New Cu and Co Metallization Enabling Multiple Integrations

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aveni¹; Leti²; STMicroelectronics³
Outline

Part I: Copper Wet Seed Deposition for TSV Integration

- Polyvalent deposition process
- Integration and electrical results

Part II: Cobalt Wet Metallization for Damascene and Packaging Applications

- Novel Zip Filling mechanism
- Film Parameters and Performance
• Headquarter in Massy + International presence
• Wet metallization for advanced features regardless of topography
  ➢ Electroplating & Electroless
• Long-term partnership with CEA Leti
# Product Portfolio

<table>
<thead>
<tr>
<th>Copper</th>
<th>Cobalt</th>
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<tbody>
<tr>
<td><strong>Sao™ &amp; Rhea™</strong></td>
<td><strong>Kari™</strong></td>
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</tbody>
</table>

## Applications:

**Copper**
- Damascene-critical metal levels
- Through Silicon Via (TSV)

**Cobalt**
- Damascene-critical metal levels
- Contact plugs
- Memory stacking
Part I : Rhea Wet Copper Seed for TSV Integration
Many Types of TSV are Targeted

**TSV Last**
- Diameter: 40-90 µm
- Aspect Ratio: 5:1
- Temp < 200°C

**TSV Mid-process**
- Diameter: 2-10 µm
- Aspect Ratio: 10:1
- Temp < 400°C

**Advanced TSV**
- Diameter: 2-10 µm
- Aspect Ratio > 15:1
- Temp < 400°C

**HD TSV**
- Diameter: 1 µm
- Aspect Ratio > 10:1
- Temp < 400°C

Increasing Technical Challenges
Why Increase TSV Aspect Ratio?

- Wafer bow compensation
- Increase silicon thickness
- Deeper TSVs
- Denser TSVs
- Smaller TSV diameter

Advanced barrier and seed layer deposition enabling multiple type of TSVs integration, T. Mourier & al., IMAPS 2019
Rhea Cu Seed Layer Applications

On standard PVD

Standard PVD seed layer

Seed repair

On Flash PVD

Flash PVD adhesion layer

Direct on Barrier

Rhea ensures excellent step coverage for 10 x 120 µm mid-process TSV

Step coverage on 10x120 µm Mid process TSV

Advanced barrier and seed layer deposition enabling multiple type of TSVs integration, T. Mourier & al., IMAPS 2019
12:1 Electrical Results – Kelvin

Cumulative TSV Kelvin Resistance

MoCVD TiN + Standard PVD Cu:
- 10x100 with Rhea seed repair
- 10x120 with Rhea seed repair
- 10x100 no Rhea

PVD 10x100 µm

Theoretical value is 32.5 mOhm

10x100 µm

10x120 µm

Rhea Cu seed gives tight distribution and excellent yield

12:1 aspect ratio mid-process TSV integration and electrical tests using advanced metallization processes, C. Aumont & al., IMAPS 2018
12:1 Electrical Results – Chain

Cumulative Resistance of 754 TSV Daisy Chain

- **10x120 MoCVD TiN + Standard PVD + Rhea seed repair**
- **10x120 MoCVD + Flash PVD + Rhea seed repair**

**Rhea on Flash PVD**

**Rhea on Standard PVD**

**TSV Daisy Chain**

- F-line
- B-RDL

**12:1 aspect ratio mid-process TSV integration and electrical tests using advanced metallization processes, C. Aumont & al., IMAPS 2018**
TSV Rhea Cu Seed Ready for 15:1

Rhea in **10 x 150 µm** TSV (15:1)

**Thicknesses**
- 400 nm
- 130 nm
- 57 nm
- 50 nm

Step coverage: 13%

Rhea in **0.7 x 10 µm** TSV (15:1)

Void-free fill

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Advanced barrier and seed layer deposition enabling multiple type of TSVs integration, T.Mourier & al., IMAPS 2019
Cu Seed Extends PVD Cu Capability For Advanced TSV

MoCVD TiN + PVD Cu  |  Rhea Cu seed  |  ECD Fill

PVD Cu seed discontinuity  |  Continuous Rhea Cu seed repair  |  Void-free fill

Rhea Cu seed is compatible with challenging TSV topology

Advanced barrier and seed layer deposition enabling multiple type of TSVs integration, T. Mourier & al., IMAPS 2019
Part II: Kari Cobalt Metallization for Damascene and Packaging Applications
Cobalt Offers Multiple Paths to Extend Moore’s Law

**Damascene**

- BEOL (N5 and below)
  - Cu replacement
- MEOL (contact, Mo)
  - W replacement

**Co Advantages:**
- Contact and line resistance
- Reliability and electromigration

**Packaging**

- Memory stacking
- Advanced TSVs

**Co Advantages:**
- Could overcome Cu limitations in TSVs
- Alternative metal when Cu is prohibited
Limitations of Current Cobalt Solutions for Damascene

PVD/CVD Reflow:
- Low throughput
- High cost
- Organic contamination

Bottom-up ECD
- Low throughput
- High oxygen contamination
- High resistivity

Kari Cobalt solution offers a novel mechanism to resolve current limitations

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1 IBM Research, Albany, New York 12203, USA
2 GLOBALFOUNDRIES, Albany, New York 12203, USA
3 IBM Research, Yorktown Heights, New York 10598, USA
Kari Cobalt Zip Fill Produces Void-Free Fill

Conventional Conformal Fill

Irregular seam; open space voids cannot be annealed out

Kari Zip Fill Technology™

Tight seam is easily removed with anneal
Void Free Fill Validated by TEM and PED with Kari™

Crystallographic study shows perfectly healed seam
## Low Overall Contaminants

### SIMS Analysis of Bulk Kari Cobalt Film (ppm)

<table>
<thead>
<tr>
<th>Element</th>
<th>Value</th>
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<tbody>
<tr>
<td>C</td>
<td>&lt; 20</td>
</tr>
<tr>
<td>O</td>
<td>&lt; 50</td>
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<tr>
<td>F</td>
<td>0</td>
</tr>
<tr>
<td>S</td>
<td>0</td>
</tr>
<tr>
<td>Cl</td>
<td>&lt; 2</td>
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<tr>
<td>N</td>
<td>0</td>
</tr>
<tr>
<td>P</td>
<td>0</td>
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</table>

### Film Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Total impurities</td>
<td>&lt; 70 ppm</td>
</tr>
<tr>
<td>Sulfur impurity</td>
<td>0 ppm</td>
</tr>
<tr>
<td>Resistivity</td>
<td>7.6 μOhm/cm</td>
</tr>
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</table>
High Throughput in One Step

Fill Time (seconds)

- 0
- 33
- 100
- 160

Fill (before overburden and anneal)

400 nm Overburden

200 nm Overburden

200 nm
Cobalt Fill is Independent of Pattern and Dimensions

No loading effect

Void-free validated for a variety of dimensions
Summary

**Rhea: Copper Seed Solution**
- Polyvalent solution
- Excellent electrical results
- Extendibility to TSV > 15:1

**Kari: Cobalt Wet Zip Fill Technology**
- Superior film purity (Sulfur free)
- High Co conductivity
- High throughput
This work was partly funded thanks to the French national program: “Programme d’Investissement d’Avenir IRT Nanoelec” ANR-10-AIRT-05
Mid Process TSV – Electrical Process Flow

Front side

1 – TSV etching

2 – TSV isolation

3 – TSV filling + CMP

4 – Back-End Of Line

5 – carrier bonding

Back side

6 – Thinning and Si etching

7 – Via reveal

8 – RDL / passivation

9 – Cu/Ni/Au pillar

eTest

25-June-2019 Leti Days