TIME-RESOLVED TEMPERATURE MEASUREMENTS DURING VARIOUS NONEQUILIBRIUM PROCESSES BEHIND SHOCK WAVES

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The problem of definition of heat balances during nonequilibrium processes such as pyrolysis and condensed particle formation is very actual and not enough investigated. Due to these processes real temperature of shock-heated reaction mixture can be different from "frozen" temperature calculated from shock wave velocity without taking chemical reactions into account. Time-resolved temperature measurements using the methods of emission-absorption spectroscopy allow one to investigate this phenomenon [1].

In this work the generalized line reversal method at wavelengths of 2.7 μm corresponding to $CO_2(1,0,1)$ vibrational band was applied to determine the temperature profiles of an investigated mixture behind shock waves. The main essence of this method is the simultaneous measurements of emission and absorption characteristics of the studied media in the same spectral range, which gives the possibility to interpret experimental results independently on the shape of the spectral lines and apparatus function [2].

Experiments were performed in a stainless steel shock tube with inner diameter 50 mm (Fig.1). In the investigated section of the shock tube alongside with the method of emission-absorption spectroscopy a piezoelectric pressure gauge was mounted and a laser absorption signal at a wavelength of 630 nm was registered. A special construction tungsten tube lamp as a reference "black body source" was used.
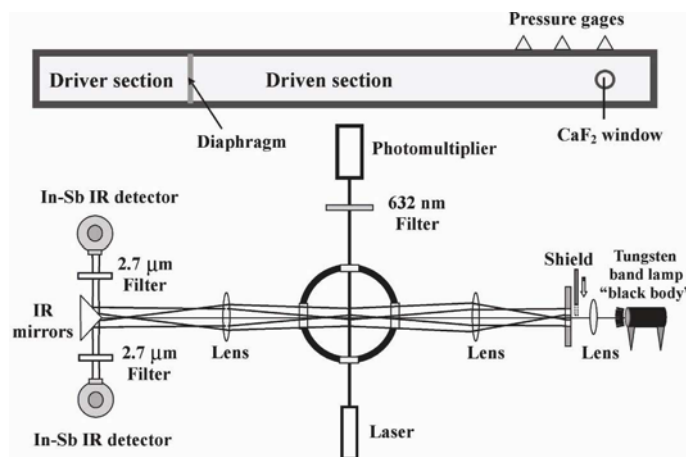

Fig. 1. Scheme of the experimental setup

The experiments were carried out in the mixture (0.5-3%)CCl_4 +5%CO_2 in Ar over the ranges of temperatures 1900-2200K and pressures 25-35 bar. Addition of CO_2 was used for diagnostics and didn't affect the kinetics of studied reactions. The typical signals of absorption, emission and temperature profile are presented in Fig. 2a for experiment in the mixture 1%CCl_4+5%CO_2+Ar at the calculated"frozen" temperature of 2135 K and the pressure 31.5 of bar. One could observe incident and reflected shock waves at the time moments t=0 and t=40 μs, correspondingly, and a subsequent increase of emission and absorption signals. A difference of about 300K between the measured and frozen temperature calculated from the shock wave velocity without taking chemical reactions into account is clearly seen. This effect can be explained by the heat consumption due to CCl_4 dissociation. Following the temperature increase is likely caused by the heat release of condensation and the

particle growth. In Fig. 2b the signals of absorption, emission and temperature profile for experiment in the mixture $0.6\%CCl_4+5\%CO_2+Ar$ at the same frozen temperature and preassure are shown. One can see that the behaviour of signals measured in the mixtures containing 1% and 0.6% CCl_4 are similar. However in the case of 0.6% CCl_4 the temperature fall is less (about 180K) according to the decrease of CCl_4 concentration.
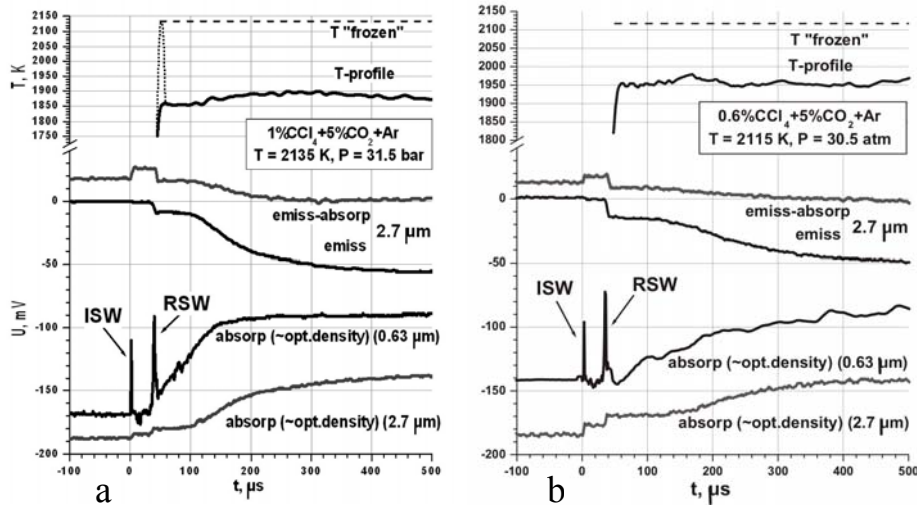

Fig. 2. Time profiles of the temperature and optical density measured in the mixture $1\%CCl_4+5\%CO_2+Ar$ (a) and $1\%CCl_4+5\%CO_2+Ar$ (b)

Similar investigations of heat consumption due to dissociation of carbon and iron containing molecules CH_4, C_2H_2, C_2Cl_4, C_3O_2, $Fe(CO)_5$ and heat release due to condensation and particle growth are under way.

References

[1] Jenkins T.P., Hanson R.K. (2001) Soot pyrometry using modulated absorption/emission. Combustion and Flame J 126:1669-1679.
[2] Gaydon A.G., Hurle I.R. (1963) The shock tube in high-temperature chemical physics. Chapman and Hall Ltd. London.