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Synthesis of polyethylene glycol-functionalized multi-walled carbon nanotubes with a microwave-assisted approach for improved heat dissipation†

Ahmad Amiri,*[a] Rad Sadri,[a] Goodarz Ahmadi,[b] B. T. Chew,[a] S. N. Kazi,*[a] Mehdi Shanbedi*[c] and Maryam Sadat Alehashem[d]

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In order to improve the dispersibility of multi-walled carbon nanotubes (MWCNT) in aqueous media, MWCNT were functionalized with tetrahydrofurfuryl polyethylene glycol (TFPEG) in a one-pot, fast and environmentally friendly method. To reduce defects and eliminate the acid-treatment stage, an electrophonic addition reaction under microwave irradiation was employed. Surface functionalization was analyzed by FTIR, Raman spectroscopy, thermogravimetric analysis (TGA). In addition, the morphology of TFPEG-treated MWCNT (PMWCNT) was investigated by transmission electron microscopy (TEM). After the functionalization phase, the convective heat transfer coefficient and pressure drop in PMWCNT-based water nanofluids with various weight concentrations were analyzed and compared with that of the base fluid. The results suggest that the addition of PMWCNT into the water improved the convective heat transfer coefficient significantly. The pressure drop of prepared PMWCNT-based water nanofluids showed an insignificant variation as compared with the base fluid and could result from good dispersivity of PMWCNT. According to the laminar flow results, as the weight concentration and Reynolds number increase, the convective heat transfer coefficient and pressure drop increase.

1. Introduction

Energy optimization plays a vital role in different fields such as infrastructure, industry, defense *etc.* To fully realize energy optimization, different kinds of cooling systems with various designs have been employed over the past century.[1–3] It is obvious that convective heat transfer can be considered as one of the most significant parameters in energy saving, especially in a majority of thermal equipment which commonly work with base fluids such as water, ethylene glycol, and different kinds of oils.[2,4–7] In order to enhance conventional heat transfer of base fluids, the addition of highly thermally conductive nanoparticles such as metal, carbon, and metal oxides into the base fluids was introduced as an appropriate technique.[8–13] Recently, a novel type of fluid, so-called nanofluid that includes nanostructures has been introduced, and different types of nanofluids have been prepared by researchers. These fluids have shown attractive properties such as good stability, suitable thermal conductivity and high heat transfer coefficient. Since the time that the concept of nanofluids was introduced by Choi,[14,15] numerous scientists studied the effects of presence of nanoparticles in various base liquids on their thermos-physical properties. In particular, considerable attention was given to the influence of nanoparticle concentration on the thermal conductivity and heat transfer coefficients of base fluids. Different carbon nanostructures like carbon nanotubes (CNT), graphene, fullerene and metal nanoparticles like copper (Cu) and aluminum oxide (Al_2O_3) have been used to enhance the thermal properties of nanofluids.[9,10,16–20]

It is known that the thermal conductivity of most carbon particles such as CNT and graphene is much higher than that of metal nanoparticles. This implies that the carbon-base nanoparticle have higher potential for enhancing the thermal conductivity of base fluids.[18,21,22] Among a variety of carbon nanostructures, CNT is a more promising material since they are economically-viable for replacing metallic nanoparticles and graphene.[23,24] According to the previous studies, CNT showed high thermal conductivity[4,21,22] as compared with most of the materials, which confirms the potential of CNT for creating thermally conductive nanofluids. Such properties and low cost suggest that CNT is an appropriate candidate for use in

[a]Department of Mechanical Engineering, University of Malaya, Kuala Lumpur, Malaysia. E-mail: ahm.amiri@gmail.com; ahm.amiri@siswa.um.edu.my; salimnewaz@um.edu.my

[b]Department of Mechanical and Aeronautical Engineering, Clarkson University, Potsdam, NY 13699, USA

[c]Department of Chemical Engineering, Faculty of Engineering, Ferdowsi University of Mashhad, Mashhad, Iran. E-mail: mehdi.shanbedi@stu-mail.um.ac.ir

[d]Department of Chemistry, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia

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