

Epoxy-Clay Nanocomposites: Dispersion, Morphology and Performance

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Abstract

The exfoliated nanocomposite is of particular interest because it maximizes the interactions between polymers and clays, and thus it should result in dramatic improvements in mechanical and physical properties. However, it seems to be very difficult to exfoliate organoclay in epoxy resins. Organoclay is always aggregated on the micro-scale in epoxy resins with conventional dispersion methods. But these agglomerates of organoclay were confirmed to have been intercalated by epoxy resins with X-ray diffraction (XRD) and Transmission Electron Microscope (TEM).

In the present work, organoclay was dispersed in a high performance epoxy resin with three mixing methods: Direct Mixing (DM) Method, Grinding Media Mill (GMM) Method and High-Pressure Mixing (HPM) Method. In the DM method, the dry organoclay was directly added into epoxy resin. The mixture was heated, mechanically stirred at high speed, and sonicated with ultrasonic. In the GMM method, first, the organoclay was broken down in acetone by 0.5mm grinding balls, and then the mixture containing acetone and organoclay was added into the epoxy resin. Finally acetone was evaporated under vacuum. Grinding time was selected as a parameter in order to form different dispersion efficiencies. In the HPM method, the mixture of organoclay and liquid was forced at more than 15,000 psi by the high-pressure mixing machine into a very small chamber, and then impinged on the wall of the chamber many times, to eventually form a paste. Two kinds of liquids were selected: one was acetone; the other is epoxy solution with acetone.

The organoclay-modified high performance epoxy nanocomposites were synthesized with these different dispersion methods at the same clay loading. Their morphology was characterized with optical microscope, XRD, TEM and Scanning Electron Microscope (SEM). XRD results showed that the basal spacing of organoclay particles in the nanocomposites fabricated with these methods is increased, but organoclay is aggregated on the micro scale in the epoxy resin made with the DM method. These agglomerates of organoclay mainly came from poor dispersion and could be broken down by the HPM method and GMM method. Moreover, the HPM shows better dispersion than the GMM.

The mechanical and hydrothermal behaviours of nanocomposites were investigated. Both fracture toughness and elastic modulus of the high performance epoxy system were

simultaneously improved by adding organoclay into the epoxy. In addition the enhancements in toughness and modulus increase with improving the quality of dispersion. Fig. 1 shows the dramatic improvements in fracture toughness for the nanocomposites formed from the HPM and GMM. The fracture surfaces were examined to investigate the fracture mechanism involved (shown in Fig. 2, 3, 4). The glass transition temperature (T_g) of all the nanocomposites decreases slightly. However, the maximum water absorption and diffusion coefficient in the epoxy system decrease with adding organoclay and with improving the quality of dispersion. The wet T_g of all the nanocomposites at the maximum water contents were also tested.

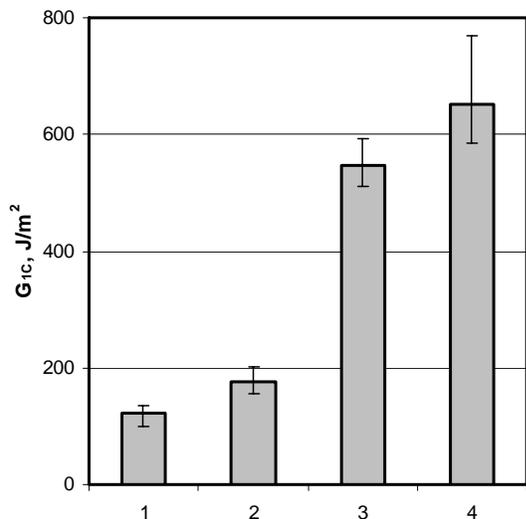
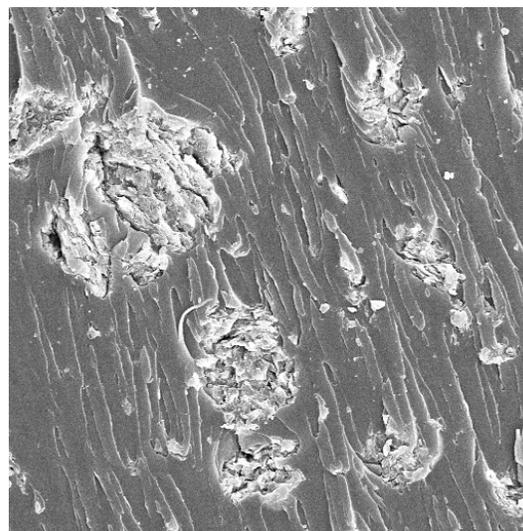
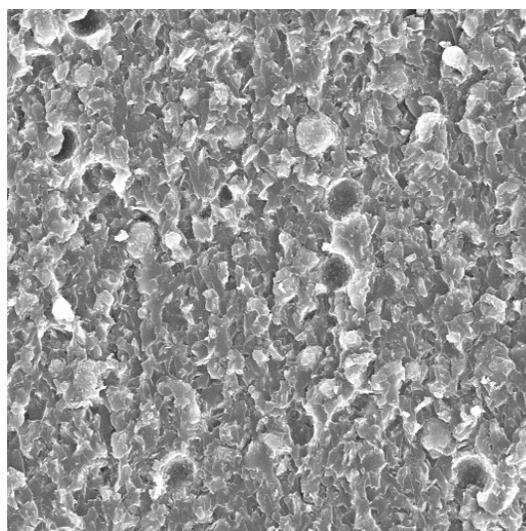


Fig.1 Fracture toughness of Nanocomposites (1. Pure Epoxy Resin System, 2. DM, 3. GMM, 4. HPM, all nanocomposites at 6-phr* clay loading)



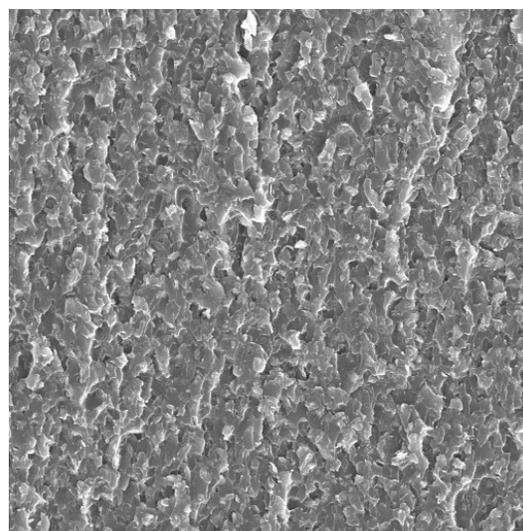
SEI 15.0kV x550 20µm

Fig.2 SEM micrographs of fracture surface of nanocomposites made with DM at 6-phr



SEI 15.0kV x550 20µm

Fig.3 SEM micrographs of fracture surface of nanocomposites made with GMM at 6-phr * phr--parts per hundred of resin by weight



SEI 15.0kV x550 20µm

Fig.4 SEM micrographs of fracture surface of nanocomposites made with HPM at 6-phr