Recent results of Multi-beam mask writer MBM-1000

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NuFlare keeps on releasing leading-edge mask writers every two years to support semiconductor industry for more than 15 years.

We will launch MBMW to comply with ITRS roadmap.

**MBM-1000** is to be released in 2017 for N5.

**MBM-2000** will be coming in 2019 for N3.
NuFlare is evaluating MBM-1000 alpha tool.

Assembly of beta tool is almost completed.

- Beam on planned at the end of July.
### Key Technologies

**VSB**
- Single Variable Shaped Beam
- High current density
- High speed deflection

**MB**
- Massive number of beams
- High-speed data path and BAA
- Gray beam writing

### Advantage

**VSB**
- Best cost performance for Med-Low pattern density/doses

**MB**
- Constant write time for all pattern densities
- Enables high doses

### Limitation

**VSB**
- High doses and pattern densities impact write time

**MB**
- Not cost effective for Med-Low pattern densities and doses
- Narrow process window due to gray beam

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**VSB**
- Electron gun
- Condenser lenses
- 1st shaping aperture
- Shaping deflectors
- 2nd shaping aperture
- Sub deflectors
- Main deflectors
- Projector lenses
- Objective lens
- Reticle

**MB**
- Electron gun
- Condenser lens
- Projection lens
- Sub deflectors
- Main deflectors
- Objective lens

**VSB**
- Single shot up to 500 nA

**MB**
- Total current 500 nA
VSB
No gray beam is used.
Dose profile is formed by VSB (rectangular and triangular) shots

Pixelated gray beam
Square beams with modulated dose are exposed

10 nm beam size can reproduce VSB dose profile
Strategy in design

Resolution
- 10 nm beam size for accurate edge position control by gray beam writing
- Low-aberration optics

Writing accuracy
- 10-bit dose control
  - 0.1 nm CD/position resolution
  - PEC/FEC/LEC calculated based on physical models
- Multi-pass writing

Throughput
- Massive number of beams with current density 2A/cm²
  - Total beam current is 500 nA, which is equal to beam current at maximum shot size in EBM-9000.
- High-speed BAA and data-path with real-time inline processing
## Tool configuration (EBM, MBM)

<table>
<thead>
<tr>
<th>Item</th>
<th>EBM-9500</th>
<th>MBM-1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accel. voltage</td>
<td>50 kV</td>
<td>50 kV</td>
</tr>
<tr>
<td>Cathode</td>
<td>1200 A/cm²</td>
<td>2 A/cm²</td>
</tr>
<tr>
<td>Beam current</td>
<td>500 nA @ max shot size</td>
<td>500 nA in total</td>
</tr>
<tr>
<td>Beam blur</td>
<td>(r)</td>
<td>(&lt; r)</td>
</tr>
<tr>
<td>Beam size</td>
<td>VSB ((\leq 250) nm)</td>
<td>beamlet (10 nm x 10 nm)</td>
</tr>
<tr>
<td>Field size</td>
<td>90 µm</td>
<td>512 x 512 beamlets in 82 µm x 82 µm area</td>
</tr>
<tr>
<td>Stage</td>
<td>Frictional drive with variable speed</td>
<td>Air bearing stage with constant speed</td>
</tr>
<tr>
<td>Data format</td>
<td>VSB12i, OASIS.MASK</td>
<td>MBF (polygon support), VSB12i, OASIS.MASK</td>
</tr>
<tr>
<td>Corrections for writing accuracy</td>
<td>PEC/FEC/LEC, GMC, CEC, GMC-TV, TEC</td>
<td>PEC/FEC/LEC, GMC, CEC, GMC-TV, EUV-PEC</td>
</tr>
</tbody>
</table>
Correction function

Offline dose modulation can be used for short range correction with VSB12i EL function.

$D(x)/2 + \eta \int D(x') g_p (x' - x) dx' + \theta \int D(x') g_F (x' - x) dx' = D_{th}$

- **Dose level adjusted by PEC/FEC**
- **Primary dose**
- **Proximity dose**
- **Fogging dose**

**No fogging effect**

**With fogging effect**

**interaction range [um]**

$10^{-3}$ $10^{-2}$ $10^{-1}$ $10^0$ $10^1$ $10^2$ $10^3$ $10^4$
MBM is capable of all corrections done by inline and real-time.

New inline correction function provides

- PEC, EUV-PEC, fidelity optimization
- Long-range correction (LEC/FEC) and beam-by-beam optimization.
Inline/realtime data path

Data integrity is checked during preceding mask writing and mask transfer.

PEC/FEC/LEC/GMC are applied.

Polygon pattern can be used

Systematic error compensation

Fidelity optimization

Create low level format data directly send to BAA

high-speed /parallel processing

EBI Initiative Taiwan seminar
## Standard specification

<table>
<thead>
<tr>
<th>Specification</th>
<th>EBM-9000</th>
<th>EBM-9500</th>
<th>MBM-1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Image Placement accuracy [nm 3σ]</td>
<td>3.0</td>
<td>2.1</td>
<td>1.5</td>
</tr>
<tr>
<td>CD Uniformity [nm]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global [3σ]</td>
<td>3.0</td>
<td>2.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Local [3σ]</td>
<td>1.3</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Beam blur</td>
<td>r</td>
<td>&lt;r</td>
<td>&lt; r</td>
</tr>
<tr>
<td>Mask write time [hours] (130mmx100mm)</td>
<td>-</td>
<td>-</td>
<td>12 @ 75 µC/cm²</td>
</tr>
<tr>
<td>Beam size [nm]</td>
<td>VSB (0.1 to 250)</td>
<td>VSB (0.1 to 250)</td>
<td>10</td>
</tr>
<tr>
<td>Current density [A/cm²]</td>
<td>800</td>
<td>1200</td>
<td>2</td>
</tr>
</tbody>
</table>
Throughput relative to Shot Count

♫ MB is advantageous with shot counts > ~200 Gshot/pass.
MB is advantageous for
- Shot count > 200 G/pass and
- Resist sensitivity > 75 uC/cm²

**VSB vs MBM-1000 Write Times**

- **MBM-1000 is better for this region**

- **EBM-9500**
  - (250 Gshot/pass)
  - (500 Gshot/pass)
  - (1000 Gshot/pass)

- **MBM-1000**
  - (independent of shot count)

4 pass writing
20 nm hp resolved within 70 um sq. area.

- Patterning quality was degraded at the area closed to perimeter of 82 um field.
## Patterning resolution test

<table>
<thead>
<tr>
<th></th>
<th>hp 16 nm</th>
<th>hp 20 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>horizontal</strong></td>
<td><img src="hp_16_nm_horizontal.png" alt="Image" /></td>
<td><img src="hp_20_nm_horizontal.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>vertical</strong></td>
<td><img src="hp_16_nm_vertical.png" alt="Image" /></td>
<td><img src="hp_20_nm_vertical.png" alt="Image" /></td>
</tr>
</tbody>
</table>

Resist images using ZEP520A
50 nm thickness @ 160 uC/cm²

MBM shows better than hp 20 nm resolution.
Local area writing by Alpha tool: Dec. 2015
- Demonstrated better resolution than EBM-9500

Test pattern full area writing: Mar. 2016

Beta tool beam on: Jul. 2016


Upgrade to high-speed data path: Q1 2017

First HVM delivery: Q4 2017
NuFlare, Integrating your needs…

Design & Development
Service
Quality
Manufacturing

THANK YOU !!!