Photoyield shows annealing decreases bandgap toward 0 eV.

Spin-off Applications of SE Studies

• Field Plate Detectors: Serves between anodes and cathodes are required to be insulating and have low SE yields.
• Plasma Fusion: SE yield of chamber wall materials is important in determining plasma conditions.
• Spacecraft Charging: SE yield of materials is an important modeling parameter of the NASA spacecraft analyzer program NASCAP.
• High Power Arching: SE yield of materials determines arc initiation.
• Scanning Electron Microscopy: Number of produced SE’s is dependent on the geometry of sample and materials studied.
• Electron Multipliers: Use high SE yield materials, for dynodes.
• Vacuum Tubes: Need low SE yield materials.

Results & Conclusions

• Measured 30% increase in \( \delta_{\text{max}} \) for g-C with a ~0.65 eV increase in bandgap.
• \( \delta_{\text{max}} \) for 1050 °C g-C has same \( \delta_{\text{max}} \) than HOPG.
• Additional measurements of other annealed samples in progress to corroborate trend.

Bandgap has been established as an important parameter in the SE emission of a small bandgap semiconductors.

Graphitic Carbon: Raman Spectroscopy

- Raman spectroscopy probe-attomole-range order in Carbon
- Anomalous causes structural changes of g-C towards nanocrystalline graphite

Graphitic Carbon: Band Structure

Graphitic Carbon: Photoyield Spectra

- Photocurrent 0.1 eV
- Photocurrent 0.4 eV
- Photocurrent 0.65 eV
- Photocurrent 0.9 eV
- Photocurrent 1.2 eV
- Photocurrent 1.5 eV
- Photocurrent 1.8 eV
- Photocurrent 2.267 gm/cm³ ~ 2.0 gm/cm³ ~ 1.82 gm/cm³
- SiC: 25% O: 25% O: 3% Si: 15% O: 16%
- Resistivity: 5 x 10⁻² S-cm
- Resistivity: (interlayer)
- \( \delta \)

Graphitic Carbon Electron Emission Spectra

Presence of similar fine structure peaks at ~0.1 eV in all spectra indicative electronic transitions involved \( \delta_{\text{max}} \) of all carbon samples.

Graphitic Carbon: SE Yield

- g-C 30% higher \( \delta_{\text{max}} \) than HOPG
- 1050 °C g-C has same \( \delta_{\text{max}} \) than HOPG
- Measurements of other annealed g-C in progress

Ground-Based Studies of Electron Emission and Spacecraft Charging

Secondary electron emission (SE) yields are the number of electrons emitted when an electron bombards a sample at a certain bias voltage and angle. The emitted electrons are detected using a number of different detection systems including vacuum chamber, detecting computers and electronics, or even by the eye. The most common detection system is the electron multiplier, and the basis of this detection system is the secondary electron (SE) yield. SE yield is the number of SE emitted per incoming electron and is an underlying attribute of spacecraft charging. Other common applications of SE include studying chemical reactivity, electron detection/classification, and measurement of materials and elements in spacecraft environments. The electronic structure in low work function is important in determining plasma conditions.

Mathematical Formulation

\[
\delta = \frac{\text{SE yield}}{\text{Incident electrons}}
\]

Egap (eV)

Properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Conductivity</th>
<th>Bandgap</th>
<th>Annealing</th>
<th>Tensile Dependence</th>
<th>Key Parameter of SE</th>
<th>Work Function</th>
<th>Surface Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>g-C</td>
<td>good</td>
<td>low</td>
<td>0.65</td>
<td>high</td>
<td>high</td>
<td>?</td>
<td>high</td>
</tr>
<tr>
<td>HOPG</td>
<td>good</td>
<td>high</td>
<td>0.85</td>
<td>high</td>
<td>high</td>
<td>?</td>
<td>high</td>
</tr>
</tbody>
</table>

Band Gap

- Graphitic Carbon: SE Yield
- g-C 30% higher \( \delta_{\text{max}} \) than HOPG
- 1050 °C g-C has same \( \delta_{\text{max}} \) than HOPG
- Measurements of other annealed g-C in progress

Central Question of Study

Does the semiconductor’s bandgap play a role in secondary electron emission?

Abstract

Secondary electron (SE) yields for the number of electrons emitted when an electron bombards a sample at a certain bias voltage and angle. The emitted electrons are detected using a number of different detection systems including vacuum chamber, detecting computers and electronics, or even by the eye. The most common detection system is the electron multiplier, and the basis of this detection system is the secondary electron (SE) yield. SE yield is the number of SE emitted per incoming electron and is an underlying attribute of spacecraft charging. Other common applications of SE include studying chemical reactivity, electron detection/classification, and measurement of materials and elements in spacecraft environments. The electronic structure in low work function is important in determining plasma conditions.

Stages of Secondary Electron Emission

1. Production of SE
2. Graphitic Carbon: Raman Spectroscopy
3. Photocurrent 0.1 eV
4. Photocurrent 0.4 eV
5. Photocurrent 0.65 eV
6. Photocurrent 0.9 eV
7. Photocurrent 1.2 eV
8. Photocurrent 1.5 eV
9. Photocurrent 1.8 eV
10. Photocurrent 2.267 gm/cm³ ~ 2.0 gm/cm³ ~ 1.82 gm/cm³
11. SiC: 25% O: 25% O: 3% Si: 15% O: 16%
12. Resistivity: 5 x 10⁻² S-cm
13. Resistivity: (interlayer)
14. \( \delta \)

Graphitic Carbon: SE Yield

- g-C 30% higher \( \delta_{\text{max}} \) than HOPG
- 1050 °C g-C has same \( \delta_{\text{max}} \) than HOPG
- Measurements of other annealed g-C in progress

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