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cleanliness control

Why surface particle counting **at submicron level** is important for **clean products**

Bart Dirkx, MSc

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Fastmicro Introduction

Growth track record

Bart Dirkx, MSc. MBI
CTOO Fastmicro

28 years experience in High-Tech industry incl. Philips, TNO, NTS, VDL-ETG and several start-ups
Founder of WittyWorX and Opus X

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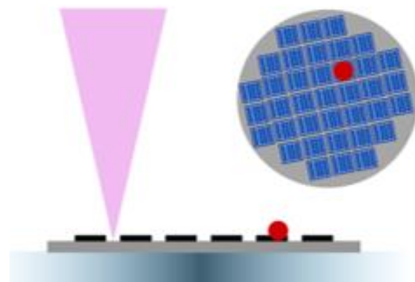
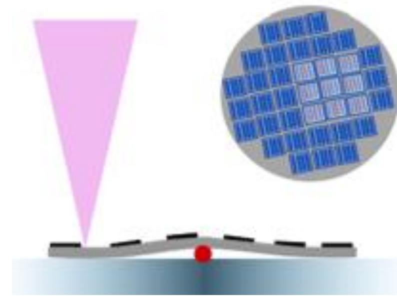
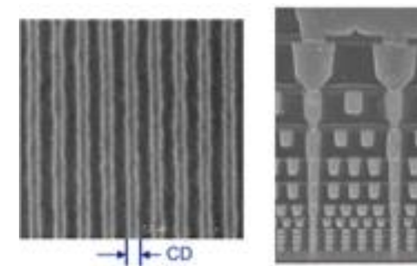
Need for ultra cleanliness

30 billion in annual semiconductor yield losses due to contamination underscores the need for ultra cleanliness

Effects of contamination on semiconductor wafers


Wafer front side


Wafer back side



(SEM section view)

Side-effects

- Non-functional die where the particle is located (front side)
- Overlay/focus errors and wafer and clamp damage (back side)

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A cleanroom is not a clean product

- Cleanrooms are not clean
- Products will not become cleaner in a cleanroom
- The longer the product says in the cleanroom, the dirtier it will get
- Dirty products in a cleanroom will contaminate other products
- To keep a cleanroom clean, the cleanroom itself must be cleaned regularly
- The cleanroom air the cleanest right after the weekend, not the cleanroom itself
- An airborne particle counter will not tell you how dirty your product is
- The biggest contributor to particle contamination is (in most cases) the operator
- Particle contamination and molecular outgassing are two discrete aspects on contamination

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A cleanroom is not enough

for a clean product and a clean process

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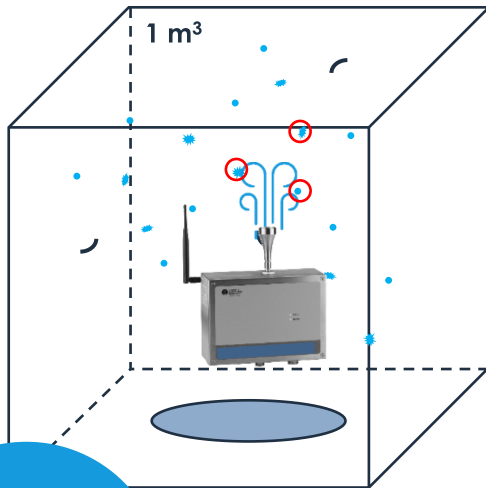
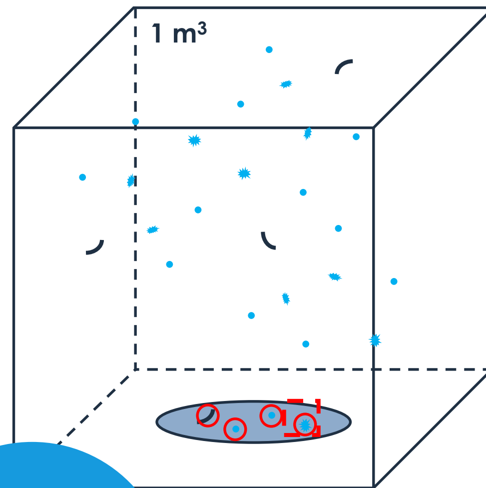
How clean is my product?

Surface and particle deposition contamination standards



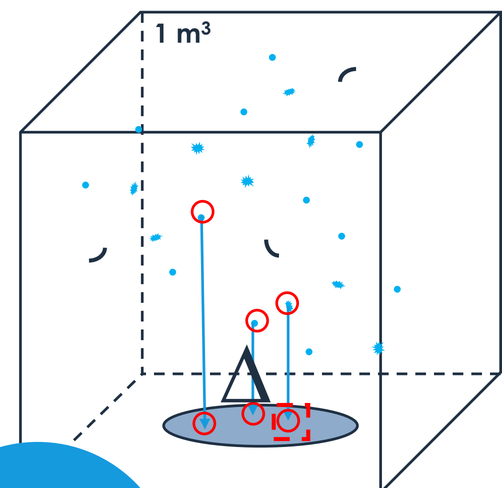
CLEAN AIR
IN CLEANROOMS
ISO14644-1

Counting airborne particle concentration
Particles/m³



CLEAN
PRODUCTS
ISO14644-9
SCP

Counting surface particle concentration
Particles/m²



CLEAN
PROCESS
ISO14644-17
PDRL

Counting Particle deposition rate
Particles/m²/hour

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How clean is my product?

Surface and particle deposition contamination standards

Airborne Particle Counting ('Cleanrooms')

Particles/m3	ISO 14644-1
10 @ ≥ 0.1 μm	1
24 @ ≥ 0.2 μm	2
35 @ ≥ 0.5 μm	3
352 @ ≥ 0.5 μm	4
3,520 @ ≥ 0.5 μm	5
35,200 @ ≥ 0.5 μm	6
352,000 @ ≥ 0.5 μm	7
3,520,000 @ ≥ 0.5 μm	8
35,200,000 @ ≥ 0.5 μm	9

Product surface cleanliness

Particles/m^2	ISO SCP GRADE 14644-9
~	~
20 @ ≥ 0.5 μm	1
200 @ ≥ 0.5 μm	2
2000 @ ≥ 0.5 μm	3
20,000 @ ≥ 0.5 μm	4
200,000 @ ≥ 0.5 μm	5
100,000 @ ≥ 20.0 μm	6
200,000 @ ≥ 50.0 μm	7
2,000,000 @ ≥ 50.0 μm	8

Deposition rate 'Particle Fallout'

Particles/m^2/hour	ISO PDRL 14644-17
6 @ ≥ 0.5 μm	0,3
40 @ ≥ 0.5 μm	2
200 @ ≥ 0.5 μm	10
2,000 @ ≥ 0.5 μm	100
9,000 @ ≥ 0.5 μm	450
56,000 @ ≥ 0.5 μm	2,800
50,000 @ ≥ 20.0 μm	10,000
20,000 @ ≥ 50.0 μm	100,000
200,000 @ ≥ 50.0 μm	1,000,000

Legend: Fastmicro solutions | Legacy solutions

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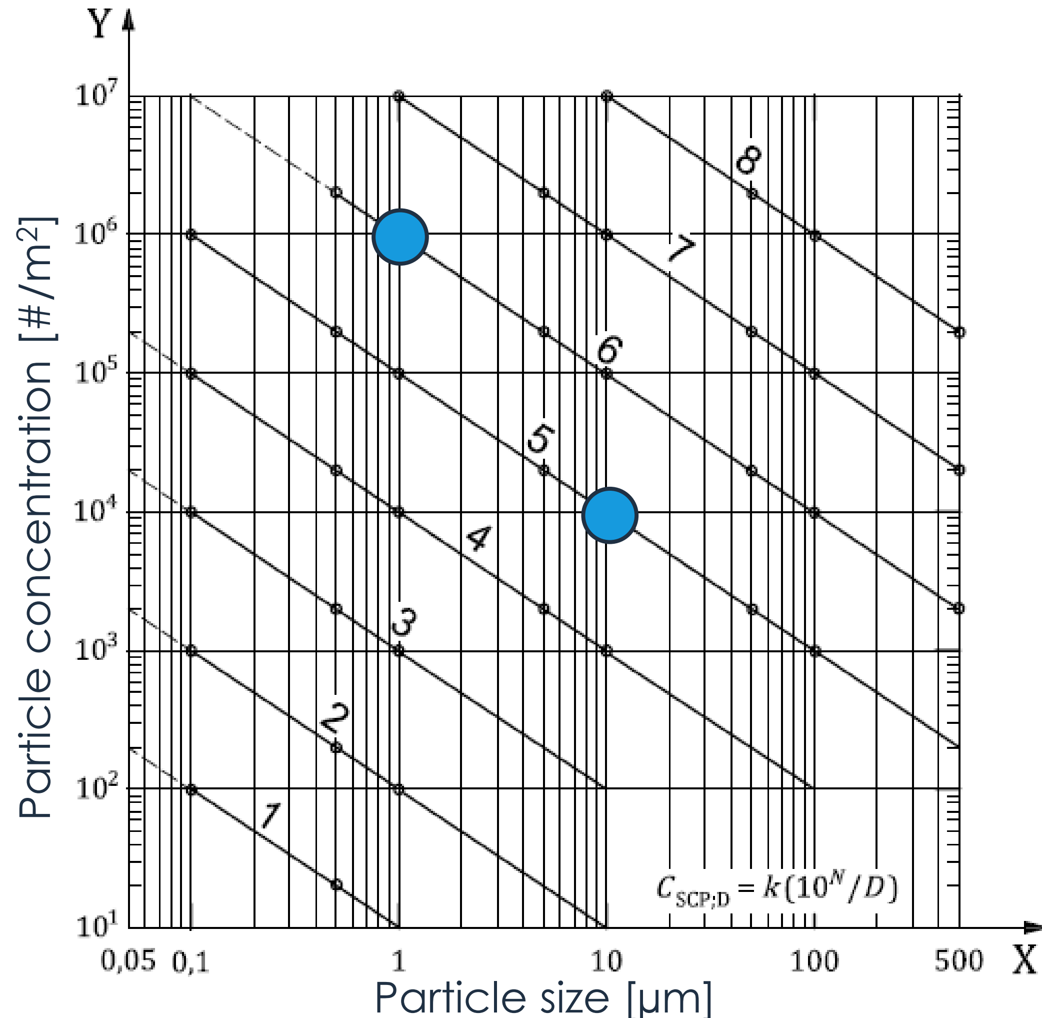
How to set quantitative specifications on surface cleanliness



1. Assess the risk
   - Particle sizes that affect yield or reliability
   - Particle sizes that can cause functional failures
   - Particle sizes that can be critical to the environment of use
2. Set your pass / fail limits (the specs) e.g:
   - SCP grade 6 at 1 µm (Max. 100 particles ≥ 1 µm per cm^2)
   - SCP grade 5 at 10 µm (Max. 10 particles ≥ 10 µm per cm^2)
3. Determine when and where to inspect the product
   - Determine at which process steps the inspection must be done (e.g. post cleaning)
   - Set inspection area size (e.g. 10 cm^2 per product)
   - Pick the inspection spots (e.g. 3 locations per product)

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Why are submicron particles important?

Use case performed by partner

Environment
- 9 cleanroom workcenters
- All ISO 6 cleanroom
- Air change 40x/hour
- 1-6 persons active

Substrates
- 22 pcs Ø 300mm blank wafers
- Placed 1 meter above ground

Measurement
- Cumulative particle count measured on a high-end laser scatterometry system (non-Fastmicro)
- Size distribution per wafer determined on a high-end SEM-system

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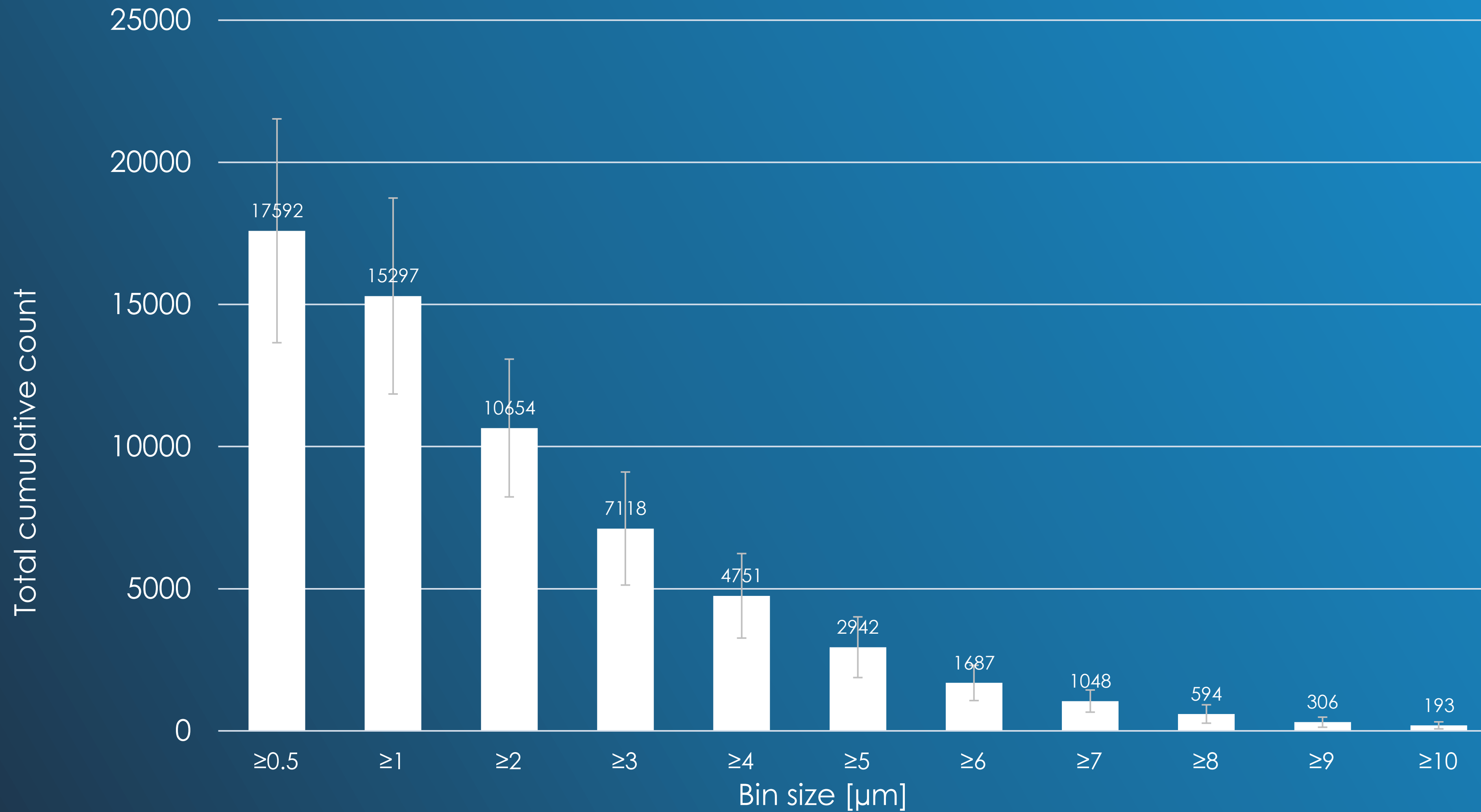
Partner use case results



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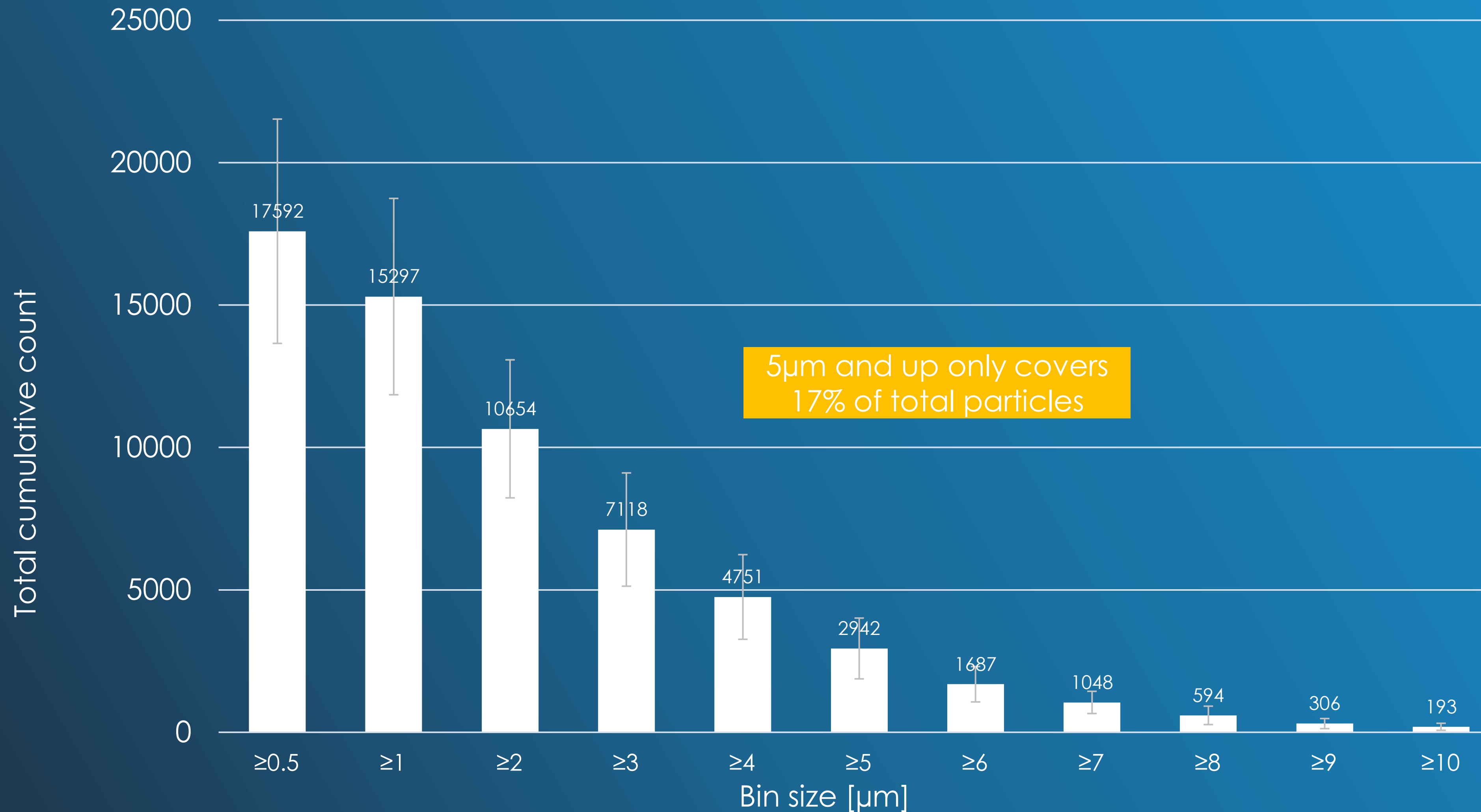
Partner use case results



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What if you measure 0 particles?

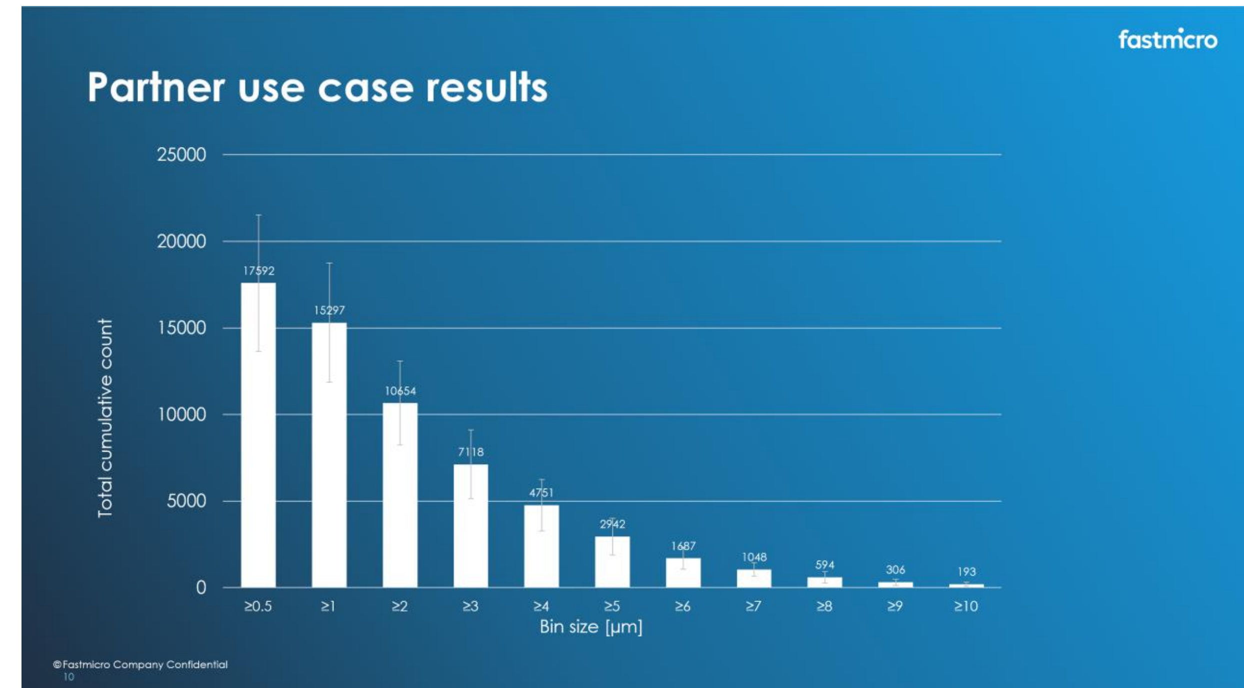
Assuming your 'killer particle' size is 5µm

- This does not mean it is completely clean → you just have not measured the first particle yet
- How do you know your measurement is correct?
- What about statistical relevance?

The answer lies in the smaller particle detections

- They are more numerous
- They can predict larger particles
- They provide statistical relevance

Measurement quality is key



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Sample Scanner

Parts qualification tool with indirect measurement

PMC 2.0 in a box
Interface (default)
+ recipe

Fastmicro Sampler
Interface + recipe

2-inch Wafer
Interface + recipe

- Measures particles from 0.5 micrometers
- Imaging in seconds, measurement results in less than one minute
- Field of View particle detection area:
  - Ø 14 mm PMC 2.0
  - Ø 20 mm Fastmicro Sampler and 2-inch wafer
- Calibration using NIST-certified PSL particles
- Samplers have more than 90% particle pickup efficiency
- Samplers leave no measurable residue
- Use with PMC 2.0 and the new Fastmicro Sampler for indirect measurements, and with 2-inch witness wafer for fallout measurements

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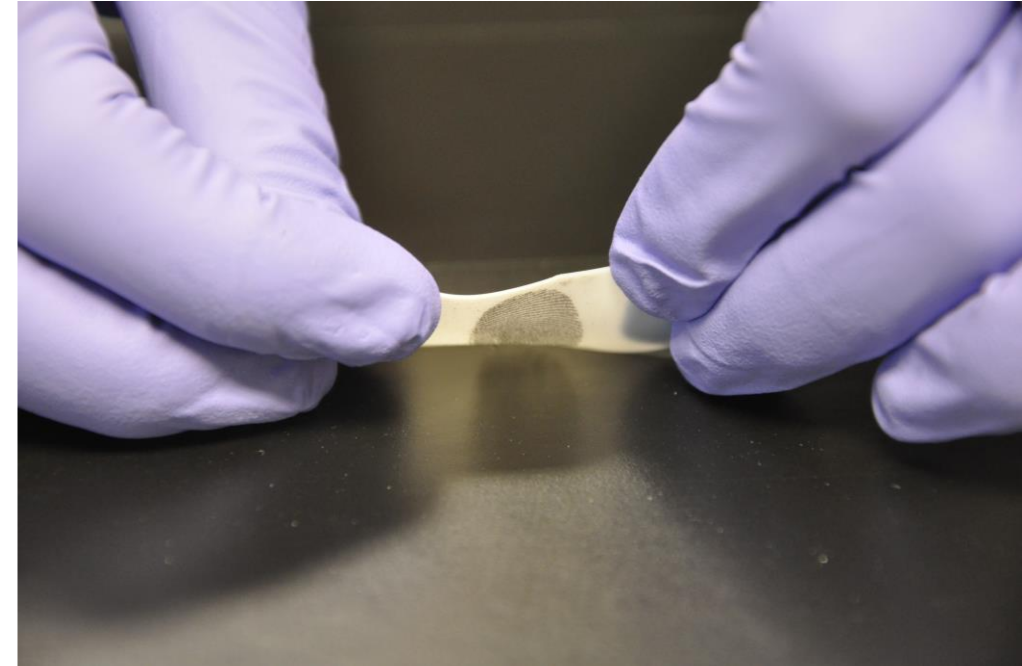
Why tape lifting

Advantages

- High pickup rate → especially for small particle sizes
  (small particles tend to stick because of van der Waals forces)
- Works on all surfaces → smooth, rough, flat, curved
- Excellent contrast
- Does not leave measurable residue behind (PU-material)
- Sampler can be stored as evidence / for post processing

Disadvantages

- Relies on sampling → not full surface analysis
- Indirect vs direct
- Contact vs non-contact → sensitive products



Source: NIST

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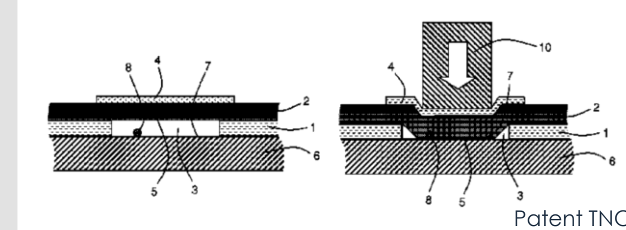
PMC 2.0 in a box ®
User Feedback

General

- Qualified solution
- Easy to operate, once familiarized
- Good overall performance, if applied well
- Foil works well, but:
  - ➢ Risk of cross contamination
  - ➢ Risk of scatter if misaligned in scanner

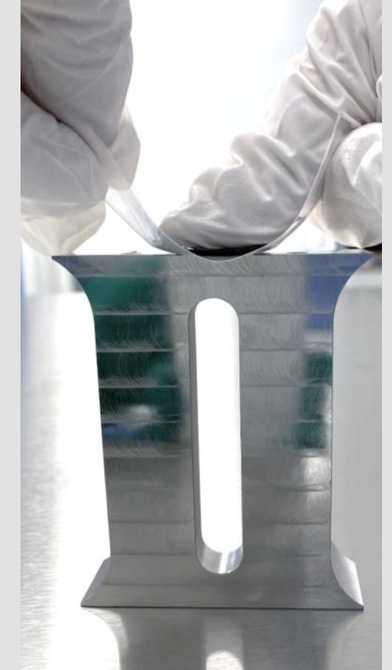
FAQ

- Can you reduce cost per measurement?
- Can you make sampling less operator dependent?
  - ➢ Easier handling
  - ➢ Confirmation on correct sampling
- Can you make the foil smaller for getting closer to edges and corners?
- Why can't we buy PMCs from Fastmicro?



Patent TNO

PMC 2.0 HQ Pack



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Fastmicro Sampler

Basic features

- Thermoplastic Polyurethane (TPU) injection molded on substrate
- Excellent surface roughness → < 0.035 µm Sa
- Ring with 3 pins (carrier) attached to the top side enabling sampler removal from the top

Benefits

- High quality, tight tolerance
- Very low ini count (SCP Class 5 (0.5 µm))
- First Time Exposure, low risk of contamination before use

Sampler with cover

Sampler after cover removal

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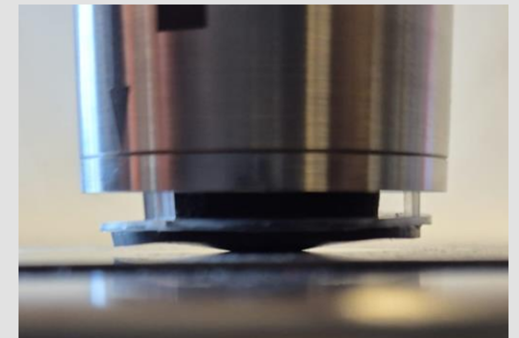
Fastmicro Sampler Tooling

Sampler Operator Tool

- Interface to sampler with locking mechanism
- Force distributor
- Force feedback
- Flexing the sampler for easy release

Sampler Holder

- Same interface as Sampler Operator Tool
- Reproducible positioning in SAS
- Compatible with SAS base plate



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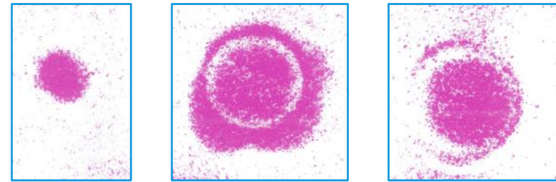
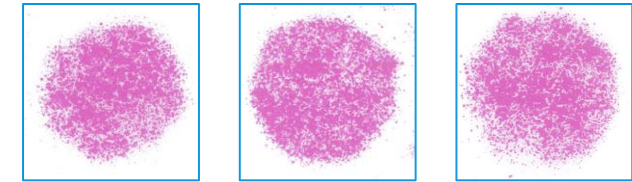
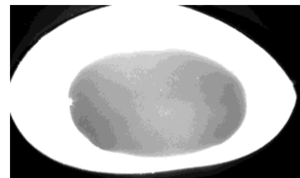
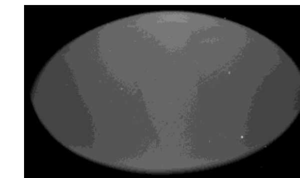
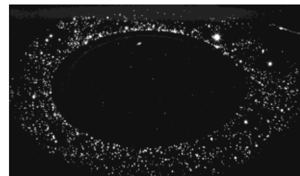
PMC 2.0 vs Fastmicro Sampler Solution

Key performance elements	PMC 2.0 in a box	Fastmicro Sampler Solution
• Reproducibility of sampling • Operator dependency • Ease of use • Force control / feedback	 PMC 2.0, if under and over applied	 Fastmicro Sampler, consistent sampling
• Field of view (~2.5x more surface area) • Better contrast (due to lack of foil)	 14 mm analyzed	 20 mm analyzed
• Leaves less residue behind on sampled surface	 Residue from foil	Only PU contacts sampled surface
• Lower sampler cost & cost per measurement	With initial measurement Without initial measurement	45% cost reduction > 60% cost reduction

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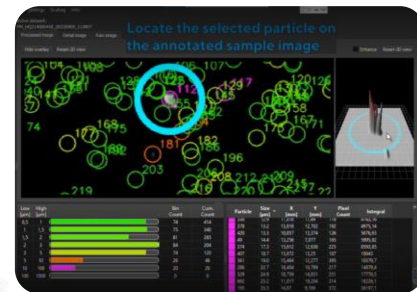
Use-case

Pre-scan **workflow** for **throughput** enhancement by combining the best of **Dark Field scatterometry** and **SEM-EDS**

fastmicro **Sample Scanner**

ThermoFisher SCIENTIFIC **Phenom XL Desktop SEM-EDS**



Information:
count, size and location

Only analyse particles of interest using SEM-EDS

Information:
morphology, composition, hardness & conductivity

Full particle characterization within minutes (instead of hours):
from particle localization by Fastmicro to detailed analysis by Thermofisher

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Enabling SEM workflow

fastmicro
Sample Scanner

fastmicro
SEM stub

ThermoFisher SCIENTIFIC
Phenom XL Desktop SEM-EDS

New sampler
with 5 markers

Processed sampler
with markers and particles

Processed sampler
with markers and particles
on SEM stub

SEM image of
one marker

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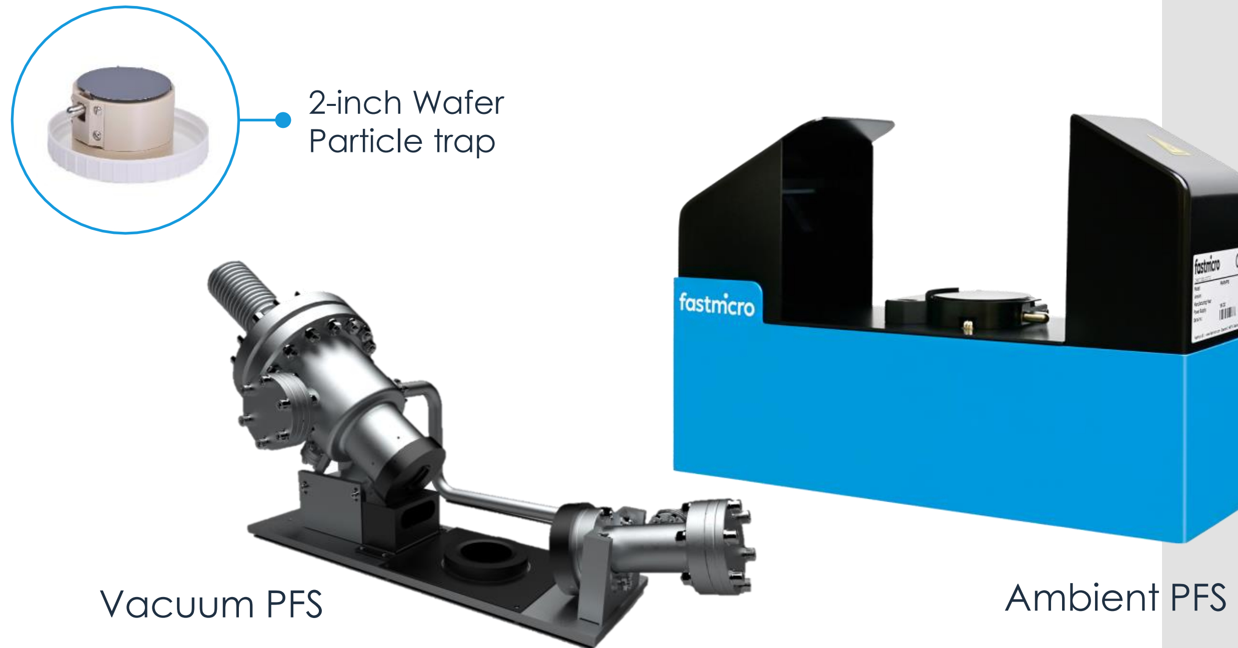
Particle Fallout Scanner

Continuous monitoring of particle deposition in vacuum or ambient environments



Basic features

- Continuous particle deposition measurement on witness wafer
- Measurement interval 10 seconds or at longer interval setting
- Particle detection from 0.5 µm
- 2-inch Field of View
- Standard KLARF and .csv export
- Compact size, (L×W×H) 300 × 100 × 200 mm
- Including Fastmicro eBox

Why particle deposition measurement?

Process validation at the critical application surface area is the only true indicator of effective contamination control

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thank you for your attention

Find us at Booth **C55/1**
and let's explore the best fit for your needs

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