Differences in light absorption and scattering by coated combustion soot and its surrogates

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Abstract

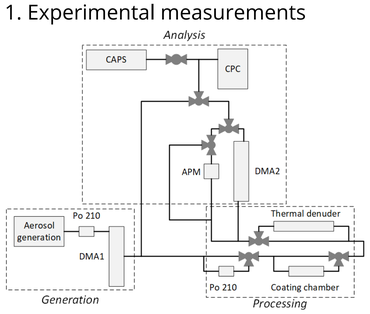
- Atmospheric soot (or black carbon, BC) affects climate through solar light absorption and scattering, which depend strongly on particle morphology and composition. Morphology and composition change as particles undergo condensational processing.
- In laboratory studies of BC optics, surrogates such as carbon black (CB) and nigrosin are often used in place of flame-generated BC. Our goal was to investigate if compositional and morphological differences between these surrogates and BC may produce differences in condensation processing and optical responses.

Introduction and Motivation

- CB is often generated from an aqueous solution. Therefore, we expect that CB particles are restructured, while BC particles sampled directly from flame retain their fractal morphology until the controlled aging process is deliberately initiated.
- Nigrosin is a light-absorbing substance that forms spherical particles when nebulized, which is also used as a surrogate for BC.
- This study explores experimentally how flame-generated BC and its surrogates (commercial carbon black and nigrosin) respond to coating by a low-volatility organic compound dioctyl sebacate (DOS).

Methodology

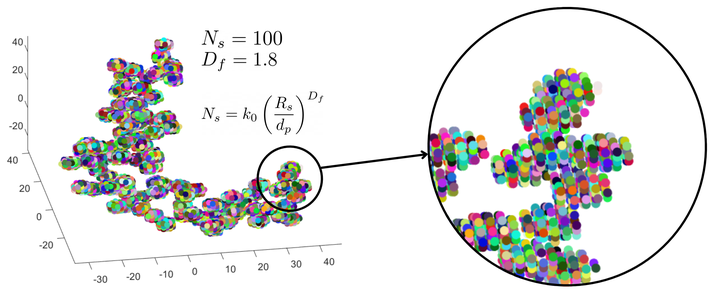
1. Experimental measurements



CAPS - cavity attenuated phase shift spectrometer
CPC - condensation particle counter
APM - aerosol particle mass spectrometer
DMA - differential mobility analyzer

Aerosol generation and processing system

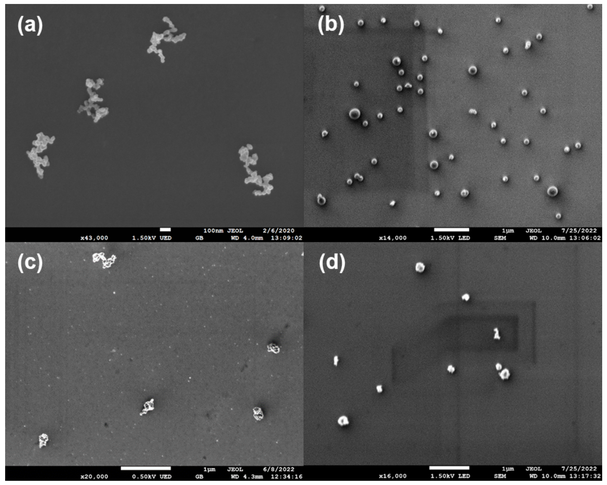
2. Optical modeling



Discretized aggregate for DDA

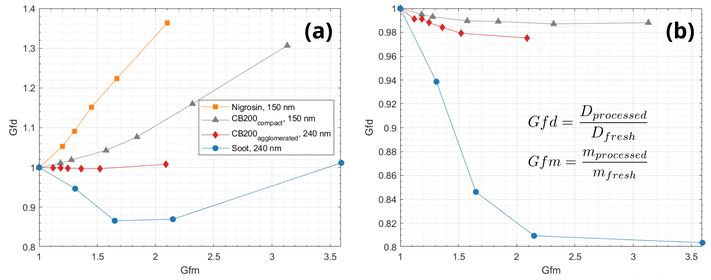
Results

1. Morphology of bare particles



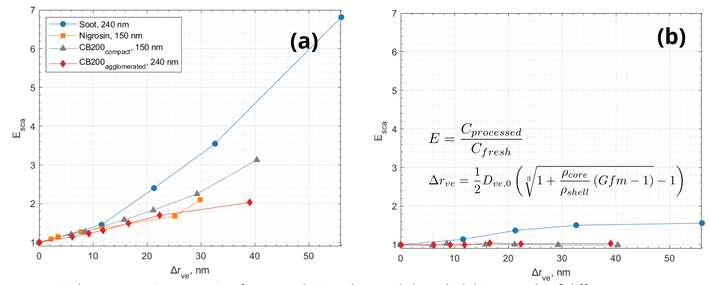
SEM images of (a) fresh soot, (b) nigrosin, (c) agglomerated Cab-O-Jet 200, and (d) compact Cab-O-Jet 200

2. Change in morphology in response to coating

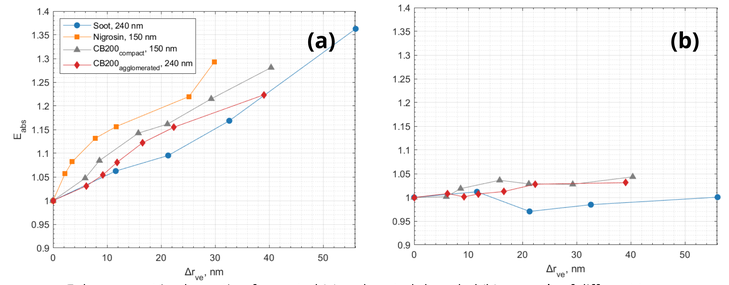


Mobility growth factor vs mass growth factor upon processing of different types of particles: (a) DOS coated aerosols and (b) DOS-coated-denuded aerosols.

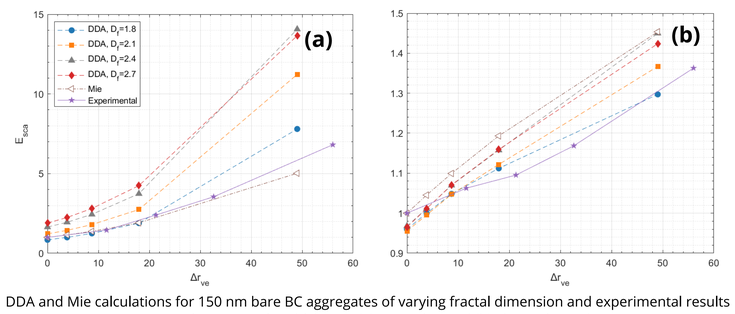
3. Optical response to coating



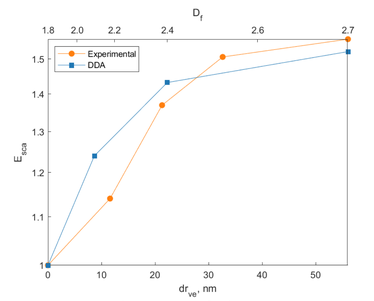
Enhancement in scattering for coated (a) and coated-denuded (b) aerosols of different types



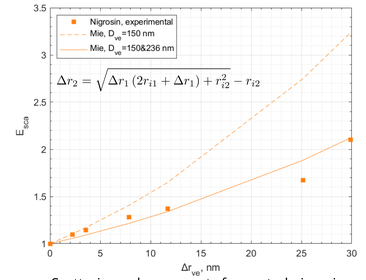
Enhancement in absorption for coated (a) and coated-denuded (b) aerosols of different types



DDA and Mie calculations for 150 nm bare BC aggregates of varying fractal dimension and experimental results versus volume equivalent coating thickness: (a) scattering and (b) absorption enhancements



Scattering enhancements for bare BC aggregates versus volume equivalent coating thickness (experimental) and fractal dimension (DDA)



Scattering enhancements for coated nigrosin: experimental data, Mie for the nominal size, and Mie corrected for multiple charging

Conclusions

- Nebulization of an aqueous carbon black suspension can produce either compact or semi-fractal agglomerates, depending on the droplet drying rate.
- The use of compact particles instead of black carbon to study the effect of coatings leads to a significantly underestimated enhancement in light scattering and a slightly overestimated enhancement in light absorption.
- Carbon black can be used as a surrogate for black carbon only when morphological effects on optics are not important.
- Nigrosin may serve as a surrogate for soot aerosols, but its refractive index differs from carbon, resulting in a significantly different optical response to particle coating.
- Mie theory can provide a good approximation for light absorption and scattering of processed BC particles.

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