Raman Spectral features of single walled carbon nanotubes synthesized by laser vaporization

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NLC

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Contents

• Raman scattering in SWCNTs

• Radial Breathing Mode (RBM)

• Tangential stretching mode-in plane

• Experimental

• Results and Discussion

• Conclusions
Raman scattering in SWCNTs

• In Raman spectra of SWCNTs there many features which can be identified with specific phonon modes and with specific Raman scattering processes that contribute to each feature

• The Raman spectra can provide us with info about the exceptional 1D properties of nanotubes. These include:
  • Phonon structure
  • Electronic structure
  • Defects with the nanotubes

• Mechanical properties, elastic properties and thermal properties are strongly influenced phonons. Thus, Raman spectra provide a very detailed info on the properties of SWCNTs
Raman scattering in SWCNTs experimental

- Raman scattering is the inelastic scattering of light
- Raman frequency plot is a measure of the energy difference between the laser excitation photon and the scattered detected photon i.e., it measures the frequency of the vibration or phonon

\[ P_{\text{laser}} = 1.2 \text{ mW} \]
\[ T = 180 \text{ s} \]
\[ \text{Spot size} = 120 \text{ micron} \]
\[ 20x \text{ objective on microscope} \]
Radial Breathing Mode (RBM)

- This frequency mode determines whether there is SWCNTs in the sample.
- Diameter and diameter distribution can be determined.

\[ d_t(nm) = \frac{\sqrt{3}a_{c-c} \sqrt{m^2 + nm + n^2}}{\pi} = \frac{C_h}{\pi} \]

Where \( d_t \) is the diameter of the nanotube in nm, \( a_{c-c} \) is the c-c distance and \( (n, m) \) is the indices describing the nanotube. \( C_h \) is the chiral vector. The chiral angle is given by:

\[ \theta = \tan^{-1} \frac{\sqrt{3}n}{2m+n} \]. The diameter can be determined from the plot by:

\[ d(nm) = \frac{223.5(cm^{-1})}{\omega_{RBM} - 12.5(cm^{-1})} \]
Tangential stretching mode-in plane

When semi-conducting

When metallic

Experimental

Set-up

Nd:YAG 2\textsuperscript{nd} harmonic 532 nm

Nd:YAG Fundamental 1064 nm

Flow controller

Vacuum pump

Pressure controller

Cooling unit
Experimental...cont.

Experimental parameters

- two laser combined and vaporize a composite target
- target in a tube furnace in continuous flow of Argon
- temperature kept at 1000 °C
- Ar flow of 200 sccm
- Pressure at 375 Torr
- fluence at target: 2 J/cm²
- targets composition is:
Experimental....cont

Target composition

<table>
<thead>
<tr>
<th>Sample Label</th>
<th>Composition(%)</th>
<th>Temperature( °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>98%C:1%Ni:1%Co</td>
<td>1000</td>
</tr>
<tr>
<td>Sample 2</td>
<td>98%C:0.67%Fe:0.67%Ni:0.67%Co</td>
<td>1000</td>
</tr>
</tbody>
</table>
Results and Discussion
• more SWCNT in sample 2
• longer SWCNT as seen by higher intensities of the G band
Sample 1: C:Co:Ni (98%:1%:1%)
Radial Breathing Mode

- Laser excitation at 488 nm (blue)
- Laser excitation at 514.5 nm (green)
- Laser excitation at 647.1 nm (red)

Intensity (AU)
Wavenumbers (cm⁻¹)

Sample 2: C:Fe:Co:Ni (98%:0.67%:67%:0.67%)
Radial Breathing Mode (RBM)

- Laser excitation at 488 nm (blue)
- Laser excitation at 514.5 nm (green)
- Laser excitation at 647.1 nm (red)

Intensity (AU)
Wavenumbers (cm⁻¹)

Sample 1:
$D_t = 1.31 - 1.46$ nm

Sample 2:
$D_t = 1.33 - 1.49$ nm
- Lower defects?
- Narrower linewidths indicate improved crystallinity
- Semiconducting tubes favoured
Conclusions

• Important spectral features of SWCNTs discussed
• Raman spectroscopy was applied to as prepared laser synthesized SWCNTs
• The Raman spectra revealed the presence of SWCNTs with low defect concentration.
• Adding a third catalyst to the composite target
  □ increased the yield as indicated by higher Raman intensities
  □ Longer tubes were synthesized as indicated by stronger G band intensities
  □ Tubes with larger diameters were synthesized
  □ Semi-conductor tubes were favoured
  □ Improved crystallinity as indicated by narrower line-widths.
Thank You

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