Interfacial Interaction in Silica or Silsesquioxane Containing Polyimide Nanohybrids

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Introduction

Polyimides (PIs) are high-performance polymers characterized by their high thermal stability and mechanical properties, low thermal expansion and dielectric constants, and good resistance to organic solvents and thus have been widely used in the aerospace, microelectronics devices, dielectric layers in multichip semiconductor packaging, and so on. Recently, its application has also been extended to opto-electronic and photonics fields, nonlinear optics, optical guide, optical interconnection, and photorefractive materials. Some applications such as circuit-printing films and semiconductor coatings need enhancement of certain properties. More specifically, thermal expansion coefficient, mechanical properties and thermal deflection temperature have to be improved for specific applications.

On the other hand, the dispersion of inorganic nanoparticles into a polymer matrix has been proved to be effective in the improvement of the performances of the organic polymers by yielding so-called organic-inorganic hybrid nanocomposites. These nanocomposites are one of the hottest issues among the today's materials scientists since its unique combinational properties from organic and inorganic materials could not be obtained by single component.

The sol-gel reaction has been one of the most widely used approaches to obtain hybrid nanocomposites. This reaction involves the hydrolysis of a metal alkoxide and the condensation of the hydrolysis products. The structure and properties of the resulting hybrids is dependent on the hydrolysis and condensation, which are controlled by pH, nature of solvent, and types of alkoxide, and so on.

In particular, an important advantage of the sol-gel synthesis route for polyimide/silica hybrid composites is that the poly(amic acid) organic matrix acts to prevent agglomeration of the silica, which can lead to nanometer scale silica clusters in the composites or, as often stated, "nanocomposites." In this talk, I want to discuss the interfacial interaction along with microstructure and some properties of the polyimide/silica or polyimide/silsesquioxane hybrid nanocomposites with reviewing recent publications including our own works[1-3].

Experimental

For typical polyimide preparation, polyamic acid (PAA) was prepared from a homogeneous mixture of a dianhydride (e.g., 3, 3', 4,4'- biphenyltetracarboxylic anhydride (BPDA) with 4,4'-oxydianiline (ODA) in dimethylacetamide (DMAC) under nitrogen atmosphere, as shown in Figure 1. Then, a metal oxide precursor solution for silica or silsesquioxane in water is added into PAA and the hydrolysis and polycondensation were carried out simultaneously. Sometimes, a catalyst such as HCl is used together with water to control the sol-gel reaction of the precursor. Typical synthetic route for preparing organic-inorganic hybrids is shown in Figure 2, where vinyl silsesquioxane(VSSQ) or titanium isopropoxide($Ti(OPr)_4$) were used for binary precursors. 3-aminopropyltriethoxysilane (APS) was also tested as compatibilizer for the PI/silica hybrid composites.

Results and Discussion

Poly(vinyl silsesquioxane) (PVSSQ), aminosilane (APS), and titania can effectively play vital roles to compatibilize the PI/silica hybrid composites by enhancing interfacial interaction or reducing agglomeration of large domains, which helps the formation of nanocomposites for the PI/silica hybrid system. Figure 3 illustrates a typical role of the compatibilizer, APS in the PI/silica hybrid composites. The homogeneity of resulting films was dominated by the presence of PVSSQ, aminosilane, or titania. The interaction of the organic and inorganic phase has a significant effect on the phase morphology of resultant hybrid composites, which can dictate the properties -resulted in improved mechanical properties. The prepared hybrids have low dielectric constant and optical transparence, which could have potential applications for optoelectronics devices.

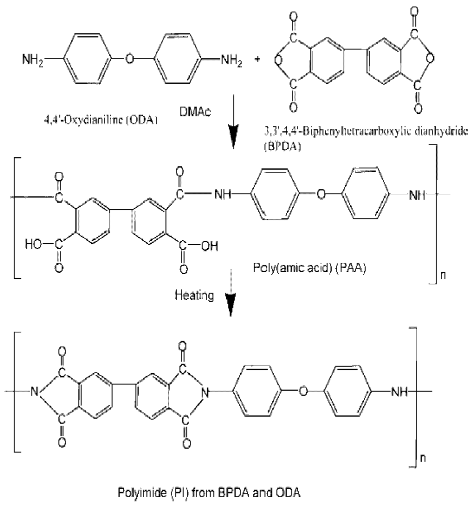


Figure 1. Conversion from BPDA-ODA PAA to BDPA-ODA PI.

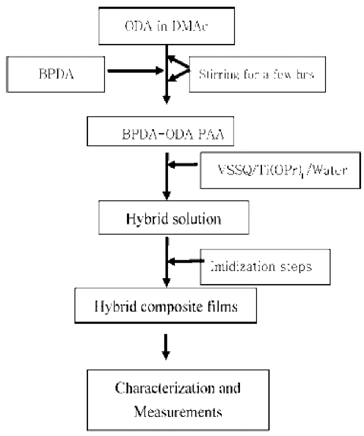
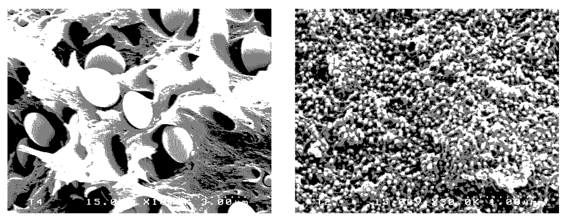


Figure 2. Typical synthetic route for PI based hybrids.



a **b**

Figure 3. SEM images of the PI/silica hybrid composites containing 30 wt.% of silica without (a) and with (b) APS.

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References

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