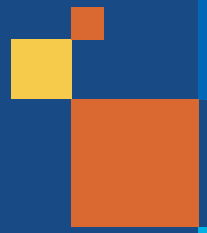
Industry Standards: from Egyptian royal cubit to SEMI Guides for CMP consumables

CMP UG meeting

April 23, 2021. Virtual Event

Alex Tregub, Don Hadder, Intel Corp.



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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

HISTORY OF STANDARDS

Egyptian Quality Rules:

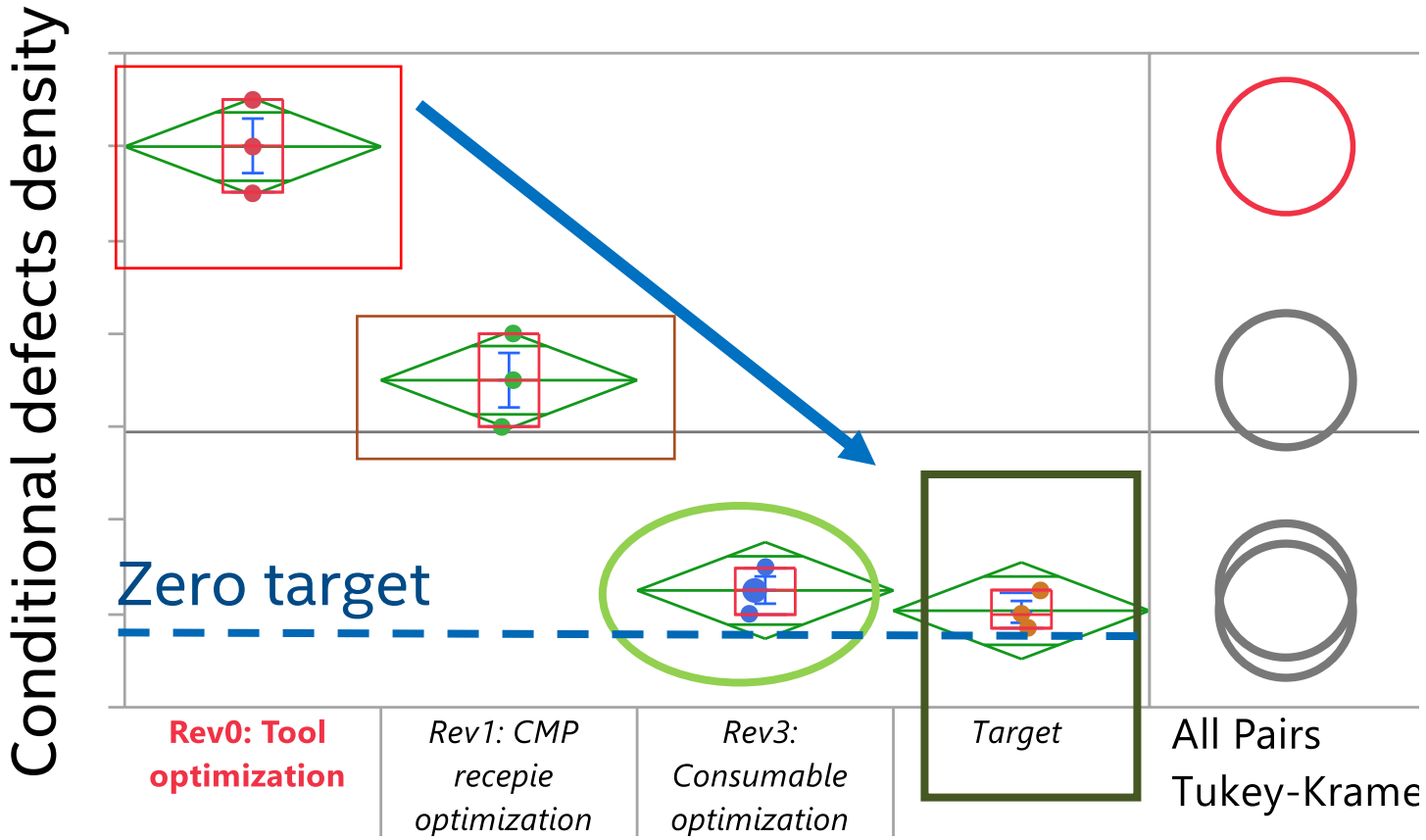
- **Standards:** All working wooden cubits be compared with the benchmark granite cubit
- **Observation Frequency**: every full moon.
- **QC management**: failure to do so was punishable by death

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 CONSUMABLES AND TARGET CMP DEFECT NUMBER



CMP Defect Reduction Evolution:

- ❑ Tool optimization
- ❑ Recipe optimization
- ❑ Consumable optimization

Process Optimization Stages-Illustration

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

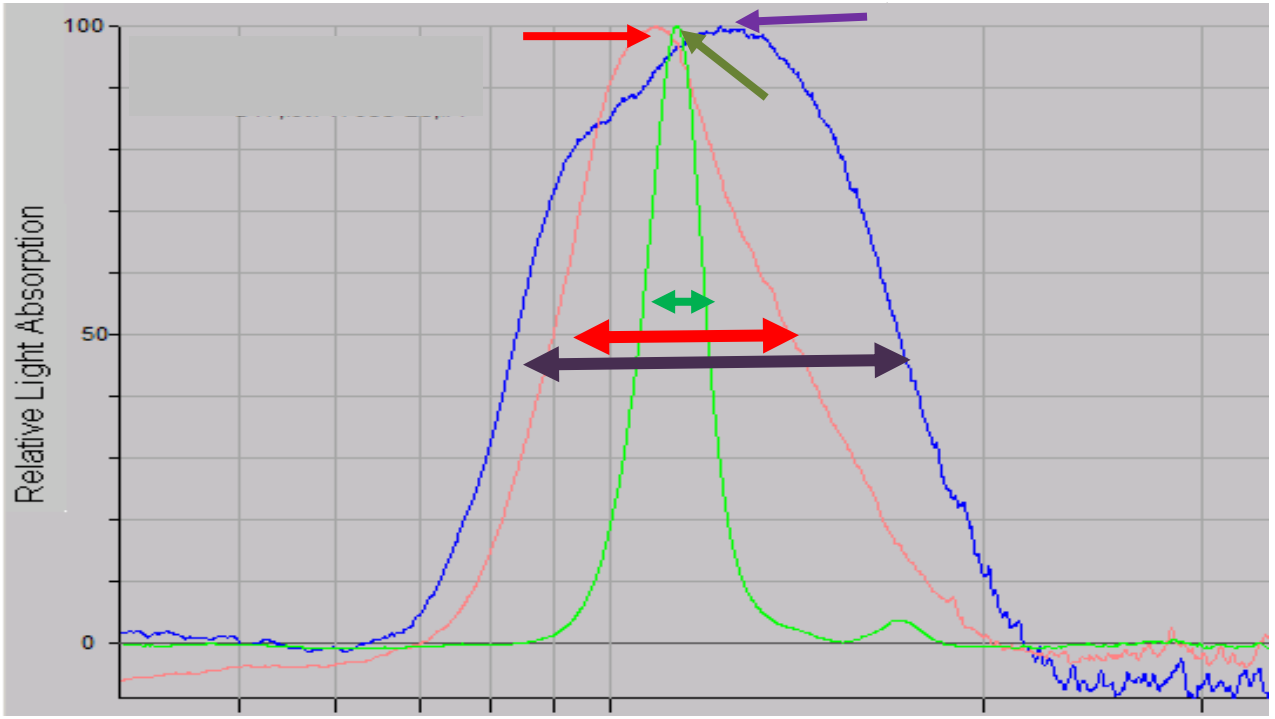
Reporting quality parameters for major CMP consumables

- CMP Slurries
- CMP pads
- CMP conditioning disks

Patrice Size Distribution (PSD) for slurry abrasives

Abrasive size affects fab performance: RR, defects

Mean Particle Size (**MPS)** is a legacy CoA parameter



Width: A > B >> C

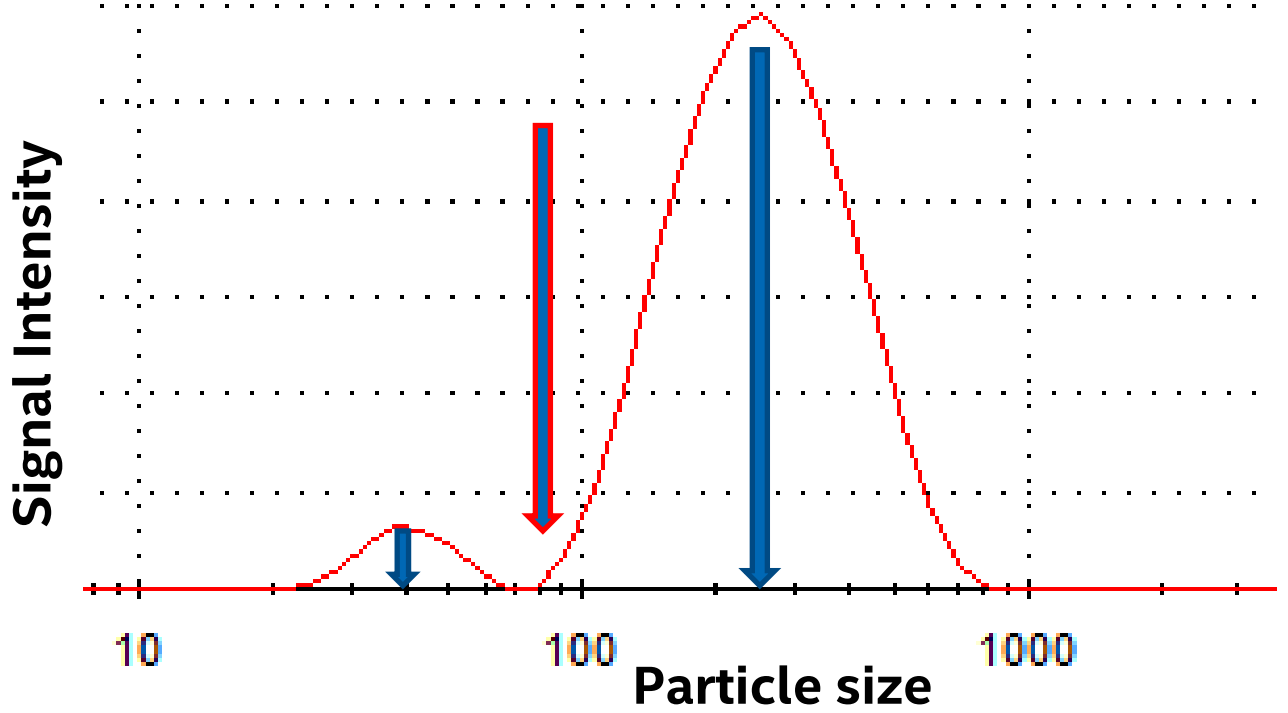
Polish time A ≥ B >> C

- 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

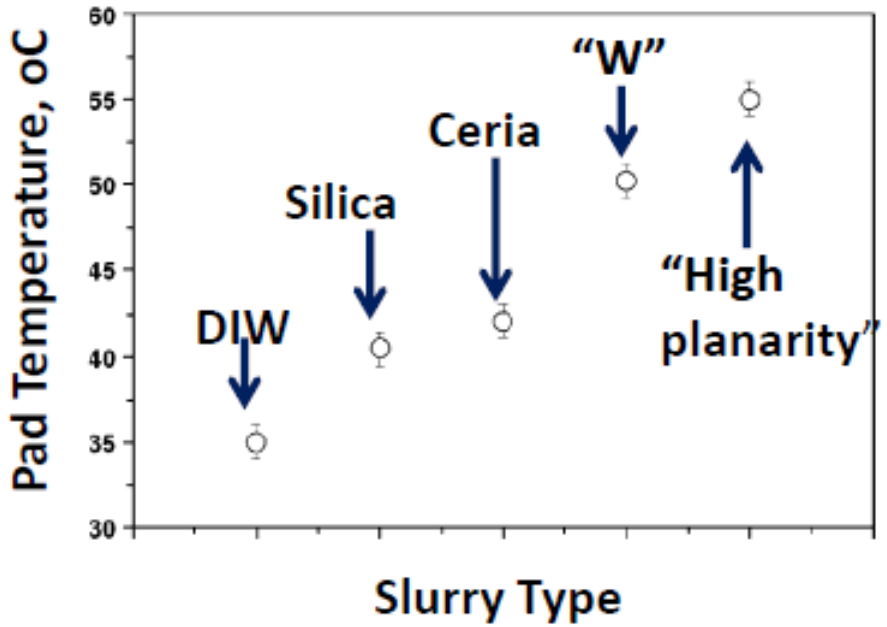
Bimodal Particle Size Distribution



Issue: reporting ONLY av. MPS for bimodal PSD

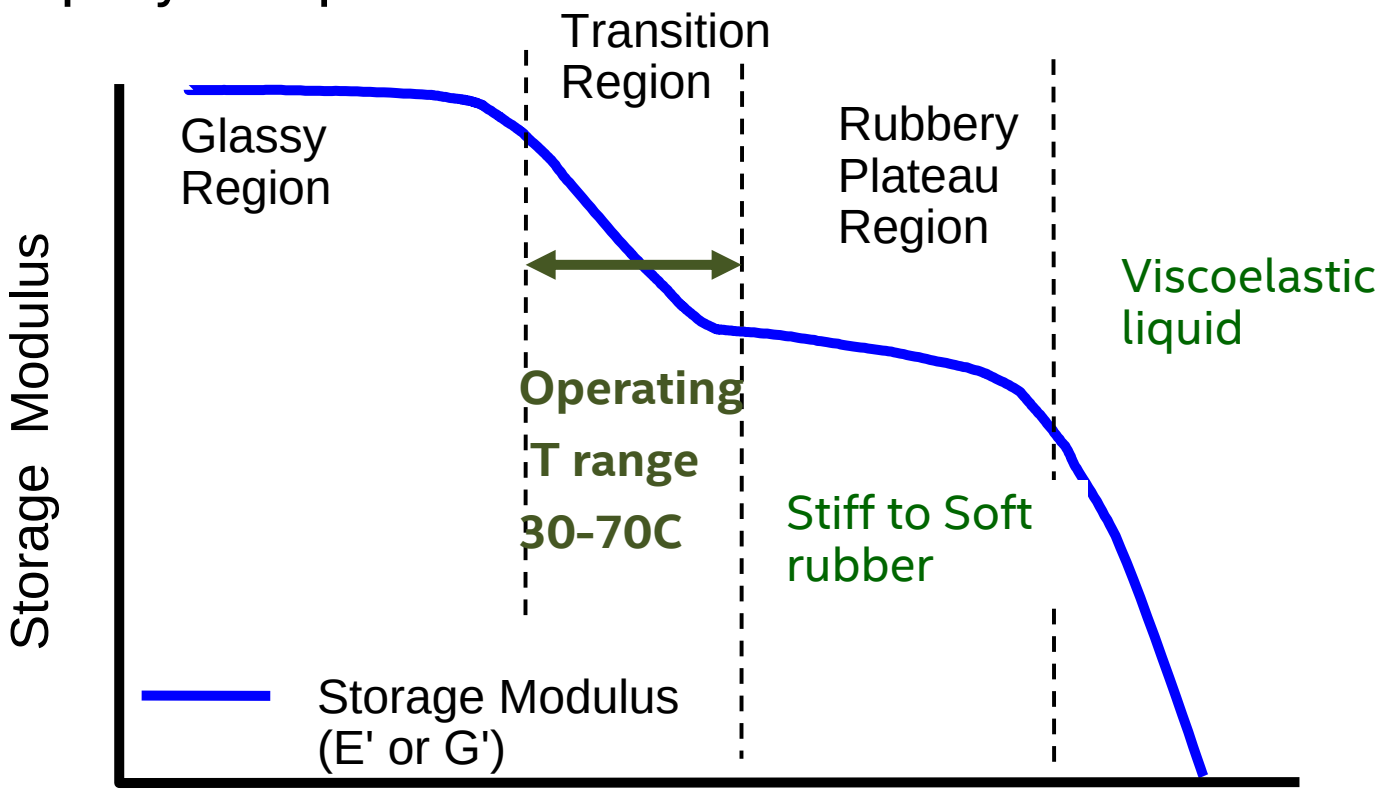
- Modality of distribution should be reported on CoA
- MPS values for **separate** peaks should be reported on CoA

CMP Pads Hardness: why temperature is important



Pad temperature in the CMP process varies depending on process conditions*.

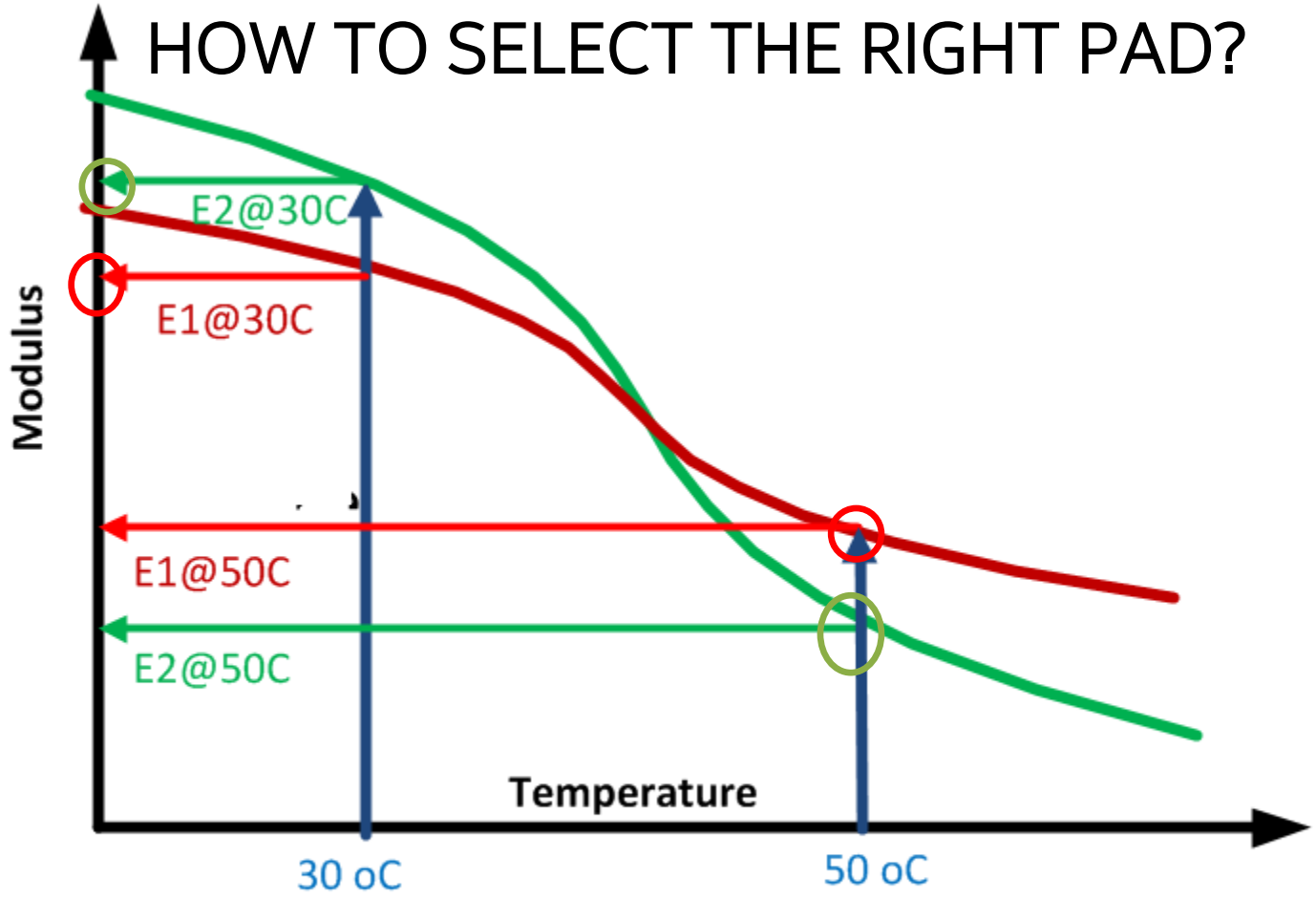
Typical multi-event DMA scan for a polymer pad



*- J. Luo, D. Dornfeld: IEEE TRANSACTIONS ON SEMICONDUCTOR MANUFACTURING, VOL. 14, No. 2,2001

Pad hardness is temperature dependent, but on CoA, it reported at only ambient temperatures

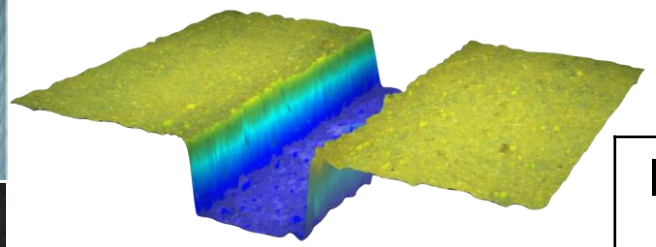
EFFECT OF TEMPERATURE ON PAD HARDNESS: HOW TO SELECT THE RIGHT PAD?



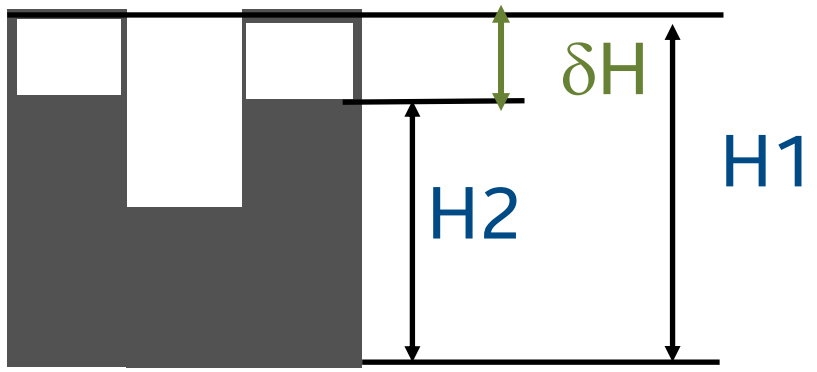
•The Intelligent Process Engineer (IPE) needs harder pads for her CMP process.

At CMP process, pad is heated to 50C; at 50C, Red pad is harder, than Green pad.
Pad modulus in operating temperature range is required for pad selection

Conditioning disks: Pad Cut Rate (PCR)



Grooved pad



δH ~ PCR

Diversity in measuring and reporting PCR

Principle	Metrology tool	Process Conditions	Consumables
Groove Height	Caliper; Non- contact spectroscopy	Pad RPM Disk RPM Disk Down Force Slurry flow	Disk Pad Slurry/DIW DIW
Fixed-zone-Intel	Automated stylus		
Pad Thickness	Caliper; Non-contact spectroscopy		
Other	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

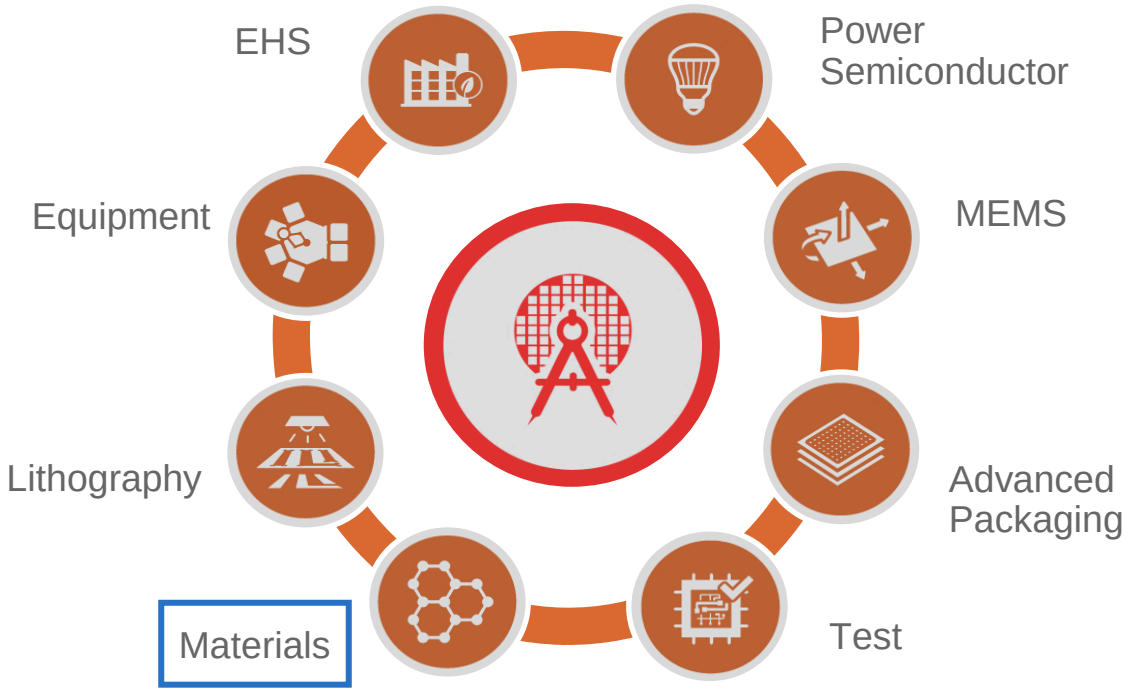
Weight standards

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



North America Liquid Chemicals Technical Committee Chapter

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Water Management

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High Purity Liquid Assemblies & Systems

MEGA FLUID SYSTEMS

High Purity Polymer Materials & Components

+GF+ GEORG FISCHER PIPING SYSTEMS

Chemical Mechanical Planarization Consumables (CMP-C)

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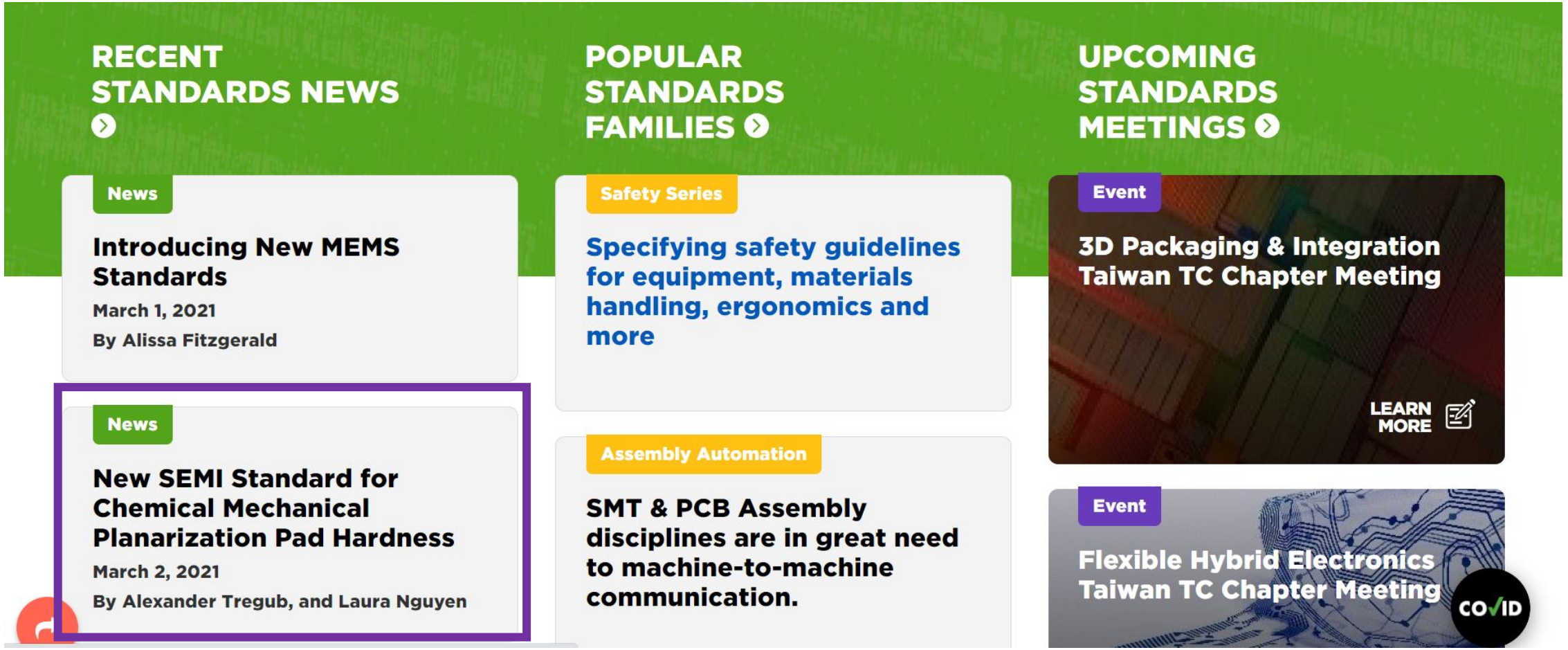
Courtesy of SEMI International Standards

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**

NEW SEMI STANDARDS



CLOSING THE GAPS IN REPORTING PARAMETERS FOR CMP CONSUMABLES

Slurry PSD: Gaps	**Slurry: SEMI Standard C98-published**
Limited PSD parameters reports (MPS)	Report additional parameters correlated to performance: Width, bins of PSD
Sample dilution not reported	Report dilution
Modality not reported	Report modality (bi-modal, 3-modal)
PSD parameters for separate peaks not reported	Report PSD parameters (MPS, width) for separate peaks
Metrologies SOPs not reported	Report details of SOPs affecting measurement values
Pad Hardness: Gaps	**Pad Modulus: SEMI Standard C100-published**
Legacy parameter, Hardness Shore, non predictive of performance, reported on CoA	Report DMA modulus
Pad hardness reported at only ambient temperature	Report pad modulus in the operating range of the temperatures
Measurement SOPs are not specified	Report DMA SOPs (temperature, oscillation frequency, deformation mode)
Sample preparation not reported	Report sample preparation details: from what part of pad it is cut, sample orientation with respect to groove orientation

CLOSING THE GAPS IN REPORTING PARAMETERS FOR CMP CONSUMABLES

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

QUALITY STANDARDS IMPLEMENTATION: **RESULTS**

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

Egyptian Cubit

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

Electronic Industry Standards

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Thank you for your attention!


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