Resistive coating on spacers by ALD

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Anil Mane, Qing Peng, Jeffrey Elam
ALD Research Program, Process Technology Research Group
Energy Systems Division.
Background:

To align 8”x8” MCP(s) stacking use of rod and spacers with appropriate resistance to reduce charging effect.

Prior to 8”x8” MCP pair testing, use of 4 pairs of 33mm MCPs with 4 holes for the rods and spacers.

**Concept #1**

A pairs of 33mm MCPs with 4 holes for rods and spacers.
Spacers resistance calculation:

- The goal is to tune the resistance of the spacers as per applied MCPs voltages.

Each pair of MCP will have 12 spacers:
- 4x 0.5mm
- 4x 1mm
- 4x 2.5mm

![Image showing spacers and calculation formula]

\[ R_{\text{spacer}} = \rho h / (\pi t (d_1 + d_2)) \]

Assume film thickness \( t = 100 \text{ nm} \)

<table>
<thead>
<tr>
<th>Name</th>
<th>Height ( h ) (mm)</th>
<th>( V ) (V)</th>
<th>( I ) (µA)</th>
<th>( R_{\text{tot}} ) (MΩ)</th>
<th>( N_{\text{spacer}} )</th>
<th>( R_{\text{spacer}} ) (MΩ)</th>
<th>Resistivity ( \rho ) (Ω·cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spacer 1</td>
<td>1.0</td>
<td>200</td>
<td>100</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>2.55e3</td>
</tr>
<tr>
<td>MCP1</td>
<td>1.2</td>
<td>1200</td>
<td>100</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>6.59e6</td>
</tr>
<tr>
<td>Spacer 2</td>
<td>0.5</td>
<td>100</td>
<td>100</td>
<td>1</td>
<td>4</td>
<td>8</td>
<td>2.55e3</td>
</tr>
<tr>
<td>MCP2</td>
<td>1.2</td>
<td>1200</td>
<td>100</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>6.59e6</td>
</tr>
<tr>
<td>Spacer 3</td>
<td>2.5</td>
<td>500</td>
<td>100</td>
<td>5</td>
<td>4</td>
<td>8</td>
<td>2.55e3</td>
</tr>
<tr>
<td>Total</td>
<td>6.4</td>
<td>3200</td>
<td>100</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>2.55e3</td>
</tr>
</tbody>
</table>
Spacers resistance measurement in-situ set-up:

Thickness monitors

Before ALD

After ALD
In-situ tuning of spacers resistance with ALD chem-1:

- Achieved right resistance range for the spacers by varying the ALD process parameters

Total resistance spacers \( R = R_1 + R_2 + R_3 \)

E.g. if
a) \( I = 100\,\mu\text{A} \Rightarrow R = 8\,\text{M}\Omega \)
b) \( I = 50\,\mu\text{A} \Rightarrow R = 16\,\text{M}\Omega \)
c) \( I = 25\,\mu\text{A} \Rightarrow R = 32\,\text{M}\Omega \)

![Graph showing resistance vs. number of ALD cycles for different spacer compositions and thicknesses.](image-url)
Batch processing of the spacers (for statistics):

- 44 spacers deposited simultaneously
- Uniform coating appearance on all spacers
Photographs of the spacers

• Prior to ALD 5min ultrasonic acetone clean/dry
• Uniform and conformal deposition on spacers
Spacers resistance range:

Spacer thickness 0.5mm $R = 6-16\,\text{M}\Omega$

Spacer thickness 1mm $R = 8-18\,\text{M}\Omega$

Spacer thickness 2.5mm $R = 14-55\,\text{M}\Omega$

Variation may cause by:
- Both side spacer roughness
- Electrical contact (No contact electrode)
- Size variation
- ALD reactant gradient across length
0.5mm spacers resistance comparison (glass vs. alumina)

- 0.5mm glass spacers are very brittle compared to alumina.
- Noticed size (height) variation for both glass and alumina.
- Alumina spacers have non-uniform cutting.
Follow-up work:

**Question: Grid or Spacers?**

- Fine tuning of spacers resistance
- Oreo cookie fabrication
- Electrical performance testing
- Work on alternative scheme “concept #2” \( \rightarrow \) grid spacer
- Grid spacer resistance tuning