STRUCTURE DEPENDENT INTERFACE ADSORPTION IN POLYMER NANOCOMPOSITES

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Abstract

The influence of interface coherence between organic polymer matrix and metal/metal oxide reinforcement is investigated, based on the anchoring density at the interface for a polymer composite. Methods of increasing anchoring density, as well as the resulting enhanced mechanical properties are also proposed. Effect of curvature on anchoring density is also quantified for various interface curvatures.

1 Extended Abstract

In order to improve mechanical properties of polymer composites inclusions (fibers, whiskers, platelets, or particles) are included in the matrix to form a composite. Improvements in properties can often be found even at relatively low filler content in traditional composites reinforced with micron-sized inclusions. Recently, more sophisticated techniques were developed to make "nanocomposites" by using nano-sized inclusions, with least one dimension in the range from 1-100 nm. Unlike traditional composites, the effect of nano-sized (vs. micron-sized) particles on the mechanical properties of polymer matrix composites and the mechanisms and factors contributing to the material response is still an open question.

Correlating material properties with filler size has become a topic of great interest; both theoretically and experimentally since current micromechanics approach, which are very effective in predicting effective properties of composites with micron size particles, are not very good with nanoparticles, although these theories are independent of particle size. Different nano-composite systems show different patterns, in some cases inclusions improves mechanical properties while in others properties are diminished. The specific reasons for this behaviour is not fully understood, but several theories have been introduced to explain some of the changes in material morphology and behaviour that are observed at the nano-scale.

In this talk experimental results with different behavioural patterns of nanocomposites will be outlined. One of main parameter that affects the behaviour of composites reinforced with nanoparticles is the structure of the interface between particles and the matrix. Mechanical properties will be correlated with the structure of the interface, for composites with nanoparticle inclusions. The polymer nanocomposite systems we study include poly(methyl methacrylate) (PMMA) and polystyrene (PS) composites containing alumina (Al_2O_3) and magnetite (Fe_3O_4) nanoparticles. The structure and density of the interface is of these systems are characterized using the results from thermal gravimetric analysis (TGA) and scanning electron microscopy (SEM). Fourier Transform Infrared Spectroscopy (FT-IR) was used to calculate the nature of bonding between polymer and nanoparticle surfaces and the density of the interface for PMMA-based nanocomposite systems. Although Al_2O_3 nanoparticles are more reactive with the polymer matrix than Fe_3O_4 nanoparticles, the interface interaction strength is not as strong as in the neat matrix, leading to an interface with lower density. Tensile testing, dynamic mechanical analysis (DMA), and nanoindentation tests are used to characterize mechanical properties. A new method for characterizing the degree of nanoparticle flocculation in a composite is also provided, which will be useful in evaluating nanoparticle clustering.

Depending on the chain flexibility and the number of potential anchoring points on the surface, the polymer chain will take different conformations. A strong particle polymer interaction will give a flat surface with a thin interface, while weak interactions result in wider interface with lower polymer density near the surface (Figure 1). The conformation of chains close to particles are characterized and a relationship for mechanical properties is developed from the number of anchoring points per chain.

Effect of interface curvature on adsorption will be discussed, both for concave and convex curvatures. Each surface, concave and convex, behave in different ways, and it is difficult to characterize the exact amount of polymer adsorbed within a concave metal/metal oxide surface, as washing the un-adsorbed polymer becomes more difficult. For convex surfaces, change in curvature is achieved through changing particle size, and it can be shown that beyond a critical curvature, the surface of the particles will act as if the radius of curvature is infinity.

This study thus covers both strong and weak interface as surface characteristics and concave and convex interface to cover the shape of the interface. Thus the geometry and properties of the interface is taken into account for our analysis, covering a wide spectrum of interfaces. Both in-situ preparation of particles in composites and adding pre-prepared particles are also used to understand the differences in mechanical properties of the resulting composites. Thus, a comprehensive understanding of the interfacial behavior is obtained from this work.

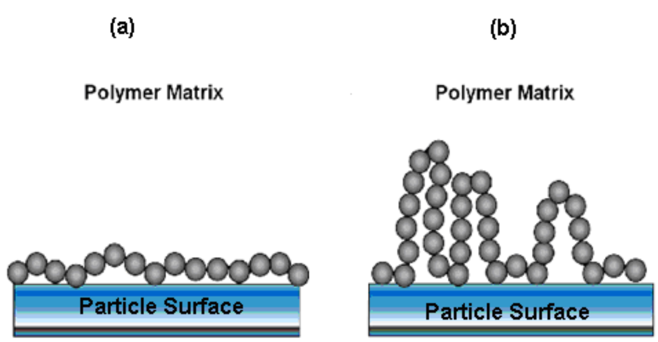

Figure 1: **Interface around nanopartices (a) strong interactions, (b) weak interactions**

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