Characterisation of different soot types regarding morphology and black carbon content

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Soot particles are besides mineral dust the major absorbing atmospheric aerosols and model calculations suggest that black carbon (BC) may be the second strongest contributor to global warming (Jacobson, 2001). Furthermore, adverse health effects are attributed to fine aerosol particles which are dominated by soot particles especially in urban areas (Laden et al. 2000). During their atmospheric lifetime of several days soot particles undergo changes in their morphology, hygroscopicity, and optical properties with profound implications for their potential impact on human health and climate forcing (Zhang et al., 2008). To determine the relevant soot concentrations and properties in the atmosphere soot characterisation techniques like the single particle soot photometer (SP2) gain increasing importance (Laborde et al., 2012). The aim of this work is a characterisation of soot particles of different composition with different measurement techniques to quantify their measurement capabilities.

Therefore we studied the dynamic behaviour of soot from a propane burner (mini CAST) and a spark generator (GfG, Palas) in a 3.7 m^3 steel vessel for time periods of typically 8 hours. Size distributions were measured with differential mobility analysers (SMPS, TSI, 3071 & 3080) in the size range between 14 and 820 nm. On the basis of the measured initial particle size distribution and particle number concentration (CPC, TSI, 3025, 3022) model calculations were done using the aerosol model COSIMA (Naumann, 2003), a computer program simulating the dynamics of fractal aerosols (Wentzel et al., 2003). The soot particles were characterised regarding their single particle mass with an aerosol particle mass analyser (APM 3601, Kanomax) and regarding their black carbon content with a single particle soot photometer (SP2, DMT). Both instruments were operated in tandem with a differential mobility analyser (DMA, TSI 3080). Furthermore, filter samples of the soot particles were analysed with an environmental scanning electron microscop (ESEM) on their morphology and by thermal treatment (VDI 2565-2) on their elemental and organic carbon content.

Figure 1 shows the evolution of the effective density of propane burner soot particles for different mobility sizes over 8 hours. The particle number decreased in this time from $1.6 \cdot 10^5$ cm^{-3} to $1.7 \cdot 10^4$ cm^{-3}. The monomers of the soot aggregates had a mean size of (32±7) nm and an organic carbon content of (4±3) %. The gas mixture burned in the mini CAST burner had a carbon to oxygen atom ratio of 0.29, hence close to the stoichiometric ratio for burning propane. The fractal dimension (D_f) of the soot aggregates was estimated to D_f = (1.99±0.1) from the experimental data which agrees with the value D_f = (1.90±0.1) determined by comparison of the aerosol dynamic model with the measured particle mass concentration, size, and number evolution within the experimental error. The particle mass concentrations determined by the APM show average deviations of less than 3% with the BC concentrations measured by the SP2 instrument for particle sizes of 200 nm and larger. For particle sizes between 140-90 nm these deviations increase to 20-35%.

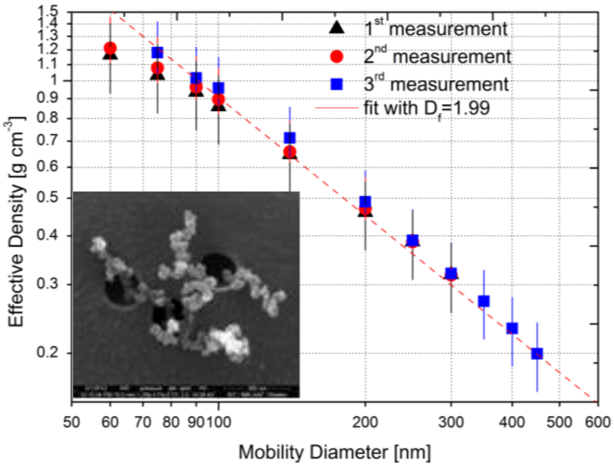

Figure 1 shows the dependence of the effective density of propane burner (CAST) soot on the particle mobility diameter for three subsequent measurements over a time period of 8 hours in a dynamically evolving soot aerosol. A typical soot aggregate is shown as an ESEM micrograph.

This paper discusses the characteristic properties of propane burner soot with organic carbon fractions between 4 and 60 % and compares the results of the APM-DMA analysis with the results of the SP2 measurements and the model calculations.

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