

NANOFILLERS IN EPOXY RESINS FOR MULTIFUNCTIONAL MATERIALS: FROM ELECTRICAL TO BARRIER PROPERTIES

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Different nano-fillers were incorporated in an epoxy resin and characterized with reference to the mechanical, electrical and barrier properties. The storage modulus increases with the addition of carbon nanotube. In a similar way, the electrical conductivity can be increased of several orders of magnitude also at very low concentration of carbon nanotubes. The Diffusivity of the water vapour can be strongly reduced by the addition of platy like nano particles.

Keyword: Epoxy Matrix, Carbon Nanotube, Mechanical properties, Barrier properties.

1 INTRODUCTION

Inorganic fillers dispersed at nanoscale, have opened up new perspectives for multi-functional materials. By choosing the appropriate synthetic polymers as well as the specific fillers, unprecedented morphological control down to the nanoscale is obtained [1–6].

Epoxy resins are actually finding broad applications in a variety of industries such as structural material, adhesives, coatings, etc. Many investigations are focused on further improving epoxy materials using nano fillers able to improve some properties as well as to impart new properties for obtaining multifunctional materials.

Carbon Nanotubes (CNTs), have demonstrated excellent strength, modulus, electrical and thermal conductivities along with low density and unprecedented multi-functional characteristics. CNTs may be characterized by different form, geometry and functionality [1,2].

Layered silicates clays belong to the same general family of 2:1 layered or phyllosilicates with one octahedral Al₂O₃ sheet between two tetrahedral SiO₂ sheets. Montmorillonite, one of the clay minerals more used as nanometric polymer filler, is available as micron-size tactoids, consisting of several hundred individual platy particles held together by electrostatic forces.

Layered double hydroxides (LDHs), also known as hydrotalcite-like compounds are a new class of versatile inorganic filler materials. The possibility to replace the counterbalancing anions, located in the interlamellar region, with other anions by an ion-exchange process, makes LDHs a unique class of layered solids to be used as filler of polymers bearing a negative charge.

In this paper the mechanical, barrier and electrical properties of the epoxy systems in presence of different nano-fillers are investigated and characterized.

2 EXPERIMENTAL

2.1 Materials and Methods

The composites are manufactured by using as base epoxy resin DiGlycidil-Ether Bisphenol-A (DGEBA), with 4,4' DiaminoDiphenyl Sulfone (DDS), as hardener agent.

Multi walls carbon nanotubes CNTs (3100 Grade) were obtained from Nanocyl S.A.

Four types of clay (three organically modified montmorillonite and one hydrotalcite) were used for the investigations. The clays, namely Cloisite[®] 30B and Cloisite[®] 93A were supplied by *Southern Clay Products, Inc.* The clays, namely Nanofill[®] 804 were supplied by *Laviosa S.P.A.* The hydrotalcite, namely ZAAB were purchased by *Sigma Aldrich*.

Epoxy and DDS were mixed at 80 °C and the nano filler were added and incorporated into the matrix by using a ultrasonication for 20 minutes (Hielscher model UP200S-24KHz high power ultrasonic probe). Such an incorporation method has been chosen among other different techniques since it leads to the composites characterized by the best mechanical and electrical properties [3,4]. All the mixtures were cured at 125°C for 1 hour and 220°C for 3 hours.

Dynamic mechanical properties of the samples were determined with a dynamic mechanical thermo-analyzer (TA instrument-DMA 2980). The displacement amplitude was set to 0.1%, whereas the measurements were performed at the frequency of 1 Hz. The range of temperature was from -60°C to 300°C at the scanning rate of 3°C/min.

The measurements of the dc bulk conductivity have been performed by using disk-shaped specimens of about 2 mm thickness and 10 to 50 mm diameter. Diffusion coefficients were evaluated, using the microgravimetric method, at different vapour activities ($a=P/P_0$), where P is the actual pressure to which the sample was exposed, and P_0 the saturation pressure at the test temperature. The penetrant was water vapour and the experiments were conducted at 30 °C.

2.2 Mechanical Properties

The storage modulus, E' (MPa) of the neat epoxy and its composites with different CNT concentrations are shown in figure 1. The effect of the CNT is well evident. A general increase is observed at all temperatures investigated [4].

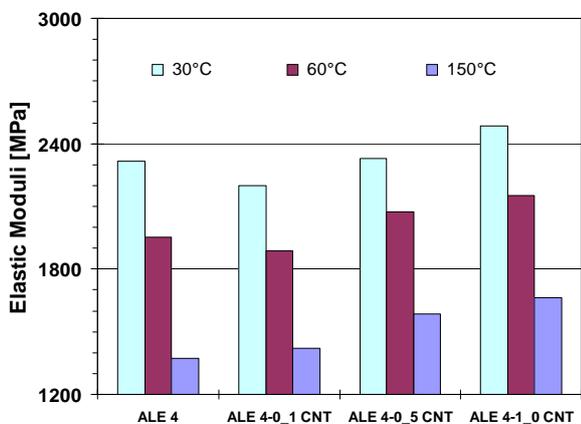


Fig. 1: Elastic modulus versus CNT concentrations at different temperatures.

2.3 Electrical Properties

The behaviour of the conductivity versus the CNT concentration is shown in Figure 2.

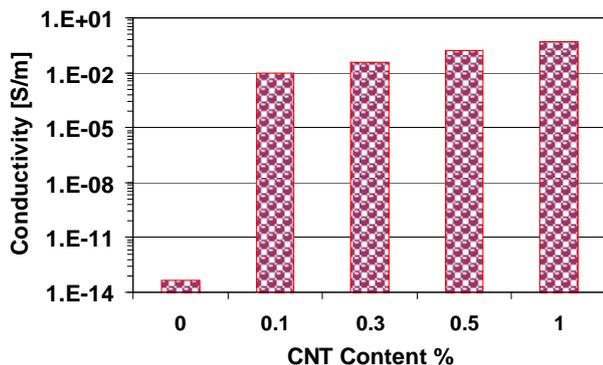


Fig. 2. Electrical conductivity versus CNT concentrations.

It is evident that the percolation threshold is lower than 0.1%, as the conductivity shows an increase of about 12 orders of magnitudes from the value corresponding to the pristine resin to that relative to the composite with 0.1%. As the plots of Figure 2 show, even at concentrations higher than 0.1%, the conductivity monotonically increases [5].

2.4 Transport properties

The diffusion coefficients of water vapour for the system epoxy-nanoclay were examined and reported in figure 3.

The addition of nanoclay exhibits noticeable improvement in reducing vapour diffusivity. This phenomenon has traditionally been explained by considering the clay sheets as impermeable obstacles in the path of the diffusion process [4].

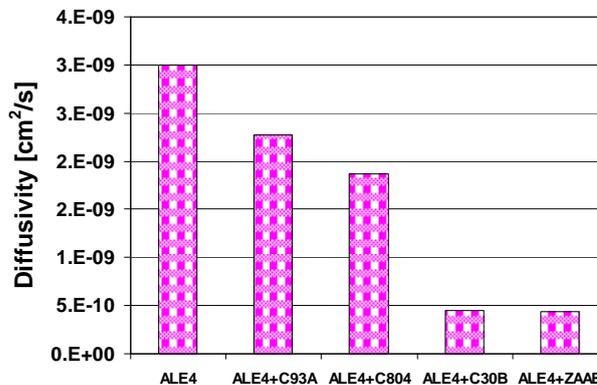


Fig. 3. Diffusion of samples obtained with 3% of different nanoclays filler.

3 CONCLUSION

In this paper the mechanical, barrier and electrical properties of epoxy nanocomposite systems loaded with different nano particles have been analyzed and discussed.

By an appropriate selection of nano filler type, concentration and modification both physical and chemical properties can be varied in according with the application requirements.

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