INFLUENCE OF FILM THICKNESS AND PATTERN DENSITY IN GRAPHOEPITAXIAL DSA

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Scope

- In graphoepitaxial DSA, template fill (local BCP thickness) is a critical parameter influencing the assembly but also the succeeding pattern transfer process.
- The template fill depends on several process parameters such as pattern density, BCP film thickness, properties of the template (height, surface energy), annealing conditions, etc.
- Understanding the relationship between these process parameters and the resulting fill is crucial to develop DSA-friendly design rules for via layers.

- We suggest a formula to estimate the template fill:

$$\text{Fill} = \text{FT} \times \text{PD}^\alpha$$

Where:
- \(\text{FT}\) is the BCP film thickness (measured by ellipsometry)
- \(\text{PD}\) is the pattern density (measured by top-down CD-SEM)
- \(\alpha\) is the conformity of the BCP coating process (determined by least squares fitting of data): \(\alpha = 0 \rightarrow\) fully conformal coating, \(\alpha = 1 \rightarrow\) all material flows into the templates

- In order to prevent variations in fill level, sub-DSA-resolution assist features that counteract pattern density changes are being explored at imec.

Examples of different fill levels

<table>
<thead>
<tr>
<th>Pattern density (%)</th>
<th>Film thickness (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5%</td>
<td>15.9 nm</td>
</tr>
<tr>
<td>14.1%</td>
<td>19.5 nm</td>
</tr>
<tr>
<td>21.8%</td>
<td>24 nm</td>
</tr>
<tr>
<td>16%</td>
<td>24 nm</td>
</tr>
<tr>
<td>19%</td>
<td>5.7 nm</td>
</tr>
<tr>
<td>24%</td>
<td>6.7 nm</td>
</tr>
<tr>
<td>4%</td>
<td>7.4 nm</td>
</tr>
<tr>
<td>10%</td>
<td>11.8 nm</td>
</tr>
<tr>
<td>13%</td>
<td>15.9 nm</td>
</tr>
</tbody>
</table>

Fitting & accuracy of formula

- Initial fitting and calibration done with regular X-SEM measurements done after BCP anneal (disadvantage: loss of accuracy due to BCP damage during cleave and uncertainty over cleave location).
- Refilling templates with SOG after BCP anneal circumvents the BCP damage problem but uncertainty over cleave location remains an issue.
-Thorough investigation of accuracy of the formula is planned using in-line AFM:
  - Correct height profile measurements
  - Allows for measuring a large parameter space

Process flows

- Flow #1: No SOG strip
  - No brush
  - Si bottom: affinity for PMMA
  - SOC sidewall: affinity for PMMA

- Flow #2: SOG strip
  - NLD: 244
  - No SOG strip
  - Si bottom: no affinity for either block
  - SOC sidewall: affinity for PMMA

- Flow #3: SOG strip
  - NLD: 330
  - Brush (higher \(\psi_\alpha\) grafts at higher rate to SOC)

Influence of fill on open hole rate

- The fill determines the confinement of the assembly in the \(z\)-direction
- For a bottom with affinity for PMMA (flow #1) a higher sensitivity to fill is observed
- Fill has a clear impact on subsequent pattern transfer (aspect ratio dependency of etch)

Conclusions

- Pattern density, BCP film thickness and template surface energy have been identified and studied as main parameters affecting the fill level
- A formula to estimate template fill based on top-down information has been suggested
- In-line AFM has been identified as method of choice to measure template fill

Outlook

- Thorough investigation of fill formula (accuracy/limitations) using in-line AFM
- Study the influence of other parameters (e.g. annealing conditions) on fill
- Determine optimal fill for assembly and pattern transfer (for different flows)
- Is there an optimal pattern density?
- Use this learning to determine DSA-friendly design rules, including fill predictions and sub-DSA resolution assist features