Motivation

In the presence of humidity, agglomerates of single primary particles (PPs) and/or chemically-bonded ones (aggregates) restructure, forming smaller and more compact structures. This is known to affect the fluidization\(^2\) and spray drying\(^3\) of soot. Here, the evolution of silica morphology and mobility size distribution processed under humid conditions is monitored for the first time and compared to humidified soot nanoparticles.

### Processing of SiO\(_2\) Agglomerates with Water Vapor

Silica agglomerates are sampled above the flame, diluted and mixed with humid air with varying temperature to achieve saturation ratios, \(S\), from 0.2 to 1.5. The diluted sample is directed through two diffusion dryers to a differential mobility analyzer (DMA) and then to an aerosol particle mass analyzer (APM), a condensation particle counter (CPC) or for transmission electron microscopy (TEM). During tandem DMA (TDMA) measurements, dry agglomerates with mobility diameters, \(d_{m}\), are selected by TDMA before mixing with humid air.

### Shrinking of Agglomerate Mobility Size

![Graph showing the shrinking of agglomerate mobility size](image)

**Graph Description:**
- Normalized Mobility Diameter, \(d_{m}/d_{p}\), as a function of normalized mobility diameter, \(d_{m}/d_{p}\), for silica and soot agglomerates.
- Silica agglomerates show a decrease in mobility diameter with increasing saturation ratio, \(S\).
- The graph illustrates the change in \(d_{m}\) with varying \(S\) values (0.2, 0.9, 1.5).

### Agglomerate Characterization by Scaling Laws

**Diagram:**
- Condensation & Evaporation
- Soot agglomerates undergo reorganization due to capillary forces, \(F\), during condensation/evaporation of a solvent.

#### Drastic Change of Agglomerate Morphology by Humidity

![Graph showing mass-mobility relationships](image)

**Graph Description:**
- Relative effective density, \(\rho_{eff}/\rho\), of silica agglomerates exposed to different \(S\) (symbols) compared to soot agglomerates with smaller PP standard deviation, \(\sigma_{p}\), and mobility exponent and prefactor.
- Data: Agglomeration Theory: \(\rho_{eff}/\rho = (d_{m}/d_{p})^{-0.78}\)
- Soot: \(0.36 \pm 0.04\)
- Silica: \(0.28 \pm 0.02\)

### Mass-mobility Relationship of Restructured Agglomerates measured by TDMA [7]

![Graph showing mass-mobility relationships](image)

**Graph Description:**
- Mass-mobility relationships measured for silica agglomerates with different primary particle sizes, \(d_{m}/d_{p}\).
- Agglomerates: Silica ▲ Soot △
- Agglomerates form larger aggregates than soot.

### References


### Conclusions

1. At \(S = 0.9\), the \(d_{m}/d_{p}\) of ramified silica agglomerates decreases with \(d_{m}/d_{p}\), following closely the agglomeration theory.\(^1\)
2. At \(S = 1.5\), silica PPs restructure into spherical agglomerates with 10 % smaller \(d_{m}\) and \(d_{m}/d_{p}\) of 0.28 ± 0.02 invariant of \(d_{m}/d_{p}\).
3. Silica agglomerates consist of large aggregates compared to those of soot due to their flame synthesis conditions. This results in less compact agglomerates with smaller \(d_{m}/d_{p}\) and \(d_{m}/d_{p}\) after water condensation and evaporation.
4. TDMA measurements can be coupled with the scaling law derived here to measure the restructured agglomerate mass-mobility relationship as an alternative to the tedious APM.