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Effect of Silica Nanoparticles on Tensile Strength and Hardness in Polyurethane Hot Melt Adhesive

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Abstract
A hot melt adhesive of polyurethane (HMPUA) was synthesized and investigate some of its mechanical properties nanosilica was used as the additive. With the addition of the nanosilica (0.4 w%), the mechanical properties such as; tensile strength, elongation at break and hardness were improved (2.02 MPa, 343%, and 50 respectively).

Keywords: Polyurethane hot-melt adhesive, Hardness Shore A, Elongation at Break, Tensile Strength.

Introduction
In recent years, there has been increasing interest in polyurethane hot-melt adhesive (HMPUR) due to its superior performance compared to traditional adhesives. HMPUR offers benefits such as temperature resistance, high initial adhesion strength, high tensile strength, easy processing, and environmental friendly. HMPUR adhesives are highly viscous or solid prepolymers with a low melting point that can yield rigid or elastic bonds and can bond to a wide variety of substrates. Additionally, HMPUR adhesives can be designed and developed with widely varying properties for specific applications [1]. Adhesives play a crucial role in various industries and everyday life. Hot-melt adhesives (HMAs) are particularly promising as environmentally friendly adhesives due to their solvent-free nature, which helps avoid the emission of volatile organic compounds (VOCs). The adhesive is widely used in electronics assembly, automotive, aerospace, wood processing, and the footwear industry [2]. Sometimes to increase some adhesive properties including; additives such as fillers, softeners, etc. are used to increase brittleness, tensile strength, increase hardness and flexibility, etc [3]. Silica nanoparticle is one of the most common fillers for polyurethane adhesives. Adding a very small amount of nanoparticle silica improves wear resistance, tensile properties, and hardness, but adding large amounts of it causes lower mechanical properties [4].

Experimental
To prepare polyurethane hot melt adhesion, polypropylene glycol (Mn=1000 g/mol, 65-75 w%), 1,4-butanediol (3-5 w%), and glycerin (0.5-2 w%) are poured into a 250 ml reactor a round bottom, were mixed and dried under reduced pressure (110-120 °C for 2-3 h). The isocyante calculated for the index [NCO]/[OH]=1.02 (toluene diisocyanate 20-30 w%) along with the dimorpholinodiethyl ether (0.1-0.5 w%) was added to the reactor and reacted for 3-4 hours at a temperature of 50-60 °C under a nitrogen atmosphere until all the calculated isocyanates were consumed, which were measured by Karl Fischer device is carried out and continues. After completing the steps to form the film, the final solution was transferred into a teflon mold and it in an oven (40-50 °C for 12-18 h). To prepare polyurethane hot melt adhesive containing silica nanoparticles, a certain amount of silica nanoparticles (0 w%, 0.2 w%, 0.4 w%, and 0.6 w%) was added to the mixture of polyols and stirred for 12 h with a mechanical stirrer. The compound was sonicated (3 times and each time for 5 minutes) to homogenize ten it was stirred (30-40 minutes).

Results & Discussion
Hardness is resistance to penetration, abrasion, and resistance to cutting and scratching. The synthesized HMPUA was a low-hardness material. hardness in the sample HMPUA-0 was 43. The thickness of the tested samples was 4-6 mm. Silica nanoparticle filler was used to increase the hardness. As can be seen (Table 1), the addition of nanoparticles up to a certain value (0.4 w%) causes an increase in hardness, further addition however decreases the hardness of the sample.

Table 1: The hardness of the HMPUA containing nano silica (0,0.2,0.4 and 0.6 w%).

	HMPUA-0	HMPUA-0.2	HMPUA-0.4	HMPUA-0.6
Shore A (mm)	43	47	50	45

Figures 1 and 2 show the tensile test results of HMPUA films with nanosilica (0, 0.2, 0.4, 0.6 w%) films, the tensile strength and elongation at break show a very good mechanical behaviour by increasing the amount of silica nanoparticles to some extent. Tensile strength for HMPUA containing nanosilica 0, 0.2, 0.4, and 0.6 w% are 1.46, 1.67, 2.02, and 1.38, MPa respectively (Figure 1). Elongation at break was for samples 0, 0.2, 0.4, and 0.6 w% are equal to 253%, 283%, 343%, and 225%, respectively (Figure 2). Therefore, similar to the tensile strength results, the addition of the nanoparticles 0.4 w% can be the optimum value according to the mechanical obtained properties.

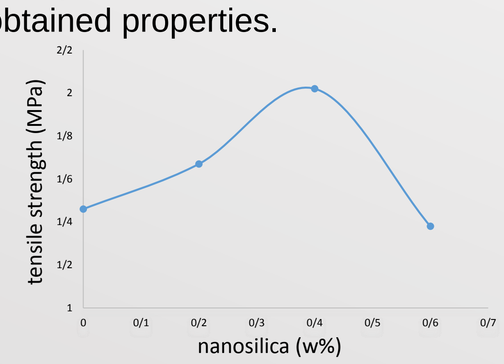

Fig. 1: change in tensile strength of HMPUA with nanosilica (0, 0.2, 0.4 and 0.6 w%).

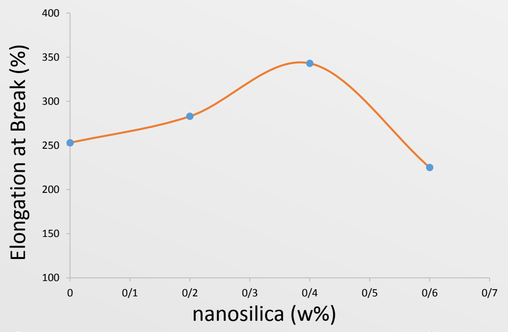

Fig. 2: change in elongation at break of HMPUA with nanosilica (0, 0.2, 0.4 and 0.6 w%).

Conclusion
There is an optimum concentration of nanosilica for the adhesive to obtain maximum tensile strength, elongation at break, and hardness. For this study, the concentration was 0.4 w% which case tensile strength, elongation at break, and hardness (2.02 MPa, 343%, and 50 respectively).

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