Industry Standards: from Egyptian royal cubit to SEMI Guides for CMP consumables

CMP UG meeting
April 23, 2021. Virtual Event

Alex Tregub, Don Hadder, Intel Corp.
OUTLINE

- Why standards
- History of standards
- Chemical Mechanical Planarization (CMP)
- CMP consumables
- Metrology issues for CMP consumables
- SEMI Standards for CMP consumables
Why Standards?

- We measure stuff all the time—how long, how heavy, how hot, etc.
- Need to know for engineering, trade, health, etc.
- Important to compare apples to apples
- 1960-System International
- Intel: participates in standards bodies worldwide:
  - Ethernet, USB, and Wi-Fi
Egyptian Quality Rules:

- **Standards:** All working wooden cubits be compared with the benchmark granite cubit.

- **Observation Frequency:** every full moon.

- **QC management:** failure to do so was punishable by death.

Metrology in action – weighing the souls of the dead and the Egyptian Royal Cubit.

One Egyptian Cubit = Length of Pharaoh’s forearm and hand.
**CMP Consumables**

- **CMP Slurries** - Largest market share, most quality issues
- **CMP Pads** - 2\textsuperscript{nd} largest market share
- **Conditioning Disk** - Criticality realized from ~P1270, followed by fast innovations in designs
- **Retainer Rings** - Criticality is being realized, lagging in new designs/materials
- **CMP Brushes** - New design development ongoing; relatively few suppliers
- **Post CMP cleaning** - Extremely critical enabler for advanced technology nodes
- **Filters** - Huge impact on purification for bulk chemicals/UPW, important for CMP
Polisher recipe optimization insufficient to meet defect target.

Consumable development key to meeting final target.

Ack.: Matt Prince, Intel
CMP consumables challenges for metrology and quality

➢ Quality parameters, incl. reported on Certificates of Acceptances, do not always correlate to Fab performance

➢ Limited number of reported quality parameters

➢ Reported quality parameters are not always clearly defined

➢ Important conditions affecting quality parameters are not always reported

➢ Reporting quality parameters is not standardized across the industry
Reporting quality parameters for major CMP consumables

- CMP Slurries
- CMP pads
- CMP conditioning disks
Patrice Size Distribution (PSD) for slurry abrasives

A abrasive size affects fab performance: RR, defects

Mean Particle Size (MPS) is a legacy CoA parameter

➢ MPS did not show difference for 3 abrasives
➢ Width of PSD correlated to Fab performance
➢ Need to report PSD parameters beyond legacy MPS

Criteria for reporting additional parameters - correlation to fab performance

Width: \( A > B >> C \)
Polish time \( A \geq B >> C \)
Issue: reporting ONLY av. MPS for bimodal PSD

- Modality of distribution should be reported on CoA
- MPS values for separate peaks should be reported on CoA
CMP Pads Hardness: why temperature is important

Pad temperature in the CMP process varies depending on process conditions*. Pad hardness is temperature dependent, but on CoA, it reported at only ambient temperatures.

* J. Luo, D. Dornfeld: IEEE TRANSACTIONS ON SEMICONDUCTOR MANUFACTURING, VOL. 14, No. 2, 2001
The Intelligent Process Engineer (IPE) needs harder pads for her CMP process.

At CMP process, pad is heated to 50°C; at 50°C, Red pad is harder, than Green pad. Pad modulus in operating temperature range is required for pad selection.
### Diversity in measuring and reporting PCR

<table>
<thead>
<tr>
<th>Principle</th>
<th>Metrology tool</th>
<th>Process Conditions</th>
<th>Consumables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groove Height</td>
<td>Caliper; Non-contact spectroscopy</td>
<td>Pad RPM</td>
<td>Disk</td>
</tr>
<tr>
<td>Fixed-zone-Intel</td>
<td>Automated stylus</td>
<td>Disk RPM</td>
<td>Pad</td>
</tr>
<tr>
<td>Pad Thickness</td>
<td>Caliper; Non-contact spectroscopy</td>
<td>Disk Down Force</td>
<td>Slurry/DIW</td>
</tr>
<tr>
<td>Other</td>
<td>Other</td>
<td>Slurry flow</td>
<td>DIW</td>
</tr>
</tbody>
</table>

$\delta H \sim \text{PCR}$

**Conditioning disks: Pad Cut Rate (PCR)**

- **Grooved pad**

- **Fixed-zone-Intel**

- **Pad Thickness**

- **Other**

**PCR metrologies standardization required**
Metrologies Gaps for CMP consumables: Summary

- Utilization of historic metrologies and parameters adopted at the early technology manufacturing nodes, when requirements to consumables were relaxed
- Relying on less accurate legacy metrologies may be a reason for costly issues in manufacturing processes
- Metrologies and reporting of the parameters are not standardized across industry
Closing gap in metrologies for CMP Consumables

Solution: utilizing historic examples:

Volume standards

Weight standards

All important parameters and metrologies were standardized across Minoan civilization in **1700-1500 B.C.E.**

Standards for CMP consumables did not exist **until 2019 C.E.**
SEMI International Standards

The **SEMI Standards Program** fosters consensus-based solutions to microelectronics manufacturing challenges and drives cross-industry collaboration to develop globally recognized Standards, Specifications, and Guidelines.
CMP Consumables Standards Roadmap

CMP suite of SEMI Standards, progress/status update:

1. 5991 New Standard: Test Method for Determining **Density** of Chemical Mechanical Polish (CMP) Slurries - published as SEMI C96

2. 6488 New Standard: Guide for Chemical Mechanical Planarization (CMP) **Slurry Particle Size Distribution** (PSD) Measurement and Reporting used in Semiconductor Manufacturing - published as SEMI C98

3. 6433 New Standard: Test Method for Determining **Conductivity** of Chemical Mechanical Polish (CMP) Slurries and Related Chemicals - published as SEMI C99

4. 6489 New Standard: Guide for Reporting Chemical Mechanical Planarization (CMP) **Polishing Pad Hardness** used in Semiconductor Manufacturing - published as SEMI C100

5. 6677 New Standard: Guide For Reporting Performance Parameters of The Chemical Mechanical Planarization (CMP) **Conditioning Disks** Used In Semiconductor Manufacturing – in approval cycle

6. 6646 New Standard: Guide For Reporting **Density and Porosity** of Chemical Mechanical Planarization (CMP) **Polishing Pads** Used In Semiconductor Manufacturing – approved

7. TBD New Standard: Test Method for Determining **pH** of Chemical Mechanical Planarization (CMP) Slurries and Related Chemicals – in development by TC

8. TBD New Standard: Guide for Reporting Parameters of **polymer windows** for the windowed Chemical Mechanical Planarization (CMP) **Pads.** – SNARF prepared
### CLOSING THE GAPS IN REPORTING PARAMETERS FOR CMP CONSUMABLES

<table>
<thead>
<tr>
<th>Slurry PSD: Gaps</th>
<th>Slurry: SEMI Standard C98-published</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited PSD parameters reports (MPS)</td>
<td>Report additional parameters correlated to performance: Width, bins of PSD</td>
</tr>
<tr>
<td>Sample dilution not reported</td>
<td>Report dilution</td>
</tr>
<tr>
<td>Modality not reported</td>
<td>Report modality (bi-modal, 3-modal)</td>
</tr>
<tr>
<td>PSD parameters for separate peaks not reported</td>
<td>Report PSD parameters (MPS, width) for separate peaks</td>
</tr>
<tr>
<td>Metrologies SOPs not reported</td>
<td>Report details of SOPs affecting measurement values</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pad Hardness: Gaps</th>
<th>Pad Modulus: SEMI Standard C100-published</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legacy parameter, Hardness Shore, non predictive of performance, reported on CoA</td>
<td>Report DMA modulus</td>
</tr>
<tr>
<td>Pad hardness reported at only ambient temperature</td>
<td>Report pad modulus in the operating range of the temperatures</td>
</tr>
<tr>
<td>Measurement SOPs are not specified</td>
<td>Report DMA SOPs (temperature, oscillation frequency, deformation mode)</td>
</tr>
<tr>
<td>Sample preparation not reported</td>
<td>Report sample preparation details: from what part of pad it is cut, sample orientation with respect to groove orientation</td>
</tr>
</tbody>
</table>
# CLOSING THE GAPS IN REPORTING PARAMETERS FOR CMP CONSUMABLES

<table>
<thead>
<tr>
<th>Conditioning disks: Gaps</th>
<th>Conditioning disks: Document 6677-In approval cycle</th>
</tr>
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<tbody>
<tr>
<td><strong>Metrology used for testing not reported</strong></td>
<td>Report metrology used for testing</td>
</tr>
<tr>
<td><strong>Consumables used for testing not reported</strong></td>
<td>Report consumables used for testing (pad, slurry/DIW)</td>
</tr>
<tr>
<td><strong>Process parameters used for testing not reported</strong></td>
<td>Report process parameters used for testing (Disk DF, Platen and disk rpm, slurry/DIW flow, etc.)</td>
</tr>
<tr>
<td><strong>Polishing tools used for testing not reported</strong></td>
<td>Report polishing tool used for testing</td>
</tr>
<tr>
<td><strong>Pad location where PCR and PSR parameters are measured, not reported</strong></td>
<td>Report pad location where PCR/PSR parameters measured (mid pad, edge, or center of the pad)</td>
</tr>
</tbody>
</table>
QUALITY STANDARDS IMPLEMENTATION: RESULTS

Great Giza pyramid, circa 2550 B.C.E., built by Pharaoh Khufu

Microprocessors on 300mm wafer, circa 2020 C.E., built by Intel

Egyptian Cubit

Electronic Industry Standards
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Thank you for your attention!