The Challenges for Semiconductor Design

The Maskmaker’s Perspective

Taiwan + China Semiconductor Industry Outlook 2004
Outline

- A mask company addressing design?!?!
- Fabless-Foundry trends
- Effects on, and of, Taiwan and China
The mask is the first point at which design data are reduced to a physical object (mask makers maintain design data “vaults”)

Mask technology drives the performance, capability, and reliability of semiconductors

Lithography/mask performance limitations cause design complexity (RETs, or Optical Proximity Correction and Phase Shifting Masks)

The mask maker’s view of semiconductor manufacturing.
EDA s/w enables lithography solutions (RETs: OPC, PSM) that weren’t required at large design rules.
To maintain manufacturability and yields, mask complexity has increased.

<table>
<thead>
<tr>
<th></th>
<th>0.25 µm</th>
<th>0.18 µm</th>
<th>0.13 µm</th>
<th>0.09 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit design</td>
<td></td>
<td>DRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mask design</td>
<td></td>
<td></td>
<td>Rules-based OPC</td>
<td>PSM, fill</td>
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<td>Model-based OPC</td>
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<tr>
<td>Tapeout</td>
<td></td>
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<tr>
<td>Mask build</td>
<td>MDP</td>
<td></td>
<td></td>
<td>mOPC</td>
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<tr>
<td>Wafer build</td>
<td></td>
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Fabless/foundry trends I

Mask merchants were the original “front end” foundries ⇒ let’s learn from this

- Captive consolidation due to high mask manufacturing costs
- Centralized R&D ⇒ technology deployment for mfg near the customer
- Customers incorporate mask effects into IC design
Less Mask Companies Over Time

~50% decrease every 10 years

<table>
<thead>
<tr>
<th>Year</th>
<th>Captives</th>
<th>Merchants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>42</td>
<td>18</td>
</tr>
<tr>
<td>1995</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>2004</td>
<td>12</td>
<td>8</td>
</tr>
</tbody>
</table>

Graph showing the decrease in the number of mask companies from 1985 to 2004.
IC foundry trends

- IDMs offload excess production demands
  Provide manufacturing technology to foundry partner(s)

- Fabless companies focus on design and distribution

- Customers incorporate foundry manufacturing rules into IC design

- Foundry may or may not have mask capability
Companies building IC fabs at each node

Chief beneficiaries at 130 nm:
Taiwan foundries

# of Companies with Fabs

130 nm
65 nm
32 nm
IC and mask foundry models

- **Integrated IC-mask foundry model**
  - Easy initial integration of mask into design process
  - No competition $\Rightarrow$ more expensive masks

- **Separate IC-mask foundry model**
  - Requires conscious, tight communication between designer and both foundries
  - Competition $\Rightarrow$ less expensive masks
## Collaboration Models

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Companies</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC process R&amp;D cost sharing</td>
<td>ST Microelectronics, Freescale, Philips</td>
<td>France</td>
</tr>
<tr>
<td>Mask R&amp;D &amp; manufacturing</td>
<td>AMD, DuPont Photomasks, Infineon</td>
<td>Germany</td>
</tr>
<tr>
<td>Chip performance, yield, and manufacturability</td>
<td>Applied Materials, ARM, Artisan, Cadence, TSMC</td>
<td>Distributed</td>
</tr>
</tbody>
</table>
Taiwan and China markets

Taiwan
- IC demand << production capacity
  ⇒ IC exporter
- Full technology range
- Very large mask market
- Strong foundry investment

China
- IC demand >> production capacity
  ⇒ IC importer
- Most technology > 250 nm DR
- Mask market < 5% of global total
- Strong foundry investment

Relative Sizes of Mask Markets

<table>
<thead>
<tr>
<th>Country</th>
<th>Relative Size (Value)</th>
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</thead>
<tbody>
<tr>
<td>China</td>
<td>Low</td>
</tr>
<tr>
<td>Europe</td>
<td>Low</td>
</tr>
<tr>
<td>Japan</td>
<td>High</td>
</tr>
<tr>
<td>Korea</td>
<td>Medium</td>
</tr>
<tr>
<td>ROW</td>
<td>Low</td>
</tr>
<tr>
<td>Taiwan</td>
<td>High</td>
</tr>
<tr>
<td>USA</td>
<td>Medium</td>
</tr>
</tbody>
</table>
Photomask technology in China

- Install mature manufacturing technology

- For most Chinese IC mfrs: 180/130 are next two nodes
  - Lithography strategy is already defined
  - Modest R&D investment is needed
  - Advantage: very fast time-to-market

- DPI approach: match market and technology requirements
  - Local capacity
  - Local capability
  - Regional support: meet advanced technology requirements

DuPont Photomasks, Inc.
Perfectly Focused.
Summary

- Masks bridge semiconductor design and manufacturing
  - Mask design is a yield enabler at advanced nodes
  - The mask is an optical element in semiconductor lithography

- The semicon foundry trend is similar to the mask foundry trend
  - Consolidation into fewer producers
  - Supplier and customer focus on what each does best
  - Collaboration models are developing and maturing

- Taiwan and China have become the foci of the foundry trend
  - Different markets, different production capabilities
  - China market is just emerging, mainly at mature mfg nodes