A STUDY ON VARIABILITY OF CYLINDRICAL PATTERNS

TOWARDS RELIABLE DIRECTED SELF-ASSEMBLY LITHOGRAPHY FOR FUTURE CMOS SCALING

CAROLIEN BOECKX, JAN DOISE, GERMAIN FENGER, YI CAO, ROEL GRONHEID, STEFAN DE GENDT

A KU LEUVEN, B IMEC, C MENTOR GRAPHICS, D EMD PERFORMANCE MATERIALS

Motivation

- In DSA there is a lack of understanding in the root causes contributing to the variability of the CD and pattern placement

<table>
<thead>
<tr>
<th>Pattern placement</th>
<th>Half-pitch</th>
<th>Total variability</th>
<th>BCP variability</th>
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</thead>
<tbody>
<tr>
<td>2014 target</td>
<td>39 nm</td>
<td>5.2 nm 3σ</td>
<td>4.3 nm 3σ (11%)</td>
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<tr>
<td>2018 target</td>
<td>28 nm</td>
<td>3.7 nm 3σ</td>
<td>2.2 nm 3σ (8%)</td>
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</table>

- Need for characterizing separate contributions to placement accuracy

$$\sigma_{total}^2 = \sigma_{overlay}^2 + \sigma_{template}^2 + \sigma_{BCP}^2 + \sigma_{metrology}^2$$

- Metrology for determining $$\sigma_{BCP}^2$$ and $$\sigma_{template}^2$$ not fully developed
  - Current measurement routine depends on simultaneous observation of template and BCP structure
  - Template contour often impacted by BCP processing

Two measurement routines

1. Robust edge detection (RED)
   - CD-SEM image (A)
   - Noise reduction in the SEM image and extraction possible edges (B)
   - First fitted shape (C)
   - Distinct fliper edges removal and redetection (D)
   - Final fitting model of a 20 nm diameters DSA hole (E)
   - Center of gravity of the template (blue) can be used as a reference for the expected position of the DSA holes (purple)

2. Design based pattern placement accuracy (New)
   - Use mask design as reference structure
   - 25 SEM images of 9 singlet holes with dimensions of 75 nm and a pitch of 75 nm were captured by Hitachi CD-SEM in a rectangular field of view with 0.45 mm in x- and y-direction
   - Contour extraction (DG Hitachi)
     - Extract edge locations to generate contours, saved in a layout
   - Contour re-alignment
   - Pattern placement accuracy extraction (Calibre MG)
     - Extract placement error from the contour (red) relatively to the target design (green)

Results

- The post-litho template CD as obtained by RED was found to be 62.4 nm with a CDU of 5.4 nm 3σ, post-SOG removal the CD was 52.9 nm with a CDU of 4.1 nm 3σ, and post-DSA the holes had a CD of 20.4 nm with a CDU of 3.9 nm 3σ
- Figure A shows post-litho contours as obtained by the design based routine, a placement accuracy of 3.5 nm 3σ in X and 2.8 nm 3σ in Y was obtained. Figure B shows the post-SOG removal contours resulting in a placement accuracy of 2.5 nm 3σ in X and 2.4 nm 3σ in Y. Figure C shows the post-DSA contours of the DSA holes giving a placement accuracy of 2.8 nm 3σ in X and 3.6 nm 3σ in Y
- Design based contours have been used to calibrate compact models to represent phenomena with fast mathematical equations

Conclusions and outlook

- RED is good for CD measurements, for placement accuracy the contrast is too process dependent
- A measurement routine is being developed to determine the contribution of separate root causes to pattern placement variability
- First pattern placement results have been obtained by using the design of the mask as a reference structure
  - Extend to doublet structures
  - There is still a significant contribution of the metrology part to the overall variability
    - Need to improve contrast in SEM images
    - New reticle development