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APT '26 - Turning Aerosol Science into Commercial Insight

Mass, Size and Density Fingerprints of Engineered Particles

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Mass, Size and Density Fingerprints of Engineered Particles

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Keywords: engineered nanoparticles, mass, size, density, instrumentation, titania

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The application of online analysis techniques rooted in aerosol science to the study of engineered particles is of increasing interest. Provided particles can be suspended in the aerosol phase, the use of one or more classifiers such as the Differential Mobility Analyser (DMA), Aerodynamic Aerosol Classifier (AAC) and Centrifugal Particle Mass Analyser (CPMA) to gain insight into size, mass, density and structure is established. However, classifiers which rely on the particles being charged such as the DMA and CPMA (but notably not the AAC) are limited in size range due to the need to charge the particles and correct for multiple charging artefacts, a process which depends upon particle morphology.

The Mass and Mobility Aerosol Spectrometer (M^2AS, Walker & Reavell 2020, Figure 1) circumvents this issue by measuring the actual charge state of particles during a CPMA scan and using that information to perform the charge correction. The mean charge is determined using the ratio of measurements from aerosol electrometry and a particle counter. A unipolar charger is used to ensure that the charge distribution is narrow (and hence the mean charge can be assumed to be representative), and to extend the range of the CPMA to several microns. To fully correct the mass scan for the transfer function of the CPMA, information on mobility size is required. Rather than running a lengthy separate scan, a new instrument called the Mobility Separator-Electrometer (MSE, Hassim *et al.* 2025) is used which determines the mobility simultaneously during the CPMA scan. It divides the incoming aerosol into two flows which are split according to electrical mobility between two electrometers which are kept in balance. The sum of the currents from both electrometers is used for the charge correction. The M^2AS gives mass spectral density, size spectral density & density.

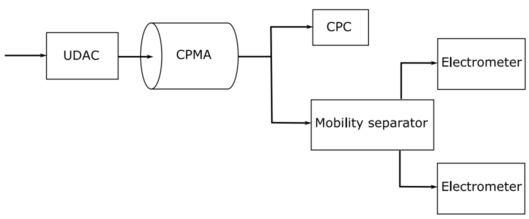

Figure 1. Mass and Mobility Aerosol Spectrometer

Recently the M^2AS has been applied to the analysis of engineered particles by femtoG AG. In a system known as the PowMaster, prior to analysis the particles are suspended in water and deagglomerated using ultrasound. The suspension is then diluted and the isolated particles extracted via spray-dispersion.

There are many engineered materials that consist of more than one material and have a complex structure. One example is titanium dioxide based white pigments. Those particles typically exhibit a core-shell structure where the TiO_2 particles are encapsulated by a layer of dense and/or porous silica. This surface-treatment reduces their photocatalytic activity, improves their dispersibility and results in a whiter paint.

For the material's performance, it is crucial that enough shell material is deposited onto the core particle and stays attached. We applied mechanical stress (similar to levels imparted in processing) by using progressive ultrasound. PowMaster analysis shows increasing shearing off of the shell material (Figure 2).

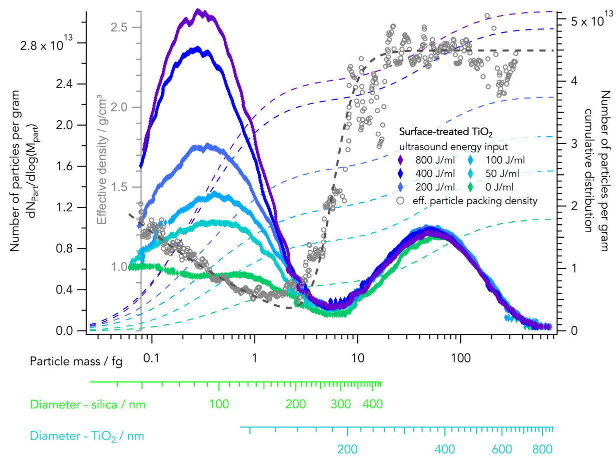

Figure 2. Mass spectral density of surface treated TiO_2 with increasing ultrasonic energy showing delamination

This compromises the material's function, costs more (as more coating is required) and raises questions regarding nanomaterial safety regulation as the delaminated particles are generally < 100 nm. Furthermore, this effect cannot be detected with established sizing methods (e.g. laser diffraction, sedimentation analysis) as the sheared- off silica particles have a different structure, density and refractive index than the TiO_2-core particles.

Walker, D., Reavell, K.St.J. (2020) in *Cambridge Particle Meeting*

Hassim, J., Hochgreb, S., Reavell, K.St.J. (2025) *Aerosol Science and Technology.* **59**, 267–291