Structural and chemical study of collected aircraft soot and generated surrogates

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Particulate emissions from jet aircraft are the most significant source of carbonaceous particles in the upper troposphere and the lower stratosphere. They also contribute to black carbon pollution in urban areas close to airports. With the continued growth of air traffic (5%/year), these particles are anticipated to increase their impacts (Masiol 2014). In the troposphere, they interact with sunlight (absorption, scattering) and act as ice condensation nuclei, increasing the cloudiness (contrails, artificial cirrus), both effects influencing the radiative balance of the atmosphere in a way that is not well fully known at present. Determining their physical structure, chemistry and their optical properties is necessary to gain a better knowledge of their toxicity, and their condensation ability with respect to water, to finally allow a better assessment of their impact on human health and climate.

In this context, the "MERMOSE" project aims at determining physical and chemical characteristics of carbonaceous particles emitted from a Snecma/NPO-Saturn SaM146-1S17 turbofan engine (certified in 2010) fueled with Jet-A1. Particles have been collected during a sampling campaign carried out on the SNECMA test bench facility at Villaroche, France. This project also aims at generating laboratory surrogates that have physical and chemical characteristics similar to those of aeronautical soot, in order to overcome the soot sampling difficulties at the exhaust of a jet engine, and the small quantities of material collected. These surrogates are synthetized by a propane diffusion combustion device (Jing AG; MiniCAST 5201 C-type model) using different flow rates (propane, air, nitrogen, dilution air), which allows the generation of soot having various morphological and chemical properties.

We present here results combining High-Resolution Transmission Electron Microscopy (HRTEM), X-Ray Photoelectron Spectroscopy (XPS) and Near-Edge X-ray Absorption Fine Structure (NEXAFS) in order to determine physical and chemical properties of aircraft soot and their surrogates. Thus the particles shape, size distribution, texture, structure, chemical composition and chemical speciation of carbon and oxygen of aircraft engine soot are presented for different thrust regimes (take-off, climb out, cruise, and final approach) (Parent 2016) and then compared to those of surrogate soots emitted from the MiniCAST device running at different set points. We show for the first time the existence of structural and chemical differences between the outermost part and the inner part of soot primary particles. Furthermore, our set of experimental results combining HRTEM, XPS and NEXAFS allows us to propose an atomic representation of the soot surface (Fig. 1), a key step toward a better understanding of the physical and chemical properties of soot aerosols in the atmosphere.

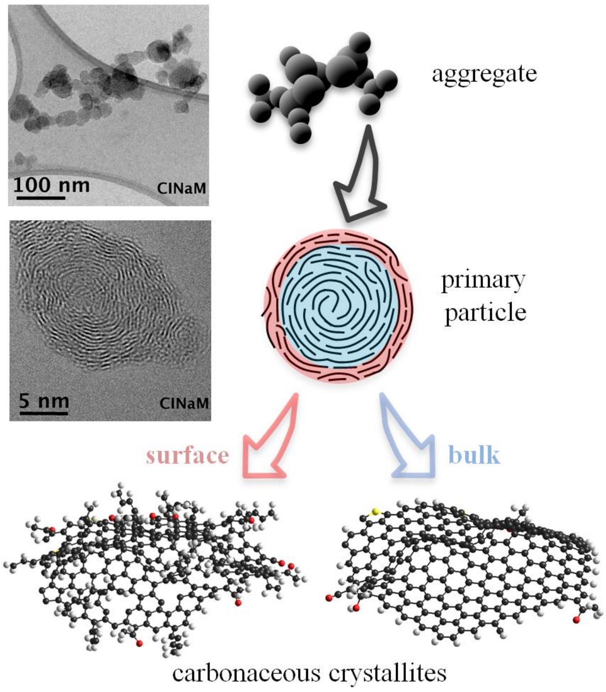

Figure 1. Multiscale structure of aircraft soot

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