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Microstructural Evaluation of Polymer Nanocomposites as Rocket Ablative Materials

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Polymer matrix composites with nano-sized reinforcements have shown superior properties for ablative materials [1-4]. To achieve the best performance of these polymer nanocomposites, an essential requirement is the even dispersion of the nanoparticles in the resin matrix. In this work, the TEM analysis was employed to evaluate the dispersion of the nanoparticles within the composites.

The polymer nanocomposites were prepared by mechanical mixing of nanoparticles into the polymer matrices by high shear mixing or twin-screw extrusion process. The TEM specimens were prepared by either ion mill or ultramicrotomy methods, with the former used for hard materials. The TEM observation was done in a JEOL 2010 at an accelerating voltage of 200 kV.

Fig. 1 shows the microstructure of carbon nanofiber (CNF)-reinforced nanocomposites. Fig. 1a depicts the SC-1008 phenolic resin matrix reinforced by a mixture of 10 wt% CNFs and 20 wt% carbon black (CB) particles, with agglomerations of CBs and CNFs. In the absence of CB particles (Fig. 1b), the dispersion of CNFs was improved. The CB particles caused interference in dispersion of CNFs and CBs in the polymer matrix. Fig. 1c shows a good dispersion of CNFs in the polyester polycaprolactone resin matrix (Pellethane 2102 series).

Fig. 2 shows the microstructure of the polymer-clay nanocomposites. Fig. 2a shows that the clay clusters are intercalated in the SC-1008 resin matrix, although the stacks of clay are distributed evenly in the matrix. Another good dispersion of clay sheets in the 2102 resin matrix is shown in Fig 2b. The framed area in Fig. 2b is magnified in Fig. 3, where single-layer as well as multi-layer clay sheets are shown. In spite of the expected standard layer spacing of d_{001}=1.9 nm, larger layer spacings are also found, as indicated in Fig. 3. This observation implies that the clay layers have been exfoliated into the polymer matrix. These nanocomposites exhibited improved ablation erosion properties [4].

References

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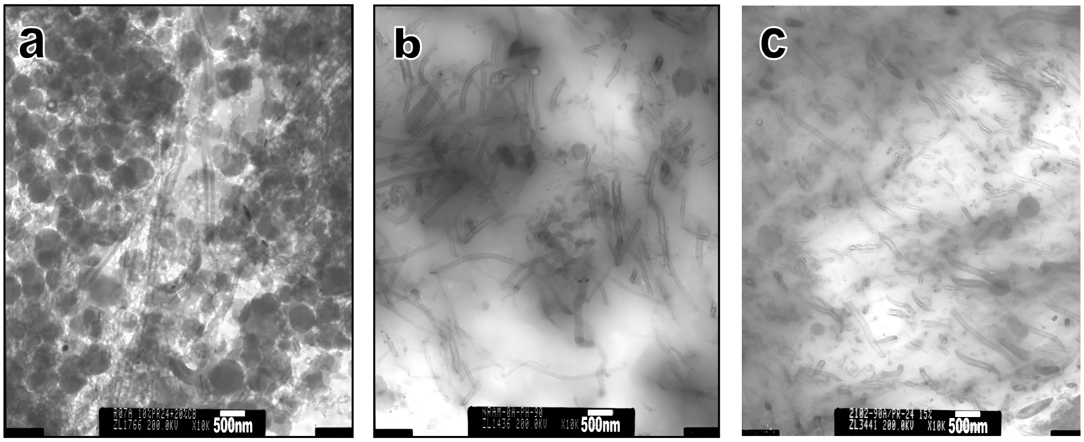

FIG. 1. Microstructure of nanocomposites with (a) 20 wt%CB+10 wt%CNF in SC-1008, (b) 10 wt% CNF in SC-1008, and (c) 15 wt% CNF in 2102, respectively.

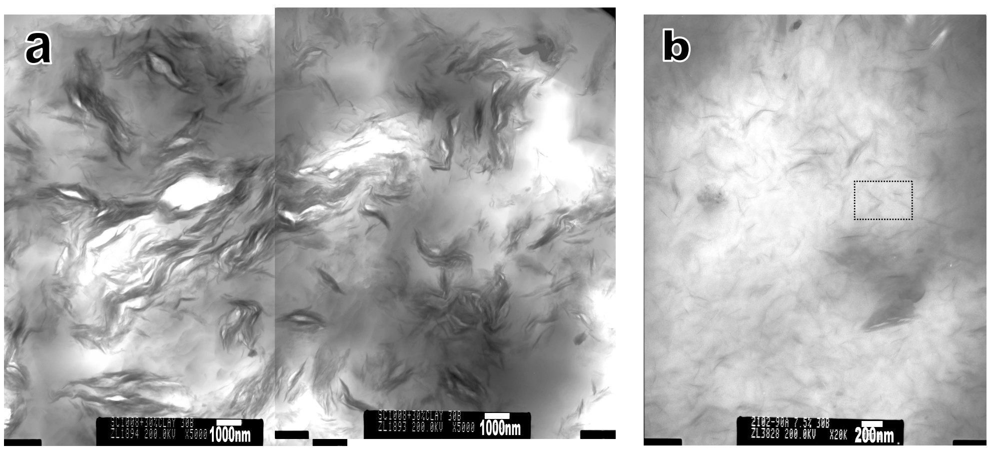

FIG. 2. Microstructure of nanocomposites with (a) 30 wt% clay in SC-1008 and (b) 7.5 wt% clay in 2102, respectively.

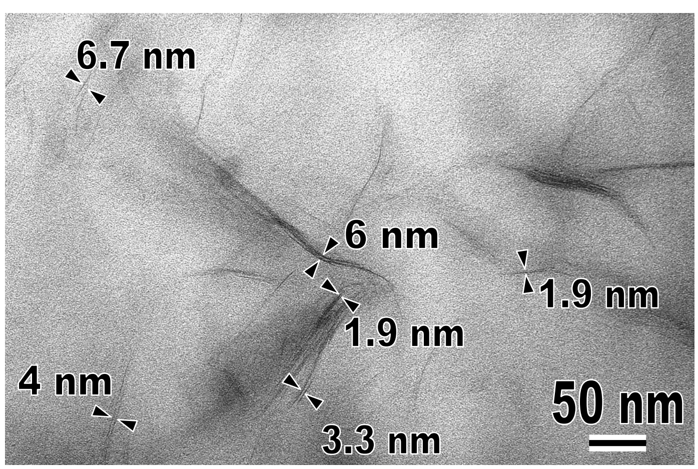

FIG. 3. High-resolution TEM image from the framed area in Fig. 2b showing the single-clay and exfoliated clay sheets.