Synthesis and dynamics of carbonaceous nanoparticles during enclosed spray combustion

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Aviation is a growing source of carbonaceous nanoparticle pollution, also referred to as soot, which is unique due to the particularly small size of the particles and the emission of particles at high altitudes. Currently, there are no commercially available soot generators on the market which can produce aircraft-like particles in the laboratory which limits our ability to calibrate instruments meant to measure aviation emissions [1], conduct research on the health impacts of such small soot particles, and to understand their roll in contrail formation. Here, enclosed spray combustion (ESC) is developed as a method for the synthesis of aircraft like particles, filling this gap in the market. ESC particles with median mobility diameters, d_m, between 15 and 180 nm were produced covering the range in which aircraft emissions typically fall while still matching the organic carbon to total carbon ratio observed in soot from aircraft at high thrust [2]. This system was then used to elucidate the dynamics of soot during ESC [3] comparing in-flame measurements to discrete element modelling simulations. This showed that the primary particles of soot reached their final diameter very early on in the flame and then particles grew primarily through agglomeration. Finally, the trade-offs between soot elimination through oxidation and emissions of nitrogen oxides (NOx) were investigated [4] using a strategy similar to the rich-quench-lean (RQL) jet engine design. At lower heights above the burner, injecting oxygen (quenching) resulted in a larger reduction in soot emissions but simultaneously more NOx emissions. Inversely, late injection of oxygen resulted in the lowest NOx emissions but the highest soot emissions. In this way, ESC is demonstrated as a versatile method for generating aircraft-like soot in the laboratory both for calibration purposes and fundamental research on soot.

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