

Project No. GOWA-08

Stress mapping around SWCNT and MWCNT in polymer-matrix nano-composites

Summary

SWCNT and MWCNT were functionalized and used to manufacture nanocomposite plates. Four different weight fractions were used in the manufacturing process (0.5, 1, 1.5 and 2 wt. %) beside the neat epoxy sample. Functionalized nanotubes were tested using the TGA to evaluate the amount of the functionalized groups attached to the nanotubes. Coupons were cut and tested in tension to evaluate the tensile moduli and strengths of the nanocomposites.

Materials

SWCNT and MWCNT were purchased from Shenzhen Nanotech. Port Co., China. SWCNTs have an average diameter less than 2 nm with a length range of 5–15 μm and a purity that is higher than 95%. The ash content, according to the manufacturer, is less than or equal to 2% wt and the amorphous carbon is less than 5% wt while the specific surface area is higher than 400 m^2/g . The MWCNT's have a diameter range of 40-60 nm, a length range of 5–15 μm , and a purity higher than 95%. The ash content is less than or equal to 0.2% wt, the amorphous carbon is less than 3% wt and the specific surface area range is 40 - 300 m^2/g .

Diglycidyl ether of bisphenol A (DGEBA), known commercially as EPON 828, was used as epoxy resin and was purchased from Miller-Stephenson. Glycolitic polypropyleneoxide triamine (Jeffamine T-403) was used as the curing agent. The curing agent was purchased from Hunsman Co. and has a molecular weight of 440 g/mol.

Manufacture

Carboxylic groups were grafted on both SWCNT and MWCNT surfaces following the acidification procedure presented in a previous report. Amidification of the SWNT-COOH was also carried out, as shown in Figure 1. Nanocomposites were manufactured by distributing functionalized and non-functionalized carbon nanotubes within a host polymer. Based on the target weight fraction, an amount of functionalized nanotubes was weighed taking into account that the required percentage should be from pure nanotubes. The amount was dispersed in a proportional amount of Jeffamine T-403 by continuous stirring for 15 minutes after which the appropriate amount of Epon 828 was added and stirred for another 15 minutes. The mixture was casted in a Teflon mold which was placed in an oven to cure at 85° C for 2 h then at 125° C for 3 h. Four weight fractions were used to manufacture the nanocomposite samples (0.5, 1, 1.5 and 2 wt. %). In addition, neat epoxy samples were prepared and tested as a reference. The samples were prepared by mixing Epon 828 and Jeffamine T-403 with 100:42 weight ratio and following the same procedure mentioned above.

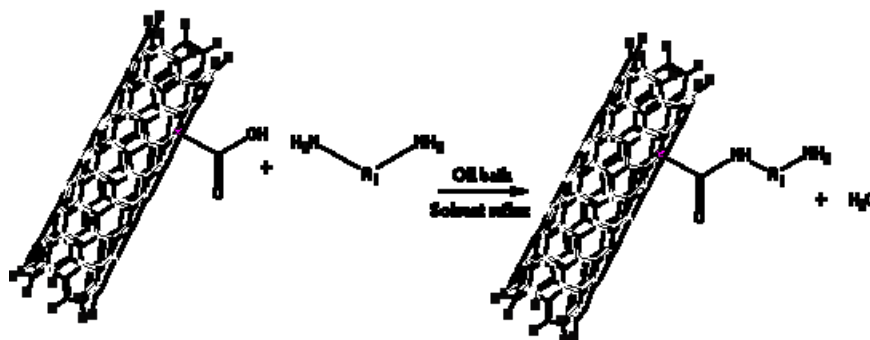


Figure 1: Amidification reaction between the carboxylic group and Jeffamine T-403.

Evaluation of amount of functional group on nanotubes

Two samples, one for the pristine SWCNT and the other for the SWCNT that is functionalized were tested using a Universal TGA tester (V 4.3A TA Instruments) to determine the amount of functionalization. The analyzer has a high-precision balance with a pan to carry the sample. The pan is placed in an electrically heated oven equipped with thermocouples to accurately measure the temperature. The analysis is conducted by gradually raising the temperature and plotting the material weight versus temperature. As Figure 2 shows, the weight of the pristine SWCNT sample did not change up to $\sim 800^{\circ}\text{C}$ while the weight of the functionalized sample started to decrease at a temperature of around 180°C and continued to decrease until it reached $\sim 60\%$ of its original weight before it stopped. Comparing the two curves it can be seen that the amount of functionalization on the SWCNT was about 40% of the weight of the nanotube.

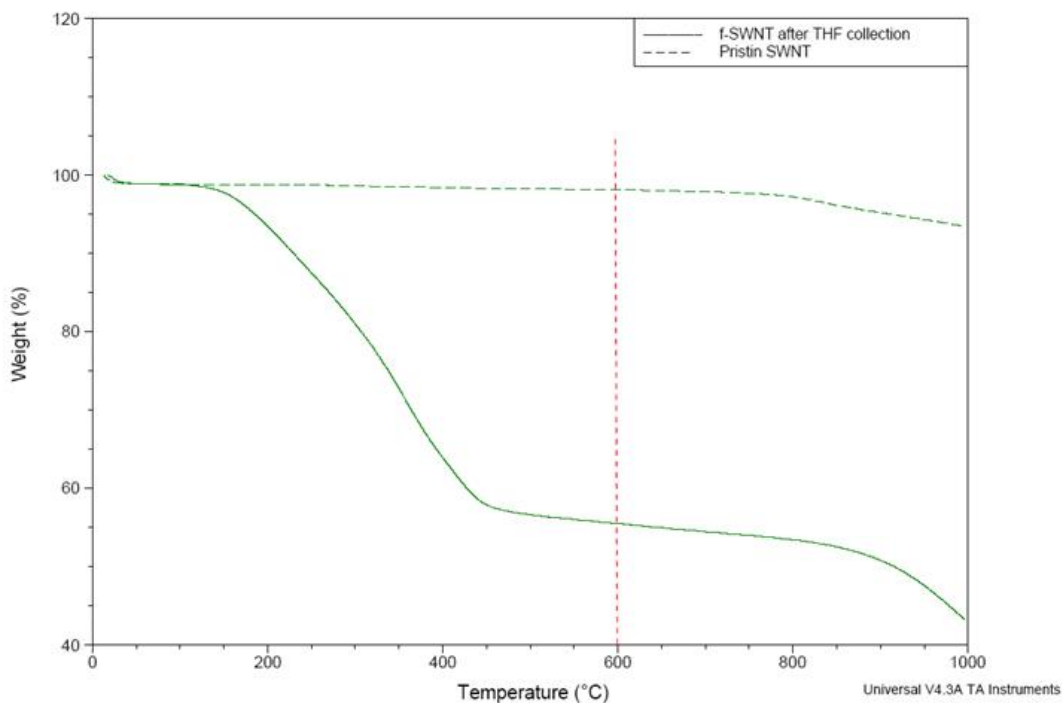


Figure 2: TGA test results for pristine SWCNT and SWCNT functionalized with Jeffamine T-403.

Tensile testing

Tensile testing was carried out following ASTM D 5026. Samples were cut into coupons with 90 mm length and 10 mm width. Sample dimensions were measured at three different locations and averaged. Edges in the length direction were polished to eliminate the effect of micro-cracks typically resulting from cutting. Three samples were tested for each data point. Tensile tests were carried out on a computerized Instron tester (Instron 5565 universal testing machine) equipped with a video extensometer (AVE with 60mm FOV lens). Before conducting the tensile test, four dots were marked on each sample to allow measuring the longitudinal and lateral strains using the video extensometer. The machine cross-head speed was set at 2.5 mm/min and the gage length was 50.73 mm following the ASTM standard. The structural dimensions for each sample (gage length, average width and average thickness) were input into the machine and the stress strain curve was obtained for each sample. The tensile modulus of each sample was calculated as the slope of the stress/strain curve in the elastic region. The value of the Poisson's ratio was also recorded during these experiments.