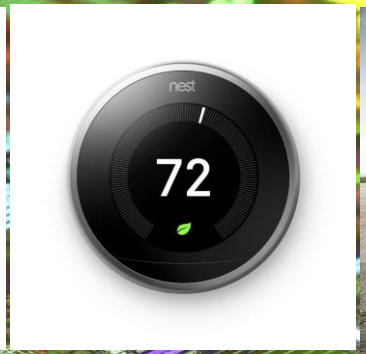
# VERSATILITY OF A CONDENSATION GROWTH TUBE FOR AEROSOL AND HYDROSOL COLLECTION USING A nanoSpotLight™

PAT KEADY, President, Aerosol Devices Inc

Aerosol Devices Inc





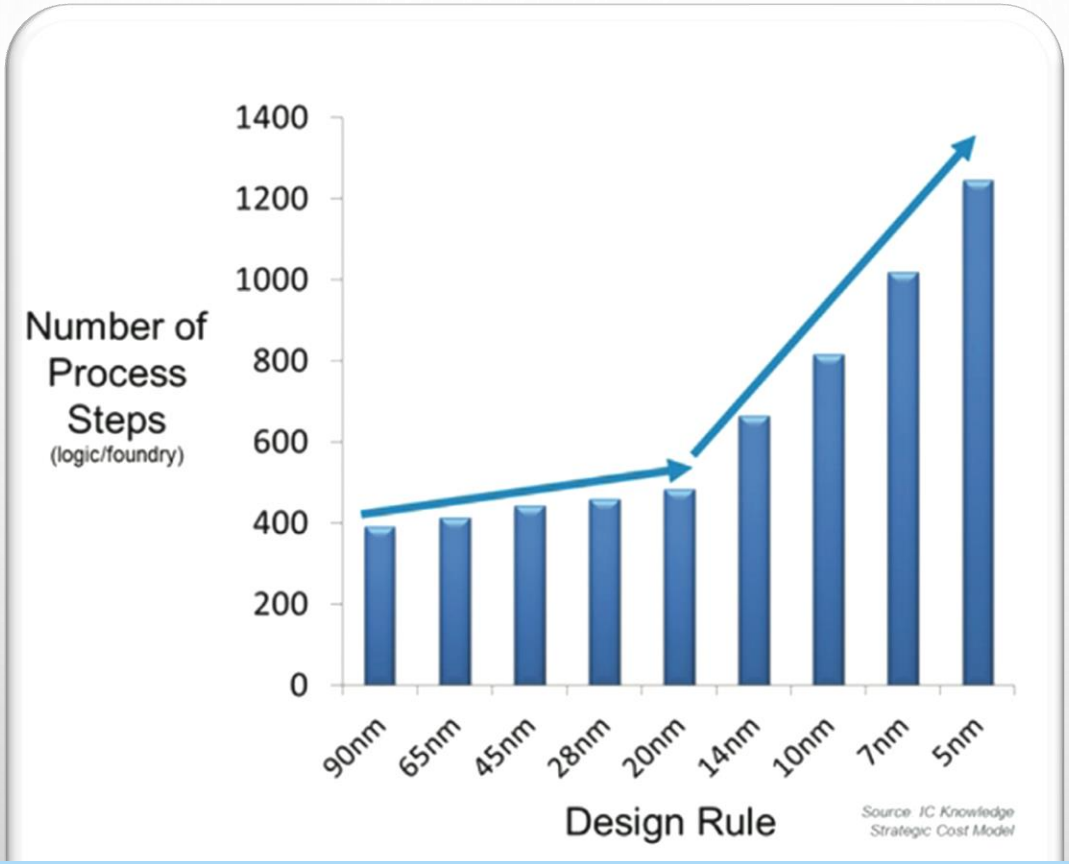


# SEMICONDUCTOR INTEGRATED CIRCUITS

# SEMICONDUCTOR ULTRAPURE WATER (UPW)

- Highest grade of water lacking contaminants: microorganisms, dissolved and particulate matter, minerals, organic or inorganic chemicals
- Used extensively for rinsing, diluting chemicals, other processes
- Purified to the level at or below our metrology detection limits – or is it?

| NODE SIZE |
| --- |
| •10 µm – 1971<br>•6 µm – 1974<br>•3 µm – 1977<br>•1.5 µm – 1982<br>•1 µm – 1985<br>•800 nm – 1989<br>•600 nm – 1994<br>•350 nm – 1995<br>•250 nm – 1997<br>•180 nm – 1999<br>•130 nm – 2001<br>•90 nm – 2004<br>•65 nm – 2006<br>•45 nm – 2008<br>•32 nm – 2010<br>•22 nm – 2012<br>•14 nm – 2014<br>•10 nm – 2017<br>•7 nm – ~*2018*<br>•5 nm – ~*2020* |
| |
| Limit of Moore's Law? |




**MOORE'S LAW**

"Transistor density on integrated circuits doubles about every two years."

SHRINKING NODES
means
INCREASING PROCESS STEPS

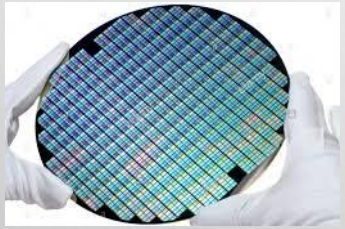
and SHRINKING KILLER PARTICLE SIZE

UPW and AIR particle contamination potential multiplies

# SEMICONDUCTOR PROCESSES
# ULTRAPURE WATER (UPW)

**PROCESS STEPS**

- FRONT END
- BACK END
- TEST
- PACKAGING



- Wafer processing
- Wet cleans
- Photolithography
- Ion implantation
- Dry etching
- Wet etching
- Plasma ashing
- Thermal treatments
- Rapid thermal anneal
- Furnace anneals
- Thermal oxidation
- Chemical vapor deposition (CVD)
- Physical vapor deposition (PVD)
- Molecular beam epitaxy (MBE)
- Electrochemical Deposition (ECD)
- Chemical-mechanical planarization (CMP)
- Wafer testing
- Wafer backgrinding
- Die preparation
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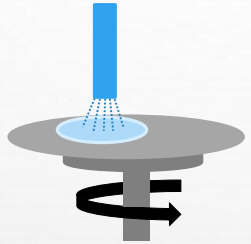
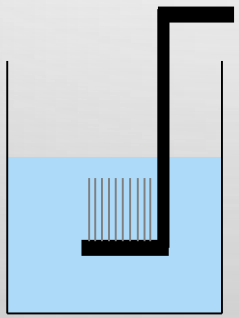
- Die cutting
- IC packaging
- Die attachment
- IC Bonding
- Wire bonding
- Flip chip
- Tab bonding
- IC encapsulation
- Baking
- Plating



**UPW RINSE**



**UPW SUPPLY**

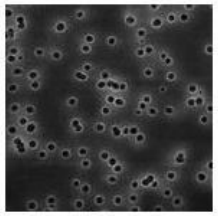
RECLAIM RECYCLE

**UPW WASTE**

TREATMENT / WASTE

**ON-LINE PARTICLE MONITOR**

**SAMPLING/ OFF-LINE ANALYSIS**



# ON-LINE UPW PARTICLE MONITORING TECHNOLOGY HAS HIT THE WALL

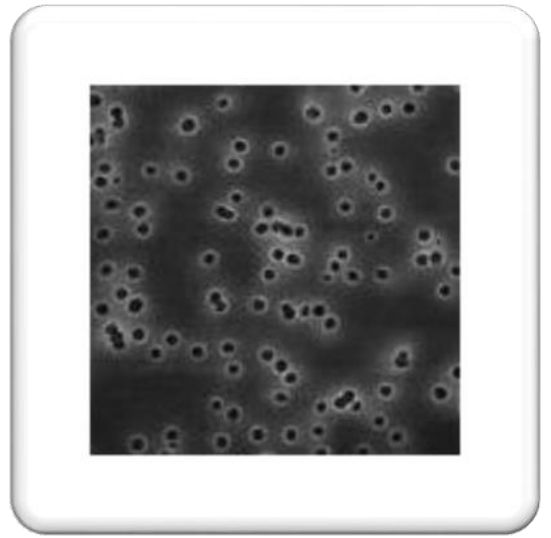
Optical particle counter (OPC) –
3% detection sensitivity at 20 nm

**BUT, industry needs PARTICLE detection down to 7 nm (or lower)!**

# PARTICLE SAMPLING – OFF-LINE SEM/EDX ANALYSIS

**MEMBRANE FILTRATION**

- ✓Slow
- ✓Hard to find the particles
- ✓Inability to retain smaller killer particles



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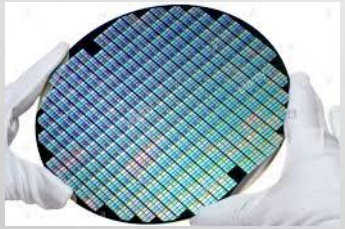

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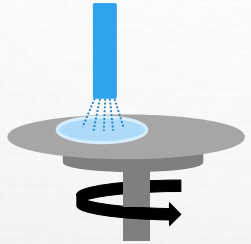

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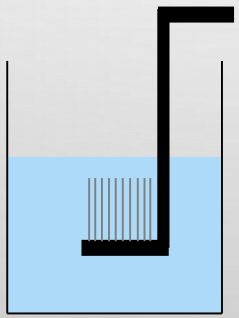

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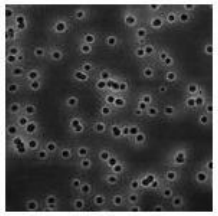

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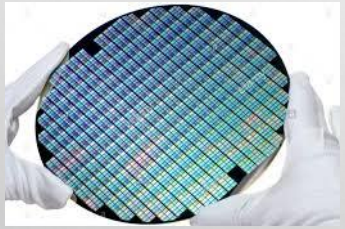

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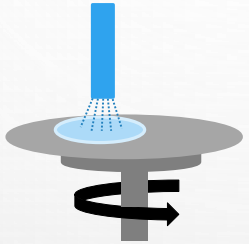

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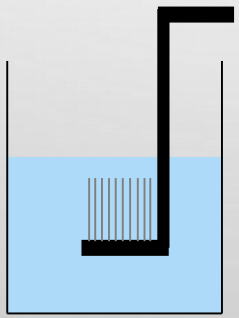


**UPW SUPPLY**

RECLAIM RECYCLE

**UPW WASTE**

TREATMENT / WASTE

**STPC PARTICLE MONITOR**

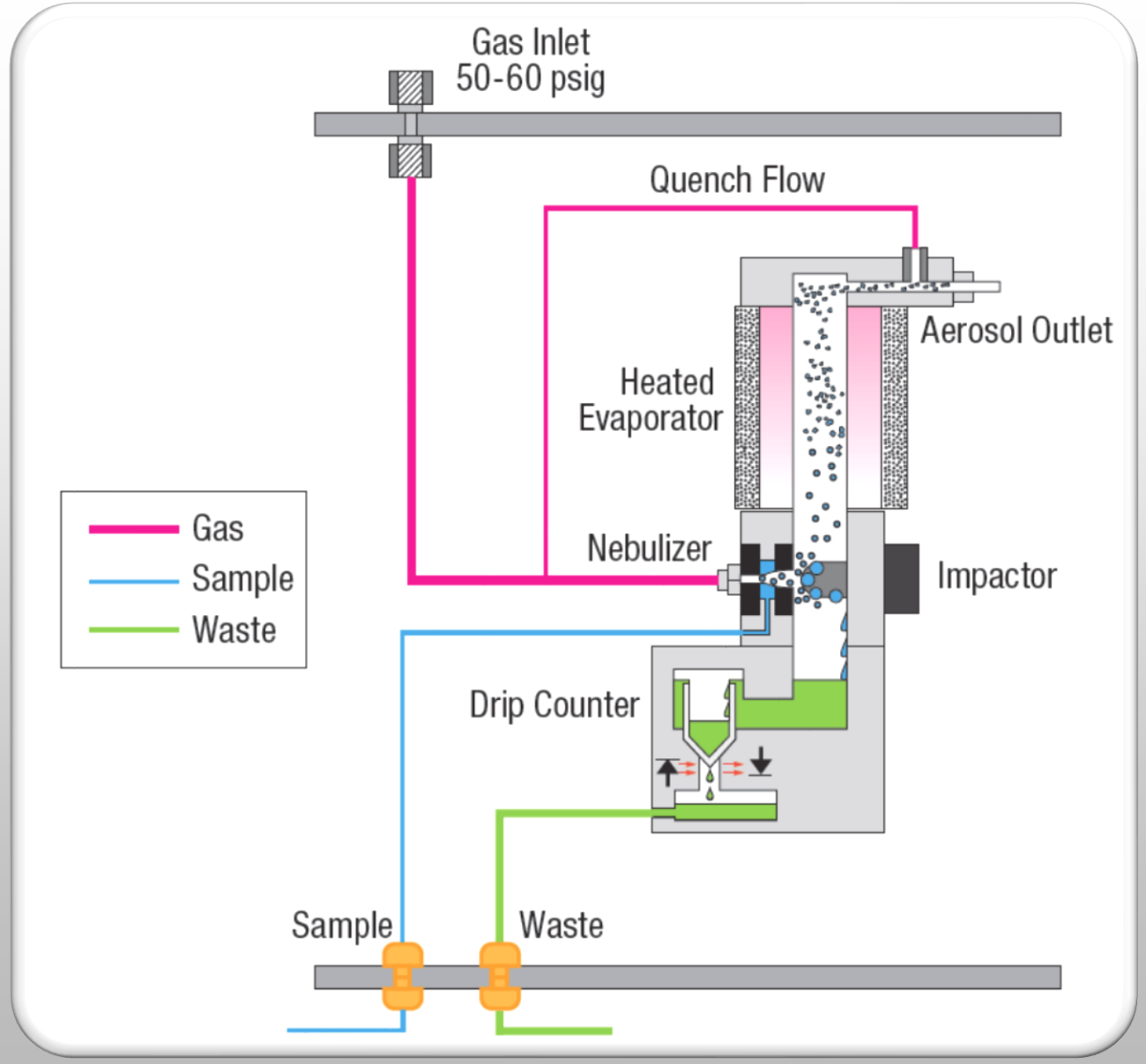
nanoSpotLight / **OFF-LINE ANALYSIS**

# A NEW APPROACH
## *from Aerosol Science*

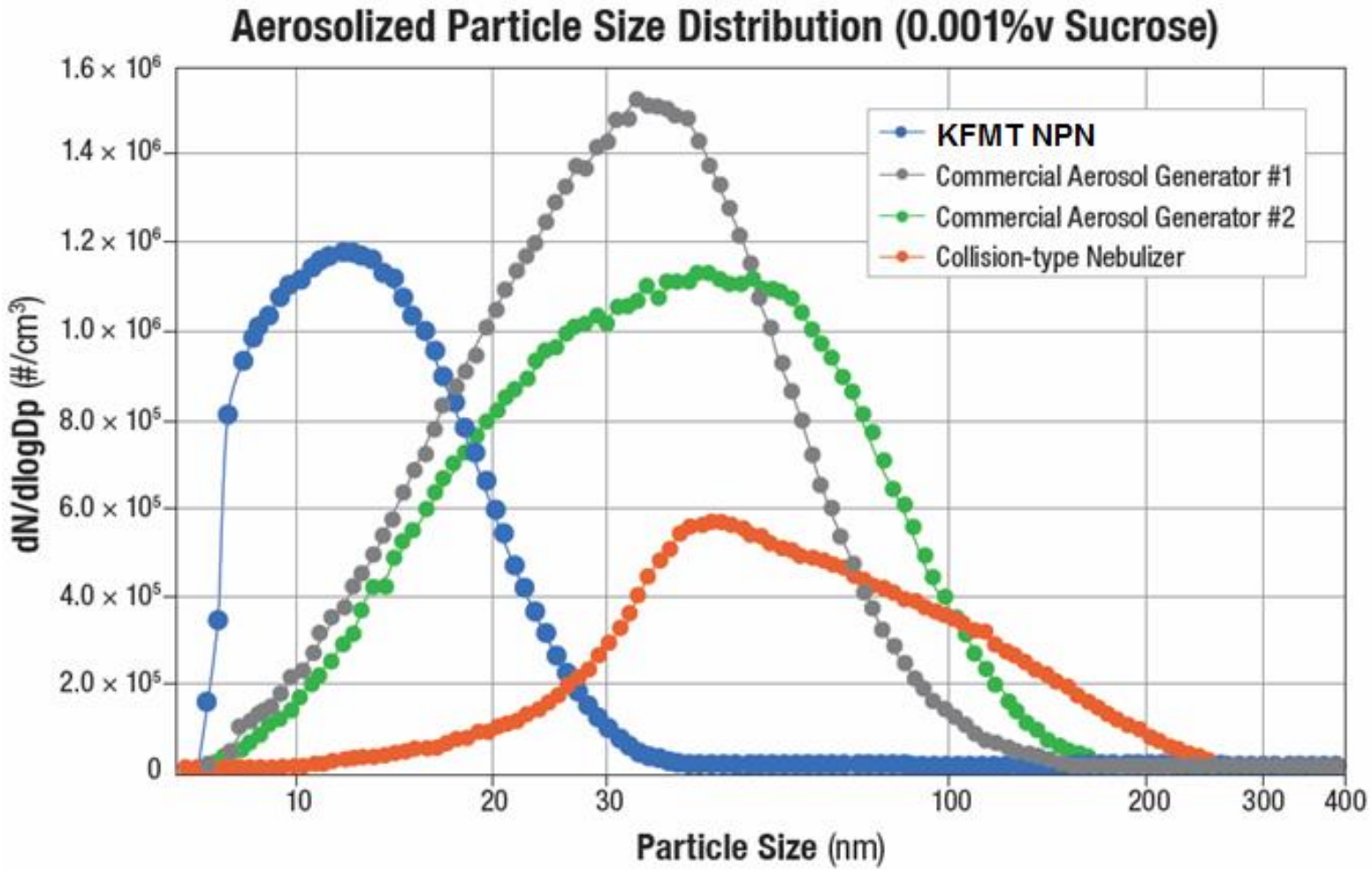
nanoSpotLight

UPW Particle Sampler


- Combines UPW nebulization with condensation growth aerosol particle collection
- FOCUSED AEROSOL DEPOSITION on a test silicon wafer or substrate on SEM pin
- Off-line analysis using SEM/EDX for physical, chemical, and biological characterization
  - ✓Count
  - ✓Size
  - ✓Shape
  - ✓Chemical composition

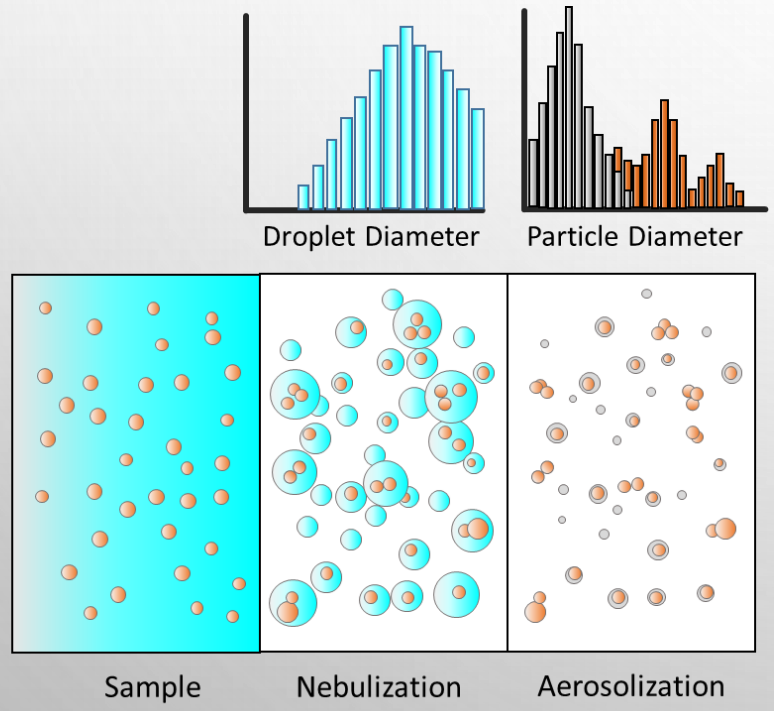



# NANOPARTICLE NEBULIZER

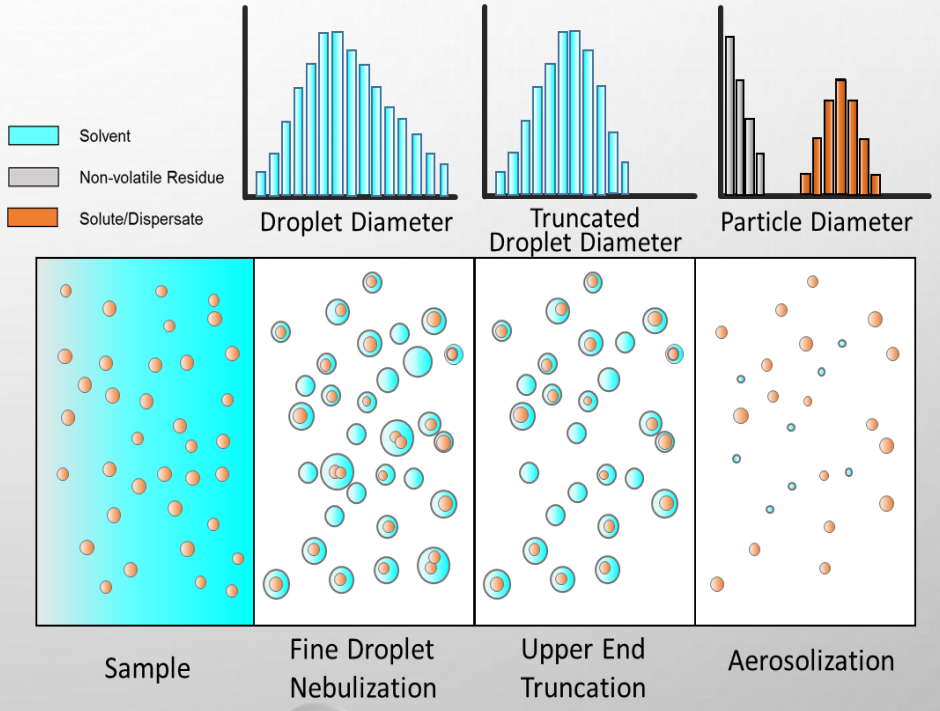

Aerosolized Particle Size Distribution (0.001%v Sucrose)
dN/dlogDp (#/cm³)
1.6 × 10⁶
1.4 × 10⁶
1.2 × 10⁶
1.0 × 10⁶
8.0 × 10⁵
6.0 × 10⁵
4.0 × 10⁵
2.0 × 10⁵
0
10
20
30
100
200
300
400
Particle Size (nm)
KFMT NPN
Commercial Aerosol Generator #1
Commercial Aerosol Generator #2
Collision-type Nebulizer

# PARTICLES SEPARATED FROM DISSOLVED NON-VOLATILE RESIDUE

## Traditional Nebulizer

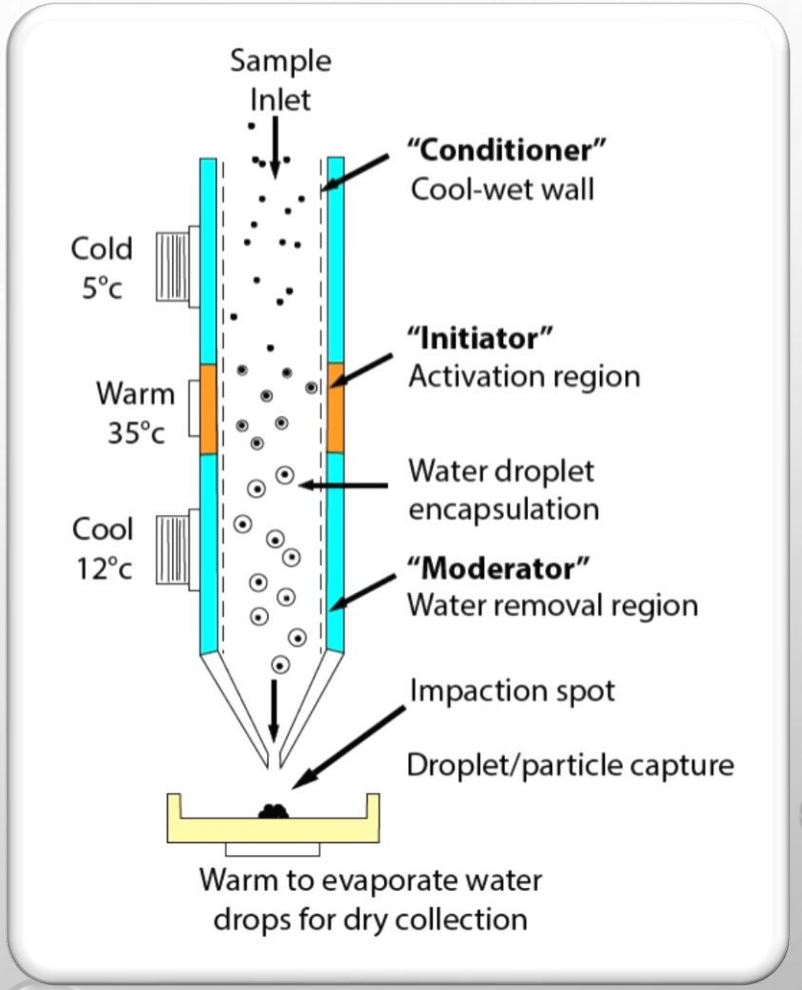


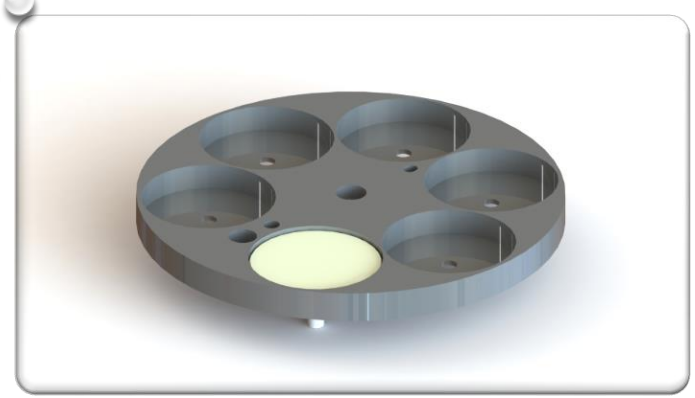

## NanoParticle Nebulizer

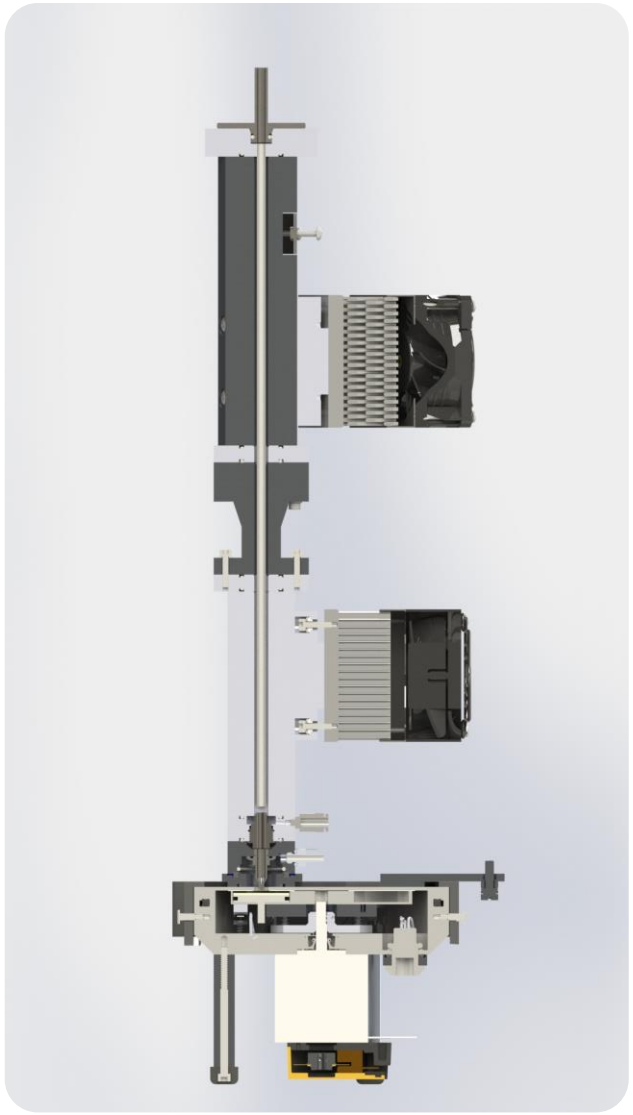


# CONDENSATION GROWTH TUBE COLLECTION

- Rapid sampling in 24 hours – or as little as 10 minutes for a contamination event
- Concentrated particle sample – 1mm "spot" deposit centered on the SEM collection plate
- High-efficiency collection > 95% for particles down to 5nm
- Time-resolved samples on a sample platen holding six SEM stubs – add sample substrate of choice
- Collects ALL particles >10nm independent of composition



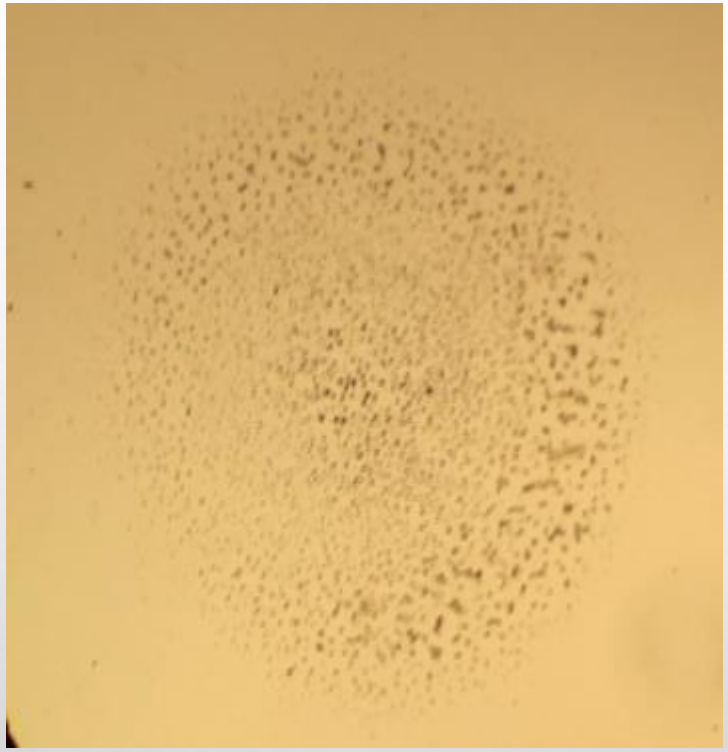




# SEM STUB PLATEN IN SEQUENTIAL COLLECTOR MODULE

# FOCUSED AEROSOL “SPOT” DEPOSIT ON SILICA WAFER

Spot pattern at
50 X magnification

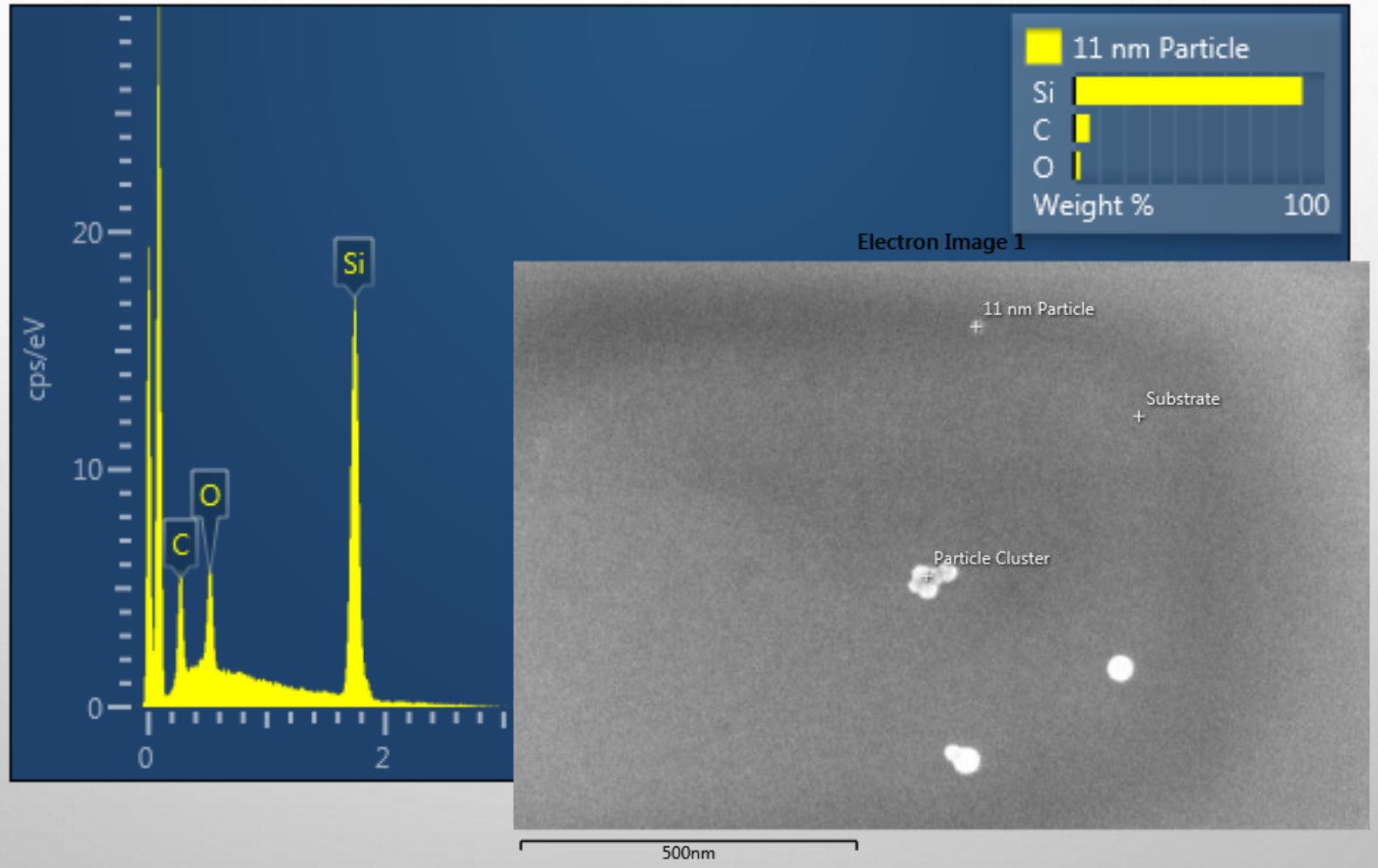


1mm

Blackford, et al, ULTRAPURE WATER Conference, Portland, OR, May/June 2017

# SEM/EDX - SILICA PARTICLES INJECTED INTO UPW

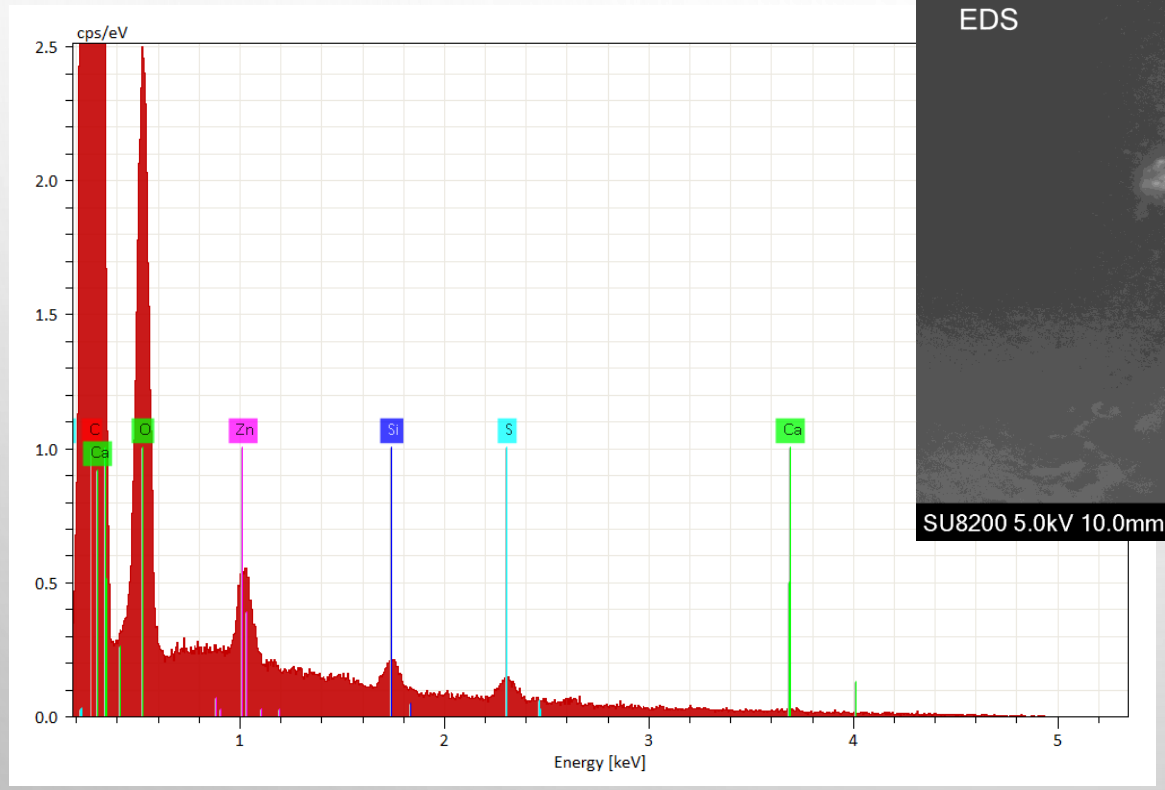
10nm colloidal silica
3 hr collection
Silica wafer susbtrate

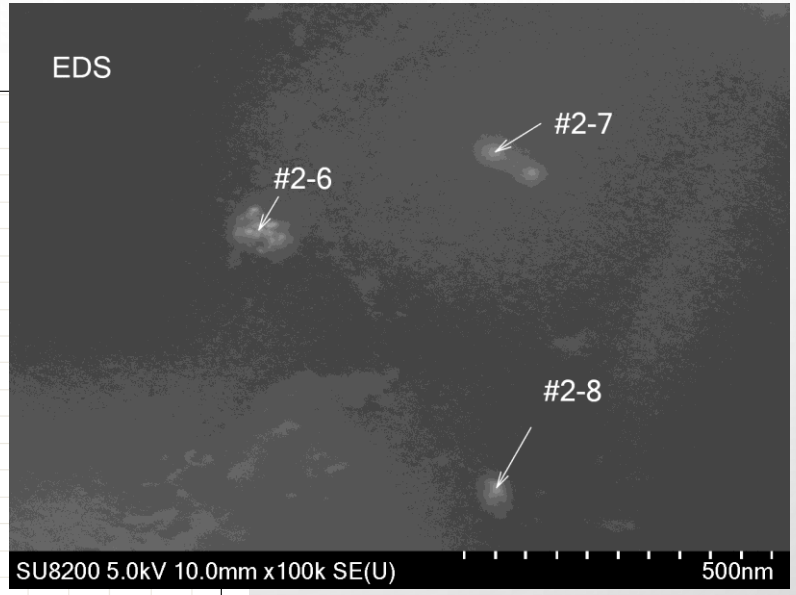



Blackford, et al, ULTRAPURE WATER Conference, Portland, OR, May/June 2017

# SEM/EDX ANALYSIS ON A CARBON SUBSTRATE

2-8

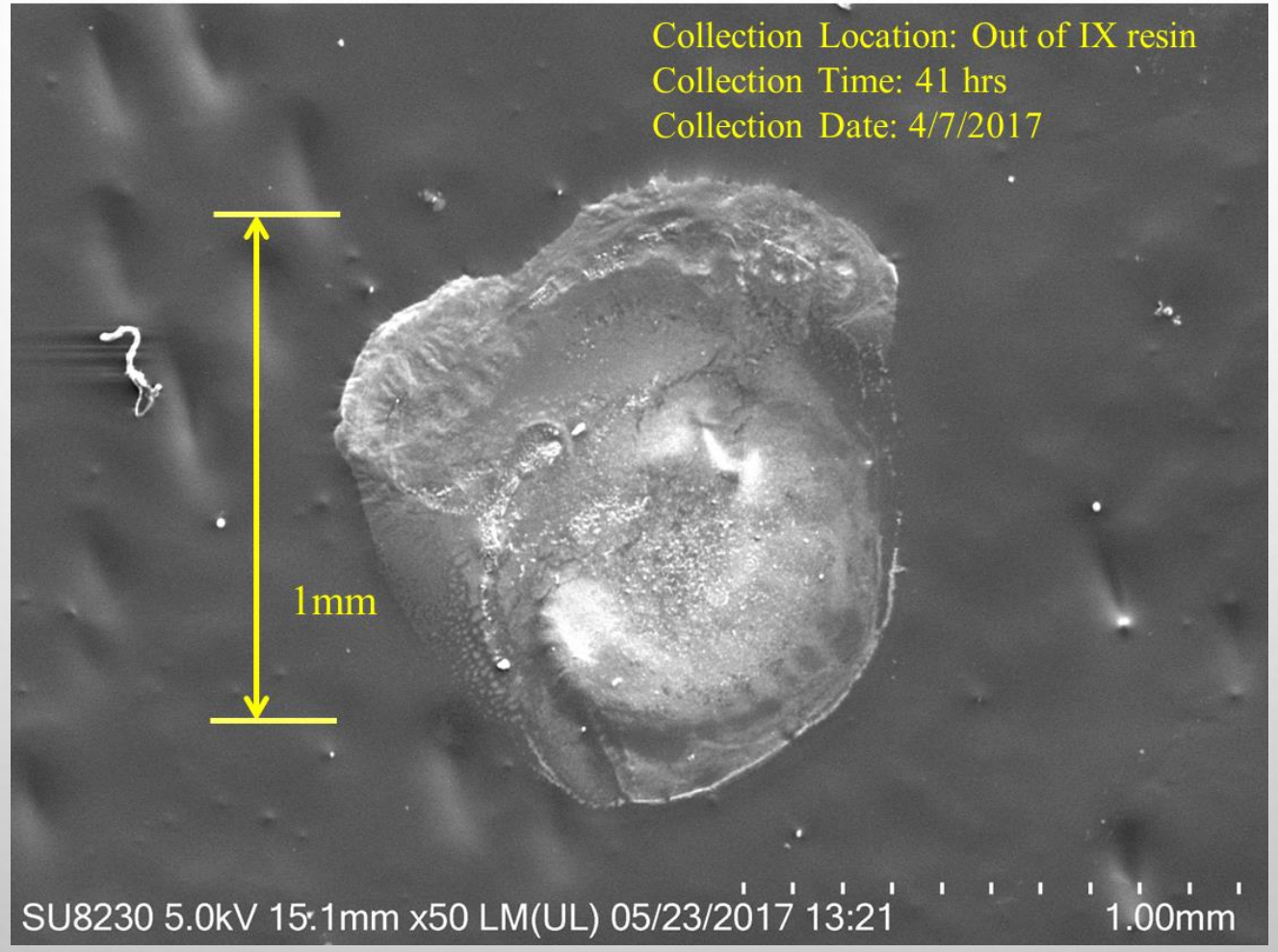



Real UPW sample
24 hr collection time

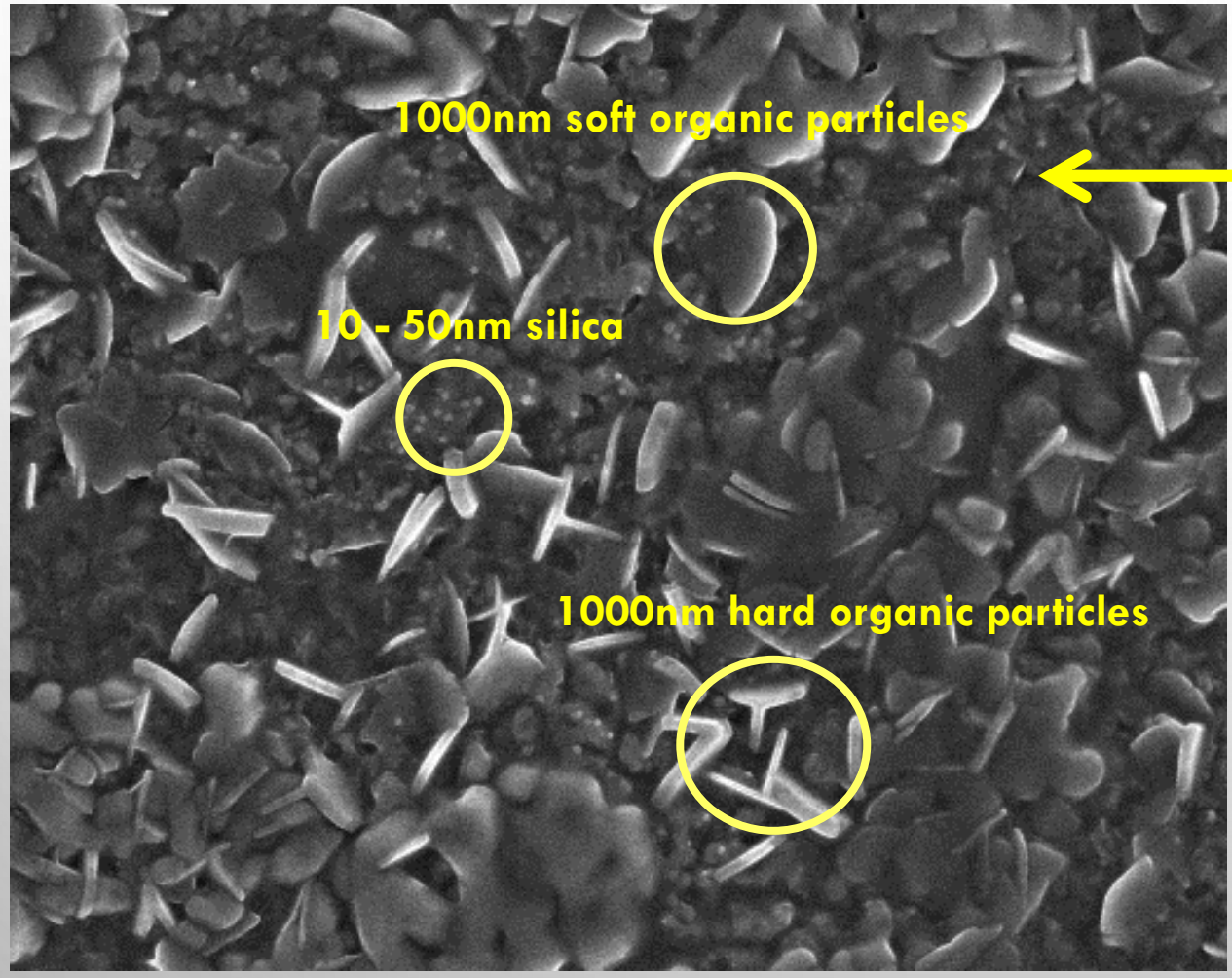
Elements detected:
Carbon
Oxygen
Calcium
Zinc
Silicon
Sulphur

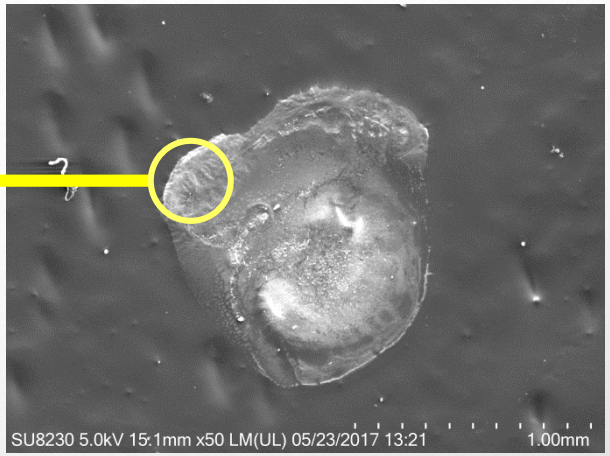
# FOCUSED AEROSOL DEPOSIT ON COPPER SUBSTRATE




Van Schooneveld, et al, ULTRAPURE WATER Conference, Portland, OR, May/June 2017

# SEM/EDX AFTER CONTAMINATION EVENT




Elements Detected:

- Carbon
- Oxygen
- Silicon
- Sulphur
- Zinc
- Magnesium

Van Schooneveld, et al, ULTRAPURE WATER Conference, Portland, OR, May/June 2017

# NEXT STEPS

Compare NanoSpotLight with STPC and laser particle counter on UPW system, round 2

Further testing of substrate materials for best SEM analysis to “see” organics, metals, silica

Sample platen pre-installed with 6 silica wafers on SEM stubs – assembled in a clean room by CT Associates Inc

Tighten focus of the droplet deposition to reduce deposition spot size

CT Associates INCORPORATED

UPW audit and analysis services by CT Associates

NanoSpotLight UPW system available from KanomaxFMT

SEM stub sequential collector available for Spot Sampler from Aerosol Devices

KANOMAX FMT
A Kanomax Company

Aerosol Devices Inc

# THE NEED FOR UPW NANOPARTICLE MONITORING IS CLEAR

THANK YOU FOR YOUR ATTENTION

Largest & Most Influential Semiconductor Companies:

Intel

Samsung

TSMC

Global Foundries

With special thanks to:
David Blackford,
Derek Oberreit, Siqin He and Gary Anderson, KanomaxFMT;
Gary Van Schooneveld, CT Associates;
Slava Libmann, FDT Solutions LLC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