FUJIMI CORPORATION

Fast is the Only Speed: Quick Turnaround Cobalt Slurry Development

Michelle Garza, Anne Miller, Brian Kim, Scott Rader
Fujimi Corporation - Research and Development

Outline

- **Time to solution: toolbox approach to Co slurry development challenges**
  - Corrosion, Selectivity
- **Fast slurry ramp: new product introduction challenges**
  - Bench to pilot to HVM
    - Process scale up - lessons learned
    - Scale up strategy - quick sample iterations, raw material vetting
    - Process control system – short run SPC
- **Future challenges**
  - Cost, large particle count (LPC) reduction, EHS requirements, metrology sensitivity limits

Time to Solution: Toolbox Approach to Co Slurry Development

Why Co Integration?: CMP Development Challenges

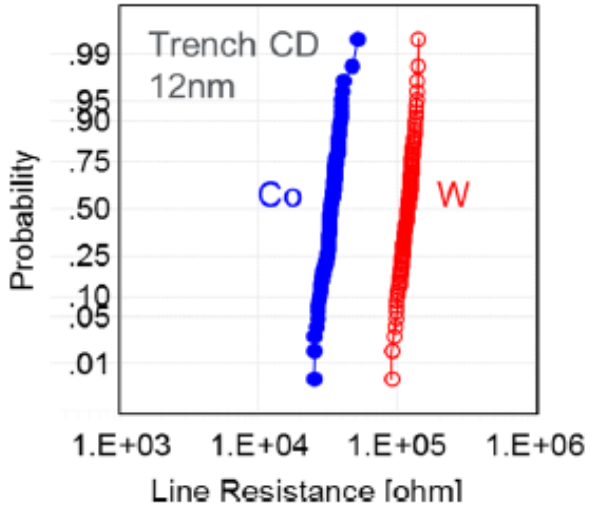


Fig. 17. Line resistance probability plot of Co and W fill with CD 12 nm line resistance.

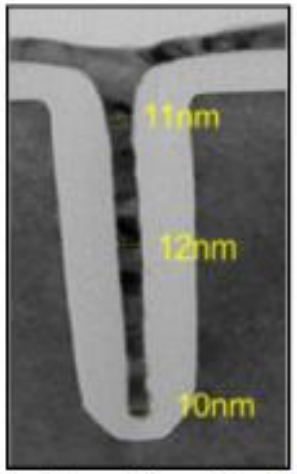


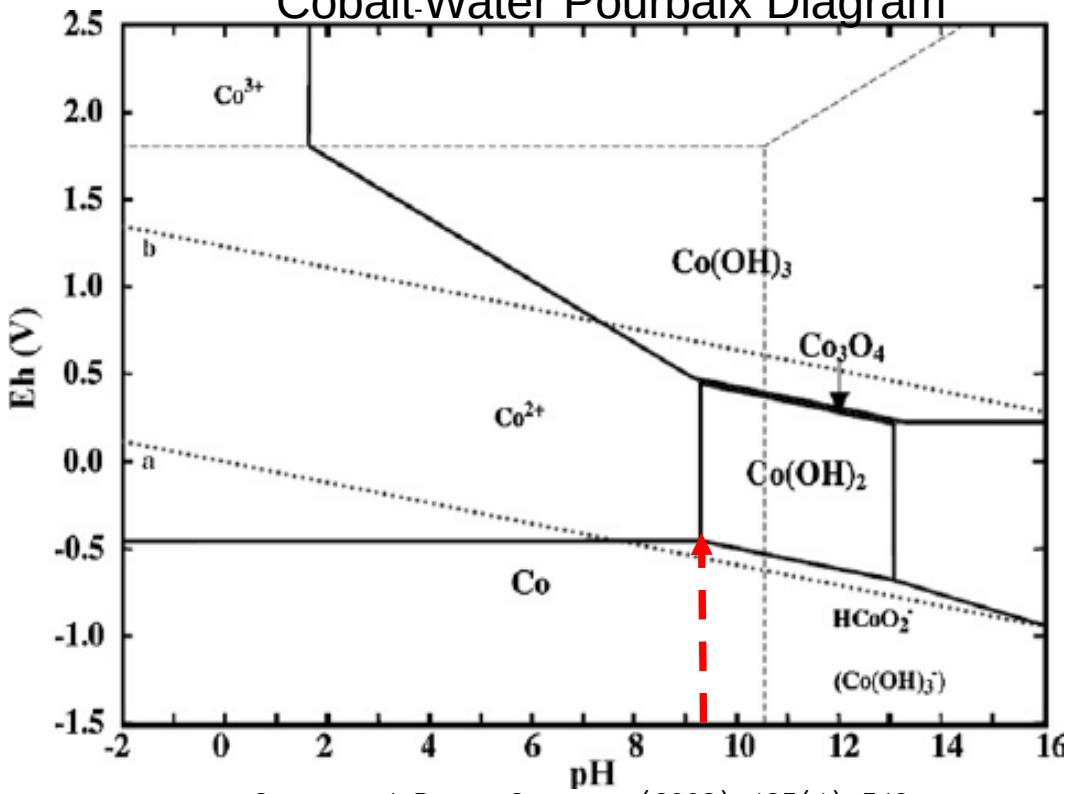
Fig. 16. Seam-free Co filled in reentrant profile trench at scaled CD on ALD TiN [9].

Source: N. Yoshida et. al "Highly Conductive Metal Gate Fill Integration Solution for Extremely Scaled RMG Stack for 5nm & Beyond,IEDM Conference 2017

- At 10nm and 7nm nodes, cobalt (Co) has been introduced at middle of line (MOL) due to resistance reduction and seam-free fill advantages
  - Scaling and introduction of new metals results in CMP technical challenges
    - Optimizing Co removal rate selectivity and corrosion inhibition

CMP Technical Challenge: Co Corrosion

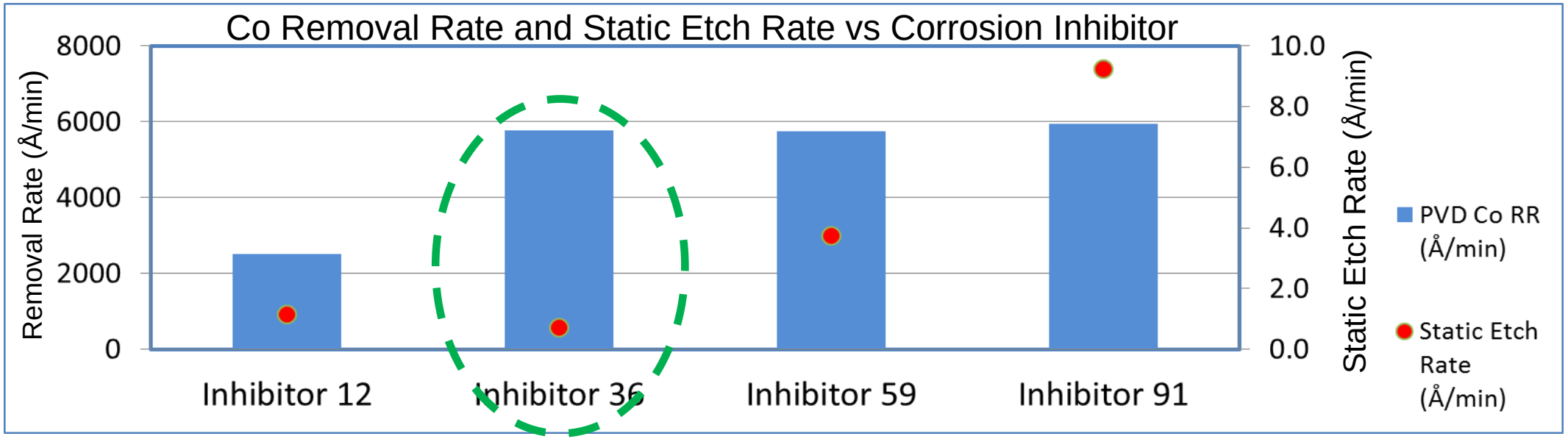
Cobalt-Water Pourbaix Diagram



Source: J Power Sources (2008) 185(1):549

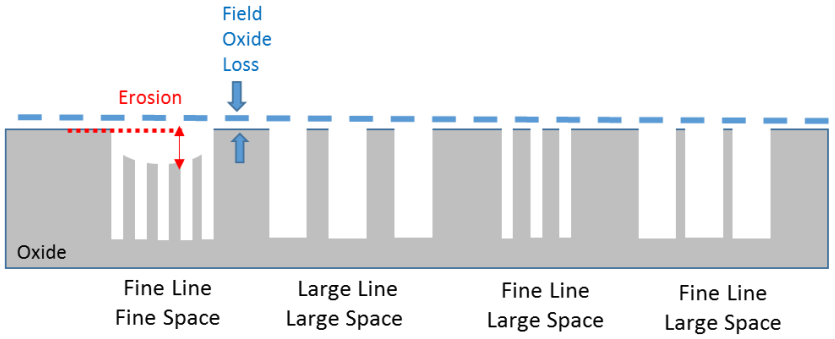
- Co has a tendency of corrosion at pH < 9.2 and is readily corroded in water
  - A Co specific corrosion inhibitor is required during CMP and subsequent water rinsing

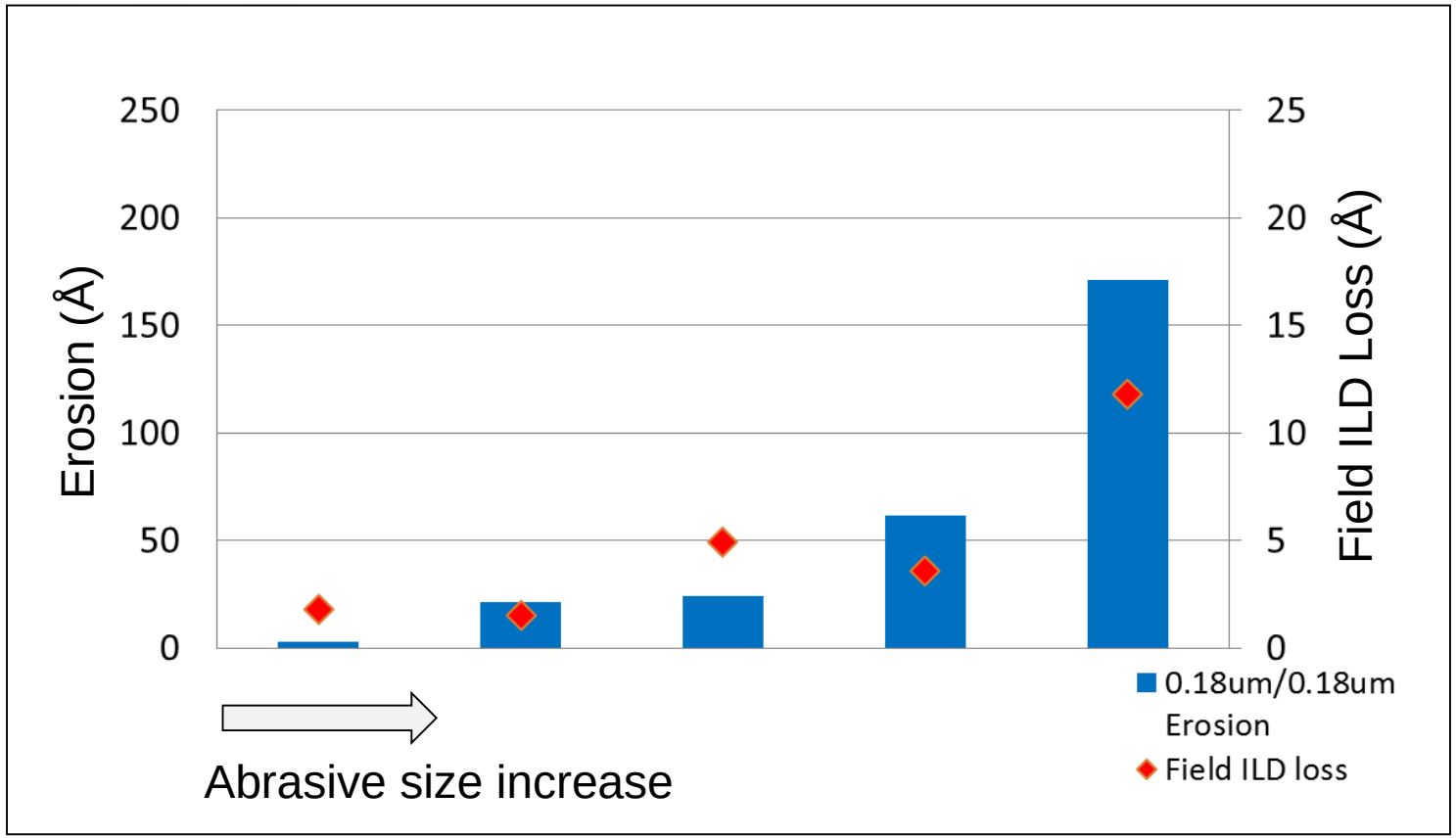
Toolbox Solution: Co Corrosion Inhibitor



- 100 different chemicals screened (vetted)
  - Inhibitor 36 selected due to high Co removal rate and lowest Co static etch rate
- Advantages of toolbox approach
  - Quick response to customer with a slurry solution that can be ramped
  - Proposals for further improvements for next generation slurries

Toolbox Solution: Right Sizing Abrasive

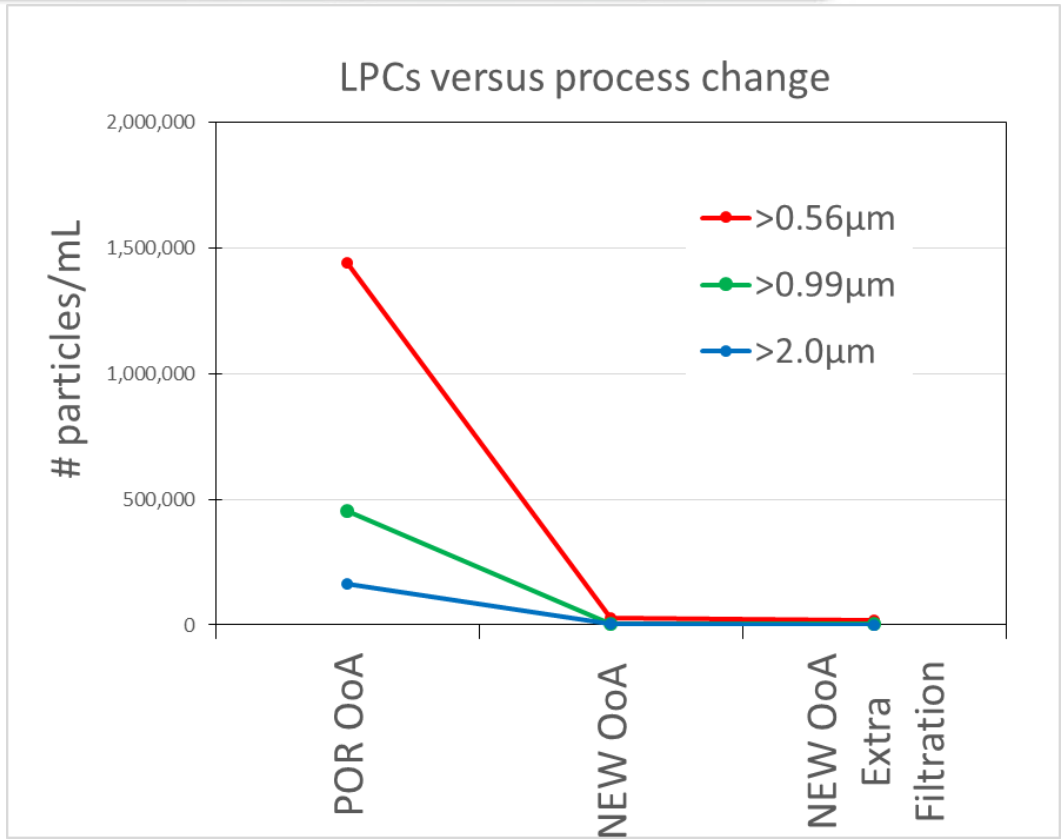


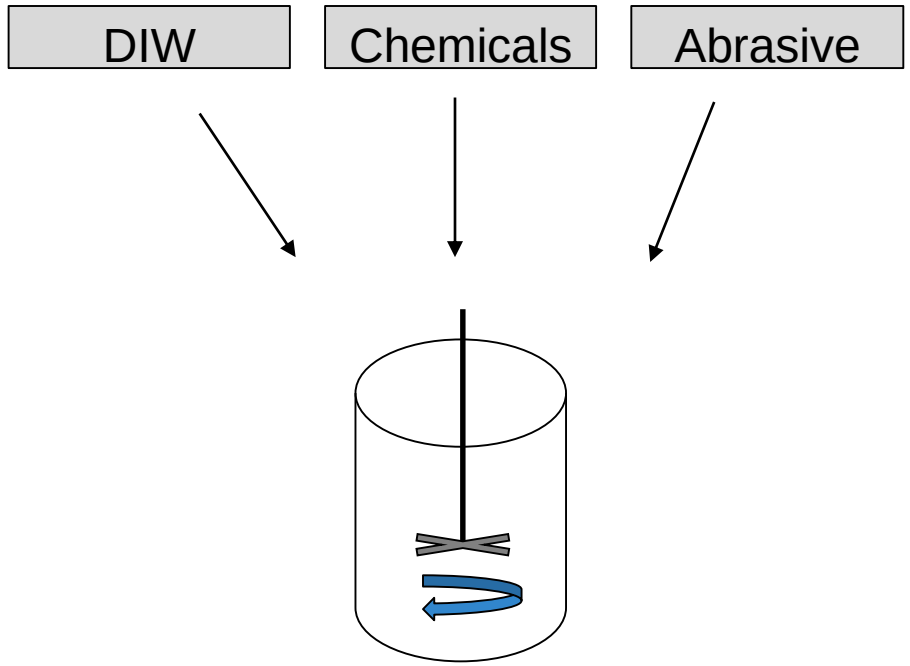


- To ensure polish stop on fine lines,10 different HVM abrasive particles were evaluated using an aggressive patterned test wafer (PTW) metric
  - A subset of abrasive particles with similar shape and surface chemistry impacted ILD loss and erosion on PTW arrays

Ramp: Lessons Learned

Bench to Pilot to HVM: Blending Order



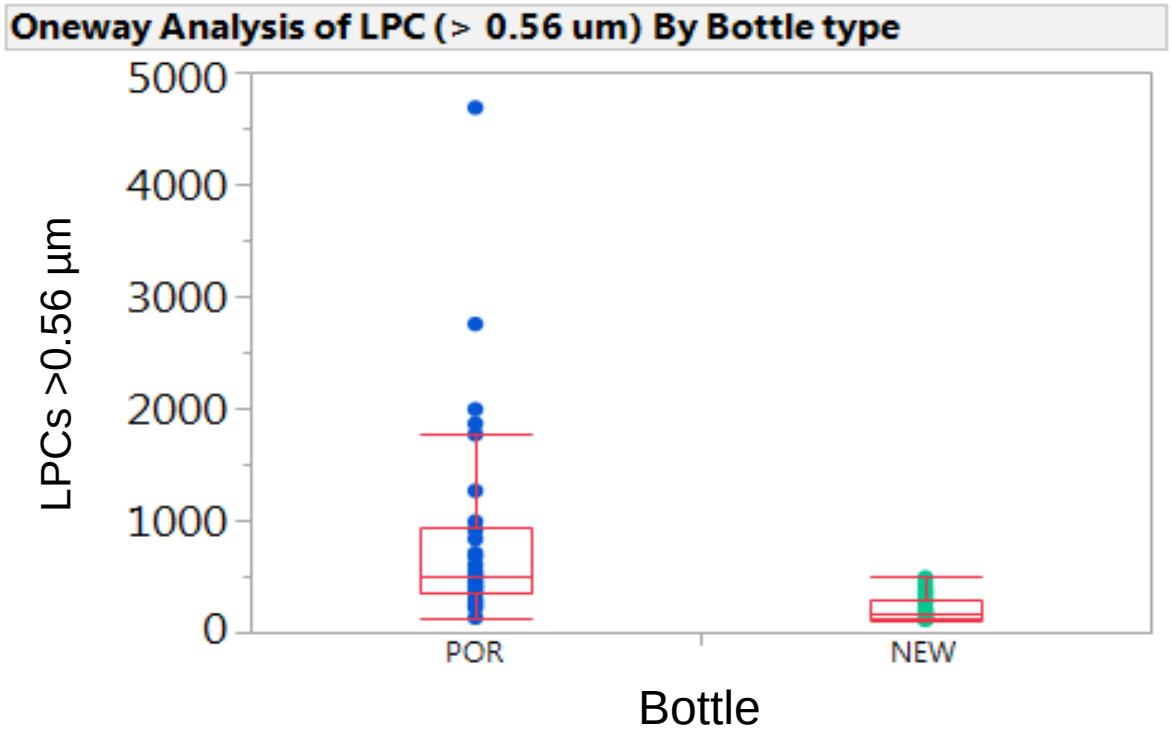


- During HVM slurry scale up, blending order of addition (OoA) impacted large particle counts (LPCs)
  - Delay in scale up and lots scrapped
  - Lesson learned applied to next generation slurry development process

Bench to Pilot to HVM: Slurry Color Variation

- Customer reported lot-to-lot variation in slurry color
- 8D method executed to identify root cause
  - sediment by-product in raw material caused slurry color variation
- Quantitative analysis implemented as an in process parameter to measure color
  - further excursions with slurry color were prevented

Bench to Pilot to HVM: LPCs vs. Bottle Type



Source: Kim, B. (2017, April). *The Impact of Sample Containers on Large Particle Count for CMP slurries.* CMPUG Spring Meeting, Portland, OR

- QC data can be affected by consumables
  - Slurry LPCs impacted by sample bottle type

The Fujimi Ramp

Bench to Pilot to HVM: Strategy

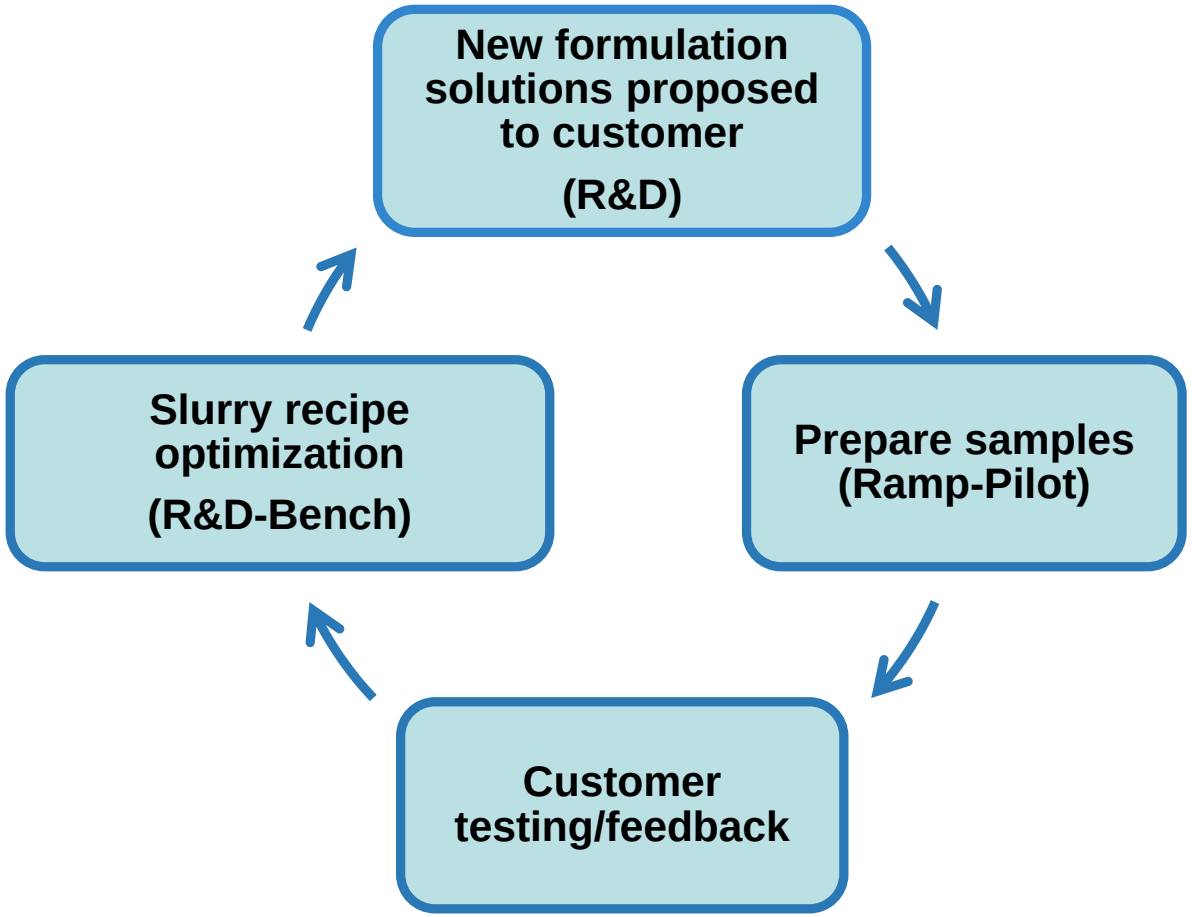
- **Advanced knowledge of potential new products (bench)**
  - Shelf life, pot life, microbiological testing
  - Raw materials used are fully vetted
- **Slurry sample preparation (pilot)**
  - Sample iterations
    - Identify potential process issues (e.g. order of addition, filtration, etc.) early in development stage to avoid scale up delays
  - Raw material lots tracked
- **Documented procedures (pilot, HVM)**
  - Manufacturing process
  - QC metrology
- **Effective communication and input (R&D, purchasing, QC, sales, ramp and engineering/manufacturing teams) during pilot to HVM ramp phase**
  - Scaled within a few weeks
  - Copy exact

Bench to Pilot to HVM: Raw Material Profiling

Slurry A Components	Cu (ppb)	Na (ppb)
Abrasive	1	1
Additive 1	1	3
pH Adjuster	3	120
Biocide	32	0
Corrosion inhibitor	0	40
DIW	0	1
Total	37	165
Slurry A	36	167

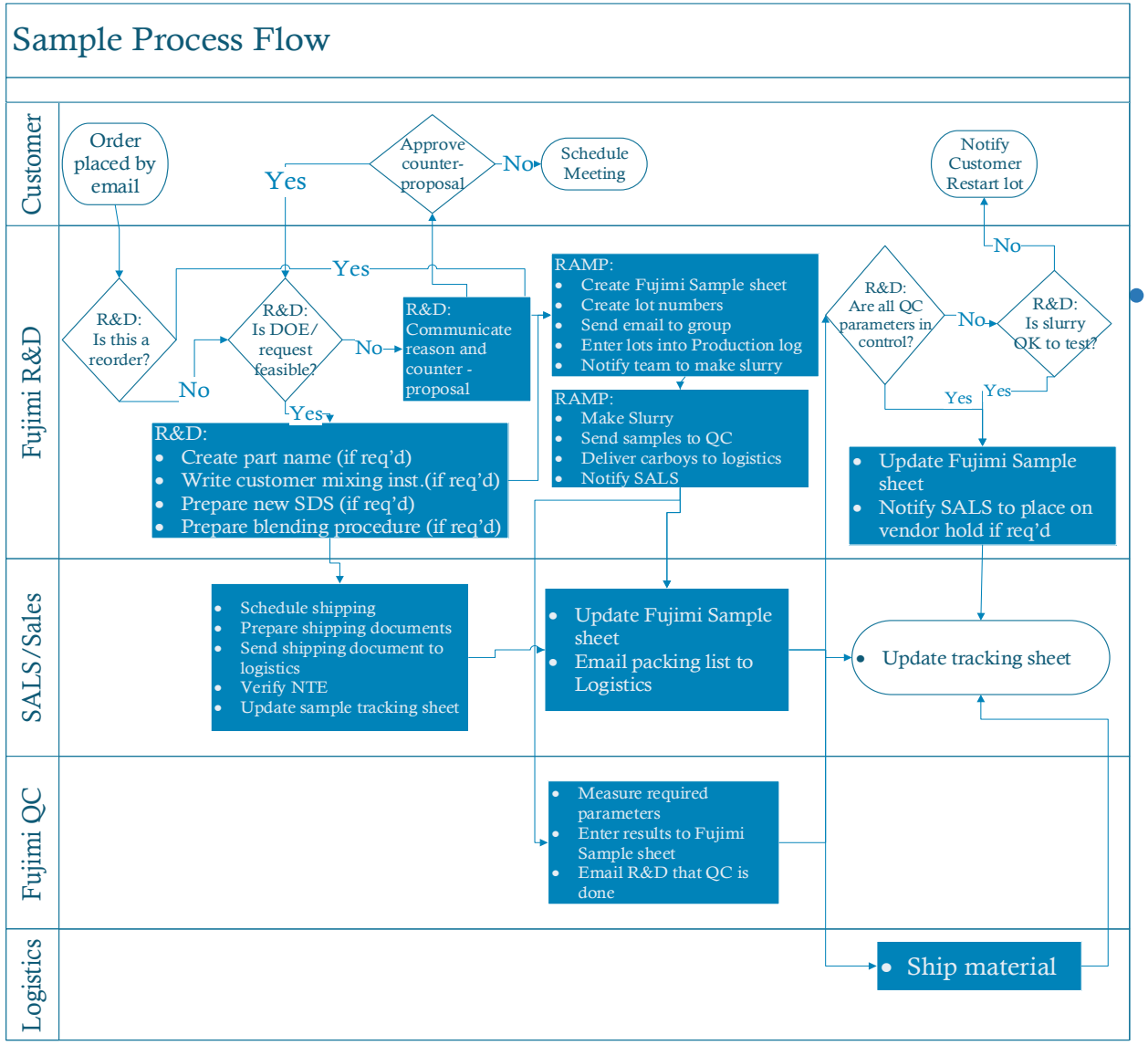
- To ensure slurry quality, the raw materials' (RM) analytical contribution to the slurry were characterized
  - HVM slurry A components were dissolved in deionized water
  - The sum of the analytical values from each RM match the slurry

Bench to Pilot: Sample Iterations



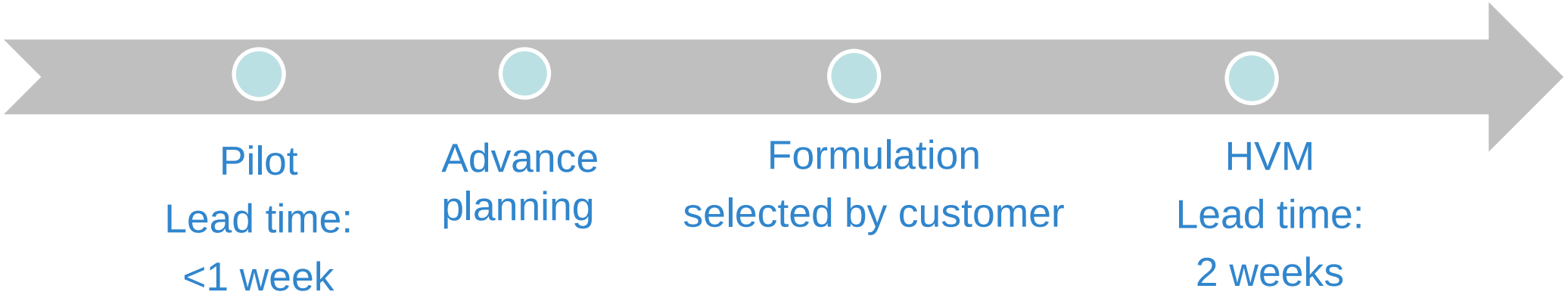
- R&D slurry formulation optimization ≤ 1 week
- 6 sample lots/day delivered to customer ≤ 24-48hrs

Bench to Pilot: Quick Turnaround Sample Process



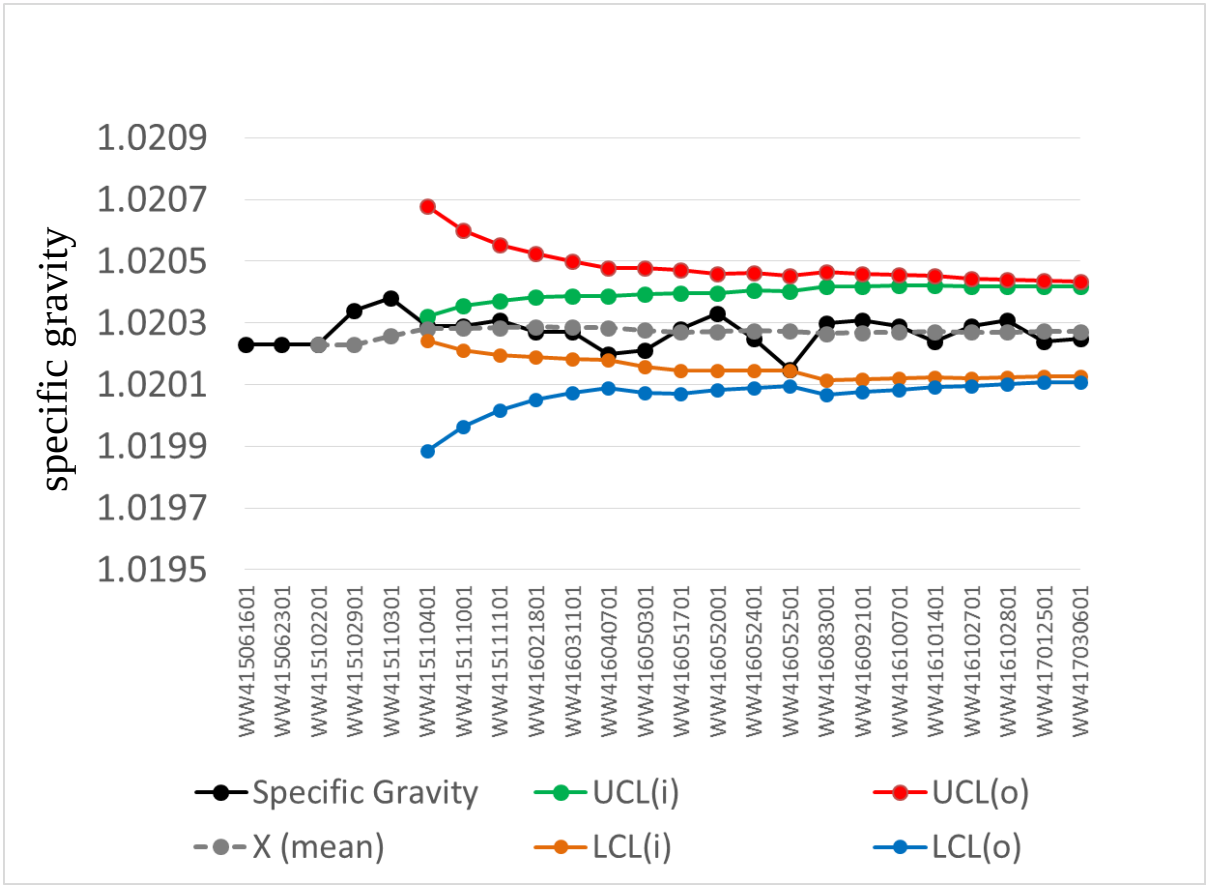
- Defined cross functional team process for delivering slurry samples to customers
  - Efficient system promotes fast delivery of samples
  - 400 samples shipped to customer in one year

Bench to Pilot to HVM: Slurry Ramp Lead Time



- Customers request fast slurry ramp < 2 weeks
  - Assessment of manufacturing gaps and options must be completed quickly

Bench to Pilot to HVM: Process Control Systems



- Short run SPC methodology used when N<30 lots
- Raw material control charts are also monitored
- Root cause investigation (8D) when lots are OOC

Future Challenges

- Cost reduction (e.g. RMs, slurry development)
- EHS (e.g. SDS approval, developing greener slurries)
- Slurry process improvements (e.g. reducing LPCs)
- Development of in process manufacturing monitors
- Metrology sensitivity limits

Summary

- Co slurry solutions are needed to enable next generation IC technology
- Fujimi has a toolbox of vetted chemistries/abrasives and efficient infrastructure to deliver quality product solutions to customers quickly
- Fast CMP solutions to future materials integration challenges will continue to be needed

Acknowledgements

- Jie Lin
- Jeff Mckinnis
- Fujimi Teams (R&D, Ramp, Engineering, QC, SALS and L&D)