Carbon Nanotube Material Quality Assessment

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Abstract

The nanomaterial activities at NASA-Johnson Space Center focus on carbon nanotube production, characterization and their applications for aerospace systems. Single wall carbon nanotubes are produced by arc and laser methods. Characterization of the nanotube material is performed using the NASA-JSC protocol developed by combining analytical techniques of SEM, TEM, UV-VIS-NIR absorption, Raman, and TGA [1]. A possible addition of other techniques such as XPS, and ICP to the existing protocol will be discussed. Changes in the quality of the material collected in different regions of the arc and laser production chambers is assessed using the original JSC protocol. The observed variations indicate different growth conditions in different regions of the production chambers.

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JSC Characterization Protocol for TEM

1. Images: Qualitative information about non-nanotube carbon impurities ("schmutz" and graphitic particles) and their distribution within a sample
2. Images: Qualitative information about metal content

JSC Characterization Protocol for Raman Spectroscopy

1. Nanotube protonation state from the C-C stretch mode shift.
2. Possible information about impurities and disorder in the sample from the 1340 cm⁻¹ disorder peak position and width
3. Qualitative information about sample homogeneity from the variability in the spectra

JSC Characterization Protocol for SEM

1. Images: Qualitative information about impurities, general morphology of the sample and its homogeneity
2. EDS: Qualitative information about metals, silicon and chlorine impurities

JSC Characterization Protocol for TGA

1. Average residual mass M_R (in %): Shows fraction of residual metals in the specimen.
2. Temperature T_m of the maximum in the burning rate dM/dT: Shows thermal stability of the specimen.
3. Standard deviation of M_R and T_m: Shows information about sample homogeneity from the variability in the spectra

JSC Characterization Protocol for UV-Visible-NIR Spectroscopy

- Provides quantitative information about how well nanotubes stay in suspension
- Can provide information on electronic properties of tubes (metallic, semiconducting, etc.)
- Possible determination of the purity of nanotubes

Analysis Results Summary Table for Laser Material

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>Inner</th>
<th>Collar</th>
<th>Sleeve</th>
<th>Main</th>
<th>Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual Mass</td>
<td>6.45%</td>
<td>13.38%</td>
<td>12.21%</td>
<td>14.26%</td>
<td>10.45%</td>
</tr>
<tr>
<td>Thermal Stability</td>
<td>1285.45 cm⁻¹</td>
<td>1289.9 cm⁻¹</td>
<td>1287.87 cm⁻¹</td>
<td>1284.84 cm⁻¹</td>
<td>1283.17 cm⁻¹</td>
</tr>
<tr>
<td>D/B Ratios</td>
<td>0.288</td>
<td>0.090</td>
<td>0.047</td>
<td>0.094</td>
<td>0.124</td>
</tr>
<tr>
<td>D-Band Position</td>
<td>404.4 ºC</td>
<td>439.0 ºC</td>
<td>405.9 ºC</td>
<td>404.4 ºC</td>
<td>405.9 ºC</td>
</tr>
<tr>
<td>Small Diameter %</td>
<td>13.31%</td>
<td>22.6%</td>
<td>8.17%</td>
<td>9.85%</td>
<td>27.5%</td>
</tr>
</tbody>
</table>

Additional Techniques

- ICP can provide a better quantitative measure of the metal impurity levels as produced and purified materials (digestion of metals major issue).
- XPS can provide information on the chemical states of non-carbon impurities to assist with TGA and ICP analysis.