Flame initiation in C_2H_2-air mixture in the cathode layer of nanosecond SDBD

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In the given work the feasibility of hydrocarbon-air mixture ignition by one nanosecond pulse of the surface dielectric barrier discharge (SDBD) is considered. The goal of work was to define the conditions of a stoichiometric C_2H_2-air mixture ignition and the combustion wave formation before the cathode area is cooled by transferring the heat on the metal electrode and dissipation of it in the unperturbed gas. The range of temperatures (depend on specific deposited energy values) and active species concentrations for the formation of combustion wave have been determined. The important role of gas-dynamics is shown.

1. Introduction and statements

In a number of works the SDBD is suggested to use as an initiator of combustion in an internal combustion engine. The ignition of fuel-air mixture in a single shot regime of SDBD and propagation of combustion wave is demonstrated in experiments [1]. The conclusion about ignition of mixture close to high voltage electrode has been made on the basis of 2D modelling of SDBD and estimations of ignition threshold [1]. However, it's not enough to talk about the formation of combustion wave.

The present work is devoted to the study of inflammability conditions and subsequent formation of combustion wave in C_2H_2-air mixture at P=1 bar and T_0 = 300 K in the near-cathode area of SDBD by one nanosecond pulse. 1D numerical modelling based on the solving of Navie-Stocks equations for the whole mixture, the Poisson equation for the electric field [2] and chemical kinetics [3] was executed. The discharge was considered as a source of active particles and heating of the mixture. The specific power deposited in the cathode layer with the width of Δx=0.01 mm was described as follows:

$$W(t)=E_0\pi/2\tau\cdot\sin(\pi t/2\tau)/\Delta x,$$

where E_0 is an amplitude of deposited energy and τ=40 ns is the pulse duration of discharge. At the end of discharge pulse the concentration of O atoms resulting from dissociation of oxygen by electron impact and quenching of excited N_2 was specified.

2. Results of modelling

The mixture ignition and formation of combustion wave depend on two values: a specific energy deposition per pulse Q and an initial concentration of O atoms. The process of ignition (increasing the gas temperature at t=30-40 μs) and combustion wave formation (widening of temperature profile) is shown in figure. The map of formation/non-formation of combustion wave has been drawn in Q-$[O]_0$ coordinates. Only heating the cathode layer does not bring to inflammation. The presence of O atoms is necessary. To simulate a flame initiation in the discharge systems with a high energy release, the gas-dynamic expansion of hot region and its cooling by heat transfer to the surface of metallic electrode is important to consider. 0-D approach may bring to an inaccurate result.

It was found that combustion is passing through the conversion of fuel to CO and H_2 which burn down later with the production of CO_2 and H_2O. The NO concentration amounts to 0.1-0.2% behind of front of combustion wave.

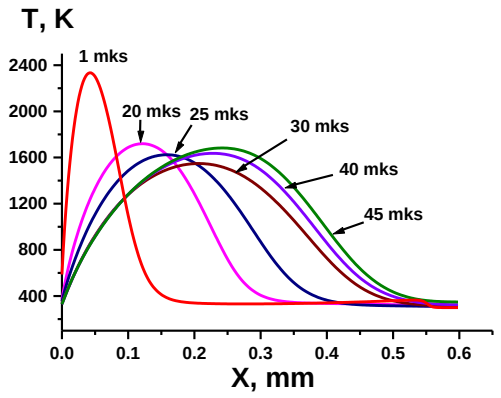

Fig. Formation of combustion wave at Q=5.48 J/cm^3 (1.4 eV/molecule) and $[O]_0$=11.7%.

This work was supported by LIA KaPPA-RFBR Grant No 17-53-16003-a (France- Russia).

3. References

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