkaline batteries.

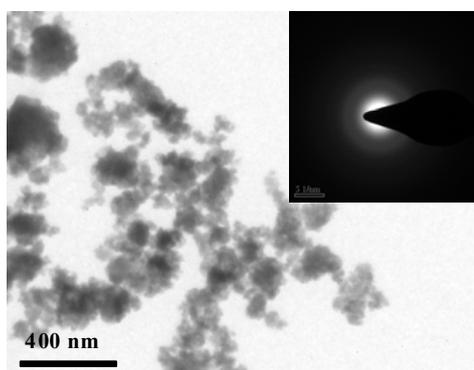


Figure 1. TEM image of the homemad nickel hydroxide. The inset is electron diffraction pattern of the homemad nickel hydroxide.

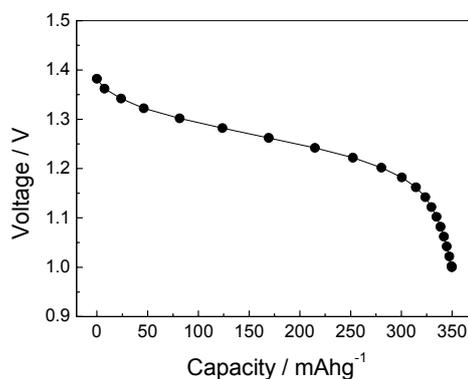


Figure 2. Discharge curve of the the homemad nickel hydroxide electrode at a constant discharge current of  $40 \text{ mA g}^{-1}$ .

## Preparation and Characterization of Polyacid Amide/Epoxy Resin Composites

XIAO-WANG YANG<sup>1</sup>, SHAO-RONG LU<sup>1,2\*</sup> AND CHUN WEI<sup>1,2</sup>

<sup>1</sup>*Department of Material and Chemical Engineering Chemistry, Guilin University of Technology, Guilin 541004, China*

<sup>2</sup>*Key Laboratory of New Processing Technology for Nonferrous Metals, Ministry of Education, Guilin University of Technology, Guilin 541004, China*

E-mail: [gllushaorong@glite.edu.cn](mailto:gllushaorong@glite.edu.cn)

Polyimides are widely used for applications that require high degree of thermal stability, excellent mechanical properties and chemical resistance. There are many studies which have used polyimides in epoxy systems intending mainly to improve the thermal stability and toughness.

In the present work, A polyamic acid (PAA) contained aromatic ester was synthesized by a directly solution polycondensation of dicarboxylic anhydride and 4,4-diaminodiphenyl ether using N,N-dimethyl formamide(DMF) as solvent, and PAA was characterized by FTIR and <sup>1</sup>HNMR. PAA solution was blended and reacted with E-51 before the addition of DDS. After DMF was removed, PAA/E-51 solution was cured by DDS to obtain the PAA/E-51 blend composites. The curing behavior was investigated by the non-isothermal differential scanning calorimetry (DSC) method, and the mechanical properties, thermal properties, dynamic thermal mechanical properties, and the crystal morphology were also investigated in detail. The experimental results showed that PAA accelerated the curing of epoxy resin, and the impact toughness, mechanical strength and thermal stability were improved greatly by addition of PAA compared with that of the neat epoxy. The flexural strength and modulus presented 1.35 and 1.65 times higher than that of E-51 when PAA containing is 1 wt%. The microstructure of the fractured surface in impact test was observed by Scanning electron microscope (SEM). There is no apparent phase separation in the PAA/E-51 blend.

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## Preparation and Characterization of the Liquid Crystalline Epoxy Resin/Epoxy Resin Composites

XIAO-WANG YANG<sup>1</sup>, SHAO-RONG LU<sup>1,2\*</sup> AND CHUN WEI<sup>1,2</sup>

<sup>1</sup>*Department of Material and Chemical Engineering Chemistry, Guilin University of Technology, Guilin 541004, China*

<sup>2</sup>*Key Laboratory of New Processing Technology for Nonferrous Metals, Ministry of Education, Guilin University of Technology, Guilin 541004, China*

E-mail: [gllushaorong@glite.edu.cn](mailto:gllushaorong@glite.edu.cn)

Liquid crystalline epoxy resin (LCEP) is a kind of thermoset which possesses advantages of conventional epoxy resin, and shows interesting properties due to the combination of a thermoset and LC formation capability. As compared to ordinary epoxies, crosslinked LCEP exhibit higher fracture toughness and mechanical properties when oriented by magnetic fields.

In this paper, a novel liquid crystalline epoxy resin (PHQEP) containing aromatic ester mesogen was synthesized from di(p-hydroxyl benzoic acid) hydroquinone (PHQ) and epichlorohydrin by phase transfer catalysis. The molecular structure of PHQEP were characterized by means of Fourier transformed infrared spectroscopy(FT-IR), hydrogen nuclear magnetic resonance spectroscopy (<sup>1</sup>HNMR),and the liquid crystalline phase behavior was observed by polarized optical microscope(POM).The curing behavior of PHQEP/E-51/DDS system was studied by non-isothermal different scanning calorimetry (DSC).The mechanical property, thermal stability and dynamic mechanical properties of PHQEP/E-51 composites were investigated too. The results revealed that PHQEP is a typical nematic liquid crystalline polymer, the impact strength of 5 wt%PHQEP/E-51 is 2.6 times than that of the value of E-51/DDS, and the initial decomposition temperature is 10 °C higher than the value of E-51/DDS. The detail reasons for the improvement of strength and thermal stability are that the origination of the mesogenic units of PHQEP was kept in the epoxy networks during the curing process.

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## Properties of Carbon Nanotubes/PMMA Composites Induced by Magnetic Field

CHUANGUO MA<sup>1,2\*</sup>, YUANRU WANG<sup>1</sup> AND YINGJUN YU<sup>1</sup>

<sup>1</sup>*Guangxi Key Laboratory of Information Materials, Guilin University of Electronic Technology, Guilin, 541004, China*

<sup>2</sup>*Department of Informational Material Science and Engineering, Guilin University of Electronic Technology, Guilin, 541004, China*

E-mail: [machuanguo@guet.edu.cn](mailto:machuanguo@guet.edu.cn)

The research of carbon nanotubes (CNTs) alignment in polymer matrixes has become increasingly valuable because the alignment of CNTs could significantly enhance mechanical, thermal and electrical properties of the corresponding nanocomposites. In previous research<sup>[1-2]</sup>, A problem was that the magnetic field to align CNTs was limited to super-high magnetic density (>3T). The objective of this work was to explore the effects of orientation and alignment of (CNTs) contained in a polymethyl meth-acrylate (PMMA) matrix under a low magnetic density (<0.5T) on the electrical and thermal properties of the resulting nanocomposites. In the research, the Ni coated multi-wall carbon nanotubes (MWCNTs) were dispersed in a PMMA matrix by solution blending and then cast onto an electrode to get composite films under magnetic field. Various magnetic fields were implemented to produce the composite films. Orientation of the CNTs in the films was characterized by SEM. Multimeter and high resistance meter were used to study the electrical behavior of the nanocomposites. The glass transition temperature ( $T_g$ ) of PMMA was determined by DSC. It was concluded that the alignment and orientation of the CNTs dispersed in the PMMA are achieved under very low magnetic density 0.1T and play a key role for improving electric conductivity and thermal property of the nanocomposite. The changes in the electric conductivity as a function of the magnetic density are dependent on the direction of magnetic field. There is an increase in electric conductivity with increasing magnetic density (0, 0.1T, 0.2T, 0.3T) under magnetic field vertical to the direction of electric current. In the case of magnetic field parallel to that, the electric conductivity increases at 0.1T and 0.2T, and then decreases at 0.3T. The alignment of CNTs at 0.2T markedly improves the stability of electric conductivity in cycling heating-up test, and results in an increase of about 4K to  $T_g$ .

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## Kinetic of Poly(ethylene glycol) Monomethacrylate (PEGMA) Grafted from Silicon(100) Surface to Form Polymer Brush

PENG JIN-WEN\*, DENG WEI-XING

*Key Laboratory of New Processing Technology for Nonferrous Metals and Materials, Ministry of Education; Department of Materials and Chemical Engineering, Guilin University of Technology, Guilin 541004, China*

E-mail: [jwpeng@glite.edu.cn](mailto:jwpeng@glite.edu.cn)

ATRP can cater for the requirements which are essential to bind well-defined polymer brushes covalently to the surface of a silicon solid surface<sup>[1-2]</sup>. In this paper the kinetics of poly(ethylene glycol) monomethacrylate grafted from silicon (100) surface to form poly(poly(ethylene glycol) monomethacrylate) (P(PEGMA)) polymer brush was investigated. A covalently bonded, (Si-C bonded), VBC monolayer (the Si-VBC surface) was formed via UV induced coupling of the vinyl group of VBC with the Si-H surface<sup>[3]</sup>. The monolayer VBC was employed for the surface-initiated ATRP. Then PEGMA was grafted from silicon(100) surface to form polymer brush via surface-initiated ATRP. The modified silicon surfaces were characterized by X-ray photoelectron spectroscopy (XPS), ellipsometry and telescopic goniometer. The presence of grafted P(PEGMA) from the Si-VBC surface was confirmed by XPS and ellipsometry measurement. The thickness of the grafted P(PEGMA) (from the Si-VBC surfaces) brushes, obtained after 2 h of ATRP, is about 11 nm. Their corresponding surface graft density was estimated to be 63 equivalent monomer units/nm<sup>2</sup>. The static water contact angle of the Si-VBC surface was about 83°. In the presence of grafted P(PEGMA) brushes, the surface still maintains hydrophilic and the static water contact angle is 55°. This data is the same as P(PEGMA) with bulk polymerization. The thickness of the grafted P(PEGMA) brushes on the initiator surfaces increases approximately linearly with polymerization time. These results suggest that the chain growth from Si-VBC surface is consistent with a “controlled” or “living” process.

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## A Selective Enzymeless Glucose Sensor Based on Nanosized Nickel Particles Embedded in Fumaric-acid-modified Rosin

JIANPING LI<sup>1,2\*</sup>, XIAOPING WEI<sup>1,2\*</sup>, KUN LUO<sup>1,2</sup>, GUOMIN ZHAO<sup>2</sup>

<sup>1</sup>*Department of Material and Chemical Engineering Chemistry, Guilin University of Technology, Guilin 541004, China*

<sup>2</sup>*Key Laboratory of New Processing Technology for Nonferrous Metals, Ministry of Education, Guilin University of Technology, Guilin 541004, China*

E-mail: [likianping@236.net](mailto:likianping@236.net)

Glucose oxidase (GOD) analysis is known as the common method for the detection of glucose. Since the GOD-based electrochemical sensor was reported in 1962, it has attracted vast interests for its high selectivity and fast responsiveness. However, the GOD relies seriously on the environment and is easy to lose its activity, which leads to the development of electrocatalytic metals and their oxides, such as platinum, gold, iridium, rhodium, ruthenium, copper, cobalt and nickel [1], among which metallic nickel is normally employed for its excellent electro-catalytic property and economic availability. The determination of glucose on nickel electrode is carried out at high oxidation potential, where other reducing substances, such as the ascorbic acid and uric acid, can interfere with the detection process.

In this paper, a chemical sensor was presented which was prepared by mixing nickel nanoparticles in the modified rosin for glucose determination. Rosin is a natural resin containing a variety of resin acids. Fumaric acid has two carbonyl bonds, which can react with rosin at elevated temperature by the Diels-Alder reaction, and leads to the formation of the fumaric acid modified rosin. The enriched carboxyls in the modified rosin exclude the anions that join the reaction on the nickel electrode, and hence improve the selectivity of the sensor. On the other hand, the employment of nickel nanoparticles can apparently enhance the response signal for its excellent activity. Under the optimized condition, the sensor has a linear range of  $1.0 \times 10^{-5} \sim 2.2 \times 10^{-3}$  mol/L, with detection limit  $7.1 \times 10^{-6}$  mol/L. The sensor can be used to detect glucose in blood within 3 seconds, and can be renewed by a simple polishing step.

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## Application of New Toughening Agent to Impregnating Resin for Dry Type Reactor

CHUANBAI YU<sup>1,2</sup> BAOLIN RAO<sup>1,2</sup>

<sup>1</sup>*Department of Material and Chemical Engineering Chemistry, Guilin University of Technology, Guilin 541004, China*

<sup>2</sup>*Key Laboratory of New Processing Technology for Nonferrous Metals, Ministry of Education, Guilin University of Technology, Guilin 541004, China*

E-mail: [yuchuanbai@qlite.edu.cn](mailto:yuchuanbai@qlite.edu.cn)

In this paper, hyperbranched star polyether polyol(DT) was synthesized with polybasic carboxylic acid and diol, which has been applied to modify impregnating resin for dry type reactor to improve the toughening of the cure system. By FT-IR, SEM, Universal testing machine, Impact testing machine, Digital high resistance, Gel test measuring system and thermal expansion measuring instrument, the chemical structures of DT was confirmed and the influences of composition of impregnating resin, molecular dimension and the content of toughening agent on the performance of impregnating resin were studied. Consequently, the optimum compounding of impregnating resin was made certain. Moreover, the post-curing reaction conditions of impregnating resin was optimized and the impregnating resin was tested and applied successfully to 10KV dry type reactor. By experiment, its results as follows: The proper ratio of anhydride group and epoxy group in the impregnating resin is 0.83~0.88. The influences of molecular dimension of toughening agent on the viscosity of impregnating resin, impact strength of solid polymer, thermal bending properties were studied in this paper, it was found that the impregnating resin for dry type reactor modified by DT633, whose theoretical molecular weight is approximately 500, has excellent integrated properties and applied conditions. The impact strength rised by inches when the content of the toughening agent is above 2.5% and barely reached 29 kJ/m<sup>2</sup> at 4.93%. When the content of toughening agent increased between 0~2.53%, there was little effect of bending strength and bending modulus at room temperature and thermal conditions. There was little various of electric volume resistivity with the content vary of toughening agent at room temperature and immersed in water for 192 hours, but there is intensively effect at 130°C. Integrating advisement, optimum content of toughening agent is about 2.5% considering the viscosity of impregnating resin, mechanical properties, thermal properties and electrical properties. The optimum composition: CYD-128: MTHPA: DT633: BDMA = 100: 73.5: 4.5: 0.25. The post-curing reaction conditions are feasible under 140°C/8h or 150°C/6h or 160°C/4h.

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## Preparation and Characterization of Nickel Hydroxide/ Multi-Wall Carbon Nanotubes Composite

ZHENGANG ZHANG<sup>1</sup>, QINGXIA YANG<sup>1</sup>, YANMEI QIN<sup>1</sup>, YANWEI LI<sup>1,2\*</sup>,  
JINHUAN YAO<sup>1</sup>

<sup>1</sup>Department of Material and Chemical Engineering Chemistry, Guilin University of  
Technology, Guilin 541004, China

<sup>2</sup>Key Laboratory of New Processing Technology for Nonferrous Metals, Ministry of  
Education, Guilin University of Technology, Guilin 541004, China

E-mail: [lywhit@glite.edu.cn](mailto:lywhit@glite.edu.cn)

Nickel hydroxide ( $\beta$ -Ni(OH)<sub>2</sub>), the active material of positive electrode of Ni/MH batteries, is a kind of p-type semiconductor and its poor electronic conductivity handicaps the high-rate dischargeability of Ni/MH batteries. Many studies of Ni/MH batteries nowadays focus on its use in electric tools, electric vehicles (EVs) and hybrid vehicles. In such situations, the characteristics of the advanced battery under high-rate discharge conditions are undoubtedly the key factors for its use.

Carbon nanotubes have excellent mechanical properties and bending strength, good tenacity, and good electrical conductivity, suggesting that it maybe of promising additives in the positive electrode of Ni/MH batteries. The purpose of this paper is to investigate the effect of multi-wall carbon nanotubes (MCNTs) addition on the electrochemical performance of nickel hydroxide. A chemical co-precipitation method is used to synthesize MCNTs doped nickel hydroxide. The XRD analysis shows that the addition of MCNTs increases the amount of defects among the crystal lattice of nickel hydroxide (Figure 1). Cyclic voltammetry and electrochemical impedance spectroscopy tests demonstrate the better reaction reversibility and lower electrochemical impedance of nickel hydroxide doped with MCNTs as compared with that without MCNTs. Charge/discharge tests show that MCNTs addition could enhance the specific discharge capacity and discharge voltage of the electrodes.

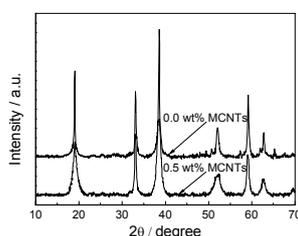


Fig.1 XRD patterns of the nickel hydroxide without and

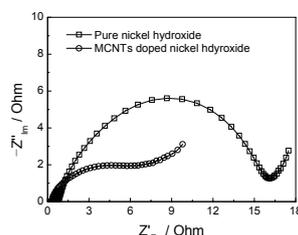


Fig.2 EIS of the nickel hydroxide without and with a

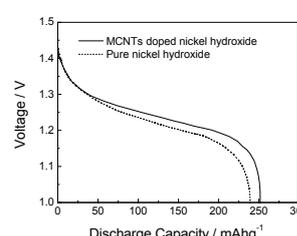


Fig.3 Discharge curves of the nickel hydroxide without and

### ACKNOWLEDGEMENT

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## **Reactive Blends of Poly(Ethylene Terephthalate)(PET) with Poly(Tetramethylene ether) Glycol (PTMEG).**

K. KWIATKOWSKI, Z. ROSLANIEC

Institute of Materials Science and Engineering, West Pomeranian University of Technology, Piastow Av. 19, 70-310 Szczecin, Poland  
E-mail: [konrad.kwiatkowski@zut.edu.pl](mailto:konrad.kwiatkowski@zut.edu.pl)

Reactive blending of high glass transition temperature polymers (e.g.  $>50^{\circ}\text{C}$ ) with low glass transition temperature polymers (e.g.  $<50^{\circ}\text{C}$ ) can provide a copolymer characterized by the phase separation. Depending on the components ratio it is possible to obtain materials with a broad range of physical properties: from hard and high-performance or high impact polymers to thermoplastic elastomers.

The present work encompasses the conditions of PET/PTMEG reactive blends production determined experimentally. It incorporates chemical synthesis and reactive mixing of these polymers. In situ production method of discussed mixtures with organic and inorganic modifying agents is also presented. It was demonstrated that specific structure and morphology of phase separation in goods produced of the presented material is responsible for elastic properties, which are not present in the polymeric components before mixing. Furthermore methods for developing required structure and morphology by nucleating agents and by appropriate processing and heat treatment of final products are described. It was demonstrated that increase in hardness and elasticity of products made of discussed materials can be achieved if the morphology of product consists of PTMO rich phase containing nanometric scale semicrystalline PET rich phases.

It was proved that the prepared materials are thermoplastic ester elastomers. Goods produced under appropriate processing conditions of here presented material display elasticity which is superior to that of commercially available TPE-E of comparable hardness.

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