Approaching High Volume Patterned Media Fabrication Using Jet and Flash™ Imprint Lithography

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Agenda

- Patterned Media Fabrication
  - Process flow overview
  - Disk cleaning
  - Adhesion layer coating – ValMat®

- Patterned Media Imprint Processes
  - Media imprint
    › DTR
    › BPM
  - Template replication

- Conclusions
**Key Technology Transitions to Support Areal Density Roadmap**

- **Longitudinal Recording**
- **Perpendicular Recording**
- **BPM**
- **BPM or HAMR**
- **Shingles/DTR**

Timeline:
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011
- 2012
- 2013
- 2014
- 2015

Graphical representation showing the transition from longitudinal to perpendicular recording and the introduction of BPM or HAMR technologies.
**Post-sputter Disk Clean Process**

- Post-sputter disk cleaning to enable imprint longevity and yield
  - Remove particles created during sputtering process
    - Minimize imprint defectivity
    - Eliminate template damage
  - Remove organic contamination
    - Prepare for a uniform adhesion layer coating

- Introduce SC-1 to efficiently clean the post-sputter disk with various top coating layers
  - Close to 100% large particle removal efficiencies
  - High Small particle removal efficiencies
    - Small particle count after cleaning are largely dependent on post sputter particle count

**Disk Particle Counts Post Cleaning**

<table>
<thead>
<tr>
<th>Disk</th>
<th>Large Particles (&gt;300nm)</th>
<th>Small Particles (&lt;300nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q4 09'</td>
<td>0.1</td>
<td>15.1</td>
</tr>
<tr>
<td>Q2 10’</td>
<td>0.3</td>
<td>4.8</td>
</tr>
</tbody>
</table>

- Representative post cleaning particle map (left) and count (above) on Ta coated 65mm disks using Candela 6120.
- Particle size is based on PSL calibration
ValMat® Adhesion Layer Coating

- **Purpose of ValMat® coating**
  - Acts as an adhesion layer between resist and substrate
  - Enable imprint longevity and yield
  - Improves fluid spread on the disk and increase throughput

- Compared to DUV30J, ValMat® demonstrates 10X enhancement in adhesion on a Ta surface
- Adhesion force on Si, SiO₂ and SiNₓ exceed Ta surface

![Graph of Adhesion Force (lbf)]

<table>
<thead>
<tr>
<th>Disk</th>
<th>Adhesion Force (lbf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>45.26</td>
</tr>
<tr>
<td>Stdev</td>
<td>4.07</td>
</tr>
</tbody>
</table>

Adhesion shear test results on 40nm Ta coated disks
ValMat® Film Uniformity

- ValMat® film forms a self-assembled monolayer on disk surface
- Self-limiting ValMat® shows an average thickness of 1nm with < ±10% non-uniformity
- ValMat® film thickness is verified by a small angle FTIR measurement

Representative Candela 6120 image
**ValMat® Process Cleanliness**

### Candela particle map

<table>
<thead>
<tr>
<th></th>
<th>Pre - Coat</th>
<th>Post - Coat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image1.png" alt="Candela particle map" /></td>
<td><img src="image2.png" alt="Candela particle map" /></td>
</tr>
</tbody>
</table>

### Coating Process Particle Adders

<table>
<thead>
<tr>
<th></th>
<th>Particle Adders</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Disk</td>
<td></td>
<td>Avg</td>
<td>Stdev</td>
<td>Avg</td>
<td>Stdev</td>
<td>Avg</td>
<td>Stdev</td>
</tr>
<tr>
<td>(&gt;300nm)</td>
<td>0.1</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.3</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>(&lt;300nm)</td>
<td>0.2</td>
<td>0.6</td>
<td>0.6</td>
<td>0.2</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
</tbody>
</table>

- **0.3 particle adders per disk surface**
- **Clean vapor deposition process**
Final Disk Particle Counts
Post Cleaning & Coating Processes

- Efficient disk cleaning process and clean ValMat® vapor coating
  - Observed particles from metrology tools and environment, i.e., manual disk handling

- Enables low defectivity imprint
  - Imprint defect area ratio <10\(^{-5}\)

<table>
<thead>
<tr>
<th>Average Particles (&gt;300nm)</th>
<th>Large Particles (&lt;300nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>17.4</td>
</tr>
</tbody>
</table>

Example Candela scan data of cleaned and coated disk ready for imprint
Defect Progression: Imprint self-cleaning

- 2 defects from Disk 1 removed by Disk 53
- 3 defects added at Disk 53

Imprint self-cleaning

Jet and Flash™ Imprint Lithography (J-FIL™)

Step 1: IntelliJet™ Drop Deposition
- Enables imprinting of variable pattern densities
- Zero imprint chemical and materials waste
- No specialized, double-sided spin-coater required
- Process is inherently cleaner than spin-on
- Disk cleaning and ValMat® layer improve the resist spread

Step 2: Controlled Pattern Fill
- Improved pattern fidelity through low, uniform pressure and resist viscosity
- Soft contact on liquid drops extends template life
- ValMat® adhesion layer improve the resist spread
- Disk cleaning is required for sub 10nm and uniform residual layer thickness

Step 3: UV Exposure
- No thermal distortions
- Fast process, no heat & cool down cycle required

Step 4: Low Separation Force
- Minimizes defectivity and improves pattern fidelity
- Eliminates template damage or breakage
Full Surface Disk Imprint – 50nm Pitch DTM

Double-sided imprint at 300+ disks/hour on NuTera™ HD7000

<table>
<thead>
<tr>
<th>Imprint Feature</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DTM region</td>
<td>14~31mm</td>
</tr>
<tr>
<td>Track pitch</td>
<td>50nm</td>
</tr>
<tr>
<td>Track line width</td>
<td>25nm</td>
</tr>
<tr>
<td>Duty cycle</td>
<td>1:1</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>1.64</td>
</tr>
</tbody>
</table>

Q_{absphase} images of representative imprinted disk on Candela 6120
Disk Imprint Feature Fidelity

Representative top-down SEM image Of an imprinted disks

Average imprint line width = 25.6nm

<table>
<thead>
<tr>
<th></th>
<th>CD uniformity &lt;1σ&gt; [nm]</th>
<th>Line Width Roughness &lt;3σ&gt; [nm]</th>
<th>Line Edge Roughness &lt;3σ&gt; [nm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Template</td>
<td>5.1</td>
<td>8.2</td>
<td>5.3</td>
</tr>
<tr>
<td>Imprint</td>
<td>1.0</td>
<td>5.5</td>
<td>4.1</td>
</tr>
<tr>
<td>After exclude template contribution</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

- SEM & Simagis are used for analysis (based 12 SEM images per disk)
- SEM resolution & Simagis analysis algorithm limits the analysis resolution

Excellent imprint feature fidelity
Reproducible Imprint

Good repeatability of imprint quality

1st imprint 50th imprint 100th imprint

Candela Q\text{phase\ scan}

AFM shows an average RLT = 10nm with RLT range = 5nm
- Noticed thin RLT of 3nm at ~50\mu m of DTM edge
  - expect to be within 5nm RLT range with improved template design

<table>
<thead>
<tr>
<th></th>
<th>RLT 1st Imprint [nm]</th>
<th>RLT 100th Imprint [nm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>8.8</td>
<td>8.2</td>
</tr>
<tr>
<td>overall range</td>
<td>4.6</td>
<td>3.1</td>
</tr>
</tbody>
</table>
1 Tb/inch² BPM Imprint

Current MII imprint technology is compatible with BPM.

Imprint with a full surface BPM template fabricated by using self-assembled block co-polymer

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>StdDev</th>
<th>Stdev/mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dot diameter [nm]</td>
<td>16.6</td>
<td>1.1</td>
<td>5.6%</td>
</tr>
<tr>
<td>Dot area [nm²]</td>
<td>216.2</td>
<td>21.4</td>
<td>9.8%</td>
</tr>
<tr>
<td>RLT [nm]</td>
<td>~8nm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
HDD Template

150 mm Template

- Fused silica
- Center mark/barcode
- Template Auto-alignment
- Disk Auto-alignment
- Patterned Media

Fabricated DTM (50nm TP) working replica template

EB Resist Image
Qz Master Template Image
Imprint Resist Image
Working Replica Cross-section Image

Quartz Etching
Nano-imprint (MII TR1100)
Quartz Etching

36nm 14nm 54nm
Conclusions

Approaching High Volume Patterned Media Fabrication Using Jet and Flash™ Imprint Lithography

- Pre-imprint disk wash enables imprint longevity, and yield improvement, and enhance template lifetime
- ValMat® vapor deposition provide excellent adhesion and uniformity, low particle adders and improve the resist spread
- NuTera™ HD7000 imprint tool demonstrates excellent imprint capability at > 300 disks/hr
  - Good feature fidelity
  - Sub-10nm average residual layer thickness
  - Good imprint reproducibility
- MII imprint technology is capable of BPM imprint beyond 1Tb/inch²