PARTICLE SIZE DOES MATTER

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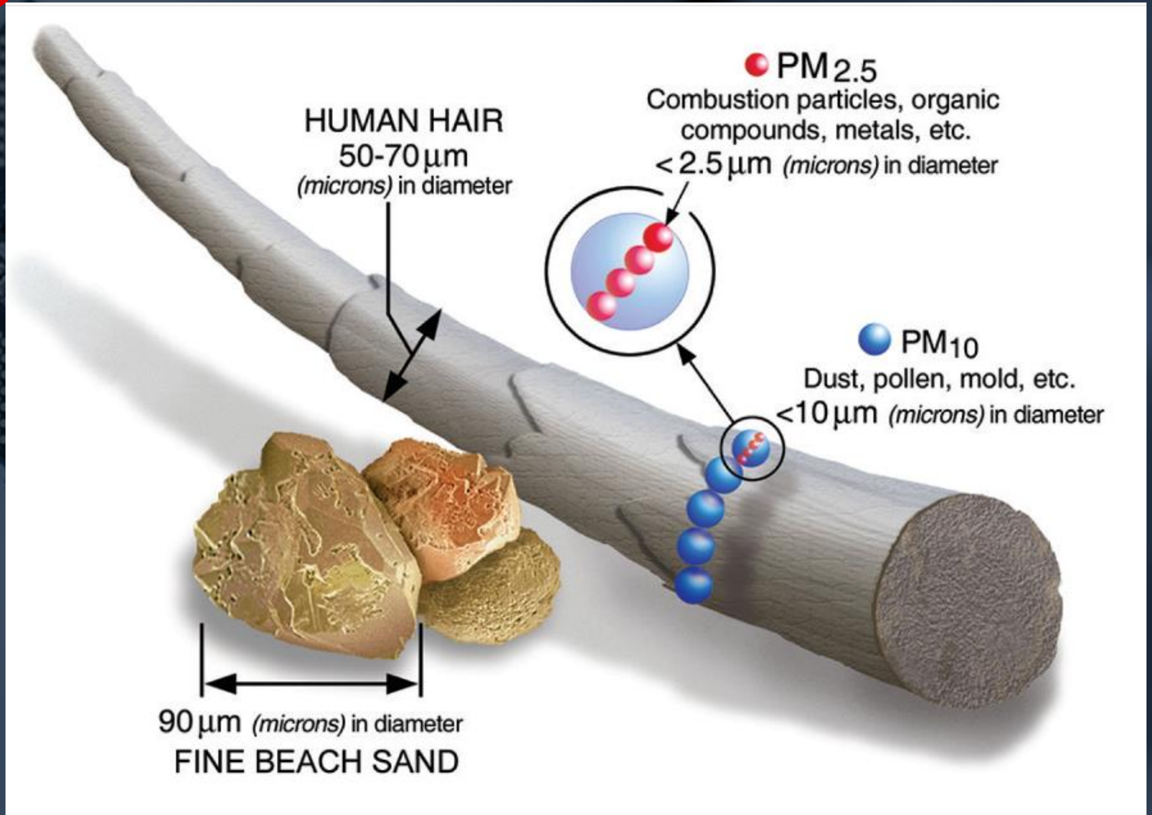
Chris Jones, Terry Chang and Shou-Nan Li

PARTICULATE CONTAMINATION IS FREQUENTLY CREATED BY SEMICONDUCTOR PROCESSES.

Sometimes the equipment used to treat process gases from the manufacturing tool also creates particles. For example, the abatement of silane, which is used to deposit thin silicon films, creates a dust of fine particles of amorphous silicon dioxide.

This dust can impact not only the operation of the FAB, but also the health of both the employees and the public.

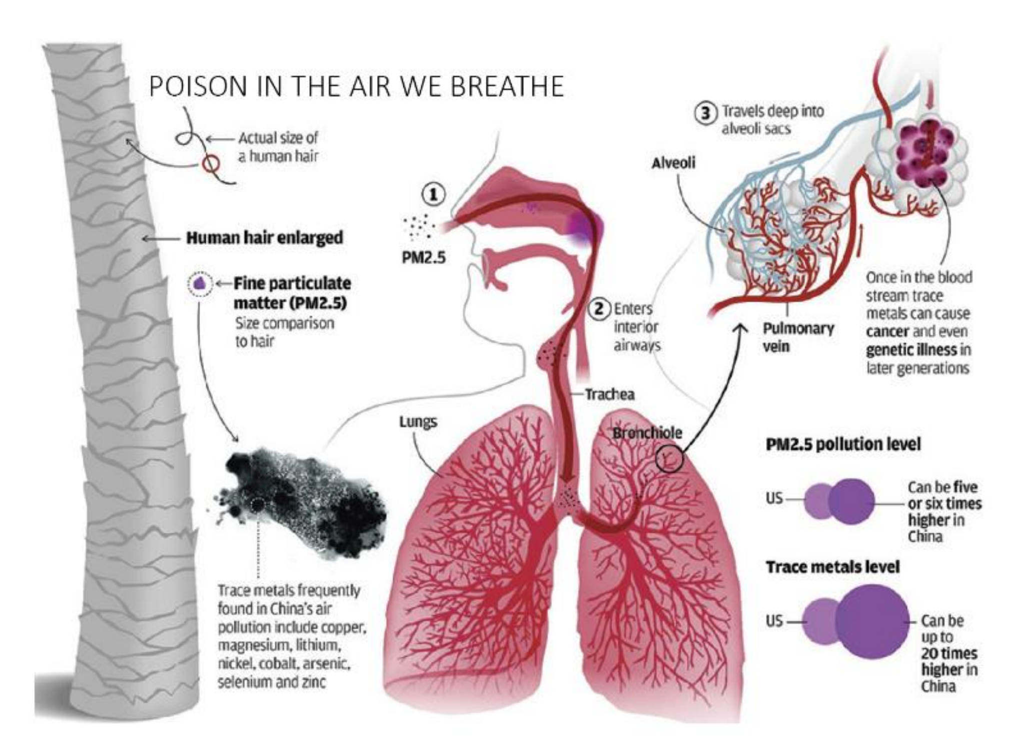
Environmental scientists refer to *particle size categories* as PM 10, PM 2.5 and PM 1, meaning particles less than 10µm, less than 2.5µm and less than 1µm respectively.



CURRENT REGULATIONS IN TAIWAN

Specifying limits for total suspended particles, PM 10 and PM 2.5.

POLLUTANT	AVERAGING TIME	LEVEL µG/M³
Total Suspended Particles (TSP)	24 hours	250
	Annual geometric average	130
Size equivalent less than 10 µm	24 hours	125
	Annual geometric average	65
Size equivalnt less than 2.5 µm	24 hours	35
	Annual geometric average	15



FAB OPERATION DOWNTIME

The mentioned dust can block ducts, leading to expensive downtime. Dust released within the fab during maintenance can damage both the manufacturing equipment and the silicon wafer products. Good dust control is needed to maximise facility uptime.

Although this oxide dust is relatively non-toxic, the health hazards associated with inhaling the powder increase with decreasing particle size.

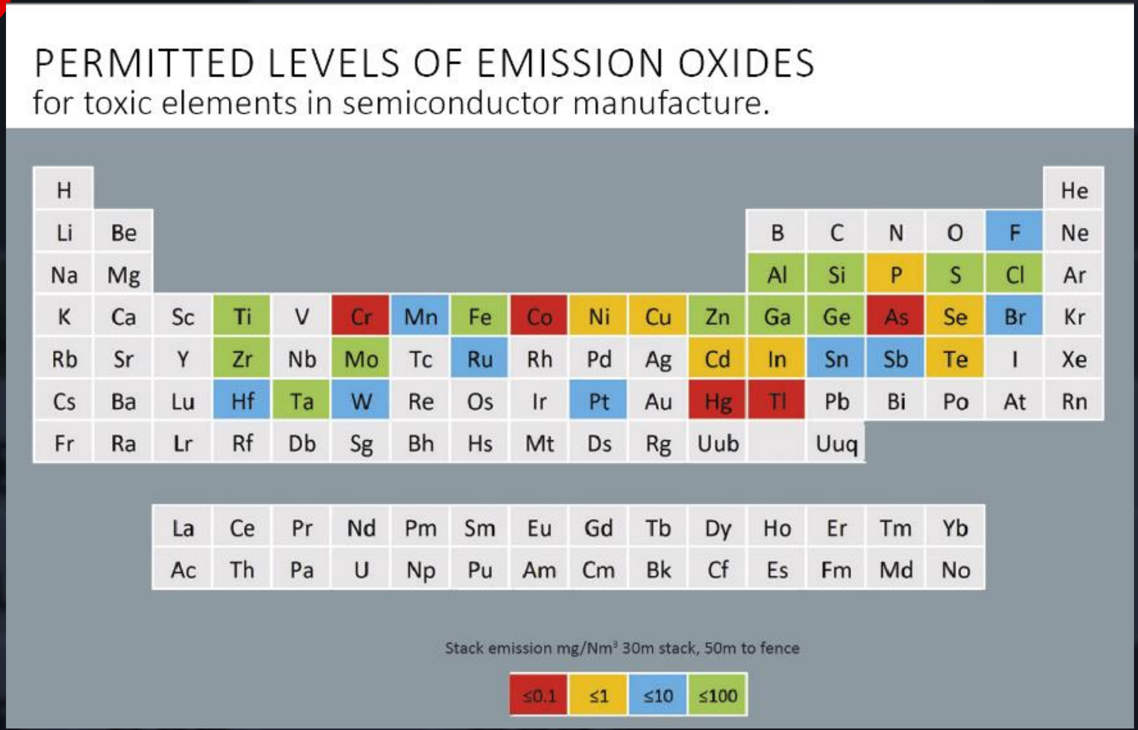
HEALTH IMPLICATIONS

Small particles are potentially hazardous to health because they can enter the body through the airways and lungs. PM 2.5 and PM 1 particles can get into fine lung structures, leading to reduced lung function. PM 0.1 can penetrate even further, and may lead to cancers and cardiovascular failure through inflammation.

Good dust control is also needed to minimise health, safety, and environmental issues. The table to the right summarises ambient regulatory limits in Taiwan, for total suspended particles (TSP), PM 10 and PM 2.5.

Regulations typically specify stack emissions to control exposure of the public beyond the perimeter fence to hazardous compounds. Toxicity of dusts, stack height, and distance to the perimeter are important considerations when establishing these limits.

The table provides an indication of emission limits for some solid compounds comprising elements of interest to the semiconductor industry. The drive to reduce particulate hazards motivates the development of not only the abatement equipment, but also rigorous analytical methods that can be readily applied in the field for both point of use (POU) and end of pipe (EOP) measurements.



Many elements used in semiconductor manufacturing are toxic. Colour coding here indicates permitted emission levels of their oxides.

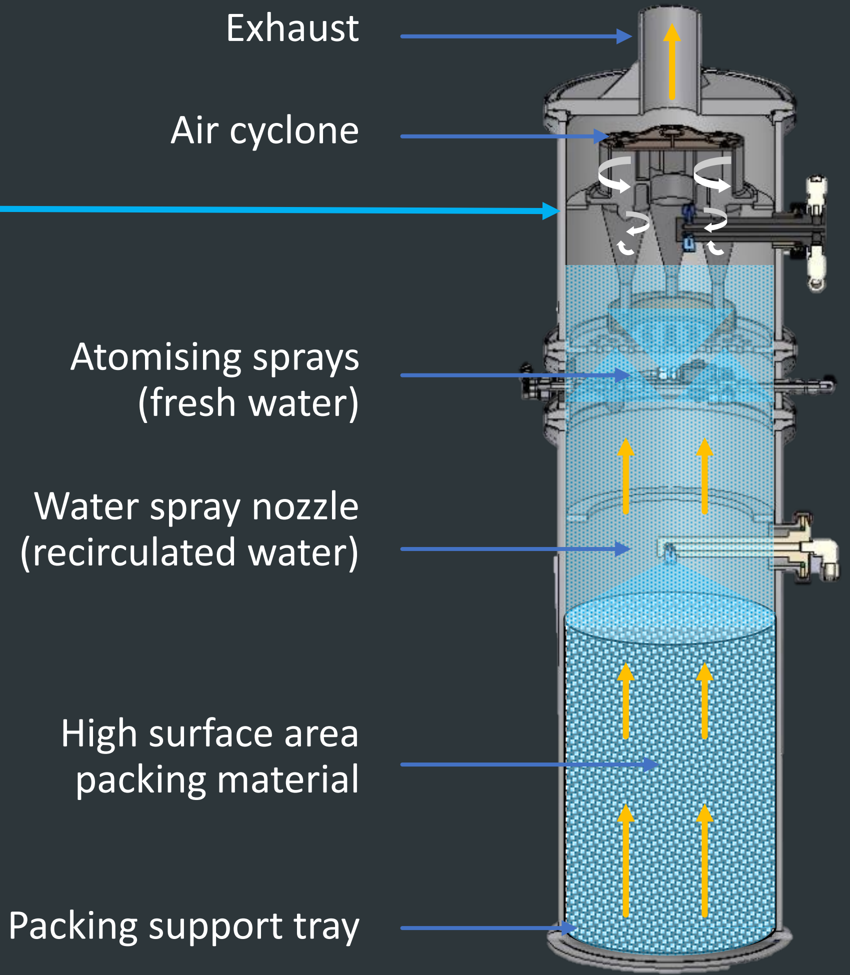
MEASUREMENT AND METHODOLOGY

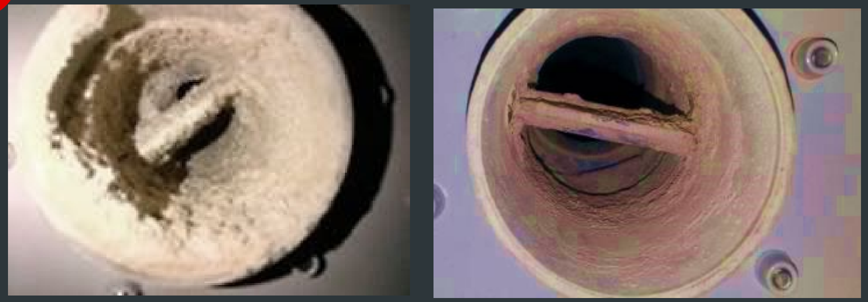
Any measurement technique used to monitor emissions and improve performance at the system level must:

- Use methods that are recognised internationally
- Be portable enough to move easily from system to system
- Be easily installed in and compatible with the fab/sub-fab operating environment and able to test both point-of-use (POU) or end-of-pipe (EOP) equipment
- Follow best practices for sampling – in duct sampling is best and any sample lines must be kept short
- Measure PM 2.5 and TSP
- Measure concentration, mass flow, and composition

In a recently published work, Shou-Nan Li and his colleagues at ITRI described a measurement methodology and its use in measuring particulate releases from an Edwards Atlas system for abating silane flows of 1, 0.5 and 0 slm.

THE EDWARDS ATLAS ATOMISING SPRAY TOWER





Left: the exhaust after 30 days of use without ATMS.
Right: 120 days use <u>with</u> ATMS.

The **Atlas** alone removes approximately 60% of solids. With the built-in atomising spray tower, the total powder removal rate increases to »75%.

It also maintains pack tower irrigation and scrubbing efficiency, avoiding excessive mist carryover to the exhaust, which then travels to the optional *Wet Electrostatic Precipitator* (WESP).

HOW ADDING A WESP TO THE PROCESS DRAMATICALLY IMPROVED THE OUTCOMES

With the addition of an optional WESP, the overall system particle removal efficiency improves to ~99.9%.

At 1slm input silane, releases from the **Atlas and WESP** were ~2mg/m3. Under the same conditions, mass releases from the Atlas alone would be ~1.5 kg/d, but the addition of the WESP would reduce this to only 3-4 g/day.

The agreement of the total suspended particulate and PM2.5 measurements confirmed that the particulate released were all no more than 2.5 µm in diameter. Separate laboratory measurements have since confirmed that the particles ***are all less than 1 µm.***

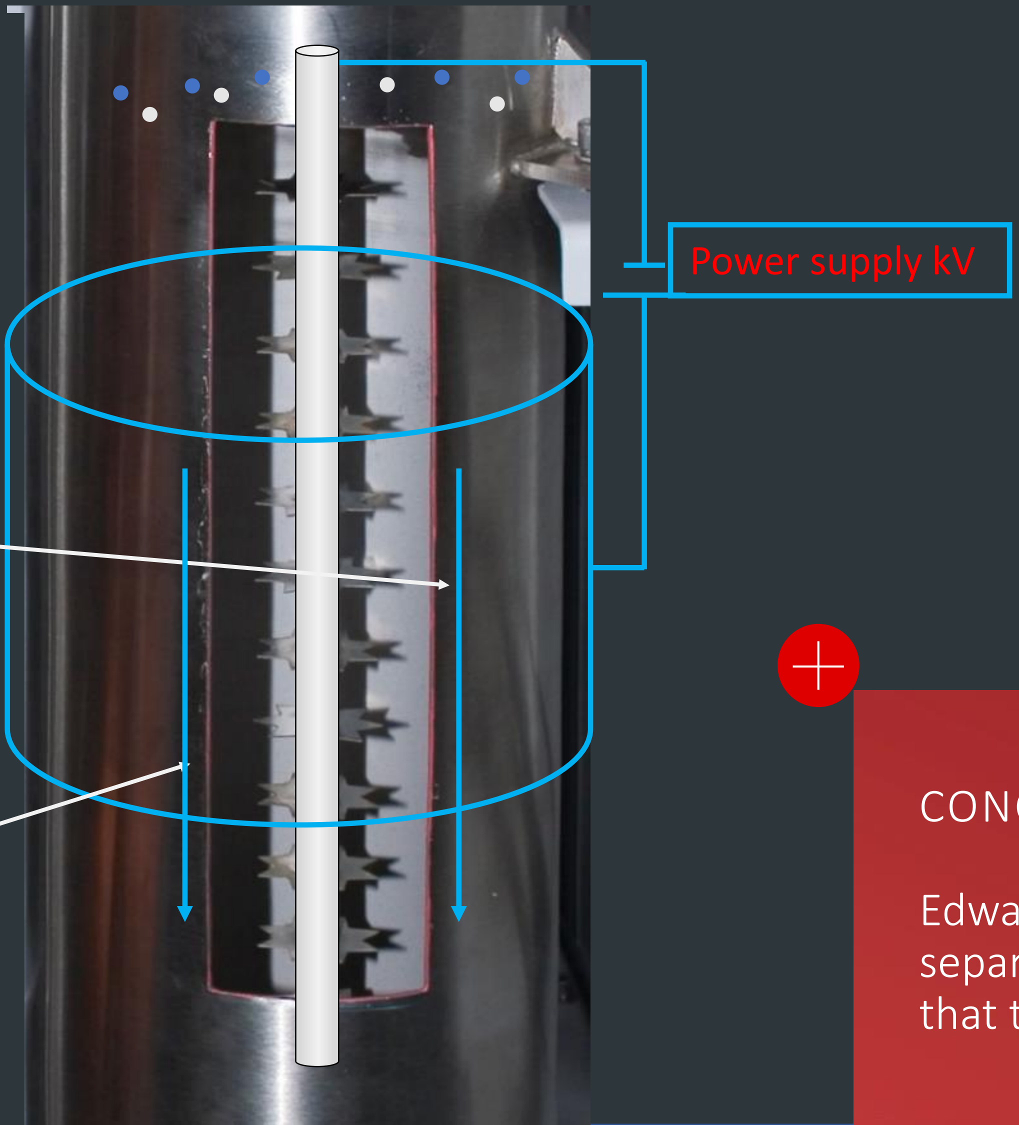
A WESP was added to the Edwards Atlas abatement system to .

HOW THE WET ELECTROSTATIC PRECIPITATOR (WESP) WORKS

OPERATING PRINCIPLE

Particles travelling in the gas stream are ionized and drawn towards the ground plate (cathode)

Gas stream direction



CONCLUSION

Edwards Atlas and WESP has been proven in separate laboratory measurements to confirm that the particles are **all less than 1 µm.**

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