MICROWAVE ABSORPTION PROPERTIES OF CARBON NANOTUBES/EPOXY COMPOSITES

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Introduction

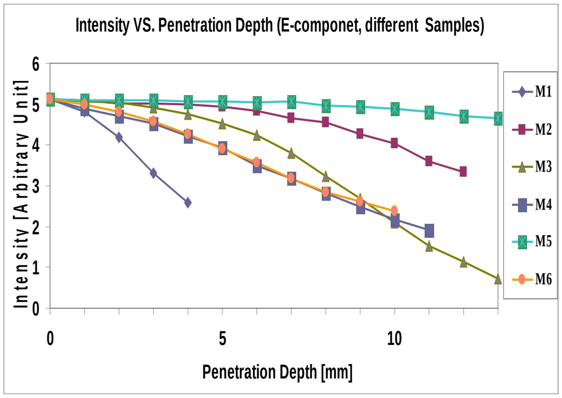
The electromagnetic (EM) absorption properties of carbon nanotubes (CNTs) based composites can be utilized for the applications such as shielding electronic devices against electromagnetic interference and other ones. Less weight, excellent mechanical properties, and high efficiency in absorbing EM wave make carbon nanotubes (CNTs) attractive for these specific applications, especially for microwave absorptions. [1,2,3,4]
Previous theoretical and experimental works have revealed that metallic CNTs in a CNT bundle could induce a super-small energy gap or pseudo-gap owing to inter-tube interactions among CNTs. The electronic properties of CNTs can be tuned by selecting single-walled or multi-walled CNTs as well as by utilizing the interactions among CNTs. [5,6,7,8] Multi-walled carbon nanotubes (MWNTs) have much higher performance-to-price ratio (PPR) than that of SWNTs in the composite applications. The outside diameter (OD) is an important parameter in MWNTs. The effect of OD distributions of MWNTs on EM wave absorption has not been fully examined. In this work, we aim to study the effect of the OD distributions of MWNTs on their microwave absorption properties.

Sample Preparation

We have fabricated six groups (M1-M6) of carbon nanotube/epoxy composite samples with OD distributions as M1 (8-15nm), M2 (50-80nm), M3 (30-50nm), M4 (20-30nm), M5 (<8nm), and M6 (10-20nm), respectively. We used the purified MWNTs obtained from Cheap Tubes Inc. The weight percentages of MWNTs in the composites were controlled in the range fro 1 to 10%. Firstly, MWNTs were blended into epoxy and stirred strongly by a blender, then sonicated to thoroughly remove gas bubbles. Each sample was then injected into a mold with a diameter of 1.5mm and a length of 3cm, and then, dried at 60C^o for 24 hours.

Measurement and Results

We have utilized a microwave resonant cavity technique to measure the microwave absorption properties of all the sixty samples around the central frequency of 9.968 GHz. Each sample was moved into the cavity by using a micrometer drive. The perturbation of the resonant cavity offers two options, by dielectric and magnetic interactions. A resonant cavity spectrometer was adapted to measure the electromagnetic wave absorption properties of all the samples with a goal to determine the frequency shifts, amplitude changes, and the changes of the width of the resonance at half-power-maximum (HPM).
We measured the microwave absorption properties of the samples at the central frequency around 9.968 GHz. It was found that the maxima of EM wave absorptions for the six groups of samples were all around 7% MWNTs weight percentage. Then, at the maximum absorption (7% MWNTs), the absorption efficiency (slope parameter of perturbation curves) of all groups of samples were compared by taking the second derivative of the perturbation curves, the amplitude curves, the central frequency shifts, and the changes of the line widths. It showed that as the weight percentage of MWNTs in the composites increases, the loss tangent of the field intensities in the cavity increases up to about 7%, at which the EM wave loss reached its maximum value. For further increases in the weight percentage of MWNTs in the composites, the rate of EM wave loss decreased.
Fig. 1 shows the effective attenuations of the electric and magnetic fields of six groups (M1-M6) of MWNT composite samples with the same (7 %) MWNT blend in epoxy. The vertical axis is in arbitrary unit; and the horizontal axis represents the penetration depth of samples in the cavity. The central frequency of the microwave signal is around 9.968 GHz. Figs. 1 shows that in general, the MWNTs with smaller diameters have higher microwave absorption at 9.968 GHz. However, sample group M5 (OD<8nm) shows unusual results, a lower microwave absorption than the other samples.



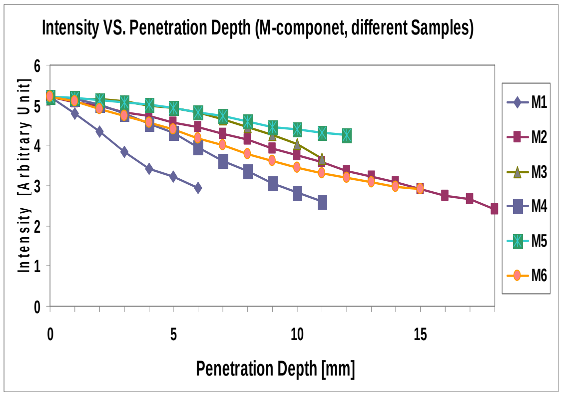


Fig. 1 Effective attenuations of the electric and magnetic fields of six groups of MWNT composite samples with the same (7 %) MWNT blend in composites. The frequency of the microwave signal is 9.968 GHz.

We have used a scanning electron microscope (SEM) to study the morphologies of the MWNT samples. It is showed that the morphology of the MWNTs in group M5 is much different from that of other groups. MWNTs in group M5 are more closely clustered together and have smaller inter-tube separations than others. The density of MWNT in individual bundles in group M5 is much larger than it in other groups. Based on SEM analysis and microwave absorption measurements, the efficiency of the microwave absorption of MWNT/Epoxy composites is strongly affected by the morphologies/structures of MWNTs in individual bundles. The final effect will depend on three factors: (1) the number of nanotubes; (2) the number of CNT bundles in the matrix material (such as epoxy in our experiment); and (3) the efficiency of each individual CNT bundles to absorb the microwave.

Conclusion

In this work, we studied the electromagnetic wave absorption properties of six groups of MWNT/Epoxy composite samples at the central microwave frequency around 9.968GHz. The weight percentages of MWNTs in each sample group are from 1 to 10%. In general, the MWNTs with smaller diameters have a higher efficiency of microwave absorption at 9.968 GHz. However, the sample group M5 (OD<8nm) shows unusual results, a lower microwave absorption than other groups, although the OD of the MWNTs in the sample group M5 is smaller than all of other groups. Our SEM analysis and microwave absorption measurements showed that the microwave absorption of the CNTs is strongly affected by the morphologies of MWNTs in the sample groups.

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