

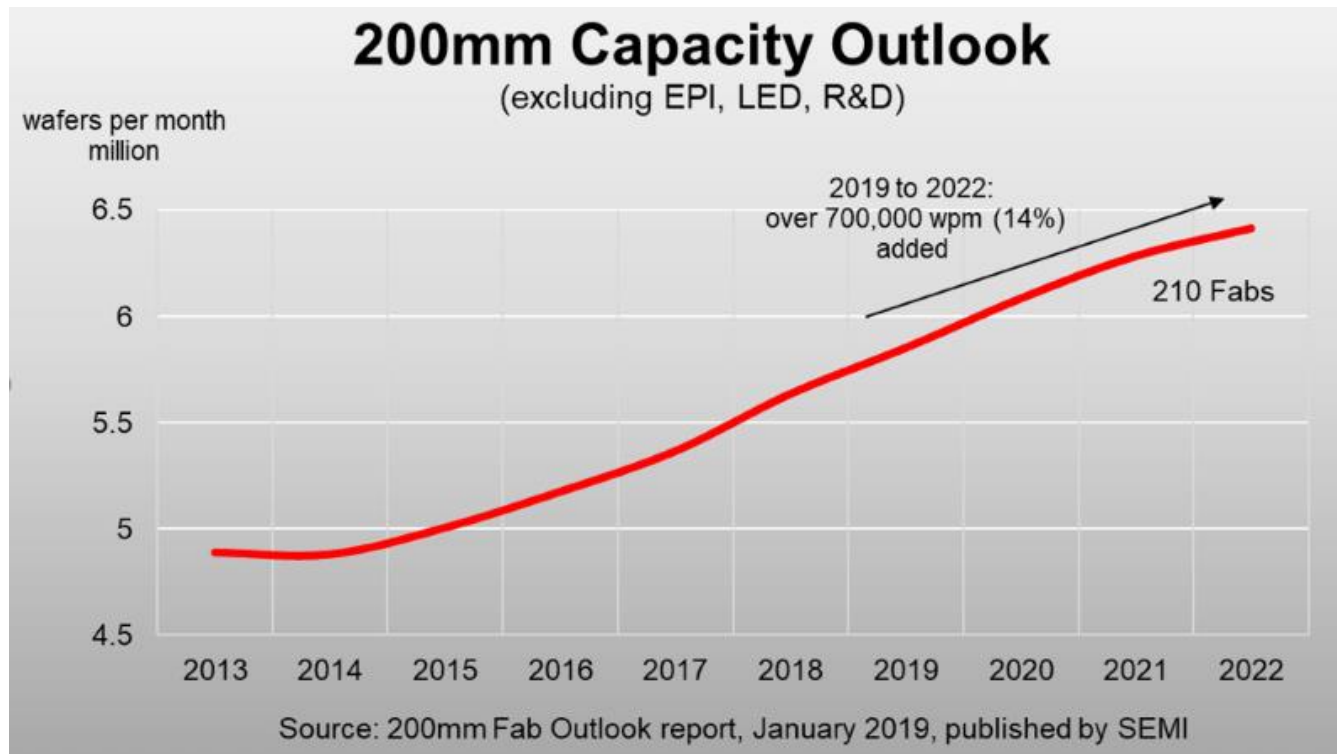
CMP- A Leap Forward Capstone

CMP Users Group Meeting

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Resurgence of 200 mm and Smaller Wafer Sizes



- Strong 200 mm growth predicted for the next years
- Additional growth expected for substrates that are only available for 150 mm and smaller
 - SiC
 - III-V (GaAs, InP, GaSb, ...)
 - Diamond
 - AlN
- Advanced CMP equipment for these wafer sizes is limited as the focus has been on 300mm wafers

Axis - Moving CMP Processing Forward



- CMP is the key technology node for TSV, Wafer Level Packaging, 3D integration wafer bonding and MEMS. Advanced CMP options for new materials and entry level wafer sizes are limited. CMP is a costly process, so efficient design for high throughput and high mix wafers are a must to keep up with industry standards.
- Axis Technology has responded to these needs by designing and building the first new CMP platform in 20 years, **Capstone**.
- Capstone is an advanced CMP system for 100mm, 150mm, and 200mm wafer sizes with dual wafer size mode, dry in/dry out, optical endpoint detection and advanced membrane carriers.
- Capstone will drive down Cap-Ex and Op-Ex while improving quality and enabling the next generation of devices.
- Capstone will enable CMP process development and manufacturability through a typical product lifecycle as wafer sizes grow with product and industry maturity.

Capstone



- System designed to enable
 - Frontside and backside polishing
 - Dual wafer processing mode
 - Versatile recipe controlled process and wafer movement sequences not available on other HVM CMP tools
 - True bridge tool, multi wafer sizes, 100mm, 150mm, 200mm
 - Slurry usage reduction
 - High throughput

Capstone Overview



- This architecture combines maximum throughput without the process constraints of other OEM platforms
- Compatible with existing OEM installation space and facility requirements
- Highest throughput per square foot available
- Novel transfer robot design for high throughput and reduced footprint
- Improved wafer handling stations for minimal defectivity levels
 - Wafer detection robust for transparent wafers
 - Wafer carrier and load stations built for fragile wafers
 - Robot paddle can flip wafers in the tool for FS and BS polish
- Dual or single wafer polishing per platen possible

Capstone Footprint and Throughput Comparison



- Polisher fab footprint including required service clearance (standalone configuration):
 - Capstone = 143.7 sq. ft.
 - Mirra = 176.2 sq. ft. (including external controller)
 - 6DS-SP = 223.2 sq. ft.
- Typical throughput based on two-step polish, 2 minutes primary, 30 seconds final, dual wafer:
 - Capstone = 40 WPH
 - Mirra = 23 WPH
 - 6DS-SP = 22 WPH

Capstone Footprint and Throughput Comparison



- “Footprint Density” (WPH/sq.ft) Comparison (based on above values):
 - Capstone = 0.28 WPH/sq. ft.
 - Mirra = 0.13 WPH/sq. ft.
 - 6DS-SP = 0.10 WPH/sq. ft.
- Capstone footprint density is 2.1 times greater than Mirra and 2.8 times greater than 6DS-SP

Axis Carriers: Summary

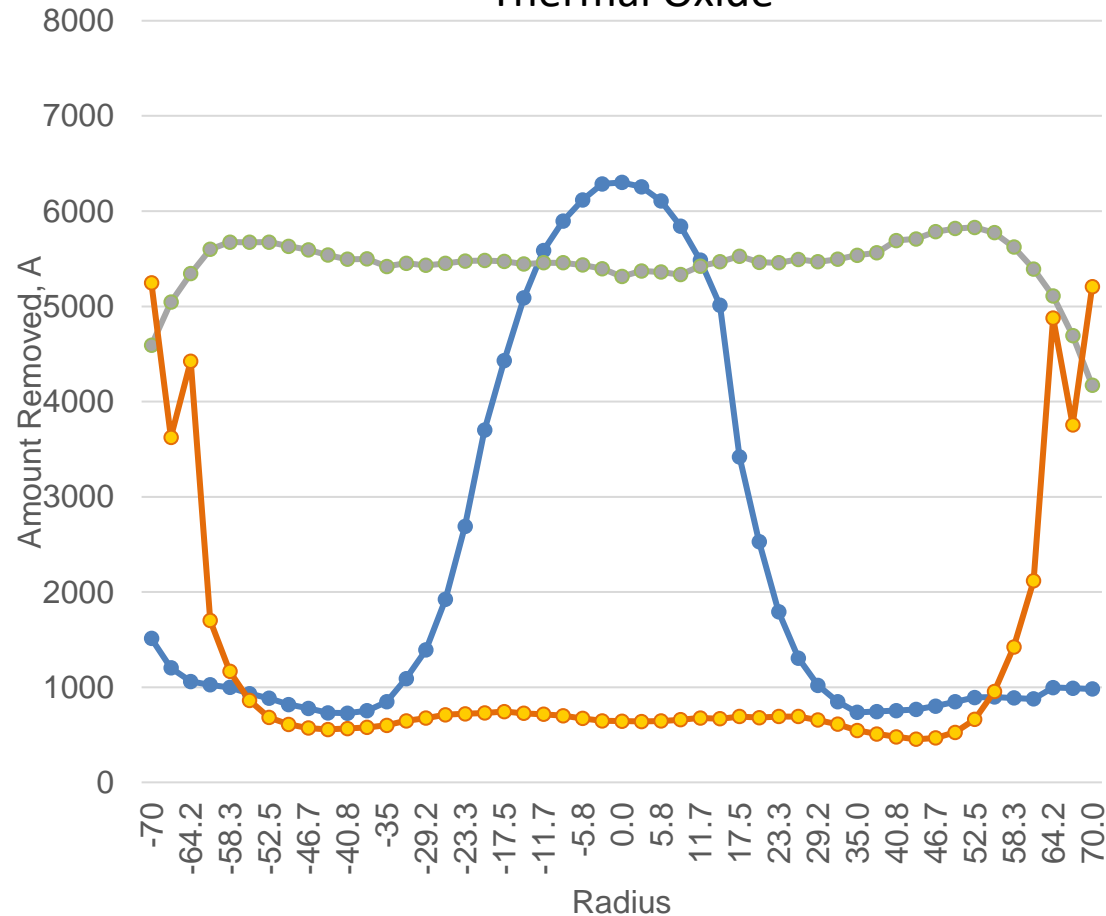


- The Avalon and Crystal 4 zone carriers provide a solution for customers looking for center zone polish control
- The Avalon and Crystal carriers provide
 - Excellent individual zone tuning without impact on other pressure zone areas
 - The center pressure zone is effective for significant adjustment in the CMP removal rate
 - Customizable CMP profile for advanced CMP modules
 - Designed for thin and stressed wafers and tested down to 250um thick wafers
- The Avalon and Crystal provide advanced CMP technology
 - Improved process and throughput
 - Repeatable run to run and between heads
 - Proven reliable wafer handling
 - Simple installation and control architecture
 - Low down time and cost of ownership
 - Tunable process for advanced CMP nodes

AVALON
CRYSTAL

Carrier Tunability

Avalon and Crystal Carrier, Zonal Control Test on Thermal Oxide



- The 4 pressure zone Avalon and Crystal carriers provide custom wafer level process control for both the center and edge of the wafer without cross talk between pressure zones
- This allows for advanced CMP tunability and reduces rework and expensive integration solutions to achieve the wafer metrics required for advanced devices

- Blue = Center Zone Pressure Only, 3.5psi
- Gray = Membrane Zone Pressure Only, 3.5psi
- Orange = IT Zone Pressure Only, 3.5psi
- Retaining Ring = Fixed for all tests at 7psi

Dual Wafer Size Capability



- Capstone is capable of polishing two different wafer sizes at one time
- This allows for product maturity without costly retooling and downtime for extensive wafer size conversion

Enabling More than Moore

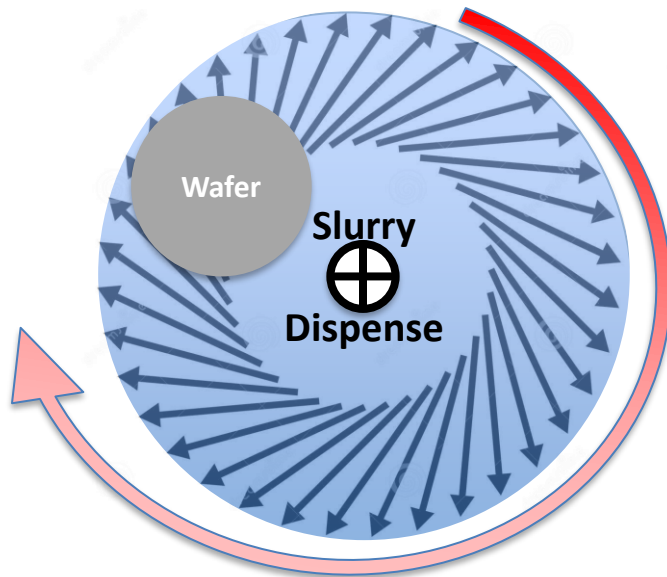


- Capstone
 - Efficient design
 - Next generation robot technology
- Advanced Carrier Technology
 - Thin, fragile, stressed films
 - Multiple wafer thickness
 - Zonal control
- OEPD – Optical Endpoint Detection
 - Advanced Process Control System
- Enabling Process Advancements
 - MEMS and Sensors
 - Micro LED displays, AR/VR
 - Medical
 - Photonics
 - TSV/TGV (Through via wafers)
 - Packaging
 - SiC substrates
 - SOI substrates
 - Si reclaim

Process and Throughput Results

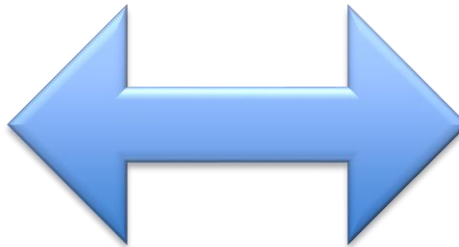
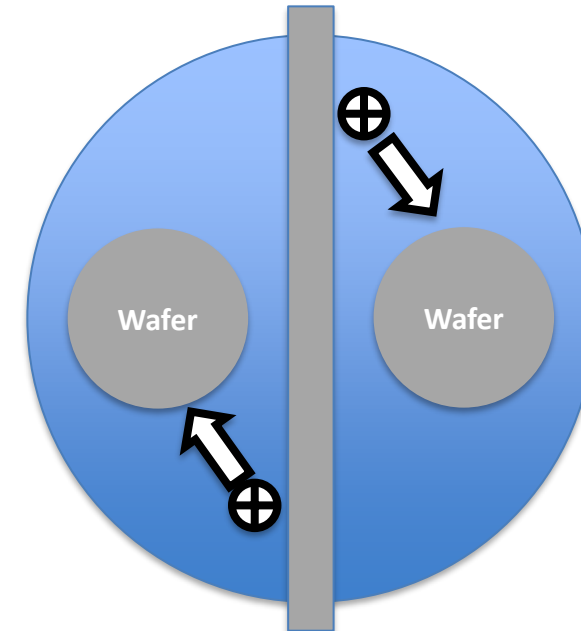
Slurry Utilization in Single vs. Dual Wafer Mode

Traditional Single Wafer CMP Set-Up

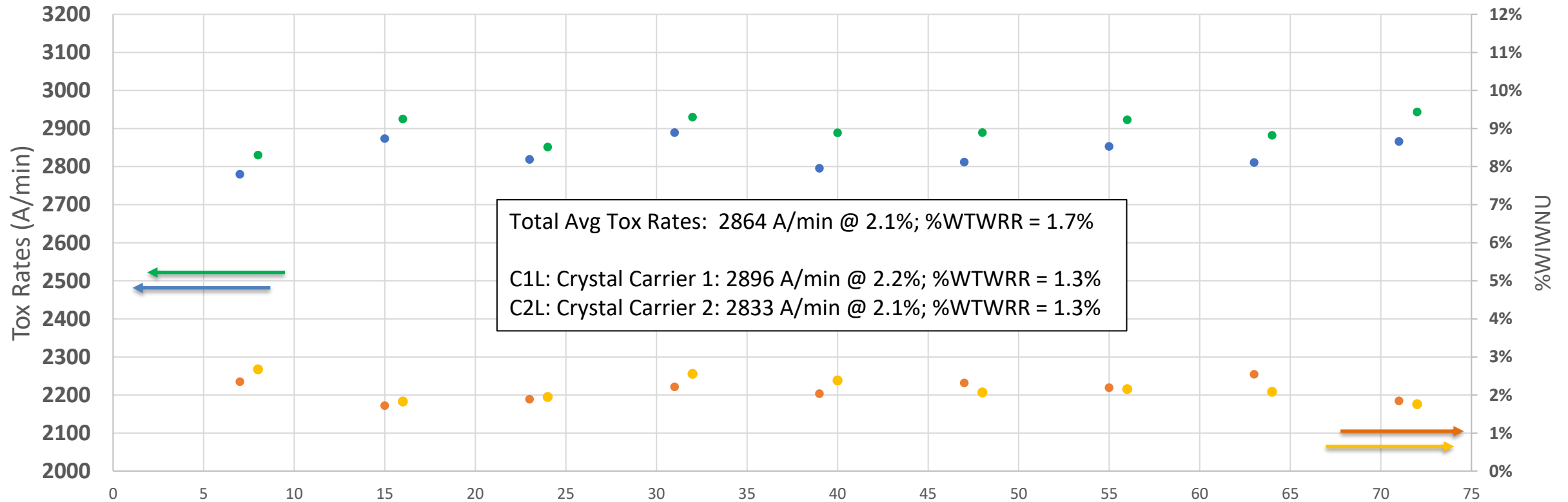


**Significant Loss
Of Unused Slurry**

Capstone Set-Up in Dual Wafer Mode



Oxide CMP: Dual Wafer Mode Stability



- With a software enabled carrier specific time adjustment, the WTW variation dropped to 0.6%

Cu CMP: Slurry Usage Reduction

Blanket 150mm Cu Wafer, 5 um Thickness



- Single wafer mode
 - Slurry flow rate: 175 ml/min
 - Time to clear: 8.5 min (30s OP time)
 - No residual Cu visible
- Dual wafer mode
 - Slurry flow rate: 125 ml/min per wafer
 - Time to clear: 7.0 min (30s OP time)
 - No residual Cu visible
- Advantages of the dual wafer over single wafer mode
 - **40% reduction in slurry consumption due to lower slurry flow rate and shorter CMP times**
 - Significant increase in wafer throughput
 - Dual wafer mode alone will increase throughput by roughly 2x
 - Reduced polish time will increase the throughput further
 - **Single mode: 6-7 wph**
 - **Dual mode: 16 wph**

Al CMP Performed on Capstone Tool

Comparison of Single vs. Dual Mode

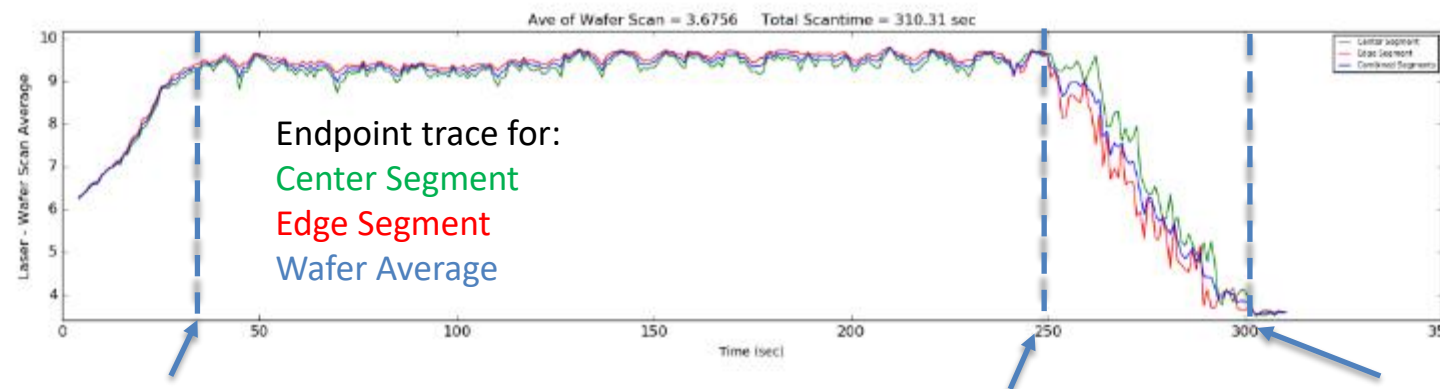
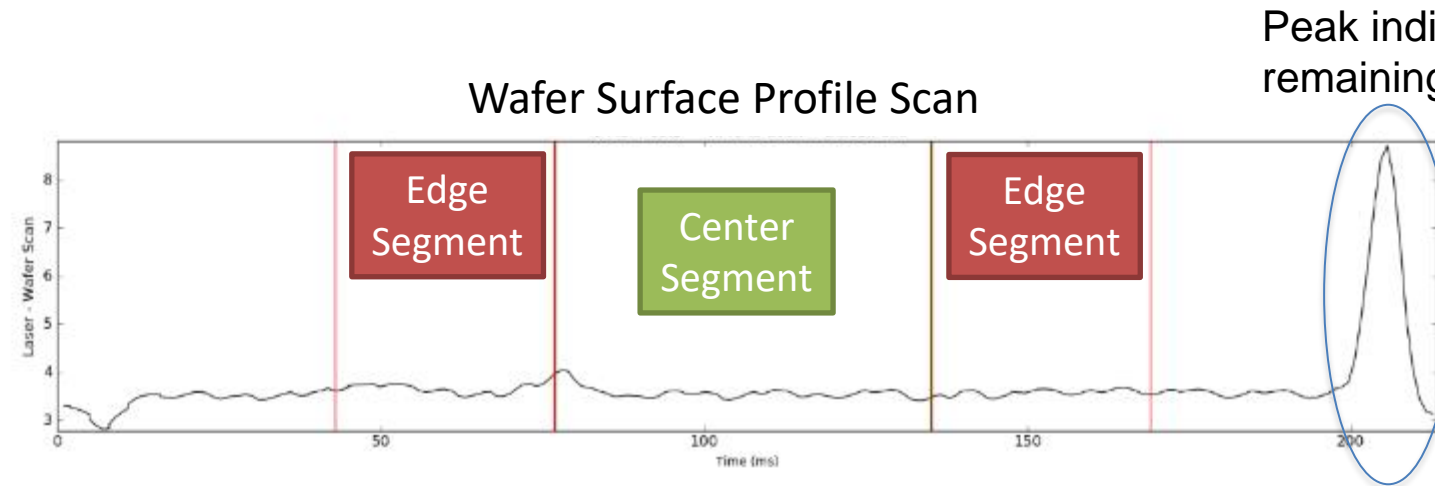
Slurry Flow Rate @ 125 and Standard 175ml/min

	Polish Time (min) Required To Clear Patterned Al Film	Slurry Flow (ml/min)	Wafer Throughput
Single Polish Mode	16min	Same 16min polish time was used to clear patterned Al layer using either 125 or 175ml/min.	With ~15min polish time, throughput estimated at 3-4 wfr/hr*
Dual Wafer Polish Mode	15min	15min polish time to clear patterned Al layer at either 125 or 175ml/min per wafer	With ~15min polish, throughput estimated at 7-8 wfr/hr*
Findings	Dual mode reduces total polish time by 1 min	>43% Reduction in Slurry Usage* when lowering the flow rate from 175 to 125 ml/min *Dual Mode benefits from reduced slurry consumption and reduced polish time	Dual mode can achieve almost twice the throughput than single mode for long polish times

*Throughput numbers assume single platen polish only for the Al CMP. However, the Capstone tool has 2 platens and four wafer carriers, which can be used in parallel. In dual mode it is possible to CMP 4 wafer simultaneously.

Optical Endpoint Detection

AXUS OEPD – Cu Pattern Wafer



Reflectance increases as surface roughness is reduced (less scattering) in first 40s

Cu clearing begins around 250s resulting in decreased reflectance

Cu is cleared at 305s with some edge residue observed.

- Cu clearing step, AXUS EP, 5:05 min
- Additional 1:00 min OP step to clear residual Copper located at the bottom edge of the wafer
- In-situ profile scan showed a peak remaining after initial polish, requiring a longer OP to clear the residual
- Total CMP polish time, 6:05 min

Capstone 300mm Product Roadmap

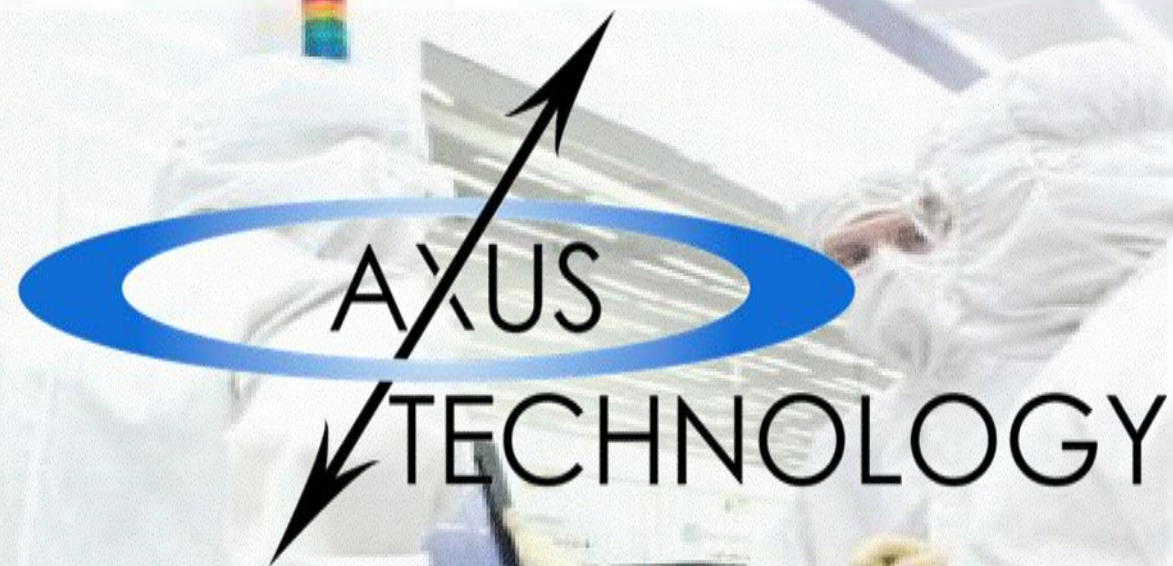


- Axis has 300mm version of Capstone in late design stage, direct scale-up of 200mm
- Capstone300 is only offered in Dry-In/Dry-Out version (no standalone version planned currently)
- For integrated cleaner options, we are partnering with established OEMs offering advanced post-CMP cleaning systems
- Cleaner integration is straightforward
 - Single-point wafer transfer
 - Polisher and cleaner communicate via local SECS/GEM interface
- Currently in early-stage discussions with established 300mm IDMs

Capstone Summary



- Axis Capstone CMP system is a leading edge, new CMP system designed to drive down wafer cost and advance processing capability. Capstone is the only CMP system to incorporate advanced membrane carriers, dry in/dry out, process endpoint and high throughput CMP for 4, 6, and 8 inch wafers. The combination of machine design for efficient processing and advanced membrane carriers allow next generation SiC, sensors, photonic interconnects, novel substrate materials including ultra thin fused quartz processing and bonded wafers.
- Capstone is ideally suited for high mix and/or high volume wafer production environments enabling product growth without a full re-tooling of the facility.
- Capstone enables lower Cost of Ownership over legacy CMP systems through slurry reduction and high throughput processing options while encapsulating the most advanced CMP hardware to enable manufacturing excellence and growth into new markets.
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AXUS TECHNOLOGY

- *Building Value for our Customers,*
- *Born from a Passion for Engineering.*