Split and Design Guidelines for Double Patterning

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Outline

- Introduction
- Simulation Methodology
- Split Analysis
- Conclusions
Introduction

45nm hp at NA=1.35 Water immersion

$k_1 = 0.31$

**Easier to Difficult to**

<table>
<thead>
<tr>
<th>SINGLE PATTERNING + Restricted Design Rules</th>
<th>MEMORY</th>
<th>RANDOM LOGIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easier to implement</td>
<td>Difficult to implement</td>
<td></td>
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</table>

<table>
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<tr>
<th>DOUBLE PATTERNING + POLYGON CUT &amp; Design Restrictions</th>
<th>MEMORY</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Limited polygon cutting</td>
<td>Complex polygon cutting</td>
<td></td>
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**Split 45nm hp Random Logic Metal**

- **Goal:**
  study split and design guidelines to ensure robust
  **stitching through process variations**

- **Test vehicle:**
  **45nm hp random logic metal**
  using 2D split test patterns
  varying systematically the design and split parameters
Outline

- Introduction
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Simulation of Induced Process Variations

- Simulation assumptions:
  - Target in resist: 65nm
  - Isotropic constant etch bias: down to 45nm final target
  - Dense-OPC (non calibrated constant threshold) + Assist features
  - Simulate contours of the image in resist

- Vary process conditions

![Graph showing process variations with DOSE and DEFOCUS parameters.]

FLAG Process Failures in Resist

- At LITHO 1 and LITHO 2 independently

- Incomplete OPC
  - BF BE / BIAS 0
  - Line-end EPE > 3nm

- BRIDGING
  - BF E+3% / BIAS +0.5nm
  - External < 15nm

- PINCHING
  - F-35nm E-2% / BIAS -0.5nm
  - Internal < 35nm
FLAG Process Failures at Final Patterning

- CD2 to CD1 induced overlay shift around a circle of 6nm radius (alignment/registration/process) with both images in F-35nm, E-2%, BIAS -0.5nm.

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- Introduction
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Minimum Stitching Overlap

- PARALLEL TRENCHES
  - Overlap > 52nm

- 90DEGREE TRENCHES
  - Overlap > 50nm

DENSE PITCH BACK

SMALL GAP BACK

<table>
<thead>
<tr>
<th>Pitch</th>
<th>92nm</th>
<th>94nm</th>
<th>98nm</th>
<th>100nm</th>
<th>102nm</th>
<th>104nm</th>
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</thead>
<tbody>
<tr>
<td>Stitching at overlap 56nm</td>
<td></td>
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<tr>
<td>Stitching at overlap 64nm</td>
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<td>Bridging at overlap 56nm</td>
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Stitching width > 25nm

Bridging at overlap 56nm

External < 15nm

@ BF/E+2%/BIAS+0.5nm
Perpendicular Trenches

- Robust Stitching requires a mask overlap $\geq 60\text{nm}$
- at stitching overlap 60nm
  Bridging can only be avoided for gap $\geq 58\text{nm}$

Pitch 90nm Mask Stitching Overlap = 60nm

Gap 46nm | Gap 54nm | Gap 58nm

Combined Aggressive Pitch & Gap

- Minimum Pitch/Gap without Failure Flag:
- Same process failure criteria at SP and DP

Target Design

Single patterning NA 1.35

Pitch 110nm
Gap 66nm

Double patterning NA 1.35

Pitch 100nm
Gap 46nm

Double patterning NA 1.20

Pitch 104nm
Gap 46nm

Pitch 88nm
Gap 74nm
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Conclusions

- We have a methodology to study the double patterning stitching robustness through process variations, that impacts the cutting positions and the design.

- Trench-end shape and position through process variations is more critical than overlay for a robust stitching.

- A robust Double Patterning does not allow a global scaling from previous node.

### e.g. in our simulation model for 45hp METAL

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<td>NA1.35</td>
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<td>NA1.2</td>
</tr>
<tr>
<td></td>
<td>split1</td>
<td>split2</td>
</tr>
<tr>
<td>pitch</td>
<td>110</td>
<td>88</td>
</tr>
<tr>
<td>gap</td>
<td>66</td>
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**Double patterning**

**Imaging limit**

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**Conclusions**

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**k1 at NA1.35**

**METAL RANDOM LOGIC**

<table>
<thead>
<tr>
<th></th>
<th>0.25</th>
<th>0.30</th>
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<tr>
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<tr>
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**32hp DP+DR**
Acknowledgements

litho: Rudi De Ruyter, Philippe Leray, Janko Versluijs
etch: Dirk Hendrickx, Herbert Struyf

DP team and Le Hong

DP team

Shiho Sasaki, Kei Mesuda

Toru Ishimoto