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Design of Thermal Conductive Polymer Nanocomposites Based on Nanoparticle Distribution Control

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Along with the miniaturization and lightweight design of electronic devices, greater demands are constantly raised on materials having high thermal conductivity and low density. Polymer nanocomposites are excellent candidates owing to the general characteristics of polymer materials such as good processability, light weight, high electrical resistivity, and low cost. However, the present polymer nanocomposites usually exhibit insufficient thermal conductivity unless impractical formulations are adopted, and key factors affecting the formation of thermal conductive networks are still unclear. In this thesis, I aimed to study the thermal conductivity of polyolefin/aluminum oxide (Al_2O_3) nanocomposites to clarify the key factors that affect the thermal conductivity. Polymer nanocomposites with continuous thermal conductive networks were designed based on controlling the selective distribution of Al_2O_3 nanoparticles. The influences of filler dispersion, filler migration and phase morphology evolution on the formation of thermal conductive networks were studied, and the relationship of filler distribution and thermal conductivity was investigated. The main research results are as follows:

In **Chapter 2**, I applied a reactor granule technology (RGT) to immiscible polypropylene (PP)/polyolefin elastomer (POE) blends to control the localization of nanoparticles at the interface of PP and POE. The RGT afforded uniform dispersion of in-situ generated Al_2O_3 nanoparticles in PP, and this guaranteed the migration of nanoparticles to the interface of a co-continuous structure when blended with POE. The selective localization of nanoparticles at the interface was never achieved when preformed Al_2O_3 nanoparticles were used, and this fact stresses the importance of uniform dispersion in controlling the migration of nanoparticles.

In **Chapter 3**, the relationship among the filler dispersion, phase morphology evolution and the distribution of fillers was revealed by studying the migration of nanoparticles during the annealing process. It was found that the uniform dispersion of nanoparticles decreased the phase domain size to facilitate the successful migration to the interface. Further, the formation of nanoparticle networks decelerated the phase coarsening during annealing. Contrary, the formation of agglomerates and clusters prevented the successful migration of nanoparticles and thus suppression of the phase coarsening became much less effective.

In **Chapter 4**, a continuous segregated structure was designed to improve the thermal conductivity of PP/Al_2O_3 nanocomposites. I achieved the thermal conductivity of 1.07 W/m K at an Al_2O_3 loading of 27.5 vol%. The same strategy was also used in combination with RGT to control the balance between the number and density of thermal conductive paths.

In conclusion, the filler dispersion, phase domain size, and filler distribution in nanocomposites have important cooperation to determine the thermal conductivity of nanocomposites (Fig. 1). RGT and other developed strategies are believed to be promising for designing practical thermal conductive polymer nanocomposites.

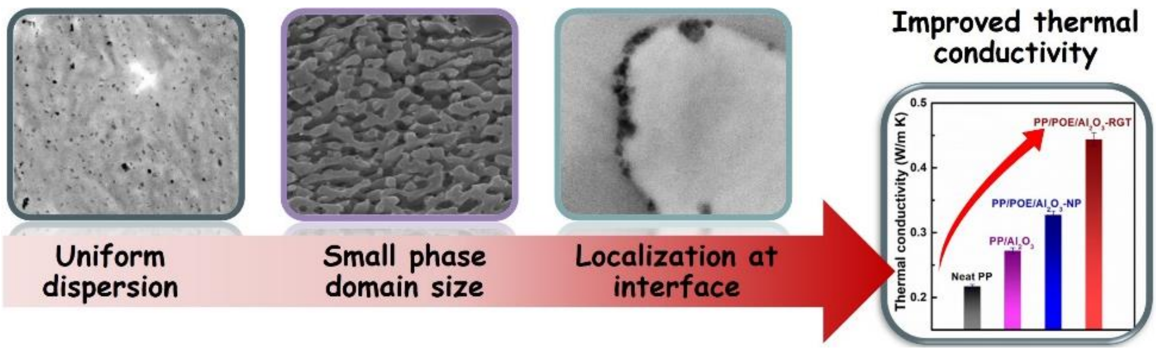

Fig. 1 Influence of filler dispersion, phase domain size and filler distribution on thermal conductivity.

Keywords: Nanocomposites; Thermal conductivity; Network; Immiscible blends; Selective distribution