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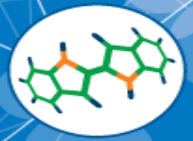
Quality of Semiconductor Raw Materials: Evolution and Challenges

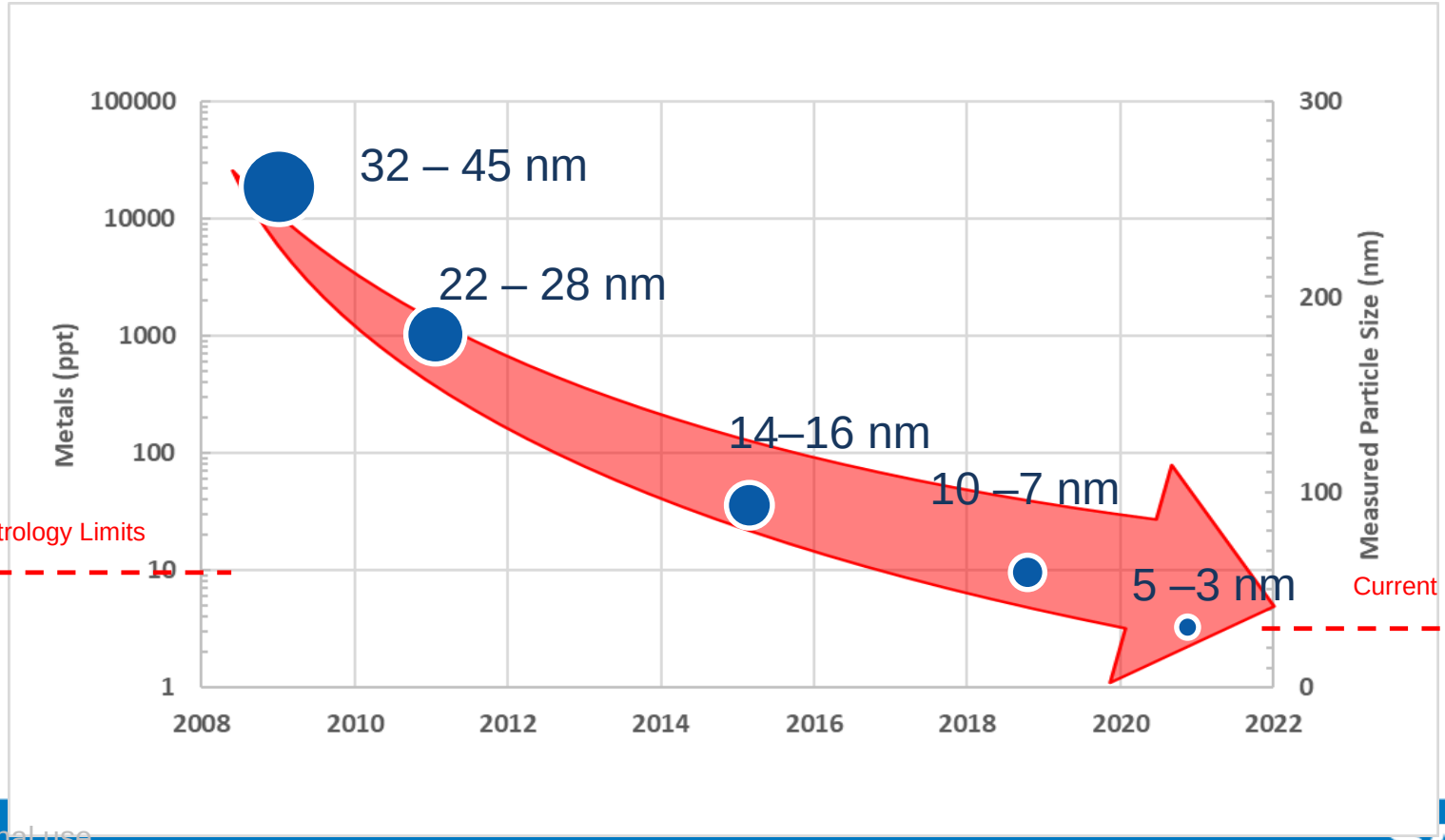
Yongqiang Lu
Kevin McLaughlin



Outline

- Advance of Fab technologies and the evolution of raw materials for ever higher quality
- Challenges: metrology
  - Case study--ICP MS
  - Case study—particle measurement
- Challenges: supply chain
  - Case study-supply chain
- Challenges: cost
- Summary

25% TMAH Quality Roadmap



Current Metrology Limits

Current Metrology Limits

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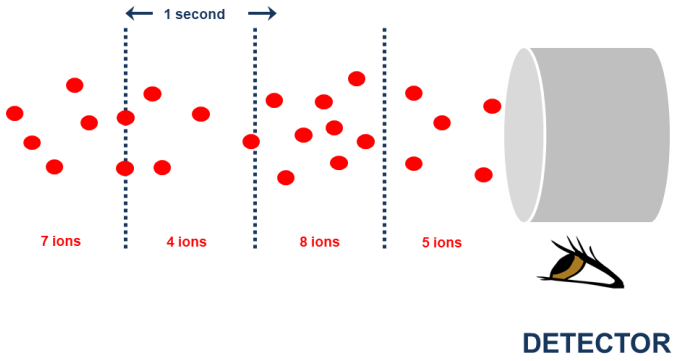
Challenges of Metrology

- Metal and particle metrologies have been pushed to their limits and lag behind the requirement
  - Metals: detection limit to the single ppt or below
    - Reality: 1~10 ppt especially in difficult matrix like TMAH
    - GR&R in the 30% or worse
  - Particles: <20 nm in liquids
    - Reality: 30nm
    - Nano/micro bubbles causing issues
- Contamination from every thing in contact with the products
  - packaging, tubing, even the instrument used to measure the samples
  - No material is clean including DIW, PTFE etc
  - In the field of Uncertainty Principle applies

Case Study –ICPMS

ppt	# "metal ions" in 40 nL/S
1000	43,000
100	4,300
10	430
1	43
0.1	4

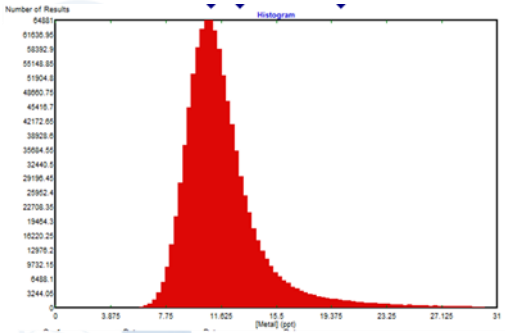


Counts
5
8
4
7

- At 10 ppt or less, only a few hundred metal ions reach ICPMS detector per second, measurement error increase significantly
- At 0.1 ppt, one metal ion from any where will contribute 25% of the measurement

Case study—ICPMS Monte Carlo Simulation

- 10 ppt solution
- 1,000,000 simulations
- Results collected in a histogram
- Distribution is asymmetric due to contamination events



	Metal in ppt
COA	8
Spec/UCL	10
IQC	12
Sigma	1.5
Sample size	**9**

- Using Poisson distribution model and process parameters
- Assume a true 10 ppt sample
- Simulation Result: Average 11.5 ppt,
- Distribution shift to the right (high) side due to contaminations events
- If the spec is 11.5, there will be 50% chance for the true 10 ppt sample to be measured out of spec

- Due to uncertainty, significantly more measurement needed to detect small difference
- Supplier and customer measurement correlation and lab collaboration absolutely key

Metrology: Metals

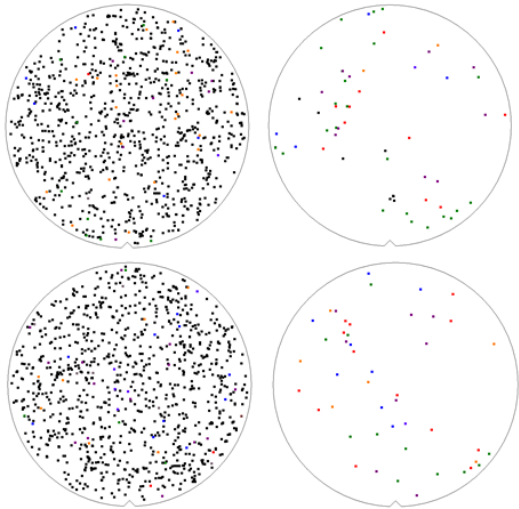
Ag	**15 ppt**	K	50 ppt
Al	**15 ppt**	Li	50 ppt
As	50 ppt	Mg	25 ppt
Au	50 ppt	**Mn**	**15 ppt**
B	300 ppt	Mo	50 ppt
Ba	50 ppt	Na	50 ppt
Be	50 ppt	**Ni**	**15 ppt**
Ca	100 ppt	Pb	50 ppt
Cd	50 ppt	Rb	50 ppt
Co	**15 ppt**	Sn	50 ppt
Cr	**15 ppt**	Sr	50 ppt
Cs	50 ppt	Ta	50 ppt
Cu	25 ppt	Ti	50 ppt
Fe	**10 ppt**	Tl	50 ppt
Ga	50 ppt	V	50 ppt
Hg	50 ppt	W	50 ppt
Ir	**15 ppt**	Zn	25 ppt

- Number of required metals continues to increase
- Increases likelihood of OOC event
- Metals levels as low as 10ppt require ICP-MS detection limits at 1ppt
- Extremely difficult to achieve in 25% TMAH matrix
- Current metrology limits closer to 10ppt
- Metrology method development required for each metal measured

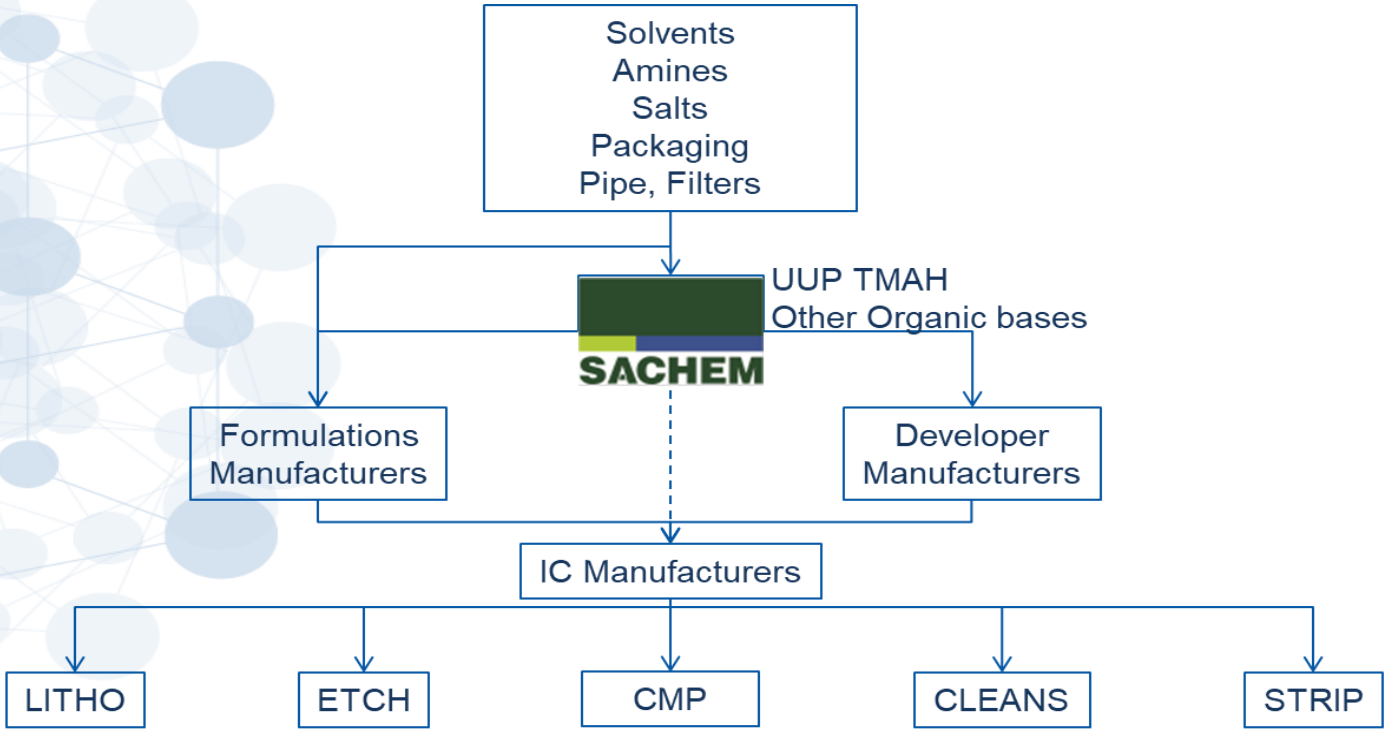
Case Study—LPC Particle Measurement

- Two different filtration systems
- LPC counted about the same for 2 samples ~300@0.03um
- Need LPC to be able to count lower than the current 30nm to 20 or even 10nm

- Huge difference on wafer particle count @ 20nm



Supply Chain



Supply Chain Challenges I

- Supplier, sub-supplier management
  - Petrochemical-based raw materials—dirty
  - Unmotivated suppliers—not willing to clean their products for semi applications –scale too small
- Management of Change moving upstream
  - “Better” may not be good, changes always “bad”, need to be closely managed
  - Bring sub-suppliers up to speed to Fab requirements
  - Freezes supply chain much earlier in development, limiting options
- Quality roadmap outpacing metrology
  - Controlling what you can’t see
    - Management of Change

Supply Chain Challenges II

- Demands for local supply
  - Challenges economies of scale
- Regional, local challenges
  - Different registration requirements and processes
  - China's pollution crackdown
- Product stewardship: Cradle to Grave has become Cradle to Cradle
  - Minimize waste, waste disposal
  - Waste composition (e.g. nitrogen content)
  - Recycle

Case Study --Supply Chain Minimizing Contaminations

Manufacturing
- Metal-free raw materials
- Metal-free process flow
- Purification and filtration

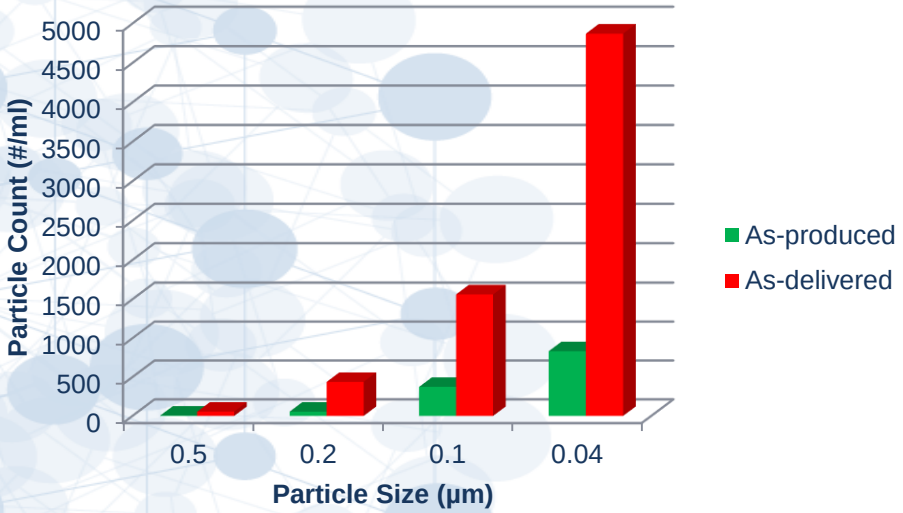
Bulk Delivery
- Metals <25 ppt
- Filtration @ 30-50 nm

Facility Side
- Metals <25 ppt
- Filtration @ 30 nm

Dilution/Chemical Distribution
- Metals <2.5 ppt
- Filtration @ 10-20 nm

Tool Side
- Metals <2.5 ppt
- Filtration @ 2-5 nm

Case Study --Product Packaging Effects



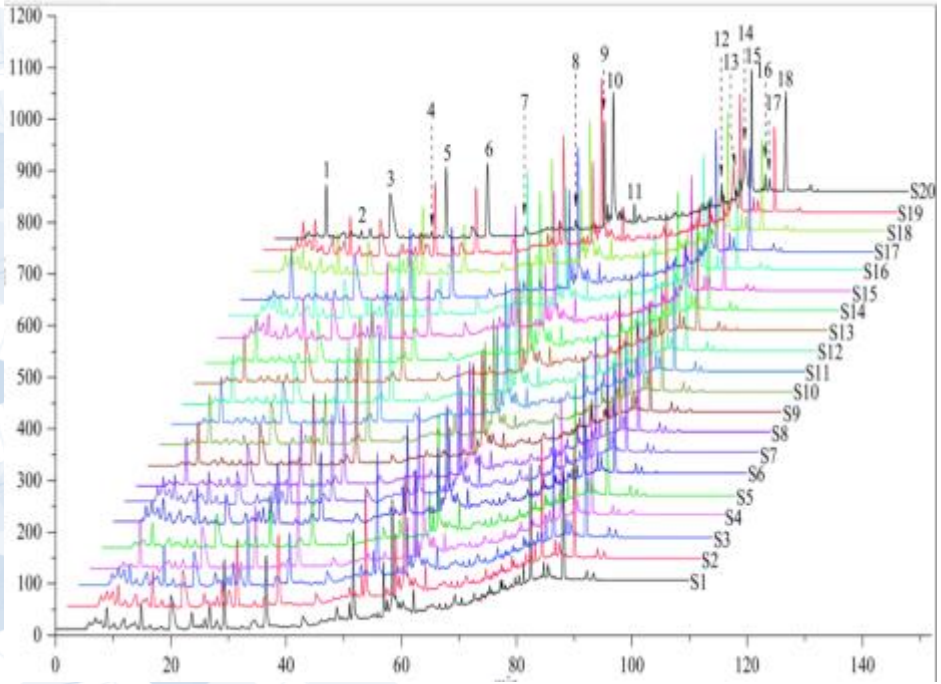
- Packaging well-known to affect product quality
  - Leaching of metals, organics
  - Shedding of particles
- Effects increase exponentially with severity of purity specifications
- Sufficiently clean packages order of magnitude more expensive than packages historically used
- Reusable packages used in closed-loop systems can meet purity requirements
- Customers generally require dedicated packaging return loops, greatly complicating logistics, inventory management

Case Study – O-Ring Metal Leaching

Element	Metal (ppt) OR1	Metal (ppt) OR2	Metal (ppt) OR3
B	234	222	< 200
Na	31	< 20	35
Mg	100	93	97
Al	171	194	169
K	< 20	24	40
Ca	< 20	< 20	25
Ti	22	< 20	< 20
Fe	< 20	< 20	< 20
Co	< 20	< 20	< 20
Ni	< 20	< 20	21
Cu	< 20	< 20	< 20
Zn	1548	< 20	< 20
As	< 20	< 20	< 20
Sr	< 20	< 20	< 20
Mo	< 20	< 20	< 20
Ag	< 20	< 20	< 20
Cd	< 20	< 20	< 20
Sn	< 20	181	< 20

- Three different O-ring from 2 vendors
- Soaked in 25% TMAH for 6 hours
- OR1 Could be a source of Zn contamination

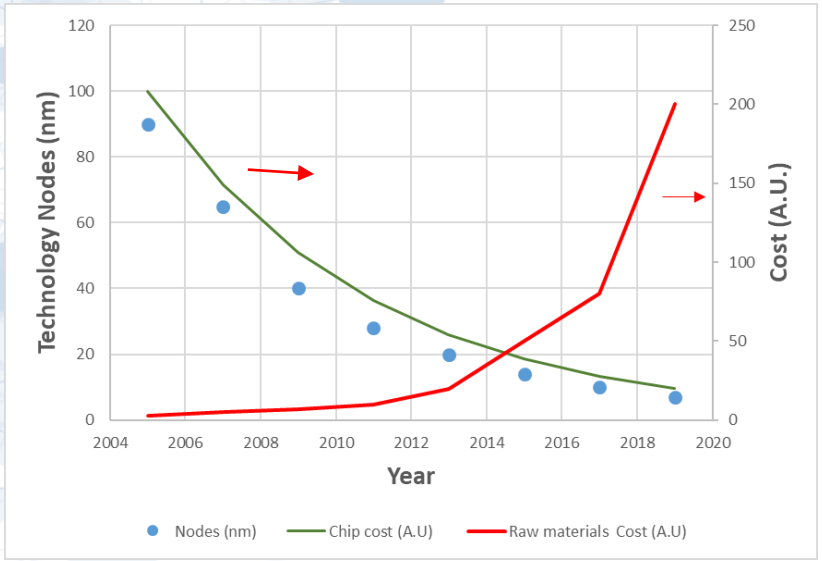
Product Fingerprinting



- Increasing requests for product fingerprinting to evaluate “unknown unknowns”
- Creates potential Intellectual Property concerns
- Raw material, manufacturing, and purification IP can be compromised through evaluation of fingerprinting data

Cost Considerations

Cost Trend of Raw Materials with Technology Nodes



Challenges

- Raw materials cost increase exponentially to meet the low ppt level metals and 30 nm particles for nodes 14nm and beyond
  - Increased PM, consumables, analytical
  - Increase packaging and package handling
  - Increase waste
  - Shortened equipment lifetime
  - Decreased process capacity etc
  - New cleanroom or upgrade
- One Sigma rule (only accepting product within 1 sigma range)
  - Will further increase the cost and waste
  - Find the use for about 40% rejected
  - Not encouraging reduce process variability

Summary

- Raw material suppliers face many critical challenges
  - Metrology not currently meeting the demands, facing a lot of Uncertainty
  - Much more complicated supply chain and processes
  - Stiff cost increase
- Develop vigorous quality control mentality
  - Working with customers, learning from customers, and serving the customers
- It's ALL about understanding and reducing variations
  - Specs is only the bare minimum
  - Stable performance of your products is the key
- Management of Change
  - Not just for customers
  - Process Change Notification, open communication with customers
  - Transparency is key, needs to be a 2-way street; Supplier to customer, customer to supplier

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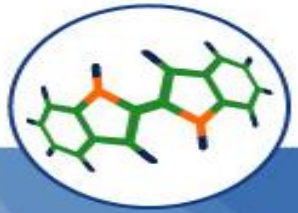
kmclaughlin@sacheminc.com
512-421-4929
ylu@sacheminc.com
512-421-4978



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