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Acoustically-enhanced particle dispersion in polystyrene/alumina nanocomposites

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Abstract. Polymer nanocomposites are advanced nanomaterials which exhibit dramatic improvements in various mechanical, thermal and barrier properties as compared with the neat polymer. Polystyrene/ alumina nanocomposites were prepared by an ultrasound-assisted solution casting method at filler loadings ranging from 0.2 to 2% and also at different ultrasonic frequencies, viz. 58 kHz, 192/58 kHz, 430 kHz, 470 kHz and 1 MHz. The composites were subjected to mechanical property tests (tensile and impact tests) and cavitation erosion tests to study the enhancement in functional properties. Filler dispersion in the polymer matrix was observed by SEM analysis. The effect of frequency on filler dispersion in the matrix was studied by SEM analysis and functional property enhancement of the composite material. The composites prepared at dual (high/ low) frequency (192/58 kHz) were found to show better property enhancement at low filler loadings as compared with neat polymer and also with composites prepared without ultrasound, thus reinforcing the finding that ultrasound-assisted synthesis is a promising method for the synthesis of nanocomposites.

Keywords: ultrasound; nanocomposites; dispersion; mechanical properties; cavitation erosion

1. Introduction

Polymer nanocomposites (PNCs) are synthesized by the incorporation of nano-sized inclusions into a polymer matrix. These materials exhibit significant improvement in physical properties as compared to those of neat polymer and also in comparison with micro and macro-composites (Giannelis 1996). PNCs are found to possess drastically different material properties compared to those of their constituents. The advantages they offer render them of great academic and industrial interest. Significant enhancement in properties such as stiffness, scratch resistance, abrasion resistance, barrier properties, solvent/ chemical resistance, erosion resistance, high temperature resistance, optical clarity, transparency, high weatherability, low water absorption, high refractive index, non-toxicity and biocompatibility shown by polymer nanocomposites is reported in literature. As a result, these materials find applications in automotive industry, packaging, protective coatings, flame retardant additives, performance plastics for office and home appliances, propulsion systems, optical systems such as hybrid solar cells, for corrosion resistance

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2.2.2 Preparation of filler dispersion

A dispersion of the nanoparticles was prepared by adding the required amount of nanoalumina particles to the solvent THF, and then subjecting this mixture to a low-frequency ultrasound (25 kHz) for 20 minutes. This helps in formation of a uniform dispersion and also prevents particle agglomeration.

2.2.3 Preparation of polystyrene/alumina nanocomposites

Polystyrene/alumina nanocomposites were prepared at different filler loadings ranging from 0.2% to 2% by weight. The nanoalumina dispersion in THF was transferred to the already-prepared polymer solution. The so-obtained polymer-filler mixture solution was then left for sonication in an ultrasonic tank for about three hours. This is intended to achieve homogenization of the mixture. The dispersion so obtained is cast into a petri-dish and left for drying. Specimens for testing were cut from the dried composite sheet as per ASTM standards.

3. Characterization studies

The tensile strength and modulus of the composites were measured using a Zwick Roell UTM. Impact strength measurement was carried out in an Izod un-notched impact tester. SEM was used to study the dispersion of particles in the polymer matrix. A cavitation erosion test was carried out to measure the erosion resistance of the surface of the composite. The data for impact strength, tensile modulus, and cavitation erosion for composites prepared at frequencies 430 kHz and 192/58 kHz (dual frequency) have been published in a previous study (Philip *et al*. 2012).

4. Results and discussion

4.1 Tensile tests

PS/alumina nanocomposites were prepared by an ultrasound-assisted method. The composites were subjected to tensile tests as per ASTM D 638 standards. Dumbbell-shaped specimen were prepared for the tests as specified. The tensile properties of the composites were obtained. These tests were conducted in a Zwick Roell UTM. Composites were prepared at frequencies of 58 kHz, 192/58 kHz (dual frequency), 430 kHz, 470 kHz & 1 MHz. The filler loadings used for composite preparation were 0.2, 0.4, 0.6, 0.8 and 1% by wt. For dual frequency alone, composites were also prepared at higher filler loadings of 1.5% and 2% by wt. Composites were prepared without ultrasound for filler loadings 0.4 and 1%. A comparison is also made between composites prepared with and without ultrasound.

Fig. 1 shows the variation of relative tensile strength (ratio of tensile strength of the composite to tensile strength of neat polymer matrix, E/E_m) with filler loading for composites prepared at various frequencies. Composites prepared at 430 kHz, 470 kHz and 1MHz, compared with the neat polymer, show an initial increase in property value at filler loadings of 0.2% and 0.4% by wt. As the filler loading is increased further, the property value is found to degrade and level off. Composites prepared at 58 kHz do not show a significant enhancement. Composites prepared at dual frequency are observed to have better enhancement in property value in comparison with those prepared at all other frequencies. Tensile strength of composites prepared at 1.5% and 2% by