UPGRADING THERMOSETS WITH CARBON NANOFIBERS

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Carbon nanofibers (CNFs) have been used in recent times to increase the mechanical properties of polymer matrices [1-3], the use of CNFs provide several advantages compared with the use of micro-sized fillers; they allow the production of micromechanical components and thin coatings and they do not cause embrittlement and deterioration of tensile strength as microscopic fillers often do. These nanofillers also exhibit excellent thermal and electrical properties which make them excellent candidates for the production of conductive polymer composites, capable of dissipating electrostatic charges or even act as shielding devices from electromagnetic radiation. To benefit from the good reinforcing properties of the CNFs a good dispersion of the fibers in the polymer matrix is crucial since a well dispersed filler network results in a more uniform stress distribution within the composite. A good dispersion also minimizes the presence of agglomerates that can act as centres for stress-concentration which decrease the general strength and modulus of the composite.

In our research nanofibers were dispersed in the polymer matrix with the aid of a three roll calender (**Fig. 1**). The use of this device for the dispersion of carbon nanotubes in an epoxy matrix was first reported by F.H. Gojny et al. [4] .This technology achieved excellent dispersion results without reducing the aspect ratio of the fillers which is important to enable a good load transfer from the polymer matrix to the nanofillers. One further advantage of the calendering method is the possibility of up-scaling the manufacturing process to meet technical demands. The manufactured composites, containing different volume concentrations of carbon nanofibers, were characterized by mechanical and electrical analysis in order to study the effects that the nanofibers had on the epoxy resin. To gain knowledge of the impact energy of the nanocomposites standardised Charpy tests were performed on notched specimens. Flexural tests were carried out in three-point bending configuration from which the flexural strength, modulus and the strain at break of the samples were obtained. The complex modulus E* and damping tanδ were examined by dynamic mechanical thermal analysis (DMTA) using a tensile testing configuration. Lastly electrical measurements were conducted at room temperature on an Ohmmeter system with a measurement range of 10^4 to 10^{14} Ω. (**Fig.2** left) shows that the impact fracture toughness of epoxy resin increased with increasing volume of carbon nanofibers. (**Fig. 2** right) shows the evolution of the electrical conductivity of the nanocomposites with increasing filler content. A steep conductivity increase was evident in with a very low volume addition of fillers. This behaviour is indicative of a percolation transition; percolation theory predicts that there is a critical concentration of conductive fillers at which a conductive path is formed in the composite causing the material to change from capacitor to conductor. This critical concentration or percolation threshold was determined at about 0.15 vol. % vol. in our CNF nanocomposites. I

Scanning electron microscopy examinations was used to study the morphology of fracture surfaces (**Fig.3**). The aim was to obtain further information of the cause and location of failure and also to study the role of the added carbon nanofibers in terms of crack propagation and reinforcing mechanisms within the samples. Compared to the very brittle and smooth occurrence of the neat epoxy fracture surface (**Fig.3 left**) the nanocomposites reveal a micro-rough surface (**Fig.3 right**), which indicates additional fracture mechanisms responsible for higher energy dissipation during fracture. The latter leads to the observed higher toughness and improved mechanical properties of the nanocomposites.

References:

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Figures:

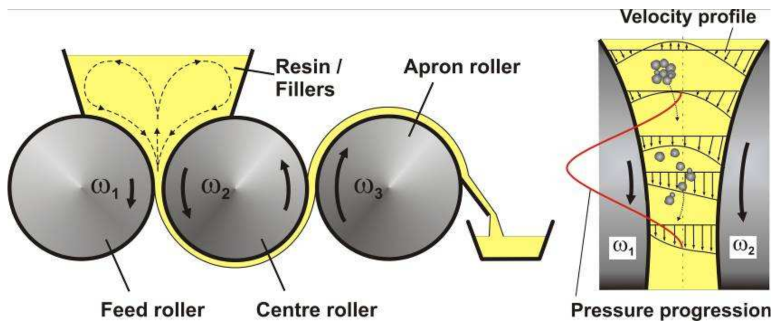

Fig. 1. Schematic view of the three roll calender and its working principle.

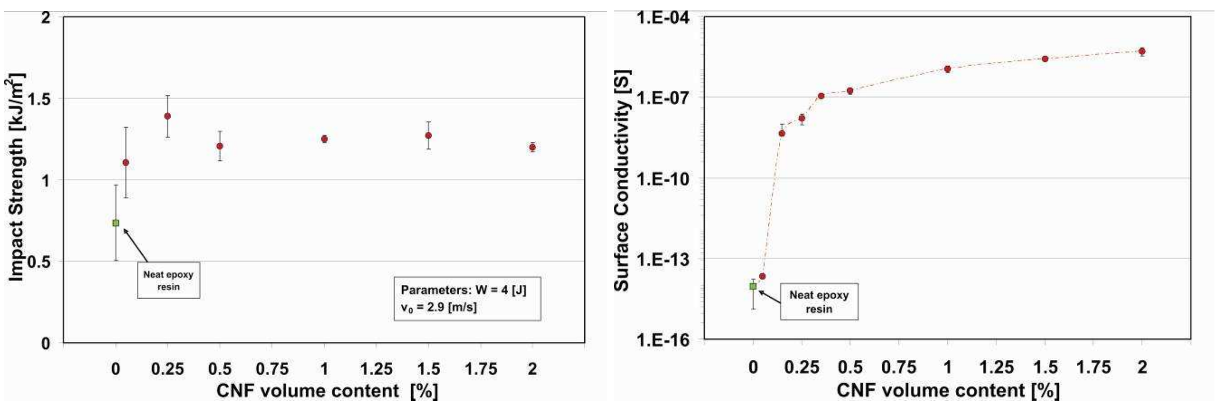

Fig.2 Impact fracture toughness (left) and surface conductivity (right) of the epoxy/CNF nanocomposites as a function of nanofiber volume content

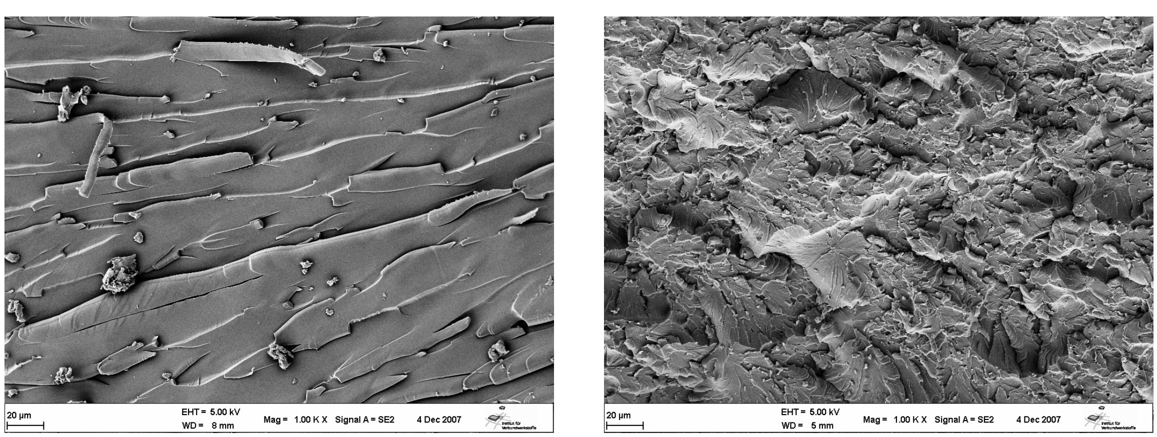

Fig.3 (Left) Neat epoxy fracture surface from flexural testing. Brittle fracture leads to a smooth surface appearance. (Right) Nanocomposite (2% vol. of CNF) fracture surface, rugged surface suggests bigger energy dissipation due to the presence of nanofibers within the resin.