ULTRAPURE MICRO 2020

Development and Evaluation of a 3 nm Ultrapure Liquid Quality Monitor

Derek Oberreit[*], Steve Kosier[*], Siqin He[*], Jihyeon Lee[*#]

[*]Kanomax FMT, Inc.

[#]University of Minnesota, Twin Cities

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NANOPARTICLE MEASUREMENT SOLUTIONS

Presentation Outline

- Native Particles and Particle Precursors
  - Importance for IRDS Yield Enhancement 2020 Roadmap
- STPC3 Principle of Operation
  - Nebulization and size-selective condensation counting at 3, 9, and 15 nm
  - Measurement of both Native Particles and Particle Precursors
- Measured Response for Important Challenges and Liquids
  - UPW
    - Side-by-side instrument matching
    - Native Particles
      - SEMI C79 Silica Challenge
    - Particle Precursors
      - KCl challenge
      - High Molecular Weight Organics (HMWO) PSS challenge
  - Isopropyl Alcohol
- Conclusion and Future Work

IRDS 2020 Yield Enhancement Roadmap Highlights

- 3 nm critical particle size
- Particle Precursors are important
- Some Important Chemicals
  - IPA
  - H2O2
  - HCl

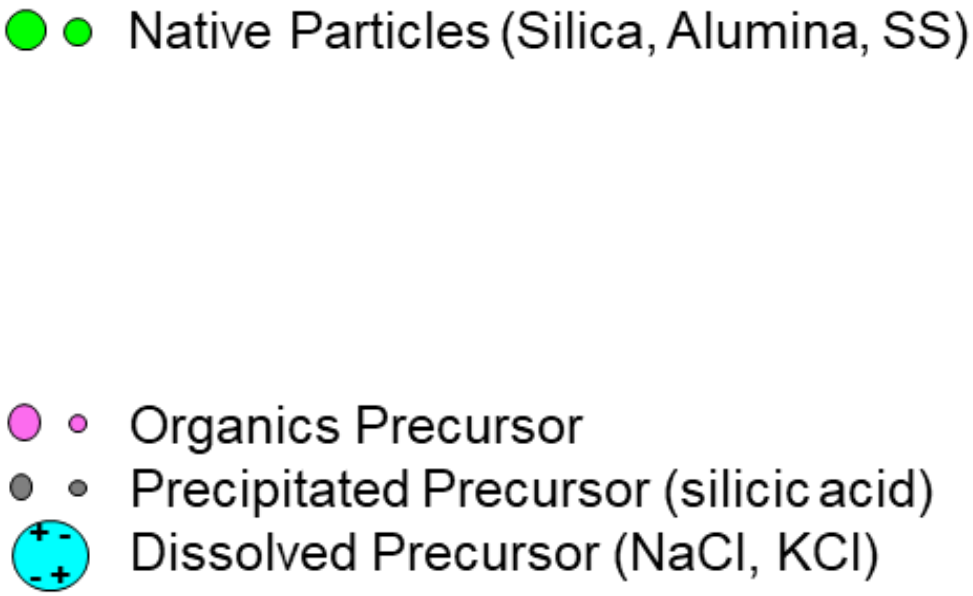
Table YE-3 Technology Requirements for Surface Environmental Contamination Control

Year of Production	2020	2021	2022	2023	2024	2025	2026	2027
Logic industry "Node Range" Labeling (nm)	"5"	"5"	"3"	"3"	"3"	"2.1"	"2.1"	"2.1"
IDM-Foundry node labeling	i7-f5	i7-f5	i3-f2.1	i3-f2.1	i3-f2.1	i2.1-f1.5	i2.1-f1.5	i2.1-f1.5
Logic device structure options	FinFet	FinFet	finFET LGAA	finFET LGAA	finFET LGAA	LGAA	LGAA	LGAA
Logic device mainstream device	FinFet	FinFet	finFET	finFET	finFET	LGAA	LGAA	LGAA
MPU/SoC Metalx ½ Pitch (nm)[1,2]	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Critical particle size non-electrically active (non-EAP) (nm) based on 50% of Logic 1/2 Pitch (nm (contacted) [1]	6	6	6	6	6	6	6	6
Critical particle size (nm) of Electrically Active particles based on 50% width of fin Logic SiGe Front End or other device critical dimensions for LGAA	3.5	3.5	3	3	3	3	3	3
Critical size (EUV mask), nm	12	12	12	12	12	12	12	12
Number of non-EAP at critical size (#/L) [26], POE	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
PROACTIVE: Non-EAP Particle Control: 50nm (#/L), Feed to the Final Filter	<140	<140	<140	<140	<140	<140	<140	<140
Number of particles for EUV mask production (#/L) [26.3], POE	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Particle Precursors, *#/L [56]*	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
100% IPA: High molecular weight organics (ppb)	300	300	250	200	300	250	200	200
100% IPA: % Assay Minimum [51] POP [Cleaning Chemistry]	99.91	99.91	99.94	99.94	99.91	99.94	99.94	99.94
100% IPA: Particle counts (50nm, #/ml) [52] POP [Cleaning Chemistry] PROACTIVE: Non-EAP Particle Control: 50nm (#/L)	<30	<30	<30	<30	<30	<30	<30	<30
100% IPA: Number of EAP at critical particle size (#/L) [26], POP	10000	10000	10000	10000	10000	10000	10000	10000
100% IPA: PROACTIVE: EAP Particle Control: 50nm (#/L) [26], POD	<30	<30	<30	<30	<30	<30	<30	<30
100% IPA: Number of non-EAP at critical size (#/L) [26], POP	10000	10000	10000	10000	10000	10000	10000	10000
100% IPA: PROACTIVE: Non-EAP Particle Control: 50nm (#/L), POD	<140	<140	<140	<140	<140	<140	<140	<140
30% H2O2: Particle counts (200nm, #/ml) [52] POP [Functional Chemistry]	250	250	200	150	250	200	150	150
37% HCl: Particle counts (200nm, #/ml) [52] POP [Functional Chemistry]	250	250	200	150	250	200	150	150

The Yield Enhancement Roadmap calls for improved liquid particle metrology in the coming years

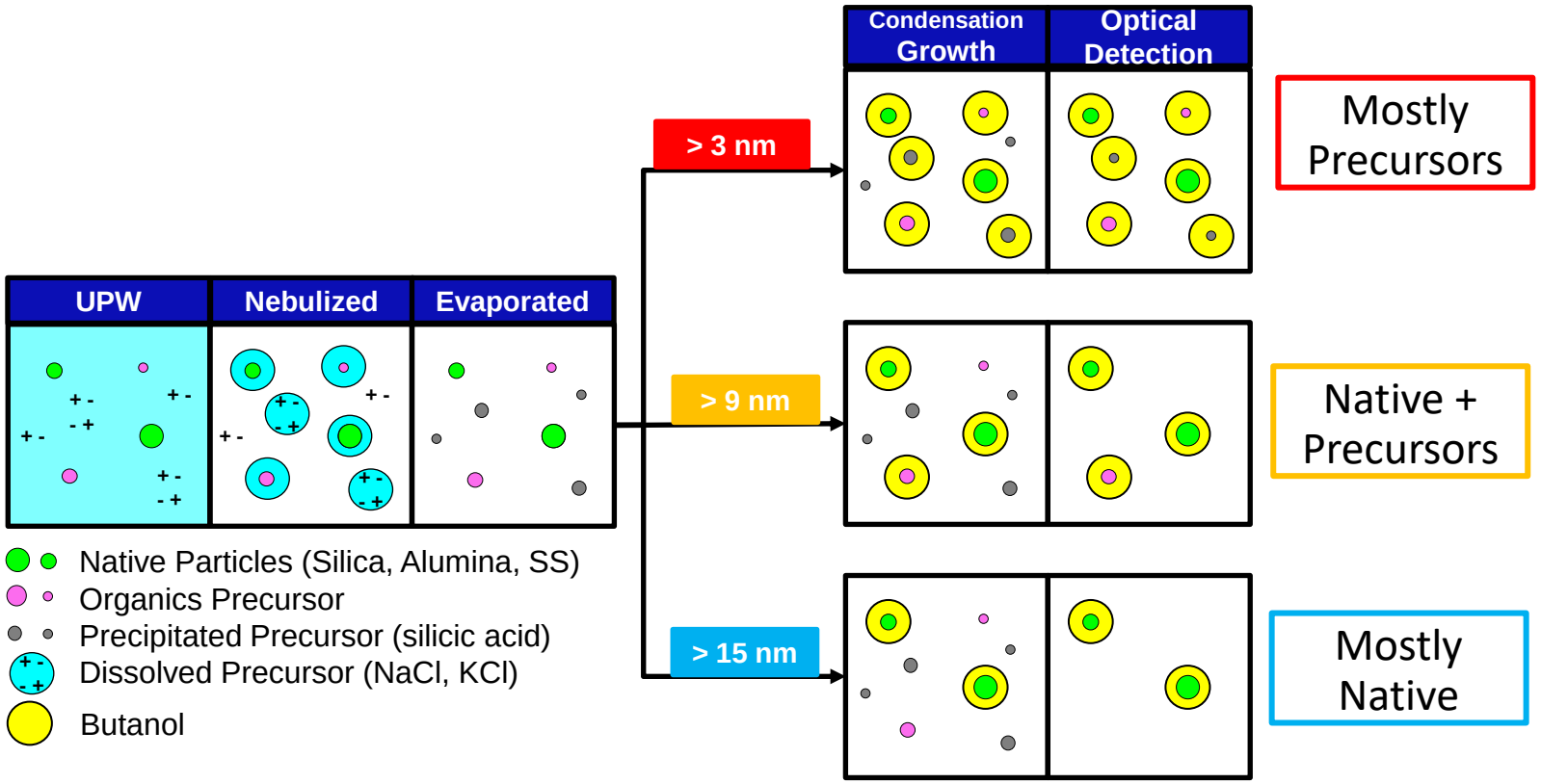
Native Particles and Particle Precursors - Liquid Quality Detractors

- ***Native particle*** – a particle that exists in a fluid at or close to its final size and shape if removed from the fluid.
  - Examples – colloidal silica, stainless steel.
- ***Particle precursor*** – dissolved or molecular material in a fluid smaller than a "critical size" that may form a particle of "critical size" when a droplet dries or may precipitate under changing conditions.
  - Examples – high-molecular weight organics, silicic acid.



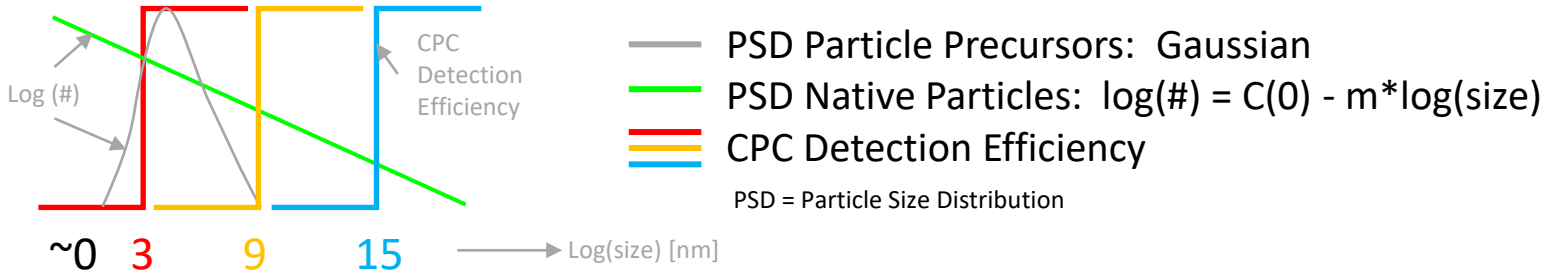
- Many types of contaminants affect liquid Quality.
- A comprehensive Liquid Quality Monitor should respond to as many contaminants as possible.

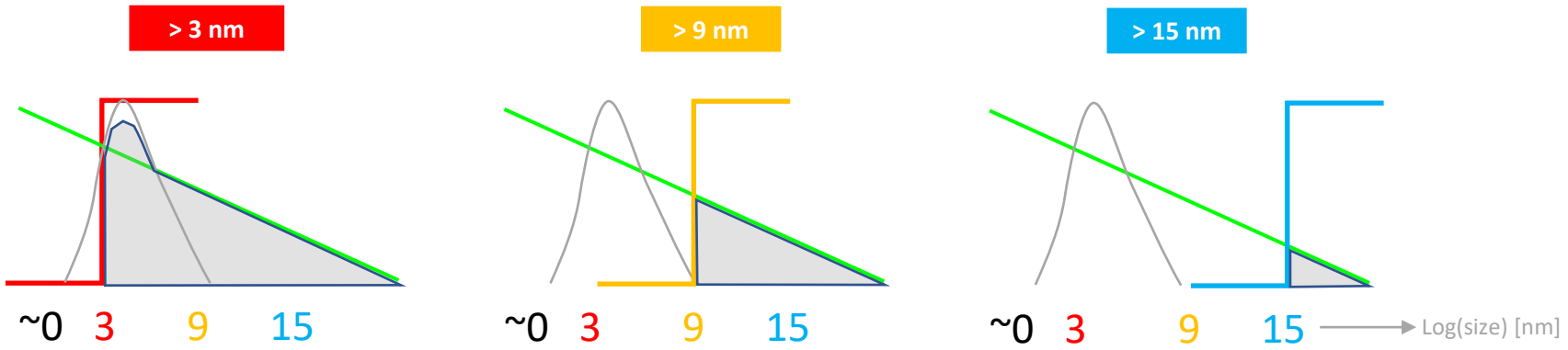
UPW Quality Measurement down to 3 nm - Illustration



Engineered aerosolization followed by size selective condensation growth and counting responds to many important UPW contaminants

UPW Quality Measurement down to 3 nm - illustration

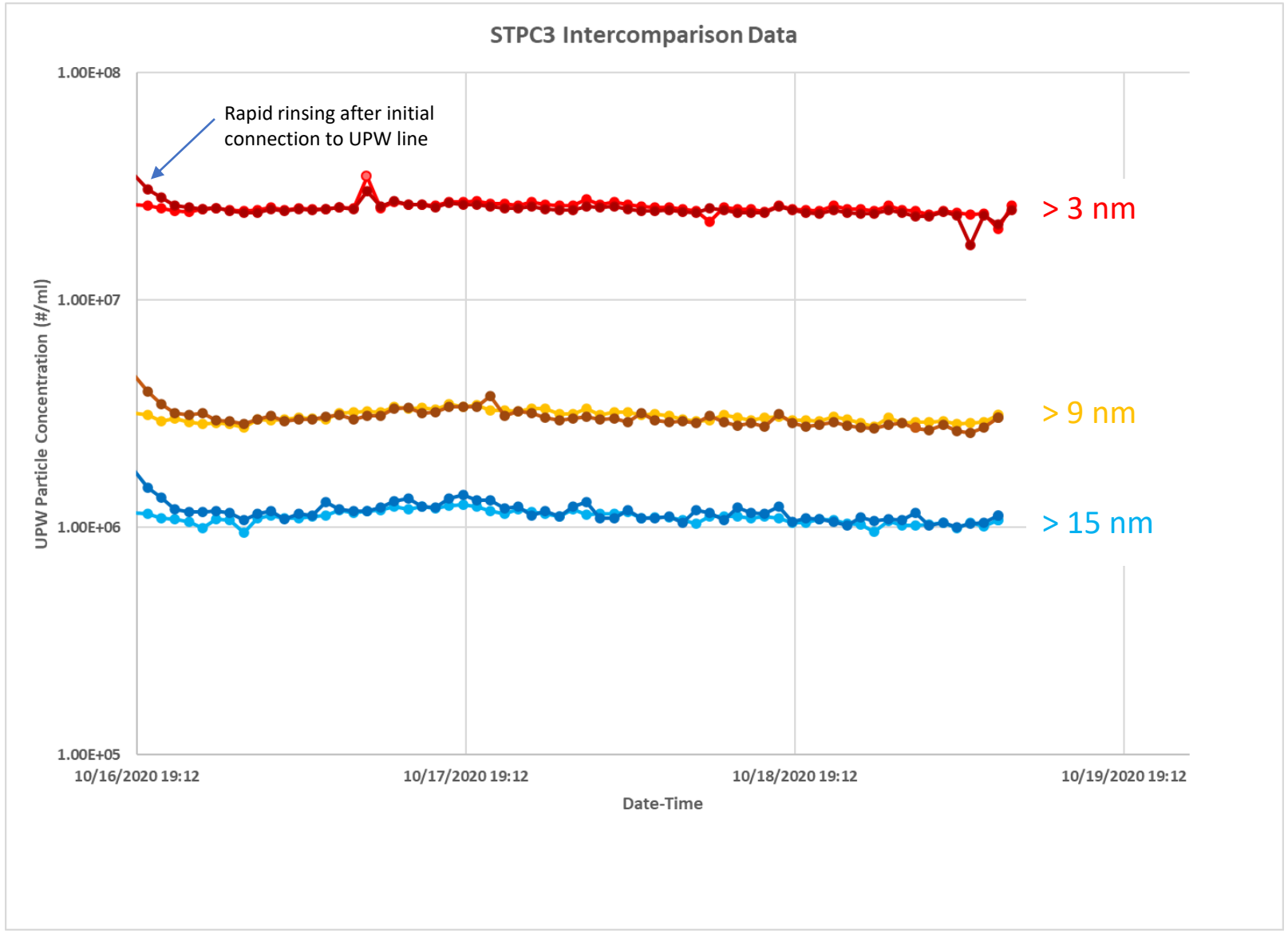




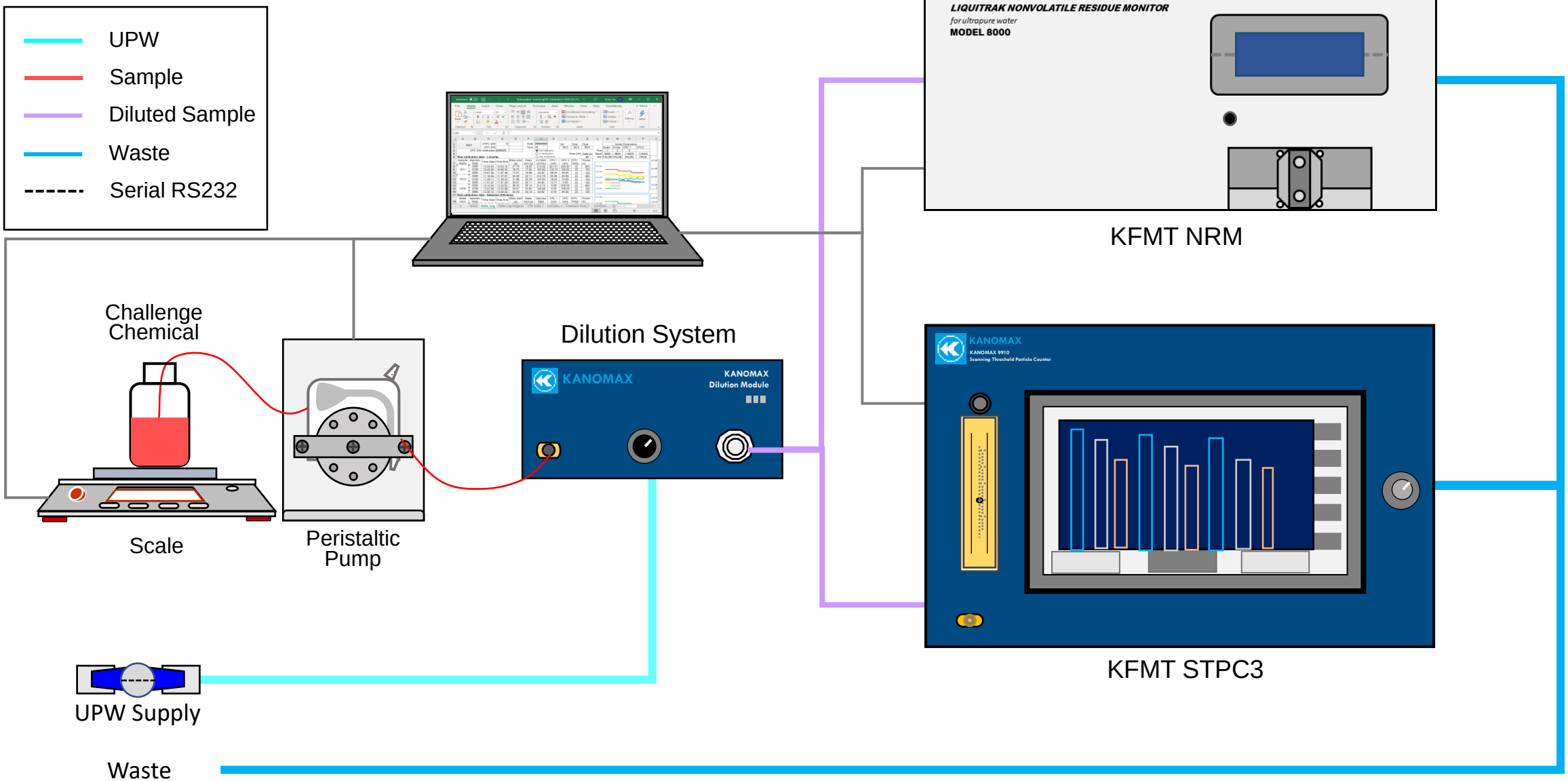
Size selective condensation growth down to 3 nm enables both Particle Precursor and Native Particle distributions to be measured.

Stable 24/7 UPW Measurement

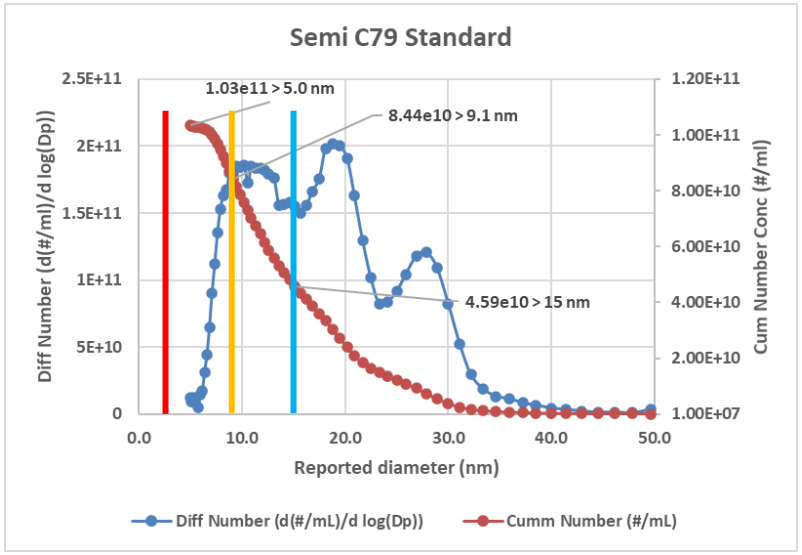
- STPC3 is a 24/7 online liquid quality monitor.
- 2x STPC3 on the same UPW at KFMT is shown
- After calibration, excellent unit-to-unit matching is observed on all 3 size channels.



Challenge Test Method

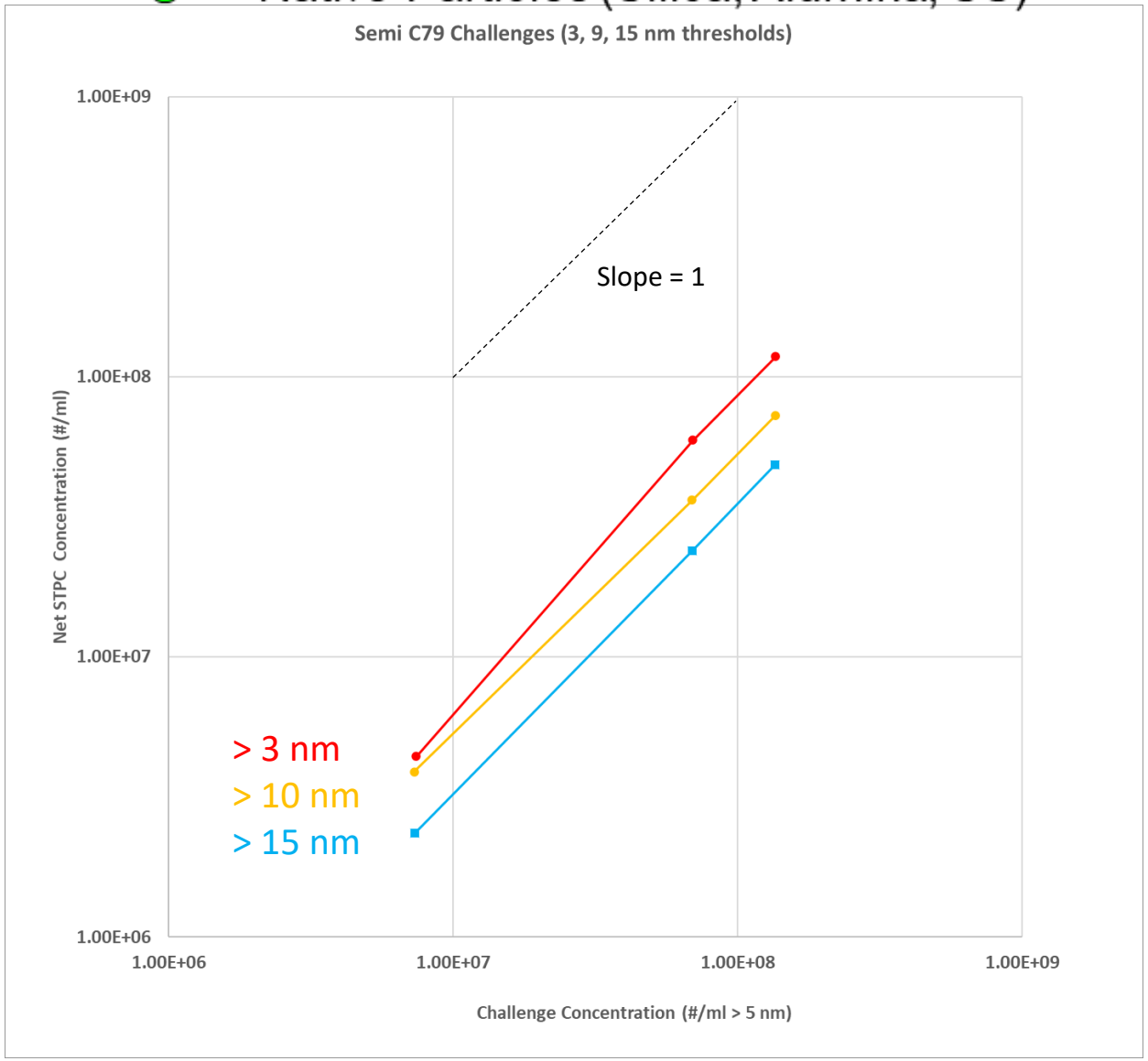


Silica Native Particle Response

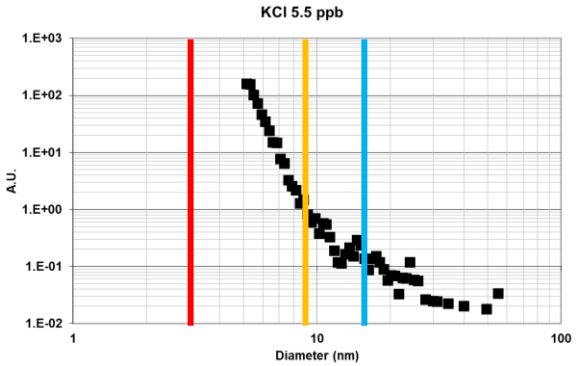


- The new C79 silica (native) particle challenge standard extends to 5 nm and below.
- The STPC3 linearly responds to the standard on all channels, in the proper ratios, as expected.

Native Particles (Silica, Alumina, SS)

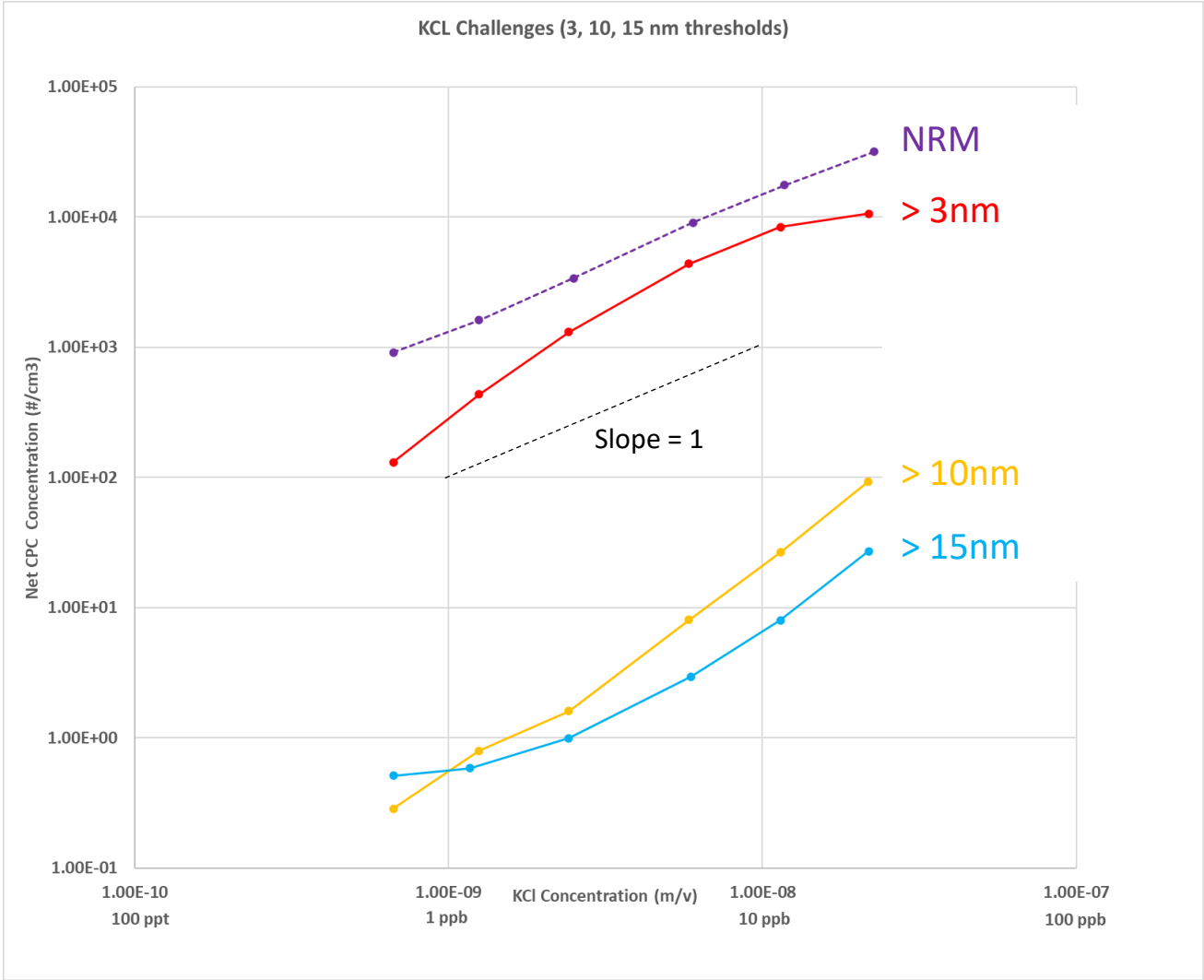


KCl Dissolved Precursor Response



- Dissolved salts in UPW are a well-understood yield and reliability concern
  - Gaussian distribution with a peak << 10 nm
- 3 nm channel shows response curve similar to a commercial non-volatile residue monitor (NRM).
  - 3 nm channel of STPC3 performs provides equivalent information to the NRM.
- 10 and 15 nm channels show little response until about 10 ppb, as expected.

Dissolved Precursor (NaCl, KCl)



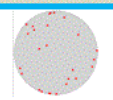
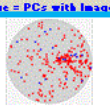
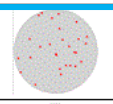
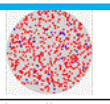
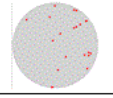
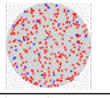
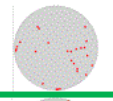
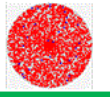
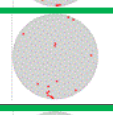
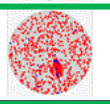
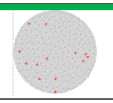
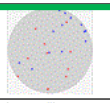
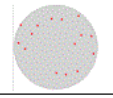
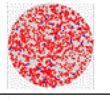
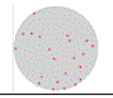
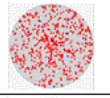
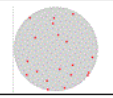
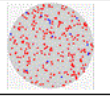
High Molecular Weight Organic (HMWO) Deposition on Wafers

Organics Precursor

- HMWO in UPW can arise from many sources
  - IX Resin, Filters, plumbing, components
- HMWO in UPW deposits on wafers.
  - 19 nm scan with KLA SP5
  - Even unspiked UPW (row 1) shows defectivity
    - Particle precursors are present in UPW.
  - ~1e7/ml HMWO (row 5) produces many adders.

Procedure:

- UPW was collected in the Fab from the chamber nozzle of a spin cleaning tool.
- The 1MDa HMWO (filtered, 3.6E11/mL) and the Resin Extract samples were each diluted with the UPW to two different concentrations, as indicated in the table below.
- Next, bare Si NPWs were processed on a spin-cleaning tool using a recipe that ran as follows:
  1) 30s SC-1 rinse, 2) 40s UPW rinse, 3) 120 mL of "Spin-Coated Solution" was poured onto the wafer while it spun at 20rpm,
  4) lastly the wafer was spun to dryness at 1500rpm for 22s under a stream of nitrogen gas .

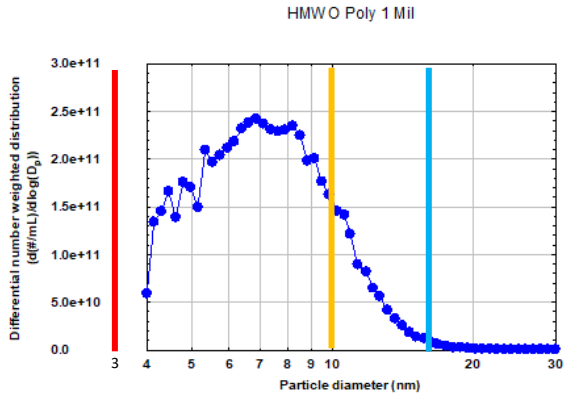
Wafer Preparation Details						19NM Defect Scan Results		
Run Order	Slot ID	Spin-Coated Solution	Process Recipe Cleaning Steps	Process Recipe Spin-Coating Step	Process Recipe Spin-Drying Step	Defect Map Before Coating	Defect Map After Coating, Only Added Defects Shown, Blue = PCs with Images	Post-Scan Details
1	24	DI Water Only	SC1 Rinse and DI Water Rinse	Pour 120 mL solution while spinning at 80rpm	Spin at 1500rpm under a Nitrogen Gas Stream			373 Added, 25 Imaged, 3 PCs found
2	22	Resin Extract 1:600 Dilution in DI Water	SC1 Rinse and DI Water Rinse	Pour 120 mL solution while spinning at 80rpm	Spin at 1500rpm under a Nitrogen Gas Stream			873 Added, 30 Imaged, 12 PCs found
3	17	Resin Extract 1:3000 Dilution in DI Water	SC1 Rinse and DI Water Rinse	Pour 120 mL solution while spinning at 80rpm	Spin at 1500rpm under a Nitrogen Gas Stream			480 Added, 31 Imaged, 11 PCs found
4	16	1MDa HMWO 1E9/mL in DI Water	SC1 Rinse and DI Water Rinse	Pour 120 mL solution while spinning at 80rpm	Spin at 1500rpm under a Nitrogen Gas Stream			3830 Added, 35 Imaged, 3 PCs found
5	9	1MDa HMWO 1E7/mL in DI Water	SC1 Rinse and DI Water Rinse	Pour 120 mL solution while spinning at 80rpm	Spin at 1500rpm under a Nitrogen Gas Stream			83934 Added, 23 Imaged, 15 PCs found
6	4	None (BLANK)	SC1 Rinse and DI Water Rinse	No Liquid Dispense while spinning at 80rpm (BLANK)	Spin at 1500rpm under a Nitrogen Gas Stream			60 Added, 23 Imaged, 3 PCs found
7	3	1MDa HMWO 1E9/mL in DI Water	SC1 Rinse and DI Water Rinse	Pour 120 mL solution while spinning at 10rpm	Spin at 150rpm under a Nitrogen Gas Stream			2506 Added, 35 Imaged, 31 PCs found
8	2	1MDa HMWO 1E9/mL in DI Water	SC1 Rinse and DI Water Rinse	Slowly Pour 120 mL solution while spinning at 1800rpm under a Nitrogen Gas Stream	Spin at 1800rpm under a Nitrogen Gas Stream			360 Imaged, 33 Imaged, 3 PCs found
9	1	1MDa HMWO 1E9/mL in DI Water	SC1 Rinse and DI Water Rinse	Pour 120 mL solution while spinning at 200rpm	Spin at 1500rpm under a Nitrogen Gas Stream			652 Added, 32 Imaged, 21 PCs found

Data courtesy of Nabil Mistkawi and Michael Rasch, Samsung Austin Semiconductor, 2020

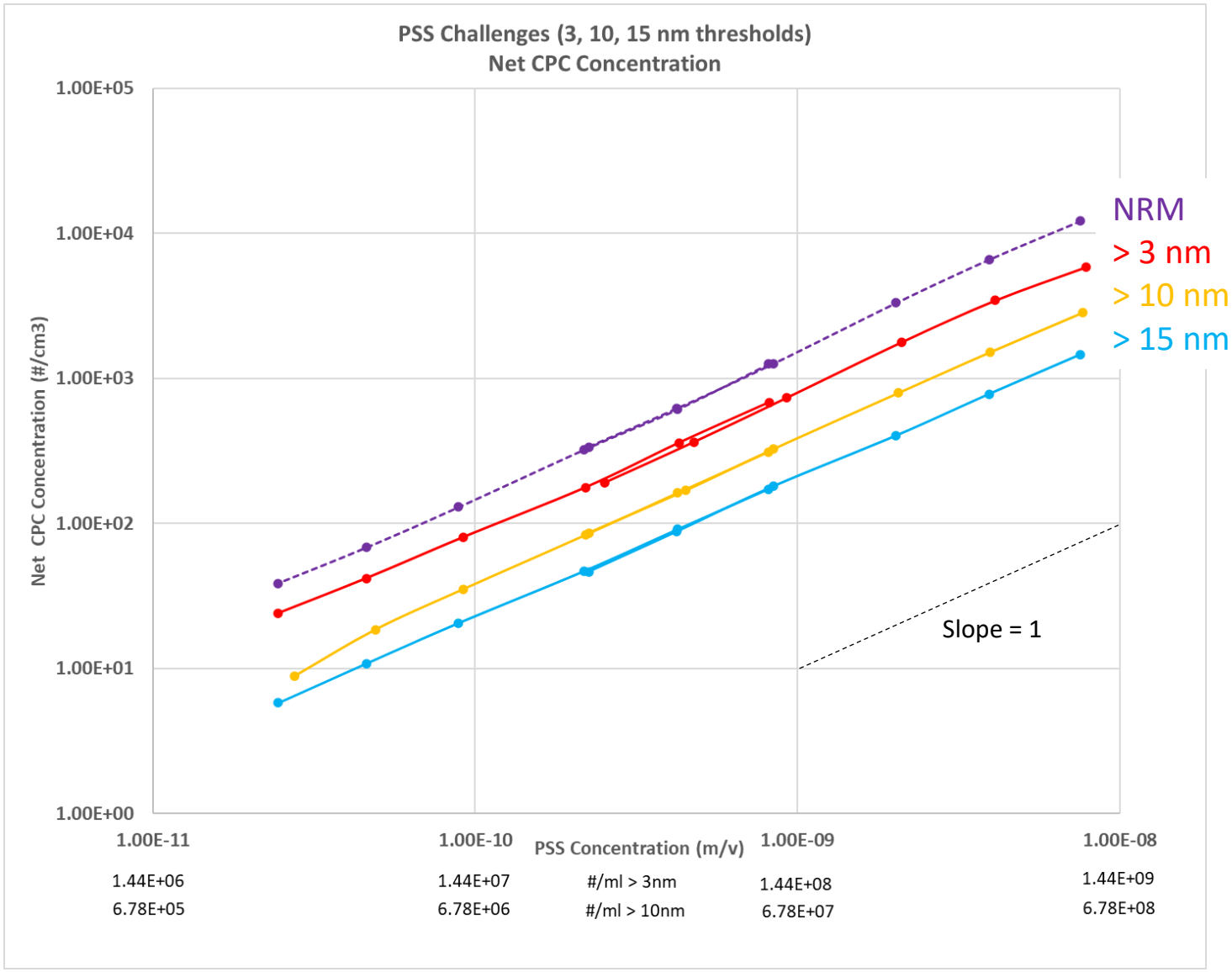
HMWO Precursor Response

Organics Precursor

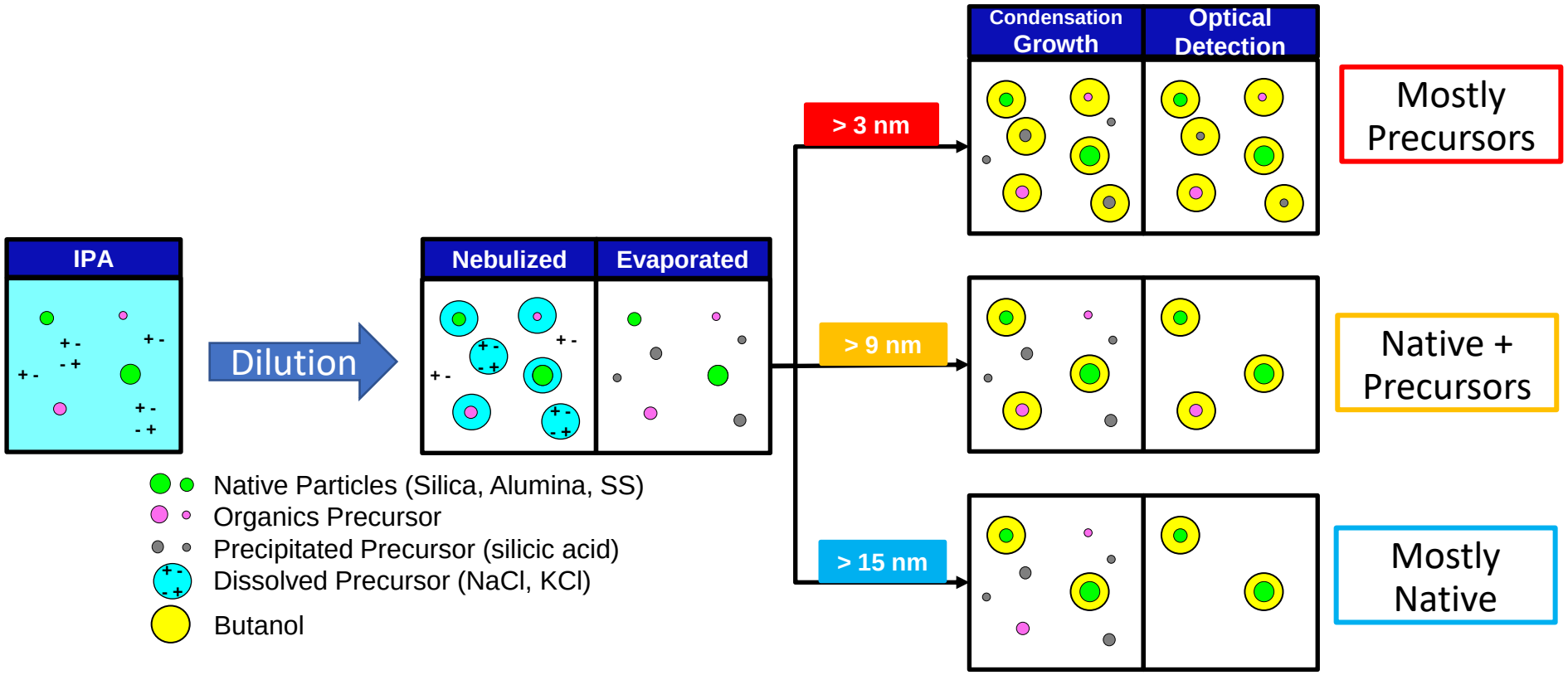
Data from CT Associates



- STPC3 and NRM responds to HMWO 1:1 on all channels.
- 3 nm channel has similar sensitivity to NRM.
- HMWO concentrations below 1e7/ml (measurable defects on wafer) are detected by STPC3.



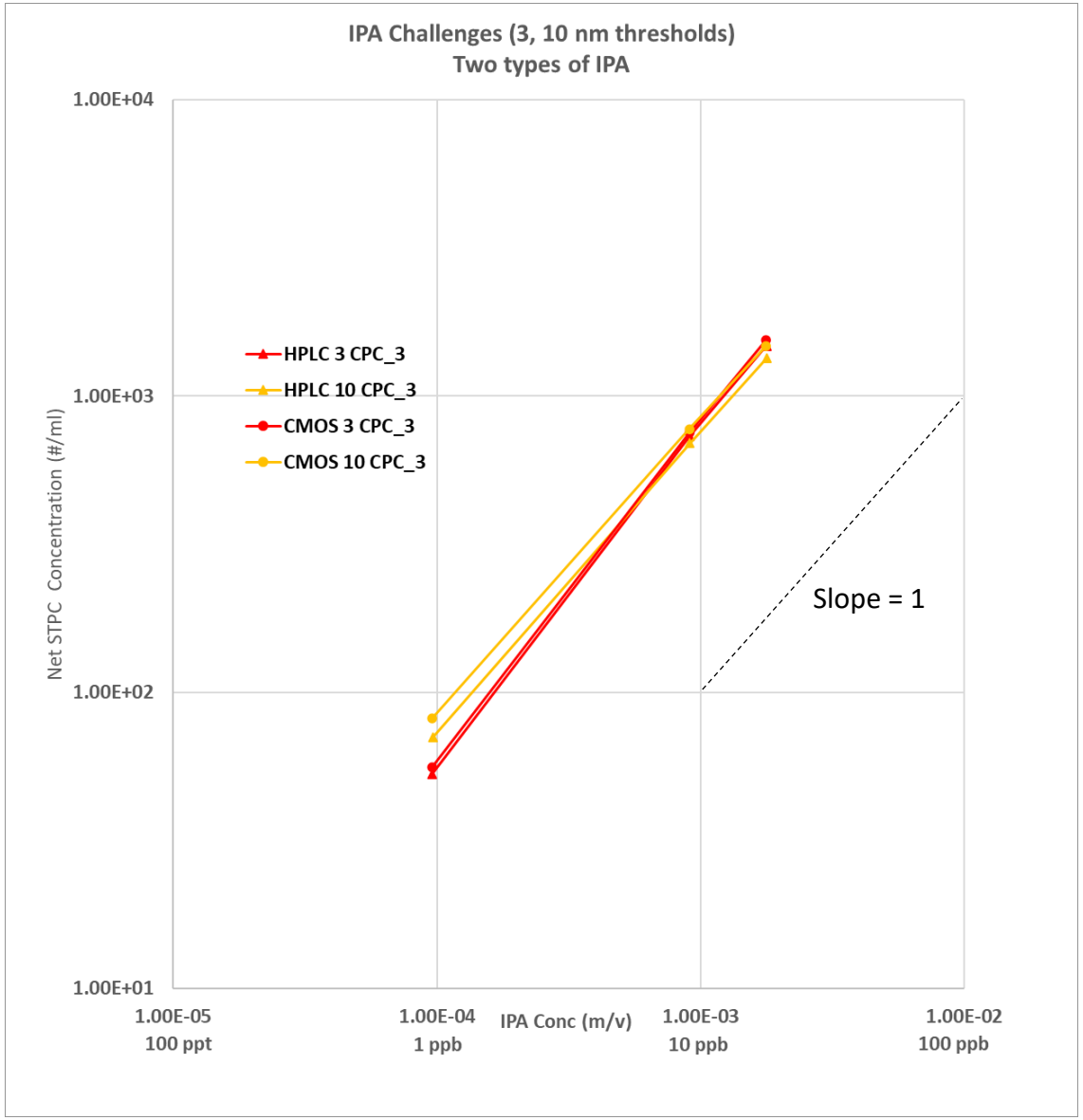
Liquid Quality Measurement down to 3 nm – IPA example



Some common and important solvents, such as IPA, can be measured with the STPC3.

Isopropyl Alcohol (IPA) Response

- Linear response to the IPA challenge.
- 3 nm and 10 nm channels have very similar response
  - Most particles are larger than 10 nm.
- CMOS grade has higher counts than HPLC grade
- STPC3 can be used to measure and monitor IPA down to 3 nm.



Conclusions and Future Work

- The STPC3 is a Liquid Quality Monitor for both Native Particles and Particle Precursors in UPW and other Liquids.
  - Operates below the detection limit of OPCs – 3, 9, 15 nm channels
- STPC3 responds to many important liquid contaminants
  - Relative responses of each channel varies depending on the challenge.
  - UPW
    - Silica response (Native Particles)
    - HMWO response (Particle Precursors)
    - KCl response (Particle Precursors)
  - IPA
    - Linear response to IPA challenge observed
- In the future, we will expand the STPC3 allowed chemicals to include dilute Peroxide, Ammonia, and HCl.

ULTRA PURE MICRO 2020

Thank You
CT Associates, Samsung Austin Semiconductor

Derek Oberreit, Kanomax FMT, Inc.

Derek.Oberreit@KanomaxFMT.com

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