The Effect of Ash Processes on Inorganic Porous Low-k Materials
Lei Jin, Anil Bhanap, Anna Camarena, Ananth Naman
Honeywell Electronic Materials
Carlo Waldfried
Axcelis Technologies, Inc.

Outline
• Background/Motivation
• Effects of Downstream Ash
• Effects of In-Situ RIE Ash
• Evaluation of New Ash Chemistries
• SLM (Single Layer Metal) Integration
• Conclusions

Why the Need for Low-k
It’s all about speed
Preservation of Porosity and Composition of Si-C-OH Materials Dictate Process Window

Low-k Materials Choices

Deposition Process | Candidate Materials | k value | Vendor
--- | --- | --- | ---
CVD | Black Diamond™ | < 3.0 | Applied Materials
| Local™ | 2.5-3 | Novellus
| Aurora™ | 2.0-2.7 | ASMI
| Orion™ | 2.0-2.5 | Trikon
| LKQ-109 | 2.2 | JSR
| HOSPER™ | 2.5 | Honeywell
| NANOGLASS™ | 1.5-2.9 | Honeywell
| NIX-2™ | 1.9-2.2 | Dow Chemical
| Zircon™ | 1.9-2.7 | Shipley

Low-k Materials Integration Challenges

Patterning
- Photo resist poisoning
- Etch profile control
- Ash damage (Surface limiting or Bulk)
- Wet clean compatibility

Metallization
- CTE mismatch between Cu and Low-k materials
- Step coverage / Side wall roughness

 CMP
- Adhesion of Low-k materials
- CMP delamination

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As transistor size shrinks, the interconnect dominates propagation delays
Effects of Conventional Downstream Ash - Dimension

Side-wall bowing was observed after conventional downstream O₂ ashing.

Effect of Conventional Downstream Ash - Composition

All organic species are lost after conventional downstream ash process as indicated by the disappearance of SiC and CH peaks in FTIR spectra.

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In-situ RIE Ash - Dimension

Use of an in-situ RIE ash preserves CD.

Effect of Etch & In-situ Ash on Surface Carbon Depletion

- Etch results in 35% carbon depletion @ surface
- Etch+Ash results in 80% carbon depletion @ surface

Effect of Oxidative Ash

<table>
<thead>
<tr>
<th>Treatment</th>
<th>%C (C-C,H)</th>
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<tbody>
<tr>
<td>Control</td>
<td>16.1</td>
</tr>
<tr>
<td>Etch</td>
<td>11.9</td>
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<td>Etch/O₂ ash</td>
<td>2.7</td>
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<tr>
<td>Etch/O₂ ash/DI</td>
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</table>

Effect of Reductive Ash

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<tr>
<th>Treatment</th>
<th>%C (C-C,H)</th>
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<tr>
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<tr>
<td>Etch</td>
<td>11.9</td>
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<td>Etch/N₂-H₂ ash</td>
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<td>Etch/N₂-H₂ ash/DI</td>
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</tbody>
</table>

Effect of Etch & In-situ Ash - Dimension

Significant carbon depletion in the bulk is measured after etch and ash processes.

Effect of Etch & In-situ Ash - Composition

- SIC/SO
- CHg%
- SiSO
Consequence of C-depletion in Porous SiCOH Materials

Voids are observed in porous dielectric layer after pre-CMP Cu anneal.

Possible Mechanism

Major factors in porous inorganic dielectric voiding:
C-depletion, Stress

Process Flow:

Process Optimization of H$_2$/He Ash

• H$_2$/He ash is less destructive than Std. Ash
• Selection of process conditions (ash temp/time) depends on resist removal rate and minimal damage to Low-k material
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SEM Images of SLM Structures

Voids in porous Low-k materials can be significantly reduced by using H₂/He plasma strip instead of in-situ RIE ash.

SLM Electrical Test Data

- Comb capacitance for O₂ ash is significantly higher than H₂/He ash before degas.
- Post degas capacitance is similar for both. This indicates significantly lower moisture absorption in the case of H₂/He ash.
- RC product is similar for the two conditions.

Summary

- Conventional downstream O₂ ash results in both dimensional change (bowed profile) and compositional change (carbon depletion) in porous Si-C-OH dielectrics.
- In-situ RIE ash does not affect etch profile, but results in significant carbon depletion (40-50%) which will lead to voiding in porous Si-C-OH dielectrics.
- Modified H₂/He ash process can minimize carbon depletion and therefore significantly reduce voiding in porous Low-k materials.
- Electrical data indicates usage of H₂/He ash results in improved dielectric performance (capacitance) to conventional ash processes.

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