ELECTRICAL VERIFICATION OF CONTACT HOLES OBTAINED WITH DSA OF BCP

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OUTLINE

1. Templated flow for DSA of BCP
2. Integration of templated DSA in Everest test vehicle
3. Metallization results
4. Conclusions
The use of SOC/SOG templates allows further processing at 250°C (BCP anneal) and the selective functionalization of the template’s wall with respect to the bottom. The dimensions (CD) and chemistry (surface energy) of the topographic features can be finely tuned through the litho and the surface modification steps, respectively.
DIRECTED SELF-ASSEMBLY OF BLOCK COPOLYMERS

- Templated DSA can be used for hole shrink or pattern multiplication.
- Surface energy control results in straight cylinders throughout the film.
- The PS-wetting flow requires smaller templates (only 1 BCP period), which can be advantageous in a real design at the 7nm node and below.

*P19- Jan Doise
**TEMPLATED DSA FOR CONTACT HOLE SHRINK**

### Blend approach

<table>
<thead>
<tr>
<th>Dose</th>
<th>18 mJ/cm²</th>
<th>22 mJ/cm²</th>
<th>26 mJ/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSA Resist (Only) + Tapered Etch</td>
<td>53.1</td>
<td>39.9</td>
<td>28.7</td>
</tr>
<tr>
<td>DSA Resist + Blend Shrink + Tapered Etch</td>
<td>36.0</td>
<td>26.2</td>
<td>19.9</td>
</tr>
</tbody>
</table>

Younkin T., et.al., PTW, April 2013

### PS-b-PMMA approach

- **NTD resist**
  - 70 nm
  - 20 nm SiOC
  - 100 nm a-C
  - 15 nm SiN<sub>4</sub>
  - W

- **NLD**
  - 10 nm NLD
  - 20 nm SOG
  - 100 nm SOC

- **Trilayer**
  - CVD
  - NLD

Romo-Negreira A., et.al., PTW 2014

- Templated DSA has been used with polymer blends and BCP using resist as template material.
- Main challenges with the PS-b-PMMA approach included resist reflow during BCP anneal and profile control of the inner cylinder (3 surfaces tested).
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Everest28 Electrical Test Vehicle
LI2-VA0-MT1 Short Loop

- Everest uses a simple short loop to obtain electrical data of V0 structures.
- The staggered holes are used for initial optimization and characterization of the process.
- The effect of pattern density is investigated through the different structures available on reticle.
We use the new templated DSA flow (PS-wetting scheme) to generate small CD, high aspect ratio structures to:

- explore different metallization approaches
- assess the DSA process as a function of template dimensions and BCP properties (fill level).
Dose = 30 mJ/cm² (Uniform wafers)

- Pattern transfer into 100nm SiO₂ has been achieved with ~30nm decrease in CD from Lithography to SiO₂ etch (averaged over full wafer).
- CD non-uniformities can be related to the litho/etch processes as a clear across-wafer signature is observed.
- Profile of the contact shows minor tapering.
The reference process was not successful at opening the SiN (etch stop layer). Increasing the etching time resulted in a large consumption of the amorphous-carbon and, in tapering of the holes in the SiO2 layer. An optimized process helped to protect the amorphous carbon and, at the same time, had a minor impact on the profile of the etched structures.
For the staggered structures (X-SEM), the optimal pattern transfer is obtained when 66nm<CD<57nm after litho, with a CD reduction of about 50% after SiO$_2$ etch.

Larger templates result in multiple holes/missing holes.

When CD<25nm, the pattern transfer becomes more challenging and variations in the hole diameter can be observed from top-down SEM.

There is a minimal difference in the final CD when spin coating the BCP at different speeds.
For the isolated features, the BCP spin speed needs to be optimized!

During the BCP anneal, the overflow of material into the templates may have two negative effects:
- The fill level increases and eventually the hole is blocked
- During the etch, the chemistry that is used for passivation/etch control may close the hole.

A new DSA-friendly approach is being explored...
Corner of chain structure – without DSA assist features

- Pattern density effects play a key role in templated DSA. Using the traditional approach, there is an overflow of material at the edges of the Chain array.
- This effect was also observed in the Everest Kelvin structures.
**ERIS: DSA-FRIENDLY DESIGN**

CHAIN – WITH DSA ASSISTS FEATURES

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**Templates before DSA**

![Templates before DSA](image1)

**After DSA application**

![After DSA application](image2)

**Corner of chain structure – with DSA assist features**

![Corner of chain structure](image3)

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- Assist features, included in the V0 layer of Eris, function as ‘trash cans’ for excess BCP material at the edges of structures of interest. Their dimensions are defined so that they contain BCP material without assembling or transferring any structures.
ERIS: DSA-FRIENDLY DESIGN
KELVIN – WITH DSA ASSISTS FEATURES

- DSA assist features proved to be needed and effective to increase the process window in templated DSA.
ERIS: DOUBLE DSA PROCESS DEMONSTRATION

Split A: singlets

Split B: doublets

Result after double DSA & etch into SiN

85nm NTD PR
30nm SoG
100nm SoC
20 nm SiN
20 nm TiN
20 nm SiOx
100 nm SoC

substrate

47 nm

37 nm
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**TEMPLATED DSA ON PATTERNED METAL**

![Diagram showing Lithography, BCP assembly, and After SiO₂ etch stages.](image)

- **Lithography**
  - Avg. CD = 65.0 nm
  - Std. Dev. (wafer) = 1.2 nm

- **BCP assembly**

- **After SiO₂ etch**
  - Avg. CD = 31.80 nm
  - Std. Dev. (wafer) = 1.2 nm

![Graph showing Dose vs. Average CD for Lithography and SiO₂ CD.](image)

- **Similar litho CD target results in good DSA and pattern transfer when changing the stack bare Si to Cu lines (Li2). Pattern transfer until the metal lines was achieved.**

- **Average CD**
  - After SiO₂ etch
    - Avg. CD = 65.0 nm
    - Std. Dev. (wafer) = 1.2 nm
    - Lithography
    - BCP assembly
    - Average CD = 31.80 nm
    - Std. Dev. (wafer) = 1.2 nm

![Image showing dose vs. CD for different doses.](image)

- **Dose (mJ/cm²)**
  - Dose (mJ/cm²):
    - 27.5
    - 28
    - 28.5
    - 29
    - 29.5
    - 30
    - 30.5
    - 31

- **CD (nm)**
  - 30.58
  - 29.67
  - 24.5
  - 26.3
  - 22.87
  - 24.5
  - 20.69
ELECTRICAL STRUCTURES: KELVINS

- Similar trend of the dependence of the DSA process and pattern transfer on the template dimensions was observed in the Kelvin structures, for the optimal film thickness.
- The transferred structures were successfully filled using imec’s standard Cu plating process.
- They were submitted for electrical tests but showed no signal. Subsequent step in the process was out of spec, however failure tests to verify the root cause are currently ongoing.
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CONCLUSIONS

- Templated DSA was successfully used as a contact hole shrink technique, with almost 50% decrease in the CD. Further shrink is possible, but etching optimization is required (work not planned).
- The PS-wetting scheme provides straight cylinders (and subsequent holes) that can be transferred into relevant stacks for integration.
- The current integrated flow allows for the pattern transfer and metallization of high aspect ratio structures using Co ELD and Cu plating.
- Electrical tests of Kelvin and Chain structures showed no signal. Failure tests to find the root cause are currently ongoing.
- Further work includes electrical evaluation of chain structures for defectivity assessment of templated DSA flows and materials (SOG and PMMA-wetting flows).
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