Comparison of Thin-Film Aluminum Deposition

By: Sarah Ip, Mills High School
OBJECTIVE

To compare thin-film aluminum deposition using:

1) Resistivity
2) Uniformity
3) Deposition Rate
OUTLINE OF PROJECT

- Cleaning Wafers & Oxide Growth
- Sputtering
  - Novellus m2i Sputtering System
  - Edwards Auto 306DC and RF Sputter Coater
  - CPA Sputtering System
- Evaporating
  - NRC Evaporator
  - Veeco 401 Vacuum System
  - Edwards eb3 Electron Beam Evaporator
- Photolithography & Etching
MEASUREMENT TOOLS & METHOD

NANO SPEC
- thickness of oxide
- reflectance

ASIQ
-step measurement

4 POINT PROBE
- resistivity

• systematic measurement of top, center, flat, left, right
CLEANING WAFERS & OXIDE GROWTH

Sink 6
- Piranha (Sulfuric Acid) with $\text{H}_2\text{O}_2$
  - strong oxidizer- removes organic contamination
  - Creates some $\text{SiO}_2$
  - HF- dissolves $\text{SiO}_2$
    - remove metallic contamination

Tystar 3
- Recipe: 3WETOX
- Temperature: 1000°C
- Time: 10 min 30 sec
- Steam to oxidize Si $\rightarrow$ faster than when dry
Plasma (Argon gas) is ejected into the sputtering target, which releases clusters of aluminum particles onto the substrate (wafer).
Metal is heated on through a filament, crucible, or metal plate. The evaporated metal is, then, condensed onto the substrate or wafer.

For an electron beam evaporator, an electron beam bombards the metal which evaporates onto the substrate or wafer.
## COMPARISON OF SPUTTERING AND EVAPORATING

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evaporating</strong></td>
<td>• consumes an efficient amount of aluminum</td>
<td>• time consuming</td>
</tr>
<tr>
<td></td>
<td>• more cost efficient (little Al per use)</td>
<td></td>
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<td></td>
<td>• versatile in ability to change metals</td>
<td></td>
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<tr>
<td><strong>Sputtering</strong></td>
<td>• quick aluminum deposition</td>
<td>• large machine (space is necessary)</td>
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<tr>
<td></td>
<td></td>
<td>• expensive aluminum sheet for large target</td>
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<tr>
<td></td>
<td></td>
<td>• difficult to change metal</td>
</tr>
</tbody>
</table>
# DATA ANALYSIS

<table>
<thead>
<tr>
<th>Wafer</th>
<th>Non-Uniformity (%)</th>
<th>Bulk Resistivity (Ω-cm)</th>
<th>Overall Time (Hr)</th>
<th>Deposition Rate (Å/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novellus (25)</td>
<td>13.45</td>
<td>0.0414392</td>
<td>1/6</td>
<td>279.6</td>
</tr>
<tr>
<td>Novellus (26)</td>
<td>11.06</td>
<td>0.02634984</td>
<td>1/6</td>
<td>550</td>
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<tr>
<td>Edwards (13)</td>
<td>10.84</td>
<td>0.1126076</td>
<td>4</td>
<td>53.44</td>
</tr>
<tr>
<td>CPA (2)</td>
<td>1.1</td>
<td>0.03399536</td>
<td>4</td>
<td>N/A</td>
</tr>
<tr>
<td>NRC (5)</td>
<td>9.48</td>
<td>0.7033494</td>
<td>2</td>
<td>242.47</td>
</tr>
<tr>
<td>V401 (12)</td>
<td>12.39</td>
<td>0.184477</td>
<td>2</td>
<td>251.8</td>
</tr>
<tr>
<td>Edwards eb3 (31)</td>
<td>21.95</td>
<td>0.06602736</td>
<td>4</td>
<td>150</td>
</tr>
</tbody>
</table>

- Non-Uniformity = (max-min)/avg
- Bulk Resistivity = resistivity*thickness
<table>
<thead>
<tr>
<th>Wafer</th>
<th>Pre-thickness of Oxide</th>
<th>Post-thickness of Oxide</th>
<th>Reflectance at 640 nm (% relative to Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novellus (25)</td>
<td>1084.4</td>
<td>1029.2</td>
<td>244.8</td>
</tr>
<tr>
<td>Novellus (26)</td>
<td>1218.4</td>
<td>1041.8</td>
<td>226</td>
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<tr>
<td>Edwards (13)</td>
<td>984.8</td>
<td>1007.6</td>
<td>217.2</td>
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<tr>
<td>CPA (2)</td>
<td>999.4</td>
<td>1432.8</td>
<td>234.4</td>
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<td>NRC (5)</td>
<td>1001.4</td>
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<td>160.4</td>
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<td>V401 (12)</td>
<td>1004.8</td>
<td>1004.8</td>
<td>212.2</td>
</tr>
<tr>
<td>Edwards eb3 (31)</td>
<td>1237.4</td>
<td>1193</td>
<td>196</td>
</tr>
</tbody>
</table>
OBSTACLES

- When using NRC(1) and V401(2),
  1) a shadow formed, not allowing an even coat of aluminum
  2) the aluminum became tinted with a golden color
Solution: Re-do 2 wafers for each machine

- When developing, some of the photo-resist did not develop properly, creating an inability for the CPA wafer to etch.
Solution: Develop the wafer for a longer duration of time by developing twice
• In a lab setting, evaporating is advantageous because it is cost efficient. Although evaporating is time consuming, labs are not mass producing, therefore, mitigating the problem of time.

• Novellus outperforms in deposition rate, time, resistivity, and reflectance.

• CPA produces the most uniform layer of aluminum.
ACKNOWLEDGEMENTS

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