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Outline

• Unique single-platen polishers by Araca that enable digital transformation.

• Polisher – simple – input and output parameters.
• Polisher – complex – input and output parameters.
• Examples of three real-life polishing tests and the richness of data obtained.

• The “Easy” approach to data interpretation and reporting vs. “Deep Diving” to gain insight.

• The Planarization Knowledge Foundry®

• Digital transformation through Araca Insights®
• Several examples of data analytics.

• Summary.
Unique Polishers that Enable Digital Transformation

• Araca’s single-platen CMP polishers and tribometers for R&D:
  ❖ APD-800X® (200 and 300-mm wafers)
  ❖ RDP-500® (100, 150 and 200-mm wafers)

• Manufactured in Japan by Fujikoshi Machinery Corporation (a major Araca shareholder) under our brand name.

• Unique, highly-sensorized systems with advanced data capture and analyses functions by Araca (FSX-800X® and FSX-500®). Can measure high-frequency shear and down forces in real-time, acquire and analyze real-time fluid dynamics and thermal data (among other things).

• Matched 1-to-1 to AMAT polishers in terms of platen and carrier sizes, tool kinematics, independent wafer and ring pressures and designs, as well as disc dwell times and conditioning zones.
APD-800X® “Simple” Process Parameter Inputs and Outputs

APD-800X®

Platen Velocity
Carrier Velocity
Disc Velocity
Disc Downforce
Ring Pressure
Disc Position
Wafer Downforce 1, 2, 3, and 4

Conditioning Scheme – Ex-situ, in-situ or mixed
Pad Type – A, B or …
Slurry Type – A, B or …
Disc Type – A, B or …
Ring Type – A, B or …
Slurry Type – A, B or …
Polish Time – A, B or …
Flow Rate – A, B or …
Wafer Size – 200 or 300 mm
Wafer Type – As-received or Pre-polished
Film Type – Cu, ILD, W, Ta, TaN or …
Pad Break-In Time – A, B or …

Shear Force
Effective Normal Force
Pad Surface Temperature
Platen MC
Carrier MC
Conditioner MC
Initial Film Thickness Profile
Final Film Thickness Profile
Dishing at L1, L2, and L3
Erosion at L4, L5, and L6
Pad-Wafer Contact Area Percentage
Contact Density
Mean Asperity curvature
Mean Asperity Height
Abruptness Factor

Quantitative Parameter measured in-line at 1,000 Hz
Qualitative Parameter
Quantitative Parameter measured off-line
APD-800X® “Complex” Process Parameter Inputs and Outputs

Pad-Wafer Relative Sliding Velocity
Effective Wafer Pressure

Coefficient or Friction
Power Density
Variance of Shear Force
Variance of Normal Force
Directivity
Pseudo-Sommerfeld Number

Amount of Film Removed vs. Radial Location
Average Removal Rate
Average Within-Wafer RR Non-Uniformity

Quantitative Parameter measured in-line at 1,000 Hz
Quantitative Parameter measured off-line
Two Real-Life Slurry-Related Examples from 2020 and 2021

• Copper-Barrier slurry tests requested by Supplier A:
  - 14 different slurry formulations
  - 5 types of wafers (i.e., Ta, TaN, PE-TEOS SiO2, BD and copper)
  - 6 PV combinations
  - Took us 3 weeks to complete all tests

• Tungsten slurry tests requested by Supplier A:
  - 9 different slurry formulations
  - 2 types of wafers (i.e., W and PE-TEOS)
  - 9 PV combinations
  - 3 polish times
  - 2 wafer types (i.e., as-received and pre-polished)
  - 2 wafer suppliers
  - 2 initial tungsten film thicknesses (i.e., 2KA and 6KA)
  - Pad microtexture
  - Took us 6 weeks to complete all tests
A Real-Life Disc Experimental Examples from 2021

• Copper disc tests requested by Supplier B:
  ❖ 9 different disc types
  ❖ 2 types of wafers (i.e., Cu and PE-TEOS)
  ❖ 12 PV combinations
  ❖ Pad microtexture
  ❖ Took us 4 weeks to complete all tests

No. of High-Frequency In-Line Data Collected > 1B
No. of Off-Line Data Collected > 1MM
How Have We Dealt With This So Far?

- When faced with > 100MM data points, human nature’s first tendency is to average things.

- This provides some useful information and trends – And it is just about all one can do without breaking the bank – So far, this is how we’ve reported data to our customers!
Examples of Critical Information that Gets Lost in Averaging

As-received DP1142-1: 4 PSI 52/49 RPM

Pre-Polished DP1142-1: 4 PSI 52/49 RPM

Temp – Tungsten CMP

Power Density (W/m²)

COF

Time (sec)
Lost Information – Sometimes we see “Hidden” Orbits!

Source: L. Borucki (2019)
We are creating an experimental network of **Copy EXACTLY!** tools and methodologies with Lewis University and three **exclusive** long-term **Strategic Partners (SP)** at an **affordable price**!

Through such a “triangulation”, we will begin to create an **exclusive** “Global CMP Knowledge Foundry” for our slurry, disc and pad strategic partners!

Looking to replicate the model with a PVA brush supplier and a retaining ring supplier.
In the next 3 to 9 months, we will:

- Together with one of our SPs, speed up the screening and development of novel CMP and post-CMP cleaning consumables.
- Enable the SP to independently characterize the tribological, thermal and kinetic attributes of myriad consumables and processes.
- Standardize the way CMP knowledge is acquired, reported and used – We will converge on a common language!
- Have processes that are easily portable to HVM polishers.
Araca Insights® – Software that Drives our Newest Business Unit

1 – Organized Central Data Bank

2a – Simple Data Analyses

2b – Complex Data Analyses

3 – Modeling, Visualization, and Reporting

4 – AI and Machine Learning (Longer Term)

DATA ≠ KNOWLEDGE ≠ INSIGHT

> 95 percent of all data generated by our polishers and cleaners is “DARK MATTER”!

Araca Insights® helps our strategic partners bring more data to light, put robust systems in place for centralized R&D data banking, management, analyses, and modeling.
Main Challenge – Too much data from too many instruments gets generated during a set of CMP experiments:

- Polisher
- Post-CMP cleaner
- Blanket wafer film thickness metrology tools
- Blanket wafer defect metrology tools
- Patterned wafer topography metrology tools
- Pad microtexture analyses tools
- In-line slurry health monitoring tools
- Others

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Carrier Velocity
Disc Velocity
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Ring Pressure
Disc Position
Wafer Downforce 1, 2, 3, and 4

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Araca Insights® – Software that Drives our Newest Business Unit

• On the STORAGE side of things, our software provides:

  ❖ Highly-organized central data center containing all of the data gathered from various tools in an easy-to-access format with a descriptive file nomenclature.
  ❖ Highly secure storage service with double authentication access for users.
  ❖ Automatic storage of newly collected data in our cloud servers.
  ❖ Automatic QC of newly collected data.
  ❖ Automatic notification to the user when data is uploaded to servers.
  ❖ Automatic parallel storage and backups for each single set of data.
  ❖ Parallel uploads from different centers (i.e., Araca, Lewis University, and strategic partners).
  ❖ Easy cross-regional access to the data collected by other centers with low latency
  ❖ Elastic and scalable expansion of centers as the amount of metrology tools or knowledge foundry centers increase.
  ❖ 1:10,000,000 durability (i.e. only 1 file per 10MM might get lost)
Araca Insights® – Software that Drives our Newest Business Unit

• **On the ANALYTICS side of things, our software provides:**
  
  ❖ Recognition of data types, data cleaning, anomaly detection and QC of data.
  ❖ Automatic aggregation of required properties to be easily accessed.
  ❖ Ability to filter test properties to reach tests done in the same category (i.e. copper or STI)
  ❖ Interactive live-selection and visualizing of required property relations within desired ranges.

• **On the GUI side of things – This is work in progress with our BETA version available in January 2022.**

• **AI and ML – Longer-term activities depending on general sentiment and customer feedback – 2022 or 2023!**
Araca Insights® – Example Output – Cu CMP

• Polar asymmetry in RR:
  ❖ A wafer edge effect (not the interior of the wafer)
  ❖ Not related to non-uniform distribution of film stress or film density

• Factors influencing polar asymmetry in RR:
  ❖ Hardware (head)
  ❖ Kinematics
  ❖ Pressure
  ❖ Consumables
  ❖ Polish time

Source: L. Borucki (2019)
Araca Insights® – Example Output (20 to 26 sec) – Cu CMP
Araca Insights® – Example Output (20 to 21 sec) – Cu CMP
Closing Thoughts

TRUE DIGITAL TRANSFORMATION IS THE ONLY WAY TO PROGRESS!

ORGANIZED DATA BANK
DATA ANALYSES
MODELLING
ARTIFICIAL INTELLIGENCE
MACHINE LEARNING