JSR CMP introduction
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COMPANY INTRODUCTION
Company introduction

JSR has 60+ years of chemical expertise and gradually diversified to 4 main business units.

“With chemistry, we can”
About 40 years ago, JSR entered the semiconductor market through g-line lithography, and gradually entered other segments including CMP in the 1990s.
JSR global network

JSR relies on its global network to offer the best support, locally and globally.
JSR CMP SLURRIES
CMP slurries

• JSR offers a series of metal and dielectric slurries with various levels of selectivity, for bulk and buff applications.

• Still active on legacy nodes, JSR is also at the forefront of innovation for emerging applications.

• Innovation is achieved through fundamental understanding of the key mechanisms at play during the CMP and cleaning processes using a comprehensive toolset.

• Today’s update focuses on Ru and W.
CMP requirements

Customer's Requirement
- Planarity
- Defectivity
- Cost

In detail
- Removal Rate
- Selectivity
- Line width dependency
- Corrosion
- Scratch
- Residue
- Concentration
- Raw material cost, manufacturability etc.

Method
- Electro chemistry
- Surface chemistry
- Particle dispersion

Application
- Cleaning solution
- Slurry

Key Technologies
Tungsten CMP

Corrosion check

Relation of W corrosion and chemical groups

Good passivate surface

Increased!!!
corrosion

Oxidation Status
Understanding of various W oxidation status

Etching
Protection

Type of chemical group

Oxidation potential with oxidizer

Corrosion check

Protection

Corrosion

Increased!!!
corrosion

Oxidation Status
Understanding of various W oxidation status

Oxidation Reaction

Etching

Understand the etching reaction with chemical groups
JSR developed several bulk/buff slurries for W featuring:
- Various levels of selectivity to oxide
- Low defectivity
- Low corrosion
- High planarity

Bulk slurry RR and SER

Buff slurry RR and SER

Tungsten CMP

Profile variation before (blue) and after (red) polishing. Left: no planarity control. Right: with planarity control additive.

SEM picture with (left) standard slurry showing corrosion traces and (right) JSR W slurry including corrosion inhibitor.
Ruthenium CMP

Advance nodes will require an alternative to Cu for local interconnects such as Ru. JSR has been working on developing CMP slurries and p-CMP cleaners to address this emerging need. Several challenges come with Ru CMP:

- Risk of toxic RuO$_4$ formation in acidic regions.
- High hardness leads to polishing difficulties (low RR, bad planarity, high defectivity).


<table>
<thead>
<tr>
<th>Mohs hardness</th>
<th>Ru</th>
<th>6.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tantalum</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>Titan</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>Cobalt</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td>2.8</td>
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</table>

Removal rate

Chemical contribution

Mechanical contribution

Oxidizer

Chelator

Abrasive

Process

Surface properties

Type

Size
Ru CMP – chemical contribution

The strength of the oxidizer is an efficient knob to tune the Ru removal rate, but it can also cause the formation of undesired by-products like RuO$_4$. 

![Graph showing removal rate and RuO$_4$ formation](image-url)
Ru CMP – mechanical contribution (I)

The abrasive size and concentration have a moderate to strong impact on the removal rate.

Ru RR vs abrasive concentration

Ru RR vs abrasive size
Ru CMP – mechanical contribution (II)

The abrasive type and concentration largely influence the Ru removal rate.

Ru RR vs abrasive type

Ru RR vs abrasive C concentration

Removal Rate [Å/min]

Silica | Abrasive A | Abrasive B | Abrasive C
--- | --- | --- | ---
57 | 25 | 207 | 340

Removal Rate [Å/min]

Abrasives A, B, C

Removal Rate [Å/min]

0.25 | 0.50 | 0.75 | 1.00
197 | 288 | 337 | 376
Ru CMP – mechanical contribution (III)

With abrasive C system (see previous slide), the addition of H2O2 leads to an increased Ru RR through the formation of •OH radicals.

Impact of H2O2 on Ru RR

Electron spin resonance for H2O2, abrasive C, and both

Black: H2O2  
Red: Abrasive C  
Green: Abrasive C + H2O2

- •O2^−  
- •OH

Elemental Composition [Atomic%]

Before CMP  
After CMP

MOx  
MOy
JSR POST-CMP CLEANERS
Post-CMP cleaning solutions

JSR formulates post-CMP solutions targeting low corrosion and low overall defectivity.

<table>
<thead>
<tr>
<th>Technology Node (nm)</th>
<th>≥ 32</th>
<th>28</th>
<th>20</th>
<th>16-14</th>
<th>10</th>
<th>7-5 ≥</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrier Metal Type</td>
<td>Ta/TaN</td>
<td>Ta/TaN, Co</td>
<td>Co, Ru?, Mn?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleaner Trend</td>
<td>Acid type</td>
<td>Alkaline type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**JSR Post Cu CMP Cleaning Solution**

- **JSR clean for legacy nodes**
- **JSR clean for advanced nodes**

**Concept & Typical Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design Concept</strong></td>
<td>TMAH-free, Metal protection</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>13 (as product) → 11 (at POU)</td>
</tr>
<tr>
<td><strong>Cu Etching Rate [Å/min]</strong></td>
<td>&lt;0.5</td>
</tr>
<tr>
<td><strong>Co Etching Rate [Å/min]</strong></td>
<td>&lt;0.5</td>
</tr>
<tr>
<td><strong>Ru Etching Rate [Å/min]</strong></td>
<td>0</td>
</tr>
</tbody>
</table>
SUMMARY
Summary

• JSR has 40+ years of experience in the semiconductor industry, among which 20+ specifically in CMP.

• We have proven HVM materials for legacy and advanced nodes and strong R&D activities for metal and dielectric polishing/cleaning with versatile properties.

• JSR R&D leverages a deep fundamental understanding of the process to design innovative and high-performance CMP consumables.
Thank you
Nitrogen-containing additives were reported as efficient Ru chelating agents.

\[
\text{Ru oxidation by H}_2\text{O}_2 \\
\text{Ru} + 2\text{H}_2\text{O}_2 \rightarrow \text{RuO}_2 + 2\text{H}_2\text{O} \\
\text{H}_2\text{O}_2 \rightarrow 2\cdot\text{OH} \\
\text{(Ru hydration)} \\
\text{RuO}_2 + 4(\text{OH})^- \rightarrow (\text{RuO}_4)^{2-} + \text{H}_2\text{O} + 2\text{e}^- \\
\text{(Ru reformation by di-amine)} \\
\text{NH}_2\cdot\text{R}^-\cdot\text{NH}_2 + 2\text{H}_2\text{O} \rightarrow \text{NH}_3^+\cdot\text{R}^-\cdot\text{NH}_3^+ + 2\text{OH}^- \\
\text{NH}_3^+\cdot\text{R}^-\cdot\text{NH}_3^-\cdot\text{RuO}_4^-\cdot\text{NH}_3^+\cdot\text{R}^-\cdot\text{NH}_3^-\cdot\text{RuO}_4
\]
Ruthenium slurries

<100 defects >110nm with abrasive 1.