Single Particle Analysis of Nanoparticles from Light Oil Combustion

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This study focuses on the detailed analysis of single particles from oil combustion. An oil burner (ELCO, type 01H 27A LD0, blue flame) for residential heating was used as a particle source. The exhaust gas was diluted using a rotating disc diluted (Matter Engineering) and the volatile fraction of the exhaust gas was removed with a thermodesorber (Dekati) operated at 250°C. Grain size distributions (10 – 500 nm) were recorded with an SMPS system (TSI, Model 3034). Particles were sampled directly on TEM grids (copper, lacy carbon) using a custom built electrostatic sampler. The oil burner was operated at oxygen deficiency and optimal burner settings.

Experiments with oxygen deficiency:

These experiments were performed to test the electrostatic sampler. The SMPS scan indicates a unimodal size distribution (mode: 41 nm). Transmission electron microscopy (TEM) images (bright field) confirmed these findings. Aggregates of various sizes consisting of numerous primary particles were found. Images taken at higher magnifications (> 100’000) revealed a turbostatic structure, typically observed in soot particles.

Experiments at optimal burner settings, operated without a thermodenuder:

Also here the SMPS scan indicates an unimodal size distributions with a mode at 13 nm. Scanning electron microscopy images confirmed that the particles were homogeneously deposited of the TEM grids. However, due to contamination at high magnifications (>200’000x) and instabilities of the particles under the electron beam the structure of the particles could not be resolved. Thus, the sample was investigated using a TEM (FEI, CM30, LaB6 source), operated at 200 kV in bright field mode. However, due to radiation damage, the particles could only be imaged very quickly under moderate magnifications (20’000x) before they completely evaporated leaving no residue. Thus, these particles appear to be volatile particles.

Experiments at optimal burner settings, operated with a thermodenuder (250 °C):

Most of the particles could be removed, when a thermodenuder (operated at 250°C) was used. However, a small fraction of particles (mode < 10 nm) remained and thus appear to be solid. High resolution TEM imaging revealed distinct lattice fringes, which point towards a crystalline nature of these particles.

In summary: In experiments with a thermodesorber operated at 250°C, crystalline particles were detected in the TEM. In experiments performed without a thermodesorber, particles were not stable under the electron beam and thus are most likely volatile particles.

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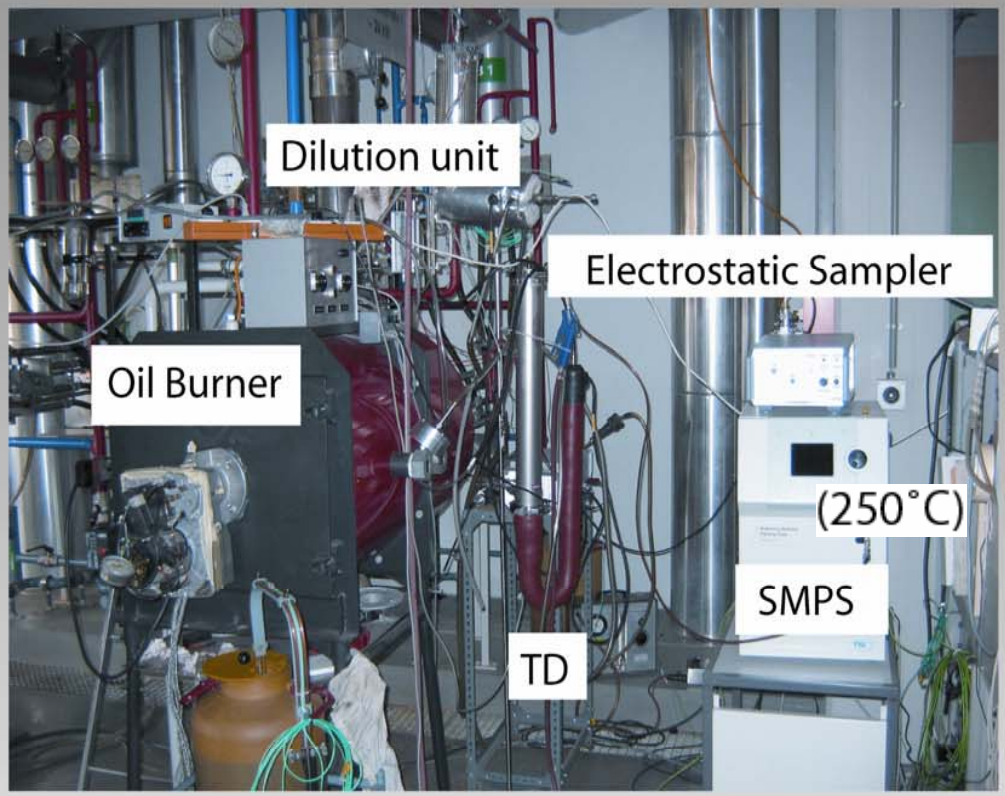
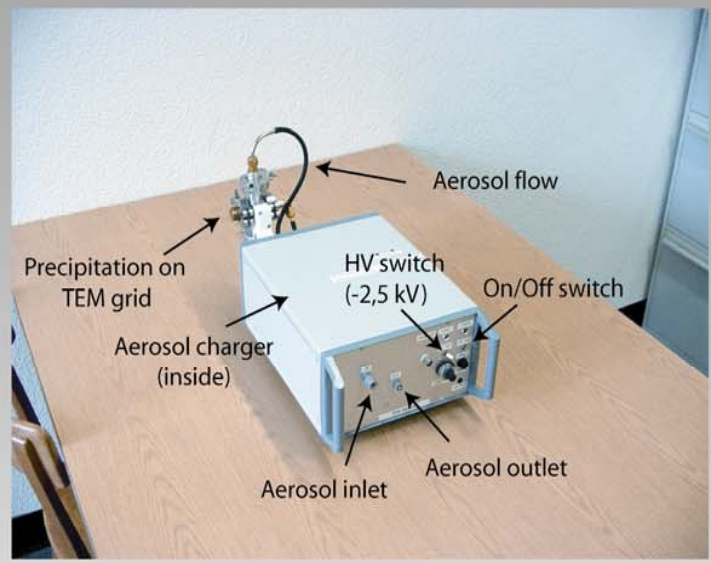
Motivation	Effects of Nanoparticles (Health, Climate) Structure of combustion particles
Goal	Contribute to the understanding of formation process of combustion particles Characterise oil combustion particles for source apportionment in ambient air

EMPA

Experimental Setup

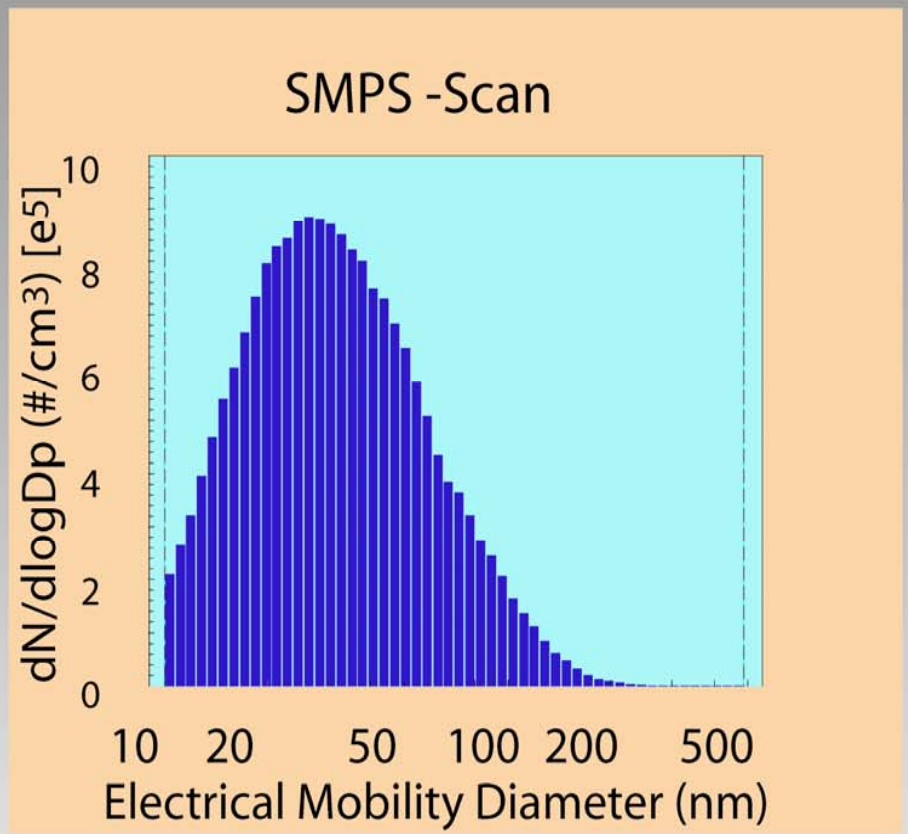


Sampling of Single Particles



Oil burner: ELCO (EL 01A 27H LD0) blue flame
Dilution unit: Rotating disc diluter (Matter Eng.)
TD: DEKATI
SMPS: TSI 3034
Electrostatic sampler: Custom built (H. Burtscher & M. Fierz)

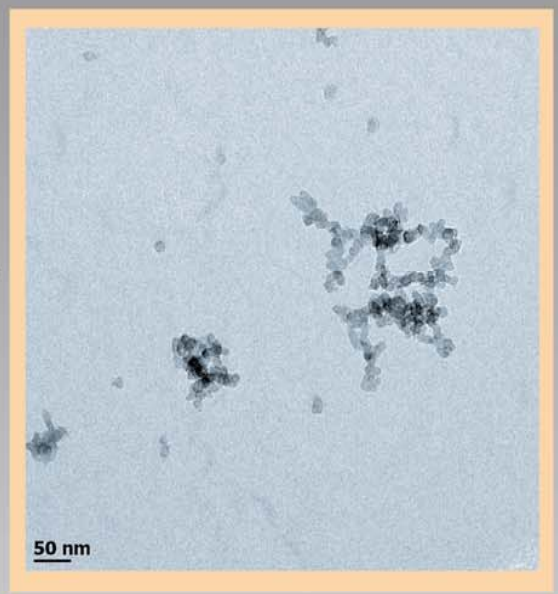
O_2 deficiency



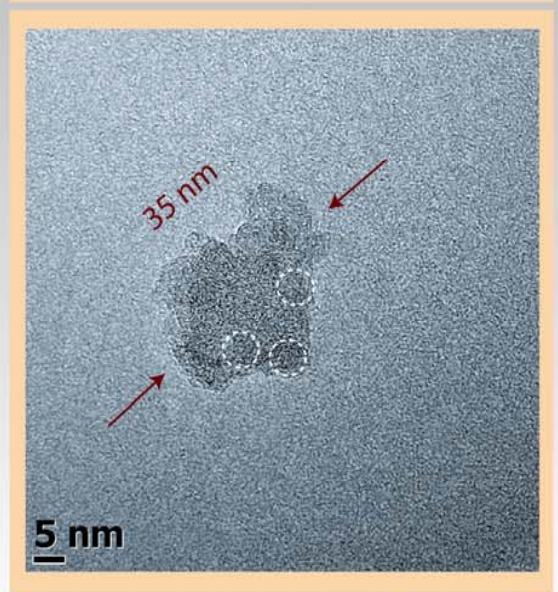
sample flow: 1 l/min
sheath flow: 4 l/min
scan time: 3 minutes

TEM analysis

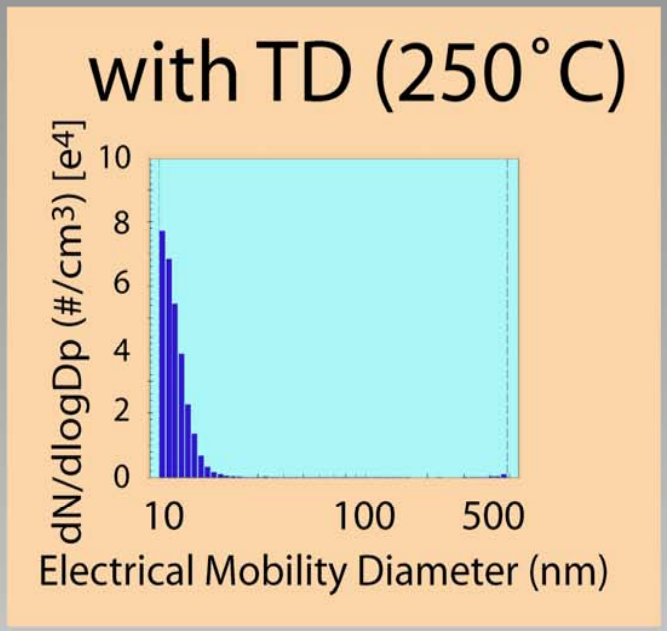
Overview

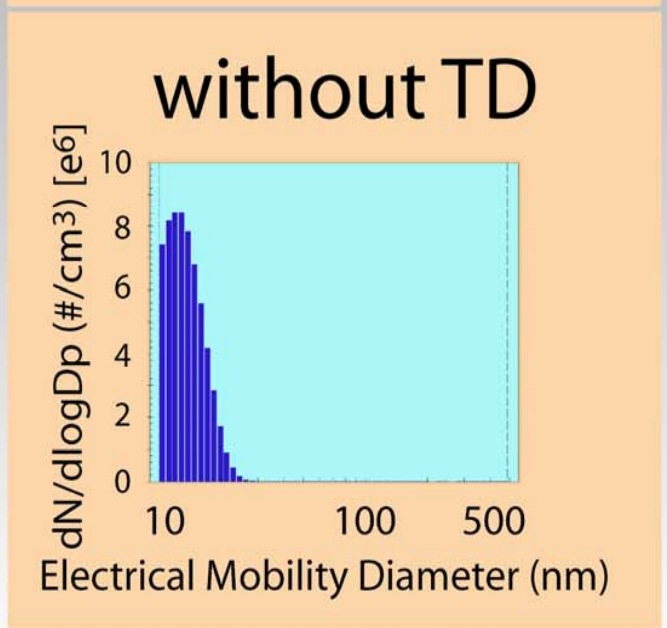


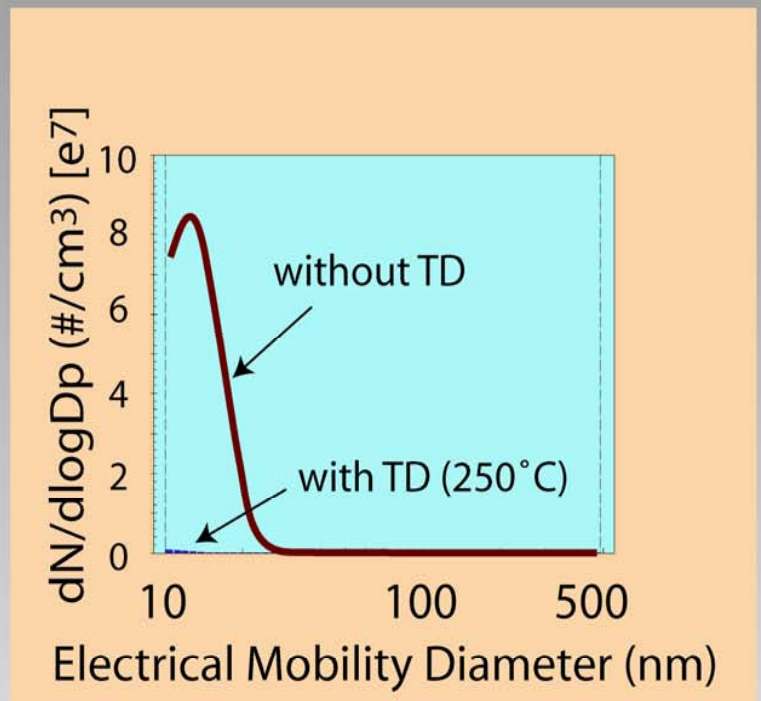
Detail



Optimal burner settings



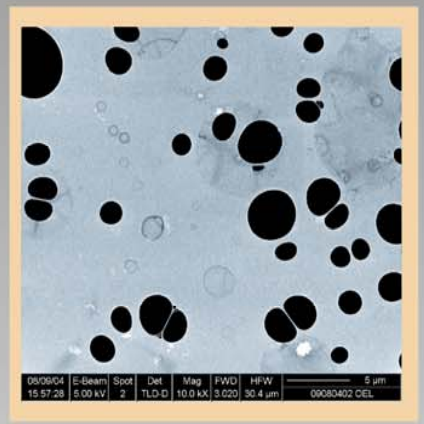


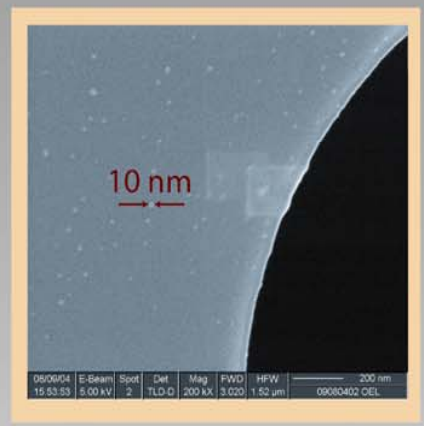


The majority of the particles could be removed with the TD. However, a small fraction of 10 nm sized particles remains and thus appears to be solid.

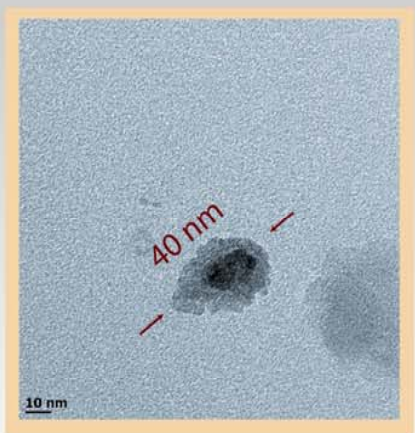
Optimal burner settings: Without TD

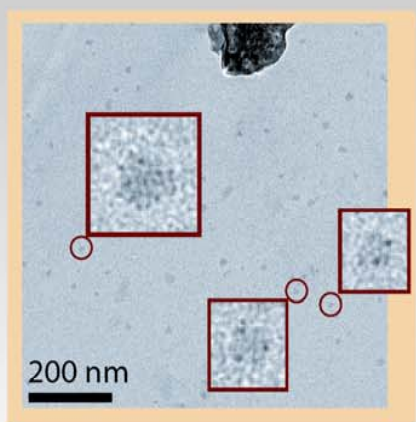
HR-SEM





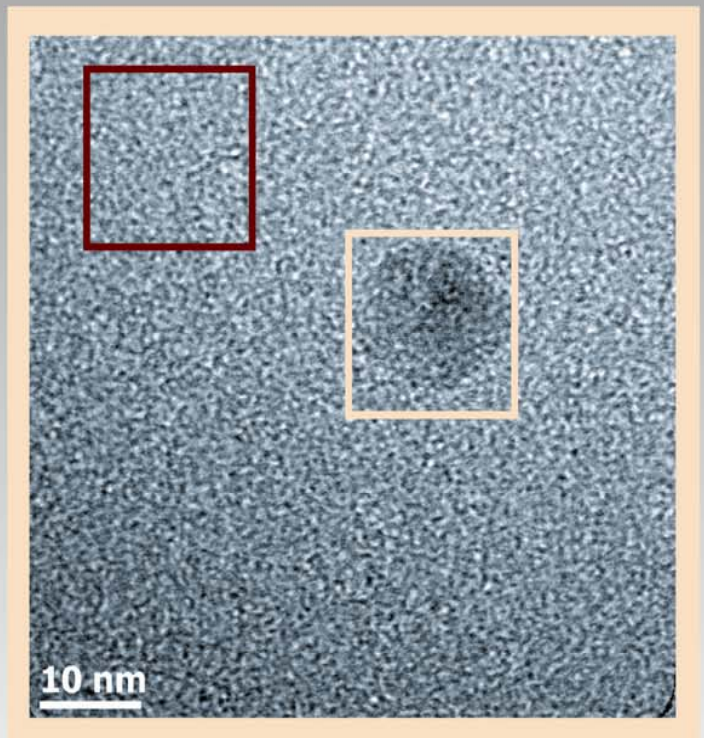
TEM analysis





Optimal burner settings: With TD (250 ˚C)

HR-TEM analysis



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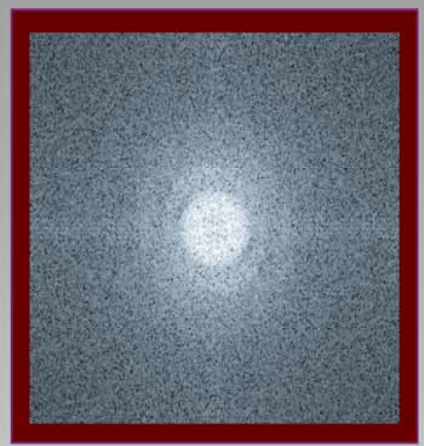

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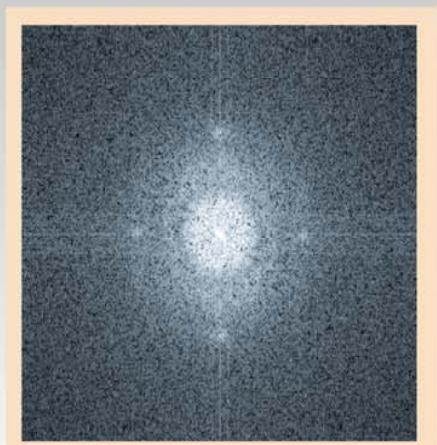
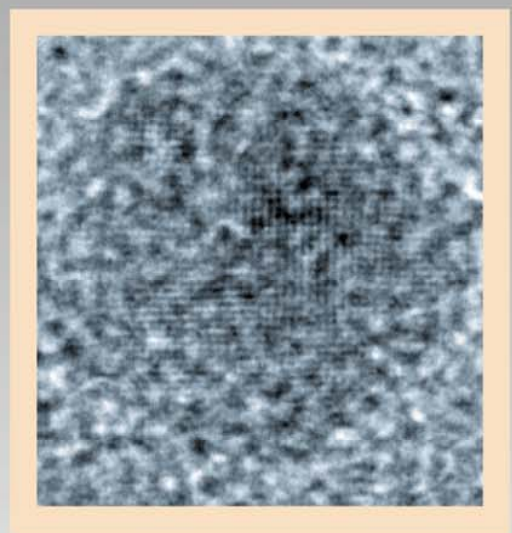


Crystalline Particles



$d_v = 0.295$ nm
$d_h = 0.257$ nm

Conclusions

Oil combustion particles (blue burner under normal burning conditions) are around 10 nm in diameter.

Measurements with a TD indicate mainly volatile particles. However, a small fraction of solid particle cannot be excluded.

Crystalline particles were detected in experiments with the TD using HR-TEM imaging. ***Volatile*** particles were detected in experiments without the TD. Thus, the existence of solid (crystalline) and volatile particles could be confirmed using TEM.

Outlook

Questions such as nature (structure, crystallography) of the particles, influence of additives on the primary particles were often answered, based on indirect evidence and thus remained sort of speculative. These questions can now be addressed again the answers can be verified.

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