Challenges, Methods, and Solutions for Concentration Monitoring During Blending of CMP Slurry

Jetalon Solutions, Inc.
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Personnel who have responsibility for blending and deliver consistent, accurate chemical CMP slurry including:

- Slurry Delivery System OEM
- Sub-Fab Tool Operators
- Point-Of-Use Tool Operators
- Slurry Manufactures

Who benefits from Slurry Concentration Measurements
Typical industry problems and challenges:

Problem 1: Incoming raw slurry may vary batch-to-batch from expected tolerances

Problem 2: Incoming H₂O₂ may vary outside of expected tolerance

Problem 3: Inaccuracies during controlled raw slurry dilution, new process visibility.

Problem 4: Inaccuracies and measurement challenges for H₂O₂ and proprietary additives

Problem 5: Monitoring global loop for consistency and degradation of H₂O₂.
<table>
<thead>
<tr>
<th>Technology</th>
<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td>Near Infrared</td>
<td>Speciation</td>
<td>• Does not work for slurries that are opaque</td>
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<td>• Challenges with scattered light</td>
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<td>Conductivity</td>
<td>Low tech</td>
<td>• Blind to non-conductive chemical species</td>
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<td>Inexpensive</td>
<td>• $\text{H}_2\text{O}_2$ in non-ionic as such concentration is not</td>
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<td>Ubiquitous</td>
<td>measureable</td>
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<td>Lab Titration</td>
<td>Industry Acceptance</td>
<td>• Variations due to sampling methods</td>
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<td>Highly Accurate Results</td>
<td>• Technician Errors</td>
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<tr>
<td></td>
<td></td>
<td>• Very long measurement time</td>
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<td></td>
<td>• Cannot measure variations in raw incoming slurry</td>
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<tr>
<td>Auto-Titration</td>
<td>Accurate Results</td>
<td>• Long measurement times</td>
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<td>Wide measurement Range</td>
<td>• High Cost of Ownership</td>
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<td></td>
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<td>• Expensive initial investment</td>
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<td>• Only measures $\text{H}_2\text{O}_2$ Component</td>
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<td>Ultrasonic</td>
<td>Measure the $\text{H}_2\text{O}_2$ Component</td>
<td>• $\text{H}_2\text{O}_2$ separation vs. variation in particles</td>
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<td>Resolve spatial distribution</td>
<td>• Single calibration for $\text{H}_2\text{O}_2$</td>
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<td>• Factory calibration</td>
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<td></td>
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<td>• Difficulty measuring lower concentrations</td>
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<td>Refractive Index</td>
<td>Relatively inexpensive</td>
<td>• Regular PM for “sticky slurries”</td>
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<td>Fast response time/ small footprint</td>
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<td></td>
<td>Monitors both slurry dilution and $\text{H}_2\text{O}_2$ addition</td>
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<td>Accurate Results, even for opaque liquids</td>
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Jetalon Products Overview

- SRS Chemical Sensor
- CR-288 Concentration Analyzers
- Plastic NX-148 Concentration Analyzer
- GS-88 VHP Gas Analyzer
- Stainless Steel NX-148 Concentration Analyzer
Refractive Index Chemical Analyzer: How it works

- Light reflects off window/liquid interface into the PDA
- Angle of reflection determined by electron density difference (i.e. chemical concentration) between liquid and window.
- Jetalon algorithm measures small changes in reflected light intensity really fast (100 milliseconds) and highly accurately (0.01 wt% and better).
- Reflection geometry and miniaturization enable unique concentration monitoring performance.
1. As liquid concentration changes, critical angle moves, and pixels on PDA “light up” and “go dark”
3. Reflected light intensity changes are used to determine critical angle
4. Critical angle determines index of refraction (IoR)
5. Simple calibration of (IoR) determines chemical concentration output in wt% or ppm.
1. Highest Cost Savings and Performance of any analyzer
2. Agile Packaging and Interface:
   * Fluidic cells come in any material (plastic, metal), and any end connection type and size
3. CR-288/NX-148 are Factory calibrated by Jetalon
4. -connect software enables on site re-calibrations in minutes:
   * Diagnostics, data logging, sensor tuning
5. The only provider of end-point detection at the wafer
6. No maintenance or replacement parts
Refractive Index based Solutions for Slurry Blending, Delivery, and Use

Refractive Index technology can be used to monitor all stages of CMP Slurry Blending including:

1. Incoming Slurry Quality Assurance
2. Incoming $\text{H}_2\text{O}_2$ Quality Assurance
3. Ensure accurate and completely homogenized slurry dilution from concentrate
4. Measurement of $\text{H}_2\text{O}_2$ addition within blend tank
5. Monitoring of the Global Loop for changes and degradation of the delivered slurry
Proposal: Total Monitoring Solution for Slurry Delivery Using Refractive Index

Sensor Description:
#1 and #2 Monitor Incoming Chemical
#3 Monitors Slurry Dilution followed by H₂O₂ addition
#4 Monitors Global Recirculation Loop for H₂O₂ Degradation

Legend
- CR-288® Sensor
- Valve
- Chemical Line
- Electrical Connection
Solution 1: Monitoring Incoming Slurry

- CR-288-slurry Monitors barrel-to-barrel incoming slurry concentration variation for 7 barrels of slurry in sub-fab CMP slurry delivery tools
- The CR-288 is able to measure lot-to-lot concentrations of slurries in real-time. With this capability, each lot is monitored in real time as the concentration can be brought to the desired range.
Solution 2: Monitoring Incoming H2O2
Solution 3: Silica Slurry Dilutions

- Customer needs to purify and blend Ammonia and DiW with raw silica based slurry, and achieve 13.7 wt% slurry ± 0.2 wt% accuracy
- Ammonia and DiW determine etch activity and corrosion resistance to metal attack by hydrogen peroxide in BEOL Chemical Mechanical Planarization (CMP) process in SEMI
Solution 3: Slurry DIW Dilutions

* Silica based slurry shows strong ΔRI/ Conc relationship
* Slope of Sensitivity Curve sets minimum limits of Detection for a chemical and Chemical Calibration Curve

*RIU is refractive index units of CR-288
Solution 3: Slurry DIW Dilutions

- Using staircase steps in concentration calculations, CR-288 measurement accuracy was +/-0.02 wt %
- Easily resolved down to customer requirement of 0.2 wt % steps in dilution (30x our resolution)
Solution 4: Monitoring $\text{H}_2\text{O}_2$ Spiking

- Monitoring the $\text{H}_2\text{O}_2$ Spiking post raw slurry Dilutions.
- For most slurries changes can be accurately resolved down to customer requirement of 0.01wt %
Solution 4: Monitoring $\text{H}_2\text{O}_2$ Spiking In W2000
Solution 5: Typical Global/Local Loop Setup
Solution 5: Refractive Index Monitors

$\text{H}_2\text{O}_2$ Spiking in CMP Slurry Global Loop

- Retrofit for existing Slurry Delivery tool.
- Accuracy for $\text{H}_2\text{O}_2$ can be $\pm 0.05$ wt% (or better).
In Summary, CR-288 as Total Slurry Monitoring Solution

- Refractive Index based monitoring can be implemented to validate and/or control slurry dilution before addition of $\text{H}_2\text{O}_2$.
- Data gathered by a CR-288 monitoring lot-to-lot slurry concentrations on production tools confirmed significant Slurry variation due to various reasons such as improper premixing, stagnant flow due to low demand, supplier differences, etc.
- Jetalon’s CR-288 Refractive Index based sensors can be used to monitor and control all stages of slurry blending, delivery and use.
Future Work

* Post CMP Cleaning Chemistries
* Recycled Slurry Purification
* POU Slurry Additives
* NX-148 OEM Single Channel System
Thank You

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