From aerosol-made functional materials to the assembly of devices

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Industrial experience with production of carbon black, pigmentary TiO_2 and fumed silica has revealed, at least, seven reasons that make aerosols attractive in materials manufacturing (Buesser and Pratsinis, 2012):

1. Aerosol processes do not generate liquid by-products that are costly and difficult to clean and dispose (a clear advantage for sites with limited water supplies).
2. Collection of particles is easier and cheaper from gases than from liquids.
3. Highly pure materials can be formed in the gas phase (e.g. optical fibers).
4. Products with unique morphology can be made (e.g. filamentary Ni, carbon black and fumed SiO_2).
5. Aerosol processes are simpler and require fewer unit operations than wet-chemistry processes (e.g. wet vs. dry scrubbing);
6. Metastable phases can be captured by rapid cooling of aerosol-made products resulting in truly new materials.
7. Transport phenomena (e.g. diffusion) in gases afford more rigorous treatment than in liquids or solids, facilitating process design from first principles.

So materials manufacturing offers opportunities for aerosol scientists to contribute in product development, process scale-up, and environmental compliance. There the goal is the optimal and sustainable synthesis of sophisticated particle compositions and morphologies as they largely determine product performance for specific applications. So, close control of primary particle and agglomerate mobility diameter, phase composition and extent of aggregation are sought at the *kg/h* production rate bringing in a new set of challenges. For example, Figure 1 shows a difference of factor of 4 in agglomerate particle radius of gyration (measured by microscopy or light scattering and typically calculated by aerosol simulations), mobility radius in the continuum and free molecular regimes (measured by differential mobility analysis) and volume- or mass- equivalent radius that is of significance in sales (Eggersdorfer & Pratsinis, 2014).

Recent advances, however, in fractal-like aerosol dynamics, deposition and characterization allow now aerosol synthesis of complex material architectures, active under visible light and comprising of titanium suboxide (e.g. Ti_4O_7, Ti_3O_5) layers onto nanosilver on nano TiO_2 (Fujiwara et al., 2014). Abundant combustion intermediates present during flame synthesis of these materials partially reduce TiO_2 and induce strong metal-support interactions (SMSI) resulting in *crystalline* Ti-suboxides that are stable upon annealing in air, at least, up to 350 °C for two hours. Under visible light ($\lambda > 400$ nm), these nanoparticles exhibit strong photo-reduction of cationic species (Cr^{6+}) & photo-oxidation of methylene blue (15-minute half-life).

Portable, highly selective sensors consisting of flame-made, metastable ε-WO_3 were made and tested on- and off-line for monitoring breath acetone, a tracer for diabetes type-1 (Righettoni et al., 2013). The end tidal fraction of the breath was collected in Tedlar bags from eight healthy volunteers after overnight fasting and after lunch. These sensors accurately detected acetone with fast response-recovery times (< 12 s) and a high signal-to-noise ratio. Best correlations were found after overnight fasting (morning) between sensor response and blood glucose and breath acetone (measured by proton transfer reaction time-of-flight mass spectrometry).

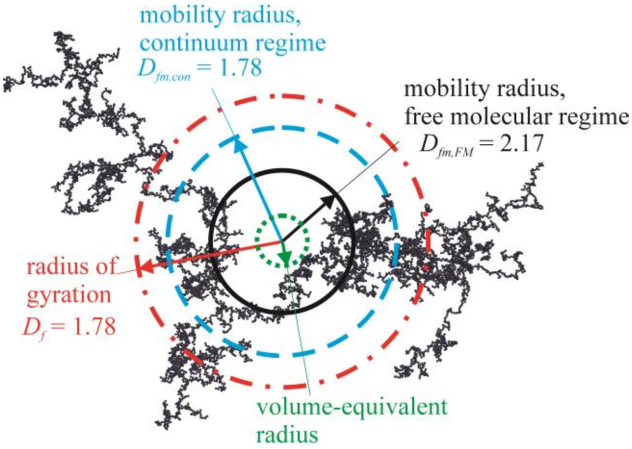

Figure 1. Agglomerate particle radii

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