Influence of LII on Soot Optical Properties in Reference Flames

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When analyzing LII emission signals, it is typically assumed that the optical properties of soot are not affected by this rapid heating. However, from the literature it is known that the laser irradiances typical of 'plateau LII' can lead to significant modification of soot particles and even the formation of new particles [1,2]. When more moderate laser fluences are used, morphological changes are not observable via high resolution transmission electron microscopy; however, there is still evidence that the heating permanently influences the optical properties of the soot [3,4]. Variation of soot optical properties during or immediately after laser heating would have impacts on the interpretation of LII signal which should be accounted for in the theory in order to accurately use the emission data.

To study the optical properties of laser heated soot, we have monitored the extinction coefficient of soot aerosols within the standard Gülder and McKenna burners as a function of time while simultaneously heating the aerosol with laser pulses typical of LII. Extinction coefficient measurements were made at wavelengths of 405, 488, 632, and 804 nm and for a range of 1064 nm pulsed laser fluences.

We present a rich database of normalized extinction measurements which give clues into the complex consequences of rapid laser heating of soot aerosols. Normalized extinction coefficients show an enhancement of the propensity of soot to absorb light over the time interval of the laser heating. A partial relaxation of this enhancement is evident on the soot cooling time frame suggesting that the enhancement is in part due to a temperature based phenomena such as particle expansion or temperature dependent optical properties. A sustained residual enhancement is observed in the McKenna soot data, indicative of a permanent change to the soot optical properties, possibly due to graphitization. The variation of the normalized extinction coefficient in the McKenna burner diminishes with decreasing probe wavelength. This relates to the presence of non-soot material which absorbs light in the UV wavelengths, but is not heated by the 1064 nm laser. For the higher soot concentrations of the Gulder burner, heat transfer to the gas phase leads to a gas temperature change and expansion which decreases the attenuation propensity of the medium. The soot is more efficiently heated than the McKenna soot, with sublimation initiated at lower fluences and greater sublimation at a given fluence. This suggests a higher refractive index absorption function, $E(m_{\lambda})$ for the Gulder soot. Normalized extinction coefficient measurements at 405 nm in the Gulder flame at very high fluences demonstrate that the materials vaporized from soot reform into species which are capable of absorbing 405 nm radiation, thus masking the sublimation effect on normalized extinction coefficient.

Both reversible and non-reversible changes to soot's ability to attenuate light have been demonstrated in McKenna and Gulder flame soot. These variations should be further quantified and incorporated into LII emission interpretation theory.

[1] R. L. Vander Wal and M. Y. Choi, Carbon **37**, 231-239 (1999).
[2] H. A. Michelsen, A. V. Tivanski, M. K. Gilles, L. H. van Poppel, M. A. Dansson, and P. R. Buseck, Appl Optics **46**, 959-977 (2007).
[3] R.L. Vander Wal, T.M. Ticich, and a.B. Stephens, Applied Physics B: Lasers and Optics **67**, 115-123 (1998).
[4] S. De Iuliis, F. Cignoli, S. Maffi, and G. Zizak, Appl. Phys. B **104**, 321-330 (2011).