Particle entrainment due solely to electrostatic forces

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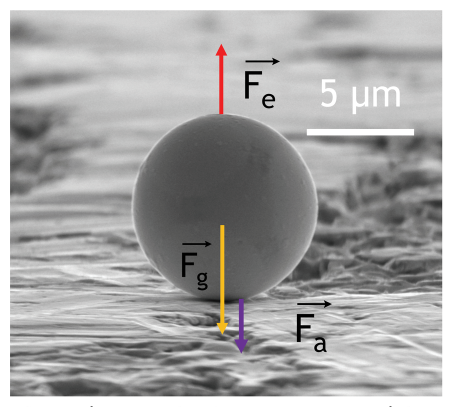
CONTEXT

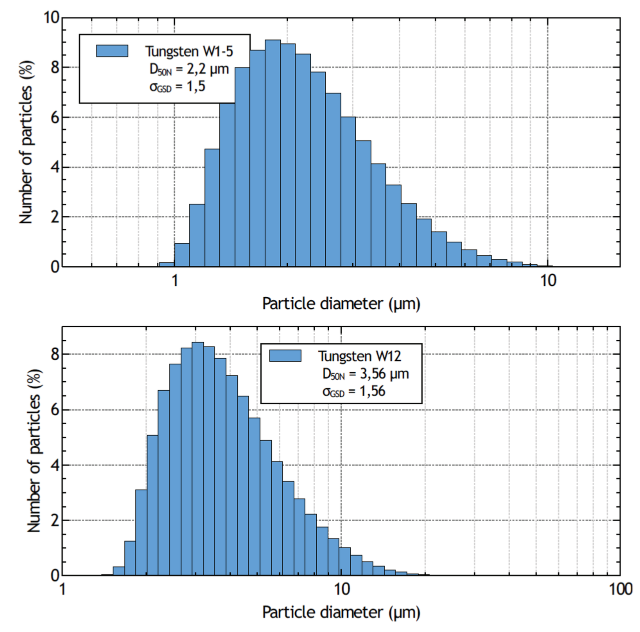
- In nuclear installations, radioactive contamination is often carried by aerosol particulates. Because of the ionizing radiation of the radionuclides they contain, radioactive particles can naturally self-charge, making them liable to electrostatic forces.
- Despite the efforts devoted to the study of aerosols resuspension mechanisms such as airflow, electrostatic interactions are often ignored.
- The divertor of the upcoming ITER Tokamak will be made of tungsten material that will be in straight contact with the plasma. Because of the severe conditions expected in the chamber, the walls will be subject to erosion resulting in the production of high amount of tungsten dust, activated by the presence of tritium.
- We designed an experimental set-up to assess the electric field strength required to overcome the adhesive forces of micron size particles laying on a metallic surface.



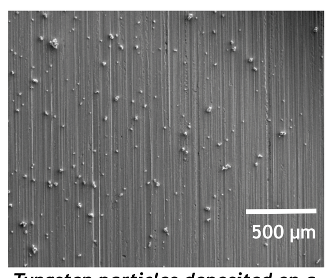
SEM micrograph of a tungsten particle resting on a tungsten surface

PARTICLES CHARACTERISTICS AND MAKING OF THE DEPOSITS

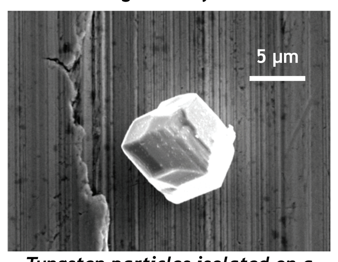
Three powdery materials of different median diameter (D_{50N}) and electrical properties were used in our experiments: aluminium oxide (Al_2O_3), silver, and tungsten particles.



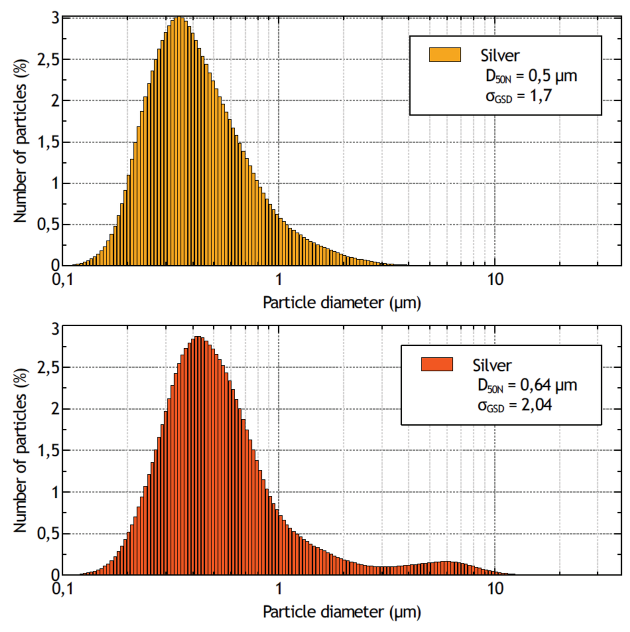
Number particle size distributions of tungsten powders with the LS™ 13 320 BECKMAN



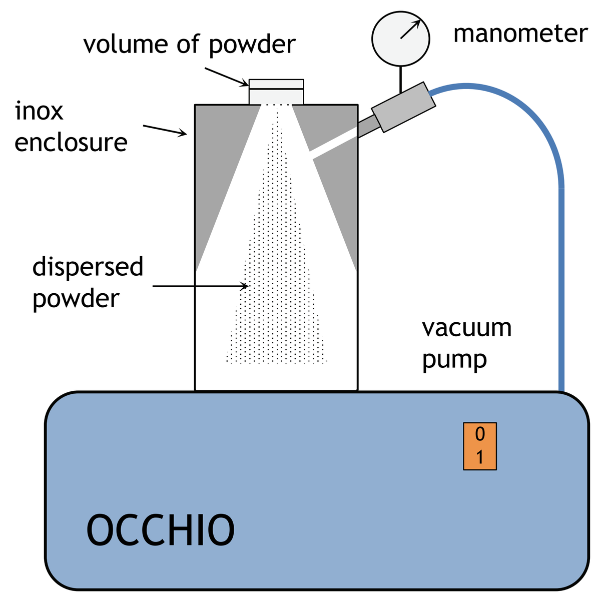
Tungsten particles deposited on a tungsten surface



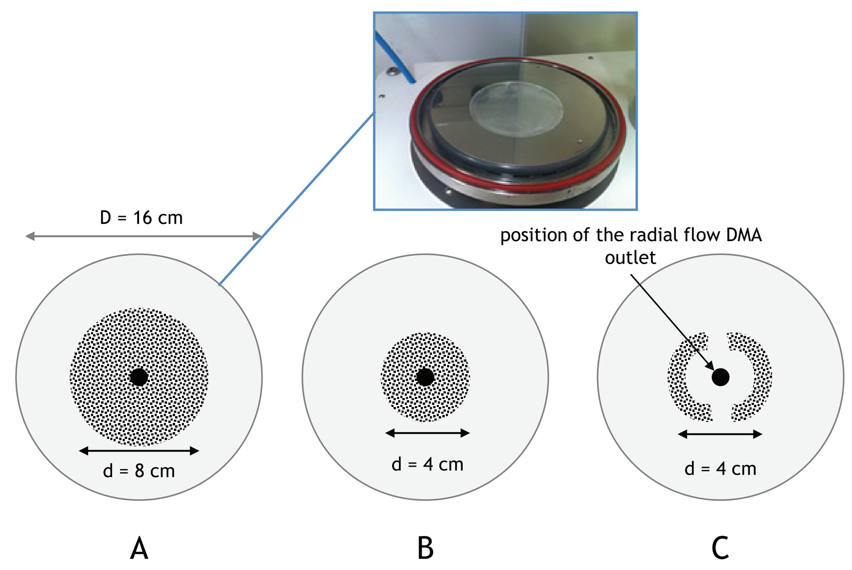
Tungsten particles isolated on a tungsten surface



Number particle size distributions of silver powders with the Aerosizer



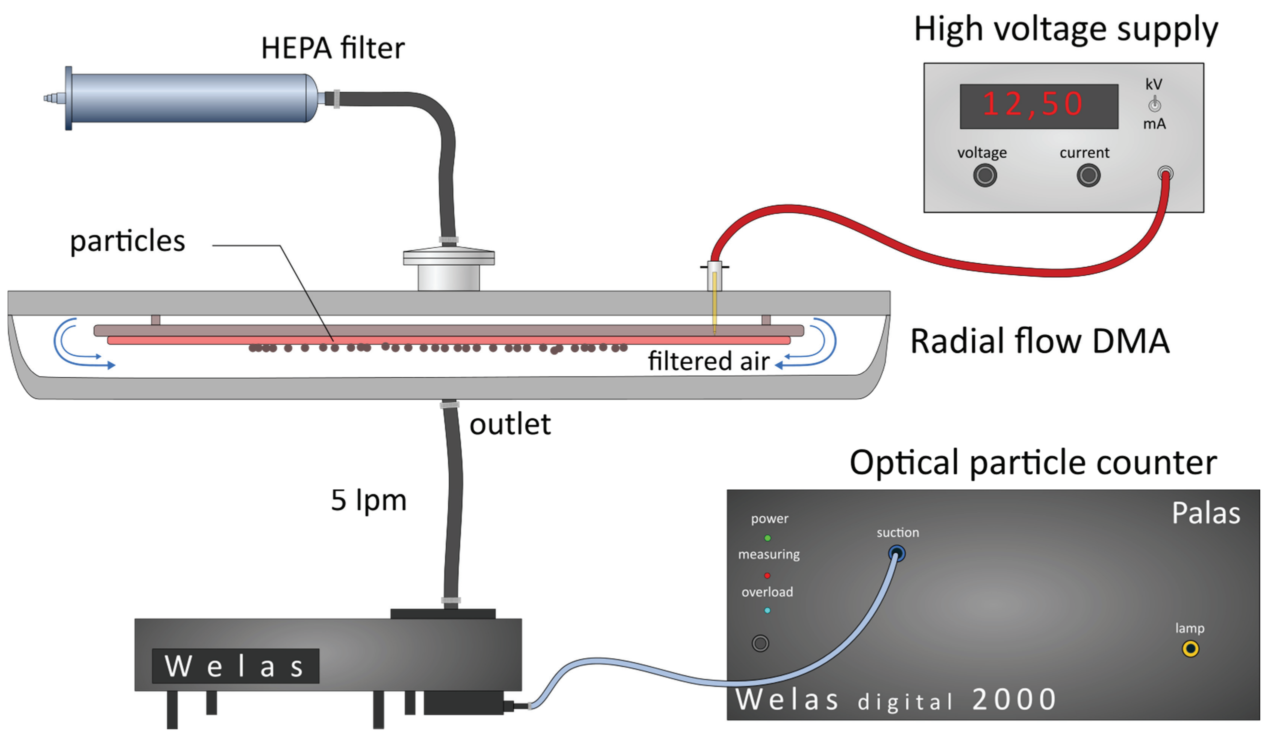
OCCHIO device for the making of powder deposits



Sketch of different types of powder deposit tested

EXPERIMENTAL SET-UP

- two circular stainless steel electrodes of 16 cm in diameter were placed in parallel and separated by a 4 mm gap.
- The top electrode was hooked to a high voltage source while the bottom one was earthed.
- A layer of particles was spread out on the top electrode near the extraction hole (deposit B).
- Increasing electric field (E) strengths were applied to the particles from 0 to 27.5 kV/cm by steps of 2.5 kV/cm.
- For each applied E, the lifted particles were pumped up to a *Palas® Welas 2100* particle counter that measured the particle number concentration.



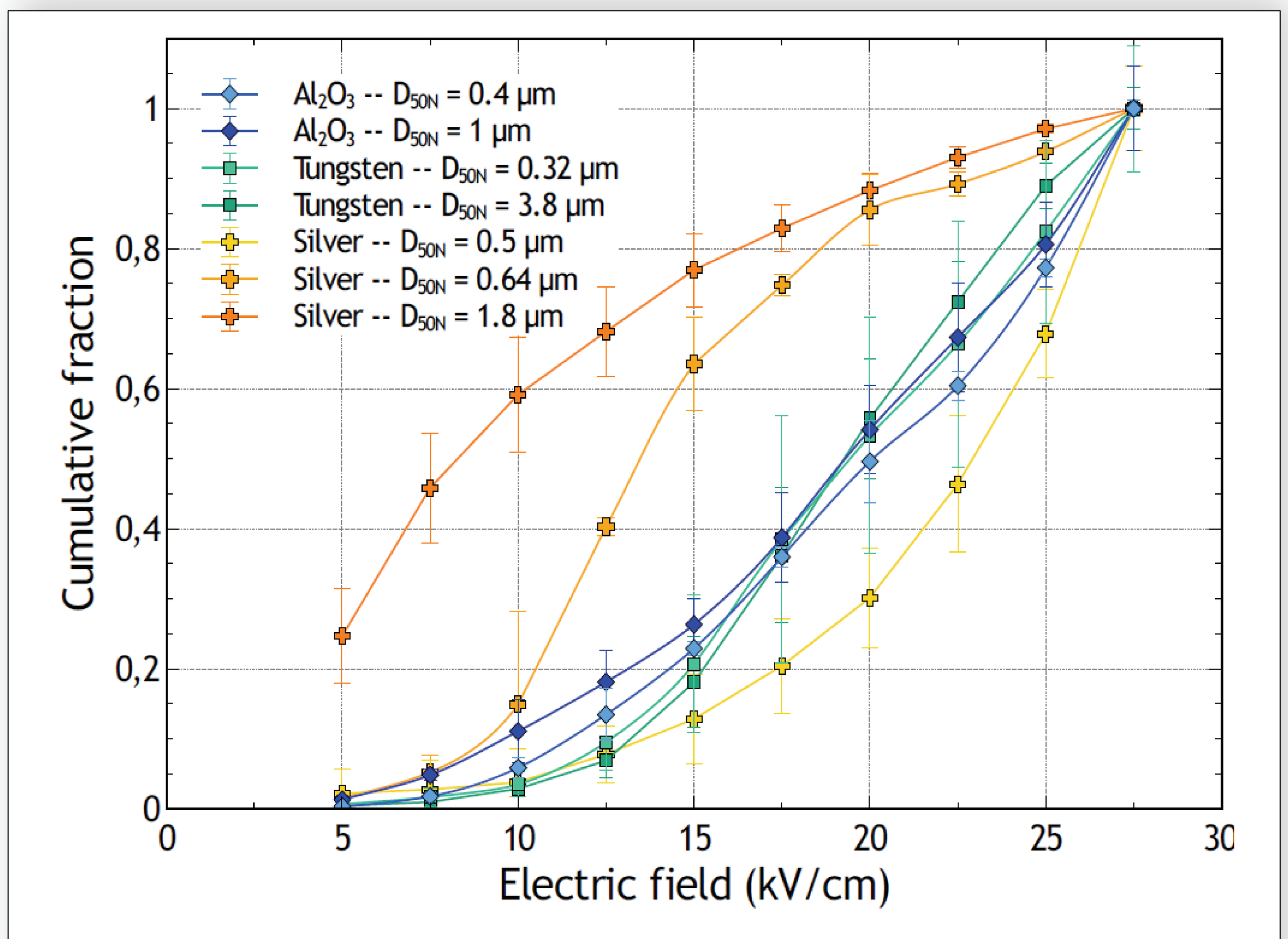
RESULTS OF THE RESUSPENSION EXPERIMENTS

- For each powder, we represent the cumulative fraction of the number of particles detached depending on the electric field strength.
- For each value of the electric field E_j, the data y on the graph is derivated by:

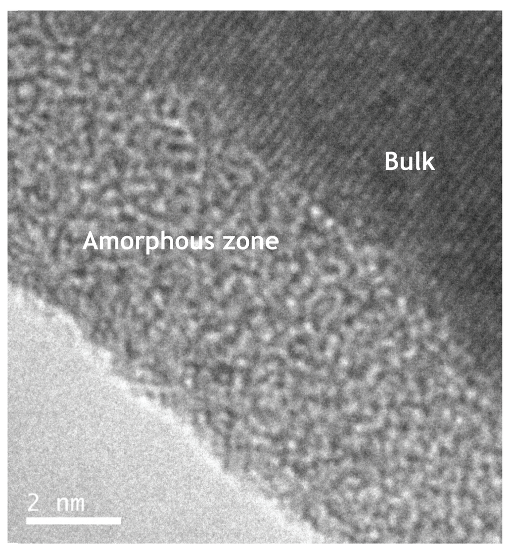
$$y(E_j) = \frac{1}{N}\sum_i n_{j,i}$$

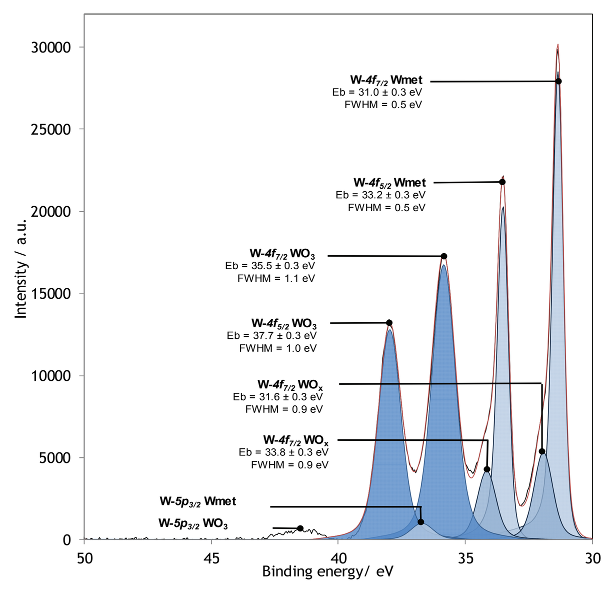
- With N the total number of particles, E_j the electric field with $5 < E_j < 27{,}5$ kV/cm, $n_{j,i}$ the number of detached particles for a specific particle size i and a specific electric field E_j, where i represent the classes of particle size bin used by the *Welas®* optical counter.
- Cumulative fractions can thus be derivated by:

$$f(j) = \sum_{k=1}^{j} y(E_k)$$



Normalized cumulative number fraction of silver, alumina and tungsten particles of different mean sizes experiencing increasing electric field strengths.





High resolution TEM micrograph of a tungsten particle (left) and X-Ray photoelectron spectrometry of tungsten powder (right)

- Tungsten particles are covered by an oxide layer with a thickness of 5 nm.
- Detachment thresholds ($E_{threshold}$ correspond to 50 % of resuspended particles throughout the experiment) for silver particles:

D_{50N}	1,8 µm	0,64 µm	0,5 µm
$E_{threshold}$ (kV/cm)	8,3	13,5	23

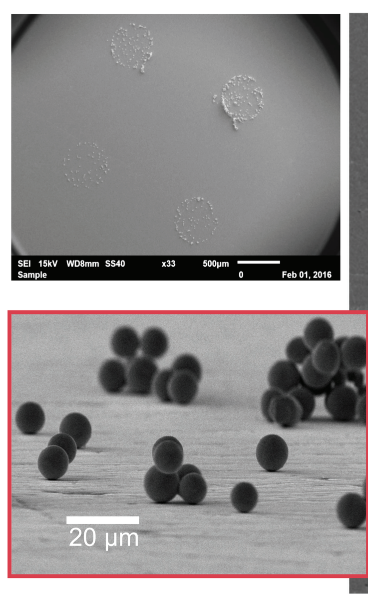
- Alumina and tungsten powders both have a detachment threshold around 20 kV/cm.
- Silver powders have detachment thresholds depending on the particle size distributions.

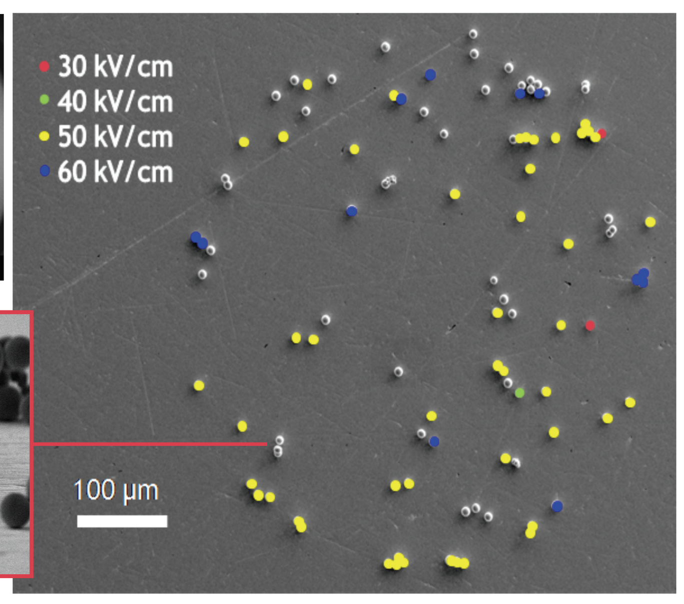
CONCLUSION

- We measured the number of particles detached for each electric field.
- Very high electric fields are required to detach micron-size particles (> 10 kV/cm).
- Significant effect of the particle size with conductive particles, i.e. silver powder, is shown.
- Tungsten and alumina particles exhibit the same detachment behavior with no noticeable effect of the particle median diameter.
- Tungsten particles are covered by an oxide layer which makes them behave like insulating particles.

PERSPECTIVES

- SEM image analysis of spherical W particles deposit on a smooth W surface.
- Each sample contains 4 spots of tungsten spherical particles with D_{50N} = 9 µm.
- Detached particles are counted after each increase of the electric field.





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