Investigating the Effect of SWCNTs in the context of epoxy resin on the electromagnetic waves absorption in the X-band

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Abstract
Carbon nanotubes have excellent mechanical, electrical, thermal and magnetic properties, among the extraordinary properties of these materials that can be traced to the absorption of electromagnetic waves. By placing these materials in the direction of electromagnetic waves, significant volumes of these waves have been absorbed and the radar cross section from a fudder view has also been reduced. In this study composite samples containing SWCNTs in the context of an epoxy resin based on standard dimensions for X-band with a multi-stage built method were produced and then the samples were analyzed by Vector Network Analyzer. Composite samples have been made in three weight percentages, 1, 3 and 10. The result of this experiment shows the high amount of wave absorption for samples reinforced by carbon nanotubes. This amount of absorption greatly increases due to increase of nanotubes weight percent, so that the average amount of absorption in the whole X-band for the mentioned percentages is 3.33712, 4.5889 and 12.6542 dB respectively. Also, the amplified samples in 1, 3 and 10 weight percentages show increase in wave absorption about 22, 67 and 362 percent in comparison with pure resin. Finally, samples were evaluated with Micro Raman Spectroscopy and SEM images.

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- wave absorption
- composite
- X-band
The electromagnetics of a device may lead to losses in the materials used, affecting its performance. This can be due to various factors, including the material's ability to absorb or scatter electromagnetic waves.

Electromagnetics at 18 GHz, styrene-b-ethylene-ran-butylene-b-styrene (SBS) copolymer, showed a significant loss in the microwave region. In contrast, polyvinylidene fluoride (PVDF) exhibited lower losses, indicating better performance in this frequency range.

The polarization behavior of PVDF was analyzed, showing its effectiveness in reducing electromagnetic wave absorption. SBS, on the other hand, demonstrated higher absorption, which could be detrimental in applications requiring high loss materials.

In conclusion, the choice of materials for electromagnetic applications is crucial. PVDF appears to be a better choice due to its lower losses, making it suitable for devices operating at 18 GHz.

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1. Polyvinylidene Fluoride (PVDF)
2. styrene-b-ethylene-ran-butylene-b-styrene (SBS)
3. 18 GHz
4. Fig. 1 A view of the electromagnetic wave released during a waveguide with a combination of electrical and magnetic fields.

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For detailed analysis and further reading, please refer to the referenced sources.
Fig. 2 A view of SEM image from these carbon nanotubes on a scale of 500 nm.

Table 1 Specification of SWCNTs that have been used in this study

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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<tbody>
<tr>
<td>Diameter (nm)</td>
<td>1-2</td>
</tr>
<tr>
<td>Chirality</td>
<td>[-1,1]</td>
</tr>
<tr>
<td>Mass density (g/cm³)</td>
<td>1.2</td>
</tr>
<tr>
<td>Electric conductivity</td>
<td>&gt; 10⁶S/m</td>
</tr>
</tbody>
</table>

1 Vector Network Analyzer
Fig. 5 A view of molded samples.

Fig. 3 Dispersion of SWCNTs in the Context of Acetone by U
erasonic Mixer.

Fig. 4 A view of two-step process for molding.

1 Coaxial

A view of molded samples.

Shaded 3 miliometer Coaxial cable (3 GHz) with a
length of 1.5 m. A view of two-step process for
molding.

A view of molded samples.

A view of two-step process for molding.

A view of molded samples.

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A view of modeled samples.
Fig. 6 A view of a multi-step method designed to make carbon nanotube composites

Fig. 7 A View of Vector Network Analyzer.

Fig. 8 A view of calibration tools in Math Load step

Fig. 9 A view of Short Load calibration step
Fig. 10 A view of the X-band waveguide and waveguide test without putting sample in it and recording the values obtained for the Open Load calibration step.

Fig. 11 (a) Front view of Device 2; (b) The device is ready for measurement 3) Putting samples in waveguide and measuring the amount of absorption

Table 3 Compare percent absorption in the samples containing 1, 3 and 10 wt% of carbon nanotubes

<table>
<thead>
<tr>
<th>Amount of Resin</th>
<th>3%</th>
<th>10%</th>
<th>13%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nomaehay 100%</td>
<td>37.51078775</td>
<td>279.1952342</td>
<td>275.7567173</td>
</tr>
<tr>
<td>Nomaehay 30%</td>
<td>22.03320412</td>
<td>67.8088203</td>
<td>362.7440942</td>
</tr>
</tbody>
</table>

Table 2 Amount of wave absorption in comparison with pure resin in different samples

<table>
<thead>
<tr>
<th>Amount of Resin</th>
<th>3%</th>
<th>10%</th>
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</tbody>
</table>
Fig. 12 Amount of wave absorption in different samples

Fig. 13 Micro Raman Spectroscopy for samples containing 0.01 and 0.03 wt% SWCNTs
Fig. 14 A view Raman Spectroscopy for D and G-bands

Fig. 15 SEM images of surface of samples

Table 4 Heterocyclic peaks related to D and G-band for samples containing 0.01 and 0.03wt% SWCNTs

<table>
<thead>
<tr>
<th>Wavenumber Cm⁻¹</th>
<th>Sample Containing 0.01wt% SWCNTs</th>
<th>Sample Containing 0.03wt% SWCNTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>485.22211</td>
<td>1583.5</td>
<td>0.01wt% D-band</td>
</tr>
<tr>
<td>1453.15283</td>
<td>1612</td>
<td>0.01wt% G-band</td>
</tr>
<tr>
<td>193.45305</td>
<td>1583</td>
<td>0.03wt% D-band</td>
</tr>
<tr>
<td>198.92757</td>
<td>1606</td>
<td>0.03wt% G-band</td>
</tr>
</tbody>
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