TR-LII and PMS particle sizing applied to soot particles synthesized in a low-pressure flame reactor

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Laser-induced incandescence with time-resolved detection (TR-LII) was applied for size measurements of soot nanoparticles in a low-pressure flame reactor. The results are compared with the particle sizes determined by a particle mass spectrometer (PMS).

Soot particles were synthesized in a rich $C_2H_2/O_2/Ar$ premixed flat flame in a low-pressure reactor [1,2]. The same apparatus has been used previously to synthesize nanoparticles from a large range of materials [3]. Fig. 1 schematically shows the main components of the experimental setup.

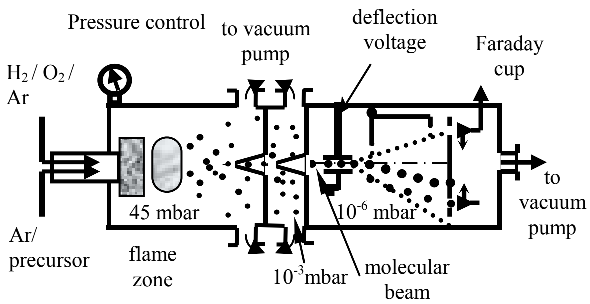

Fig. 1: Premixed flame reactor

The pressure in the reactor was maintained at 45 mbar while the inlet gas velocity was kept constant at 0.87 m/s. High soot concentration caused a bright yellow flame. The soot particle-size distribution was determined with a particle mass spectrometer (PMS) [1,2] attached to the premixed flame reactor. The residence time in the reactor can be changed by moving the burner head relative to the PMS sampling location and the LII probe volume, respectively. Depending on the residence time the mean particle diameter varied between 15 and 18 nm. The geometric standard deviation σ_g was within the range of 1.44 and 1.69. TR-LII experiments were performed simultaneously in the reactor close to the PMS sampling location. The reactor was equipped with three fused silica windows used for the incident and transmitted laser beam and for signal detection. The Nd:YAG laser for particle heating is operated at a wavelength of 1064 nm (Beam diameter: 8 mm) and has a pulse duration of 6 ns. The pulse energy was about 240 mJ for the present experiments. The detection system was arranged perpendicular to the laser beam axis and was composed of a f = 150 mm lens, which collected the particle radiation. A narrow band-pass filter with a center wavelength of 550 nm limits the radiation to a small spectral range. Finally, a collecting lens (f = 50 mm) focuses the beam onto the photo cathode of a high-speed photomultiplier with integrated amplifier (SMT MEA 1030 V8DA with HAMAMATSU R7400U-04, rise time: 0.78 ns). The signal was stored by a digital oscilloscope (TEKTRONIX TDS 3052, 500 MHz) at a sample rate of 5 Gs/s.

Results and discussion

Figure 2 shows a typical individual normalized TR-LII signal reduced for the period of particle cooling measured in the flame reactor and the best obtained fit as a function of time.

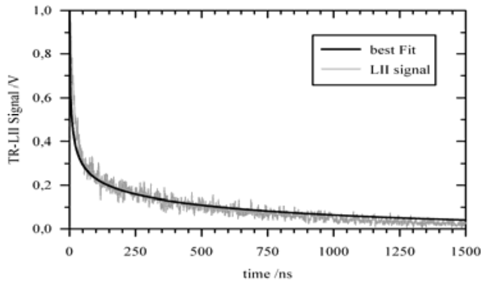

Fig. 2: Measured TR-LII raw signal

The measured signal was evaluated in terms of particle size by fitting a simulated signal curve by least-squares method. The used TR-LII model is presented in [4], while the required thermal accommodation coefficient α_T of the soot particles was assumed to be 0.23 in the present case. For further simplification it was assumed that the particles were heated up to the evaporation temperature of 3900 K. For a lognormal size distribution of the particles best fit conditions were obtained at a count mean diameter (CMD) between 17 and 20 nm and a geometric standard deviation of 1.1. These results are in good agreement with the results of the PMS-measurements. The combination of TR-LII and molecular-beam with subsequent particle-mass spectrometry in low pressure flames is a promising approach for fundamental research on the characteristics of LII of various well characterized nano-particular materials.

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