Control of Particle Size and Morphology by Humidity

Swiss Federal Institute of Technology Zürich

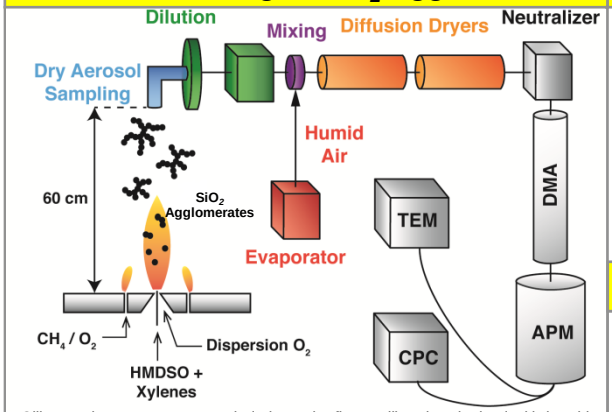
G.A. Kelesidis, F.M. Furrer, E. Goudeli, K. Wegner and S.E. Pratsinis
Particle Technology Laboratory, ETH Zürich, CH-8092 Zürich, Switzerland
gkelesidis@ptl.mavt.ethz.ch

PTL
www.ptl.ethz.ch

Motivation

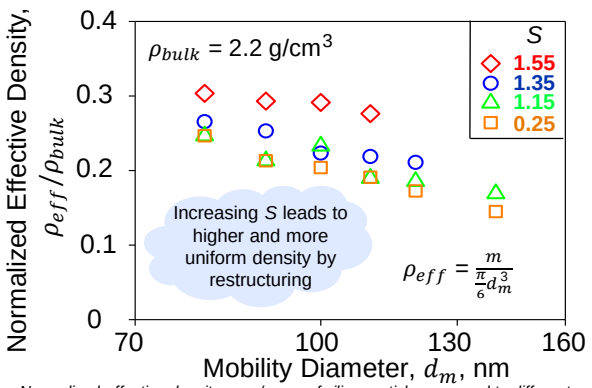
In the presence of humidity, nanoparticle agglomerates restructure forming smaller and more compact entities.[1,2] For soot agglomerates, this changes their impact on health and environment.[1] For other nanoparticles, such characteristics can be very attractive, e.g. for biomedical applications, where large, ramified silica agglomerates are currently used.[3] Here, flame-made silica agglomerates are processed by different humidity conditions to control the particle size distribution and morphology.

Water Processing of SiO_2 Agglomerates



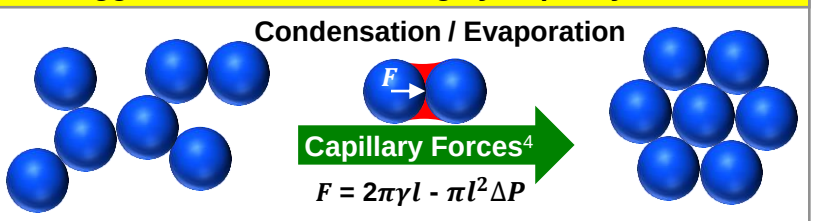
Silica agglomerates are sampled above the flame, diluted and mixed with humid air before passing through two diffusion dryers into a differential mobility analyzer (DMA), an aerosol particle mass analyzer (APM), a condensation particle counter (CPC) and then collected for Transmission Electron Microscopy (TEM) analysis.

Agglomerate Effective Density



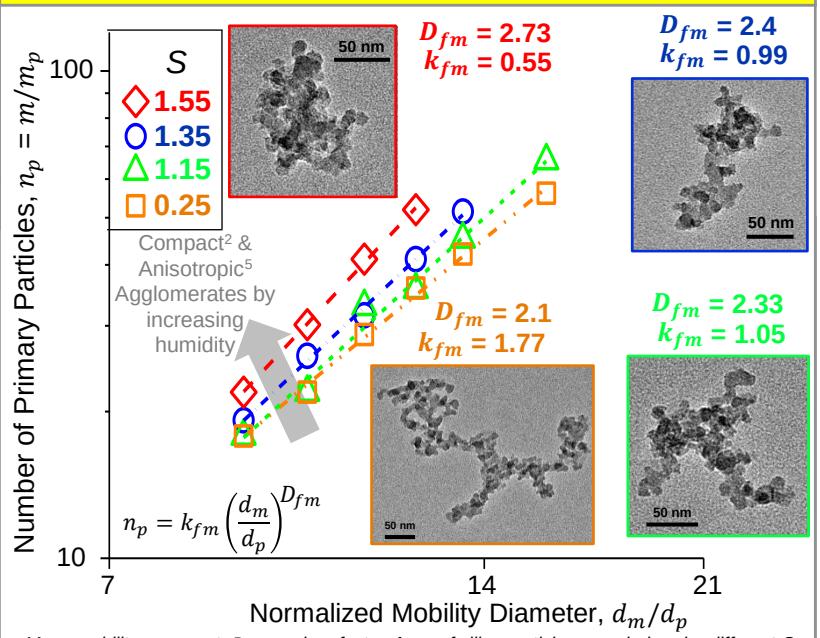
Normalized effective density, ρ_{eff}/ρ_{bulk}, of silica particles exposed to different saturation ratio, S.

Agglomerate Restructuring by Capillary Forces



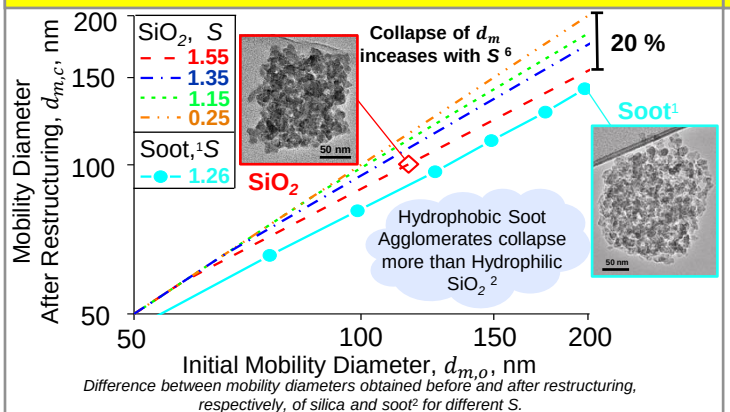
Agglomerates restructure due to capillary forces, F, during condensation / evaporation of a solvent. (γ: solvent's surface tension, l: liquid meniscus size, ΔP: gas/liquid pressure difference)

Evolution of Agglomerate Morphology



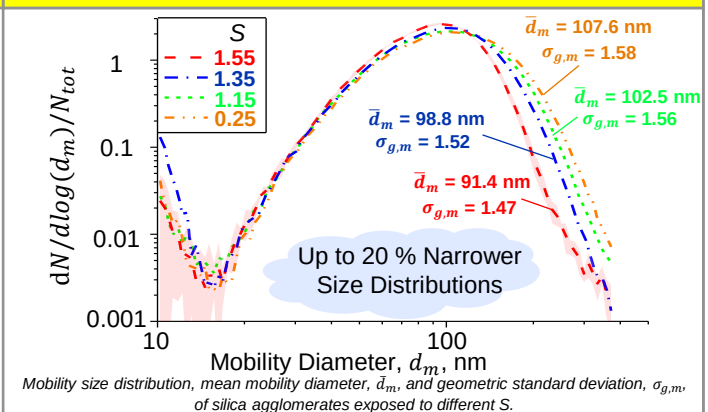
Mass-mobility exponent, D_{fm}, and prefactor, k_{fm}, of silica particles sampled under different S.

Shrinking of Agglomerate Mobility Diameter



Difference between mobility diameters obtained before and after restructuring, respectively, of silica and soot[2] for different S.

Mobility Size Distribution After Restructuring



Mobility size distribution, mean mobility diameter, $\bar{d}_m$, and geometric standard deviation, $\sigma_{g,m}$, of silica agglomerates exposed to different S.

References

[1] Weingartner E, Burtscher H, Baltensperger U. (1997) *Atmos. Environ.* **31**, 2311
[2] Ma X, Zangmeister CD, Gigault J, Mulholland GW, Zachariah MR. (2013) *J. Aerosol Sci.* **66**, 209
[3] Sotiriou GA, Starsich F, Dasargyri A, Wurnig MC, Krumeich F, Boss A, Leroux JC, Pratsinis SE. (2014) *Adv. Funct. Mater.* **24**, 2818
[4] Butt HJ, Kappl M. (2009) *Adv. Colloid Int. Sci.* **146**, 48
[5] Heinson WR, Sorensen CM, Chakrabarti A. (2010) *Aerosol Sci. Technol.* **44**, I
[6] Ghazi R, Olfert JS. (2013) *Aerosol Sci. Technol.* **47**, 192

Conclusions

1. Silica agglomerate morphology and size distribution can be tuned by varying the humidity during sampling.
2. More compact (D_{fm} = 2.73) and anisotropic (k_{fm} = 0.55) agglomerates are formed with increasing S.
3. Agglomerates with larger and more uniform ρ_{eff} are formed with higher S.
4. The mobility size distribution shifts to smaller $\bar{d}_m$ and narrows up to 20 % for S = 1.55.
5. The decrease in d_m observed for silica agglomerates is smaller than that for soot due to their hydrophilic surface, consistent with literature.[2]