Two-color time-resolved LII study of iron oxide nanoparticle formation in a premixed flat low pressure flame

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Two-color time-resolved laser induced incandecsence is evaluated with respect to metal oxide particle sizing in a low pressure premixed H_2/O_2/Ar flame doped by iron pentacarbonyl. To influence the heat conduction/sublimation ratio the laser fluence and the height above burner are varied to determine the parameters of heat conduction and vaporization. Typically the decays of the LII signal occurred within 250ns. For comparison the iron oxide nanoparticles are characterized in-situ by particle mass spectrometry, elastic scattering, extinction measurements, ex-situ by TEM analysis and dynamic light scattering.

Introduction

The laser induced incandescence (LII) is quite well established for particle sizing of carbonaceous particles, typically of soot from various gas-phase processes [1]. Two-color time-resolved LII (2C-TR-LII) determines as pyrometric method directly the temperature evolution of the particles in the probe volume during the LII, avoiding some uncertainty in modeling the laser absorption. For non carbonaceous particles only very few studies are available. Significantly lower melting and vaporization temperatures, a small data basis of the relevant particle properties like e. g. heat conduction, accommodation coefficients, vaporization enthalpy, complicate the signal evaluation. Furthermore by the lower melting and vaporization points the particles cannot reach as high temperatures as soot particles, which with regard to Planck's law shifts the emitted radiation to the red with much smaller signal amplitudes. Additionally the temperature difference between the laser heated particles and particles within a reacting flow like a flame, becomes smaller, making particle formation and growth studies in a hot environment challenging.

Experimental

The versatile experimental setup with the applied laser diagnostics and the particle mass spectrometer is shown in figure 1:

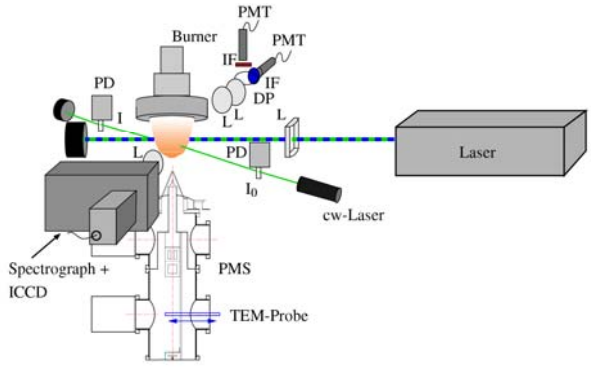

Fig. 1: Experimental setup

The formation and growth of iron oxide nanoparticles within a burner stabilized premixed flat low pressure H_2/O_2/Ar flame doped by iron pentacarbonyl (approx. 2.5 Vol-‰) are studied in situ by 2C-TR-LII, elastic scattering, spectral analysis and extinction measurements as optical diagnostics. As further in situ particle diagnostics particle mass spectrometry [2] is applied. As ex situ methods molecular beam probed TEM samples and in various solvents dispersed powder samples were investigated by dynamic light scattering.

Preliminary results

Although the spectral analysis with the blue sensitive ICCD did not permit the observation of LII broadband emission, the LII signal can be recorded with good S/N ratio by two PMT and interference filters with $\Delta\lambda$(FWHM)=50nm as shown in figure 2.

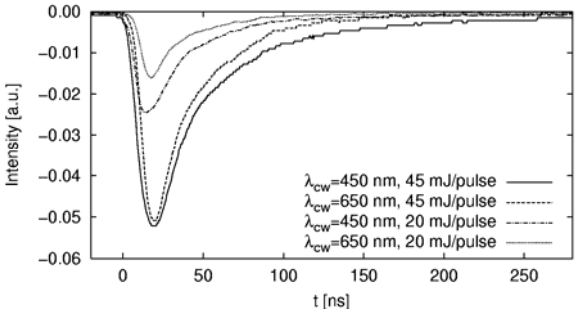

Fig. 2: Variation of laser flux density

The height resolved measurements indicates the applicability of particle sizing by 2C-TR-LII even in the hotter flame zones at lower height above burner values.

The data evaluation is based on modeling LII for various laser fluences to elucidate the first and second moment of a lognormal size distribution.

[1] C. Schulz, B.F. Kock, M. Hofmann, H. Michelsen, S. Will, B. Bougie, R. Suntz, G. Smallwood, Appl. Phys. B 83 (3), 333 (2006).

[2] H. Dörr, R. Suntz, and H. Bockhorn, VDI-Bericht 1839, 185 (2004)

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