Low temperature ECR-PECVD microcrystalline SiC growth by pulsed gas flows

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Abstract: The SiC layers have been grown by ECR-PECVD on (100) Si substrates at substrate temperatures of 850°C and low pressure (mTorr). SiH₄ and CH₄ were used as precursor gases, added to a continuous Ar flow that maintains a stable plasma all over the process. One or both precursor gases were pulsed in order to perform a layer-by-layer growth. Different conditions and flow ratios have been used, while maintaining the microwave power fixed. Previous carbonization of the silicon surface has been also investigated and the presence of plasma during this step is discussed. Composition and effective thickness of the samples has been determined by FTIR and spectroscopic ellipsometry. AFM measurements reveal the presence of ordered microcrystals under certain process conditions of carbonization and growth. These crystals with an apparent cubic structure have average height and diagonal length of about 16nm and 335nm respectively, from the focused analysis of one of them. Its density seems to be related to the carbonization pre-process.

Purpose of the work:
To reduce the SiC growth temperature, taking advantage of the high density of ions and radicals generated in ECR plasmas.

Films grown under continuous gas flows show amorphous structure, as was observed in previous experiments. In this work, pulsed precursor gas flows in Ar maintained plasmas are investigated as growth processes.

Experimental conditions:

<table>
<thead>
<tr>
<th>Reference</th>
<th>Carbonization</th>
<th>Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>No</td>
<td>Continuous H₄ flow, Pulsed SiH₄</td>
</tr>
<tr>
<td>B</td>
<td>CH₄ flow</td>
<td>Continuous CH₄ flow, Pulsed SiH₄</td>
</tr>
<tr>
<td>C</td>
<td>CH₄ flow</td>
<td>Pulsed CH₄, &amp;SiH₄</td>
</tr>
<tr>
<td>D</td>
<td>CH₄ plasma</td>
<td>Continuous O₂ flow, Pulsed SiH₄</td>
</tr>
</tbody>
</table>

Growth system:

FTIR analysis: SiC band
FWHM of samples A, B and C are similar, but FWHM of sample D is about 42–50% wider than the others.

Best conditions:
- Carbonization under CH₄ flow
- Growth: continuous CH₄ flow

Ellipsometric measurements:

<table>
<thead>
<tr>
<th>Reference</th>
<th>Effective thickness</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>~135Å</td>
<td>100% SiC</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>398Å</td>
<td>65% SiC + 21% SiO + 14% graphite</td>
</tr>
</tbody>
</table>

AFM images of samples without plasma carbonization:

(A) (B) (C)

Conclusions:

* Thin SiC layers have been grown by ECR-PECVD on (100) Si at 850°C under pulsed gas flows and pressures of mTorr
* CH₄ plasma presence at the temperature ramp, as a carbonization step, results in a graphitic phase appearance
* SiC growth takes place in two different ways depending on the presence or not of CH₄ during the temperature ramp:
  a) In absence of CH₄, the growth corresponds to a mainly homogeneous SiC layer with few nucleation structures
  b) With CH₄ presence growth by nucleation is enhanced
* Pulsing CH₄ during the growth step results in a softening of the structure edges

Acknowledgements:
The work has been supported by the Spanish MCyT C03-40654-A-645 project.