Surface Dust Contamination Analysis Introducing Darkfield Microscopy at EGO

Dust Control

- Virgo towers
  - Maintenance operations
  - Vacuum cycles (pumping and venting)
- Virgo clean rooms
  - Mirrors and Payloads
- Two-fold control:
  - Volume (Particle counters)
  - Surface (Optical inspection)

Surface Dust Control

- SiO2 Wafers (3’’, 1 side polished, 1 flat, Ra<4 nm) are placed in towers and clean rooms
  - Before closing towers
  - After opening towers
  - After operations in towers
  - Vertical & Horizontal positions

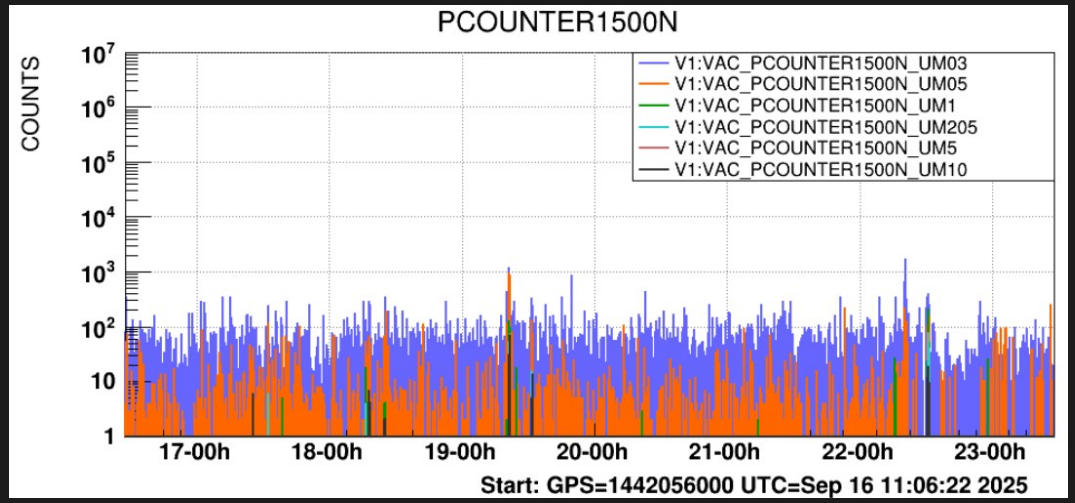
- Optical inspection of wafers
  - Evaluating dust size and number

Optical Inspection

- Why using Darkfield Microscopy
  - Easy set-up:
    - 1 large CMOS sensor (5496 × 3672 pixels, pixel size 2.4µm)
    - 1 focal lens (f = 15cm)
    - 1 plan fluor objective (x 10 Nikon)
    - Grazing illumination with 550nm green light
  - Optical resolution: ~0.9 µm
  - Pixel resolution: 0.32 µm
  - Translating wafer using precise translation stages (X,Y)
  - Automatic (x,y) scan acquiring 280 images ~ total 5.8cm^2 scan.
  - Tests in 1500N Clean Room

Darkfield Microscope at 1500N

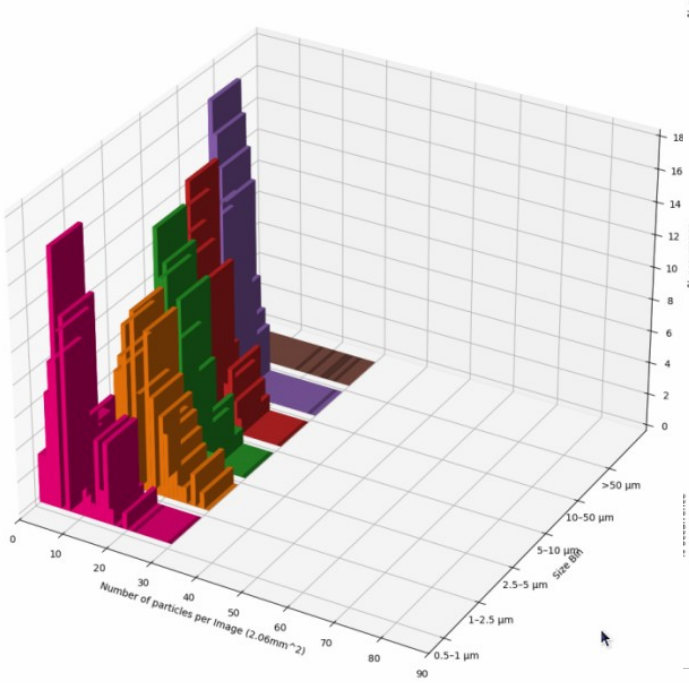
- Clean room environment ~ISO 5

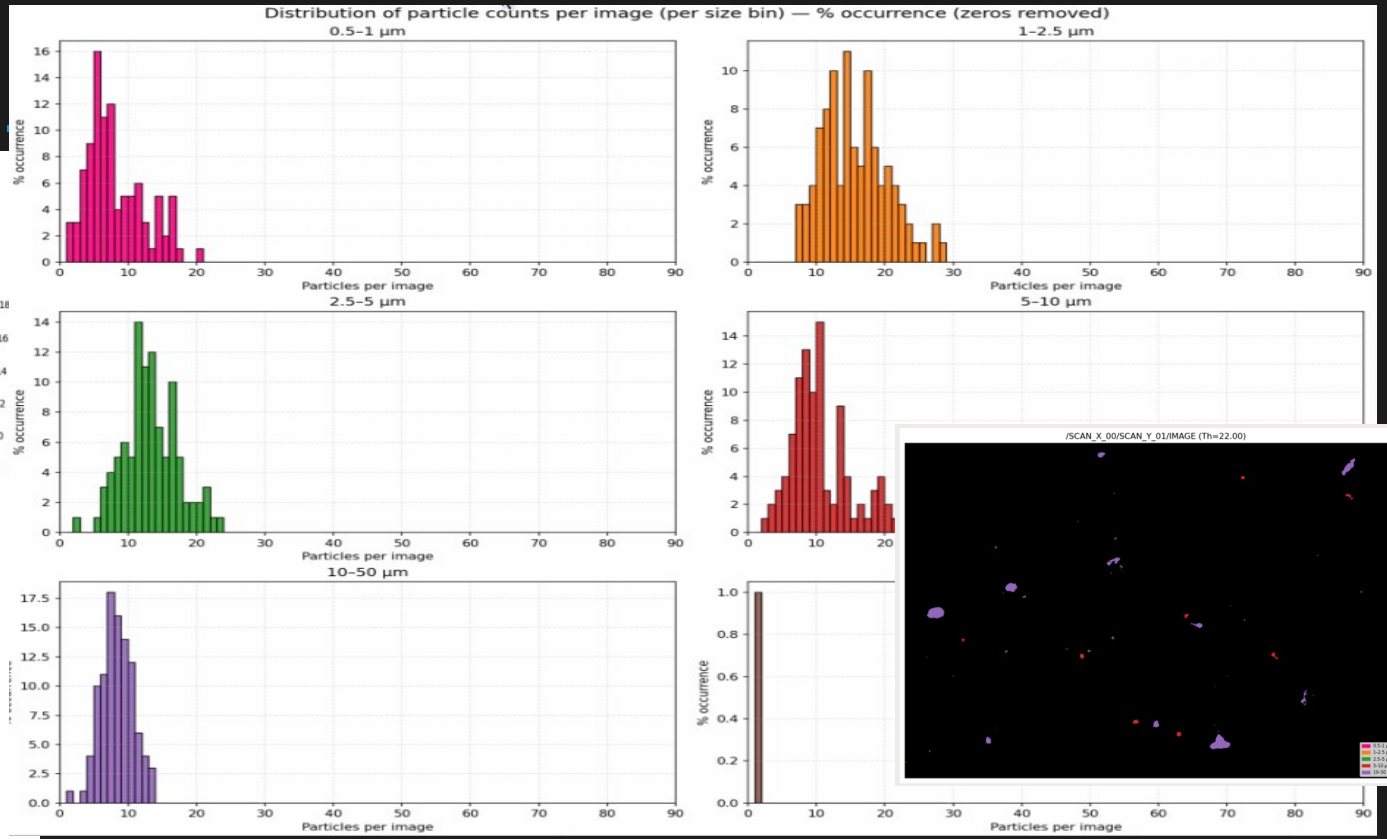


- Stable support
- Millimetric screw for objective focus

Dusty sample

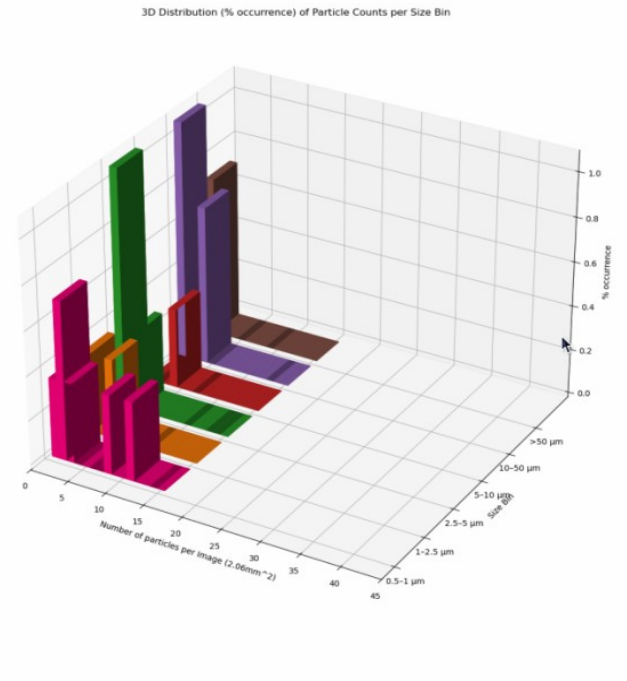
Left in air for days..



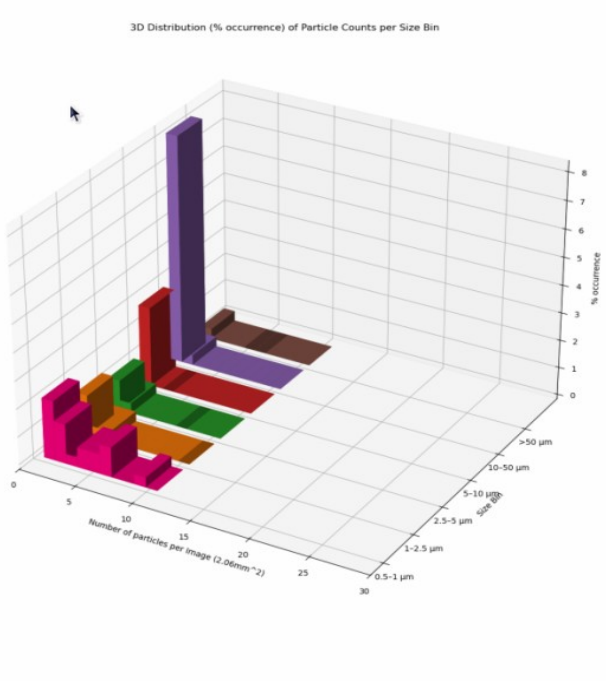


Clean sample

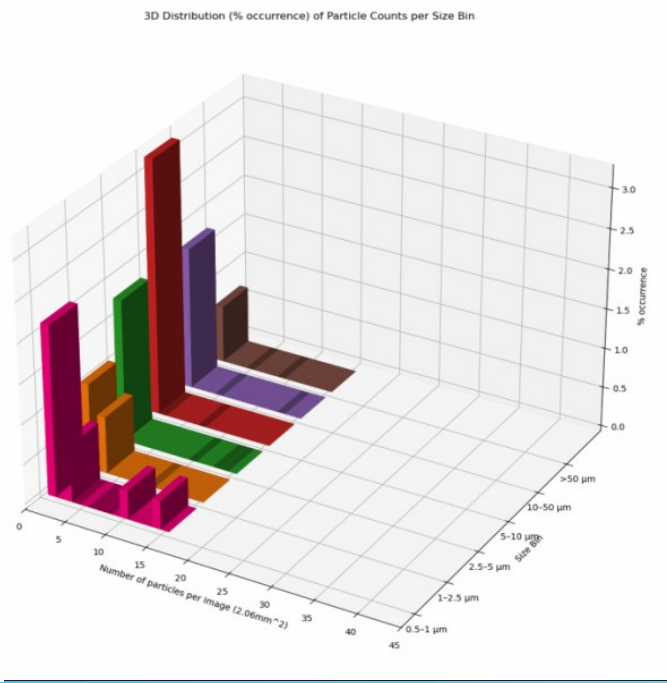
out of the box..



after ultrasonic bath & Nitrogen drying..

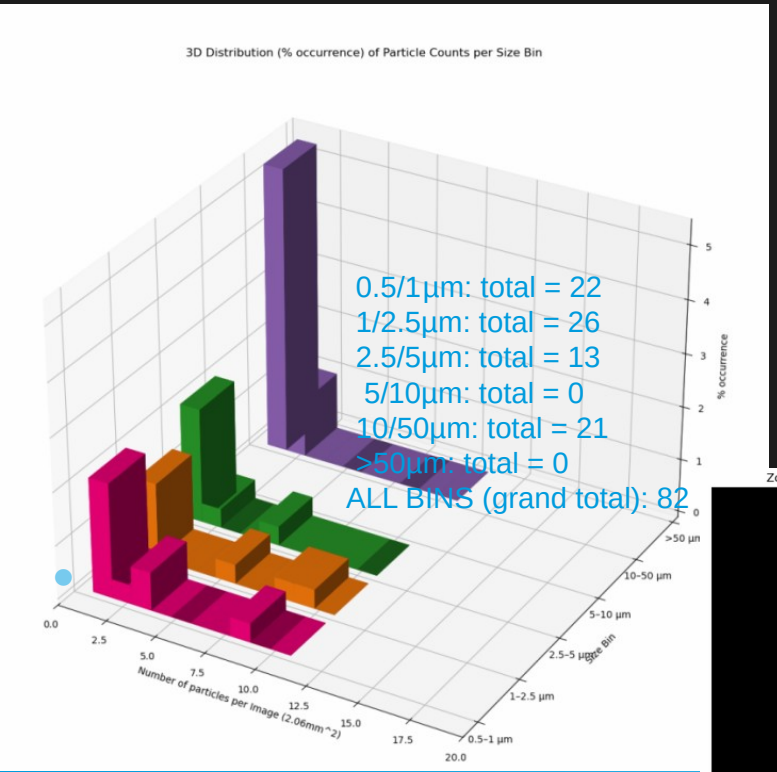


after manual cleaning..



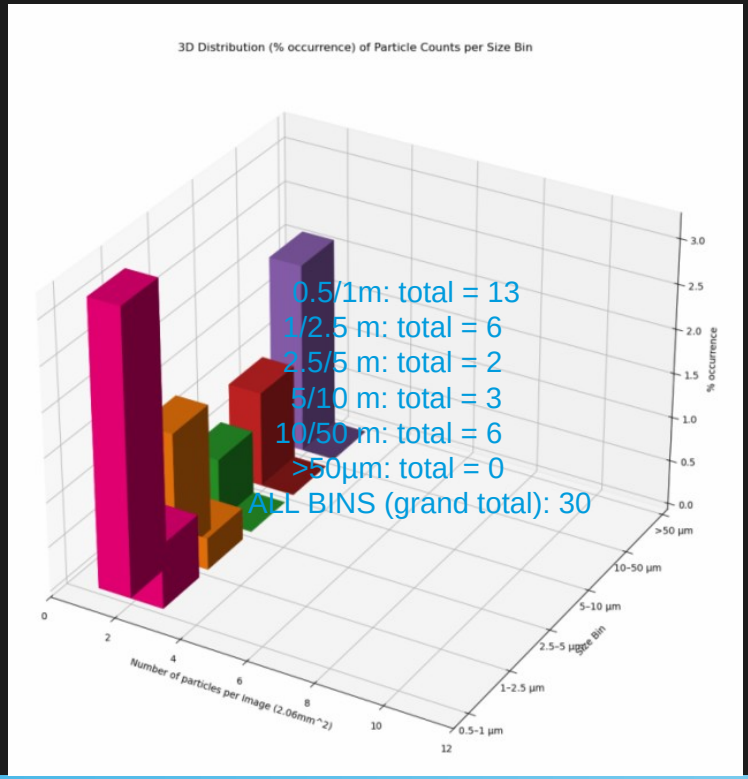
Detection Tower

Bottom flange Sud/H



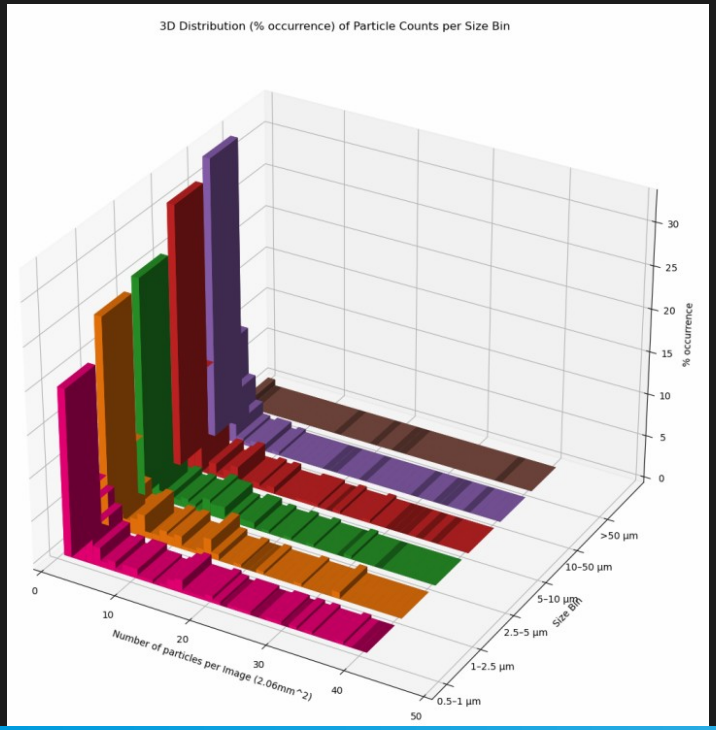
- 1 pumping
- 200 days in vacuum
- 1 venting (23/07/2024)

Bottom flange Nord/H



WE Mirror replacement in Clean Room at 1500W ~ISO5 (23/05/2025 during 4 days)

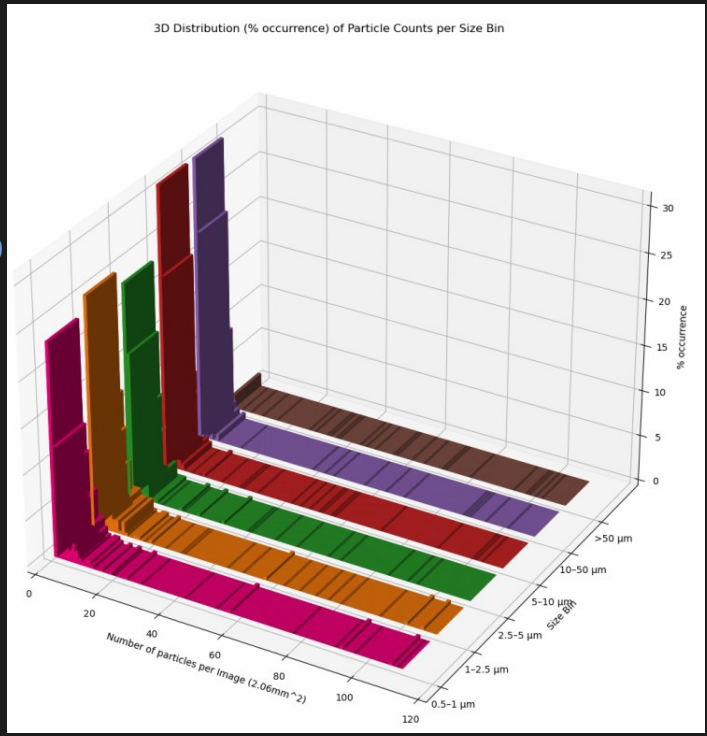
Wafer on payload table



0.5–1 µm: total = 802
1–2.5 µm: total = 667
2.5–5 µm: total = 539
5–10 µm: total = 503
10–50 µm: total = 269
>50 µm: total = 2
ALL BINS (grand total): 2782

Wafer under the payload

0.5–1 µm: total = 863
1–2.5 µm: total = 825
2.5–5 µm: total = 475
5–10 µm: total = 416
10–50 µm: total = 347
>50 µm: total = 4
ALL BINS (grand total): 2930



Observations

- Successive scans after days in control room do not reveal significative change in dust distribution
- Check wafers cleanness, use spin-coating technique to clean
  - Make a background before using wafer
- Surface contamination control now part of the tower operations

Here we report the details of the microscope at 1500N Lab. The microscope is composed of 5 parts:

1) Camera AlliedVision CMOS 5496 × 3672 pixels, with pixel size 2.4um
2) tube lens with focal length (f=150 mm)
3) Nikon Plan fluor objective x10, numerical aperture (Na=0.3), suits with tube lens f=200mm
4) x2 translation stages in X,Y directions, with 25mm full range each
5) grazing incidence illumination using diode 550nm (green)

The microscope is in Dark Field configuration: It means that the illumination is done in grazing incidence on the sample. Most of the light is reflected in specular direction, i.e. out of the objective. The light going vertically through the objective is reflected only by defects on the wafer like impurities and scratches. Below the calculation of the spatial resolution of the setup:
Nominal optical magnification is determined by:
M = f_{tube}/f_{objective}
Since we are using a 150 mm tube lens, the effective magnification is:
M_{effective}=150/200 = 7.5
The effective pixel size is: 2.4 / 7.5=0.32µm
Each pixel images have 0.32 µm × 0.32 µm ~ 2 µm area
The diffraction limit (optical resolution) is given by the Abbe criteria: d=λ/(2*Na)
We use a 550nm green light for illumination and Na=0.3. This leads to an optic resolution d=0.916µm
The setup is limited by the optics, not the sensor which resolves it. The finest detail is ~ 1 µm size