Characterization of airplane soot surrogates using Raman spectroscopy

R. Ikhenazene[1], C. Pirim[1], Y. Carpentier[1], C.Focsa[1], B.Chazallon[1], F.X. Ouf[2], I.K. Ortega[3]

[1]Laboratoire de Physique des lasers, Atomes et Molécules (PhLAM) Université Lille 1, UMR 8523 CNRS, 59655 Villeneuve d'Ascq, France

[2]Institut de radioprotection et de Sûreté nucléaire (IRSN), Gif-sur-Yvette, 91192, France

[3]Onera- The French Aerospace Lab, F-91123 Palaiseau, France

Keywords: soot, combustion aerosol, Raman spectroscopy

Presenting author email: arc.ikhenazene@ed.univ-lille1.fr

In the upper troposphere aircraft engines emit solid particles such as soot. These particles can have a direct or indirect effect on climate that both bear consequences on the atmospheric radiative forcing, cloud formation and their lifetime (Lee et al. 2010). In fact these soot particles might aid the formation of ice crystals, thereby producing a condensation trail in the troposphere. Many studies have been conducted to characterize soot particles as they are involved in several physico-chemical processes in atmosphere (Hoose et al. 2012). A better understanding of these atmospheric processes can be achieved using a non-destructive approach, which consists in investigating the molecular structure of these soot particles.

In this work, we used micro-Raman spectroscopy (at both 514 and 785 nm excitation wavelengths) to characterize soot particles produced by either a kerosene flame or a Combustion Aerosol Standard (CAST) burner supplied with various propane-air mixture ratios producing soot samples with a wide range of organic carbon to total carbon ratios (OC/TC). The analysis of the first-order Raman bands of these soot samples is based on the deconvolution model proposed by Sadezky et al (2005). This fitting approach uses five different bands: G band, corresponding to ideal graphite lattice (E_{2g} symmetry), D_1 band corresponding to a disordered graphite lattice (contribution from the edges, A_{1g} symmetry), D_2 band corresponding to a disordered graphite lattice (contribution from the surface, E_{2g} symmetry), D_3 band corresponding to amorphous carbon, and D_4 band corresponding to disordered graphite lattice (A_{1g} symmetry), polyenes or ionic impurities.

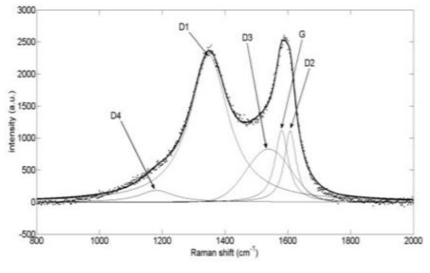

Figure 1. Application of Sadesky's fitting procedure to the Raman spectrum of our airplane soot sample

We investigated the effects of three Raman parameters (laser wavelength, irradiance at sample, and exposure time) on soot samples. From the deconvolution analysis, we have retrieved information relative to soot structure from samples produced with different combustion conditions, showing hereby the relationship between the former and the latter. In addition, these results have been compared to those recently published for soot collected from the exhaust of an airplane engine operating at different regimes (Parent et al. 2016). By comparison, we now have identified the best CAST working point that will produce the closest airplane soot surrogate from a structural point of view.

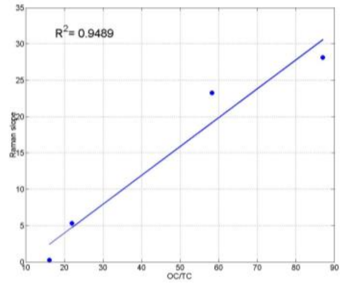

Figure 2. Baseline slope versus OC/TC ratios for studied CAST samples

Though Raman soot bands are not sensitive to surface chemical composition, we found a direct correlation between the amount of organic carbon present at the sample surface and the observed Raman fluorescence continuum that appears as a steep slope baseline in the 800-2000 cm^{-1} region. We found that this slope can be used as a proxy for assessing the organic content in the samples (Fig. 2).

This work was supported by the CORAC MERMOSE project, funded by French Civil Aviation Authority (DGAC) and by the French National Research Agency (ANR) through the PIA Programme d'Investissement d'Avenir) under contract ANR-10-LABX-005 (LABEX CaPPA - Chemical and Physical Properties of the Atmosphere).

Hosse, C., Möhler, O. (2012) *Atmos. Chem. Phys.* **12**, 9817-9854.

Lee, D.S., G. Pitari, V. Grewe, K. Gierens, J.E. Penner, A. Petzold, M.J. Prather, U. Schumann, A. Bais, T. Berntsen, D. Iachetti, L.L. Lim, R. Sausen (2010). *Atmos. Environ.* **44**, 4678-4734.

Parent., P., Laffon, C., Marhaba, I., Ferry, D.,Regier, T.Z., Ortega, I.K.Chazallon, B., Carpentier, Y., Focsa, C. (2016) *Carbon*, **101**, 86-100.

Sadezky, A., Muckenhuber, H., Grothe, H., Niessner, R., Pöschl, U. (2005). *Carbon*, **43**, 1731-1742.