

Rheological characterization of nanoparticle filled polymer systems

Byoung Chul Kim,* Dong Wook Chae

Division of Applied Chemical & Bio Engineering, Hanyang University, Seoul, 133-791 Korea
bckim@Hanyang.ac.kr

Introduction

Owing to unusually large specific surface area of a nanoparticle introduction of the nanoparticle to a polymer leads to some unpredictable physical properties. In some cases the nanoparticle plays a role of a nucleating agent, resulting in decreasing induction time to crystallization or resulting in increasing or decreasing dynamic viscosity. In addition, the dispersion state of the nanoparticle in the polymer matrix also has a significant influence on the physical properties of the nanocomposites. Hence the method of introducing the nanoparticle to the polymer makes another contribution to the rheological properties of the nanocomposite systems.

This study focuses on the effects of dispersion method of a nanoparticle in a polymer matrix such as melt mixing, solution blending, and *in-situ* polymerization on the physical and rheological properties of the nanocomposites.

Experimental

Materials. Commercially-available polymers and extra-pure grade solvents were used without further purification. The polymers completely dried prior to use.

Measurement of Physical Properties. Thermal properties were measured by DSC 2010(TA Instrument, DuPont) in nitrogen atmosphere. The sample was held at a preset temperature for 5 minutes, then cooling scan was obtained at the cooling rate of 10°C/min. Heating scan was obtained at the heating rate of 10°C/min. Structure was measured by WAXD (Rigaku Denki D/MAX-2000) with Ni-filtered CuK α radiation of 40kV and 100 mA. Scanning was carried out on the equator in the 2 θ range from 5 to 80°. Morphology was observed by Nikon polarized microscope. Rheological properties were measured by Advanced Rheometric Expansion System (ARES, Rheometric Scientific, Inc.) in nitrogen atmosphere. A parallel plate geometry whose diameter was 25 mm was employed. The plate gap was 1 mm and the strain level was 5%. The specimen was completely melted in between the plates and the excess flushed-out dample during gap-setting was trimmed off. The specimen was kept for 5 minutes at the preset temperature to relax residual stresses. Dynamic frequency sweep measurement was conducted over the frequency range of 0.05 to 500 rad/sec. To trace the effects of the nanoparticle on the crystallization under shearing and time-sweep measurement was performed at a given frequency at a predetermined temperature at which crystallization takes place.

Results and discussion

Effects on crystallization behavior. In the case of nylon/Ag nanocomposite system Ag nanoparticle played the role of nucleating agent as shown in Fig. 1.

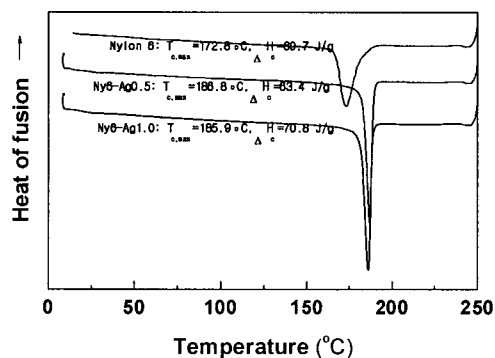


Fig. 1. DSC curve of nylon 66/Ag nanocomposites.

Effects on Mechanical Properties. In the case of mechanical properties the dispersion state and interface between nanoparticle and polymer matrix had a significant influence. Fig. 2 shows the effects of ferrite nanoparticle on the mechanical properties of nylon 66.

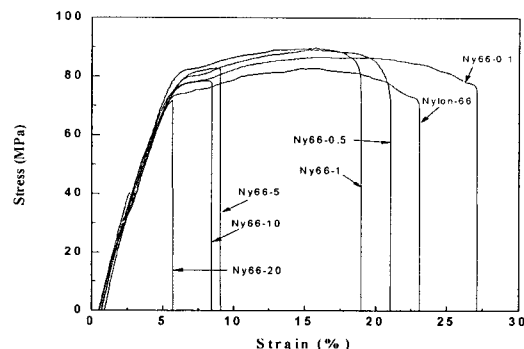


Fig. 2. Stress-strain curve of nylon 66/ferrite nanocomposites.

Effects on Crystalline Structure. On the whole nanoparticles had little effect on the crystalline structure although it promotes crystallization process. Fig. 3 shows the effects of ZnO nanoparticle on the crystallization behavior of polyacrylonitrile(PAN), whose nanocomposite was solution-blended in dimethyl acetamide. The newly-appearing peaks with increasing ZnO nanoparticle content correspond to the crystal structure of ZnO nanoparticle.

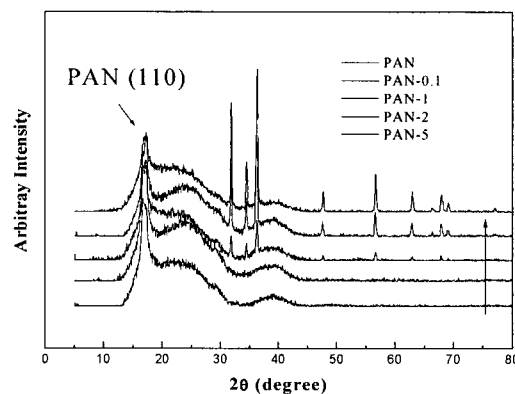


Fig. 3. WAXD profile of PAN/ZnO nanocomposite.

In addition to these consequences, the method of incorporating nanoparticle into the polymer matrix has very decisive effects on viscosity of the nanocomposite, which was most notable with poly(ethylene terephthalate). On the whole, *in-situ* polymerized nanocomposite gave much lower melt viscosity than the melt-blended nanocomposite. In this case, however, the reason is not clearly explained.

References.

- [1] Chae, D. W. and Kim, B. C., *J. Appl. Polym. Sci.*, **2006**, *99*, 1854.
- [2] Chae, D. W., Lee, K. H., and Kim, B. C., *J. Polym. Sci. Part B, Polym. Phys.* **2006**, *44*, 371.
- [3] Chae, D. W. and Kim, B. C., *Polym. Adv. Technol.*, **2005**, *16*, 846.
- [4] Chae, D. W. and Kim, B. C., *J. Mater. Sci.*, (in press).