**References**

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## ADVANCED COMBINED DISCHARGES IGNITION IN DIFFERENT FUELS

It is well understood that achieving an ignition process that combines energy efficiency and engine emissions reduction in spark-ignition engines is a very complicated problem. The ignition system must function with the engine operating at high pressures, over a wide range of loads, with different turbulent intensities and optimum timing and must provide the reduction of greenhouse gas emissions associated with vehicles. One of the ways to address the above problems is to use combined discharges ignition with different controllable characteristics for enhanced ignition and combustion, when a first short-pulsed laser discharge serves as a source of initial seed electrons and excited particles for the second discharge with a controllable energy input. Main theoretical question here is connected with an ambipolar recombination decay of the laser discharge in different fuels because this process is responsible for the different ignition delay time.

Dynamics of the ambipolar recombination decay in the lean methane-air mixture is shown in Fig. 1 at time t=40 ns. It was obtained that at t=20 ns we still had a quasi-neutral plasma channel but stratification of charge increased with time and since 30 ns a positive column had formed with a pool of negative ions and electrons on the boundary with a neutral medium ( Fig.1).

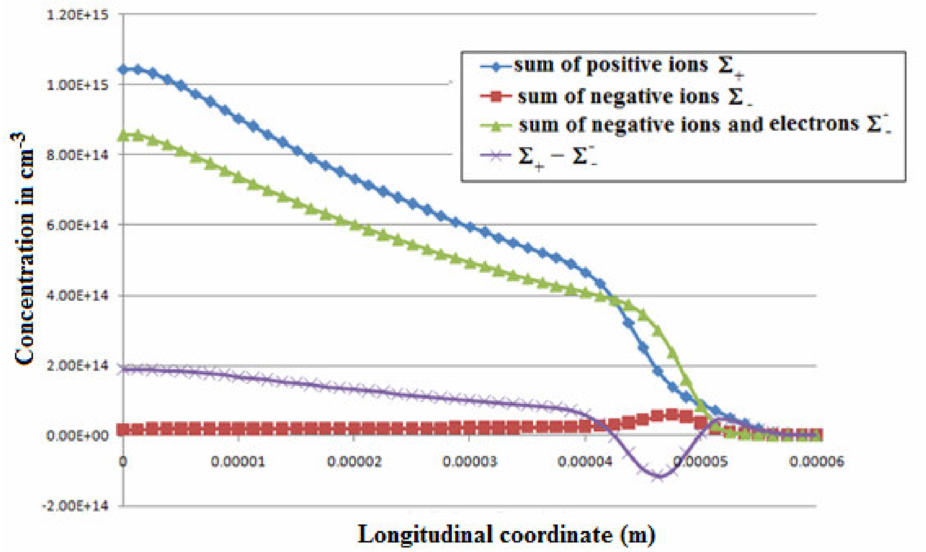


Figure 1 - Charged species distribution across the channel at t=40 ns

Concentration of negative ions is negligible small, but increases with time and these ions are mainly located on the boundary between plasma channel and the neutral medium. According to calculated results not so much difference between ambipolar recombination decay in different fuels. Because of the high reduced electric field values some part of fuel are cracked by the discharge. For example, for the lean ethylene-air mixture ( Φ=0.5) at t=30 ns – 4% of fuel are cracked, at t=60 ns – 8% of fuel are cracked mainly according to reaction

$$C_2H_4 + e^- \rightarrow C_2H_3 + H + e^-$$

The same dependence is observed for the lean methane-air mixture but the main cracking reaction is

$$CH_4 + e^- \rightarrow CH_3 + H + e^-$$

Concentration of formed atoms of hydrogen as well as concentration of $CH_3$ and $C_2H_3$ is maximum on the channel axis. All that leads to the non-uniform distribution of fuel across the channel (Fig.2) with a minimum on the axis (leaner mixture) and maximum on the boundary of the channel with the neutral medium (richer mixture).

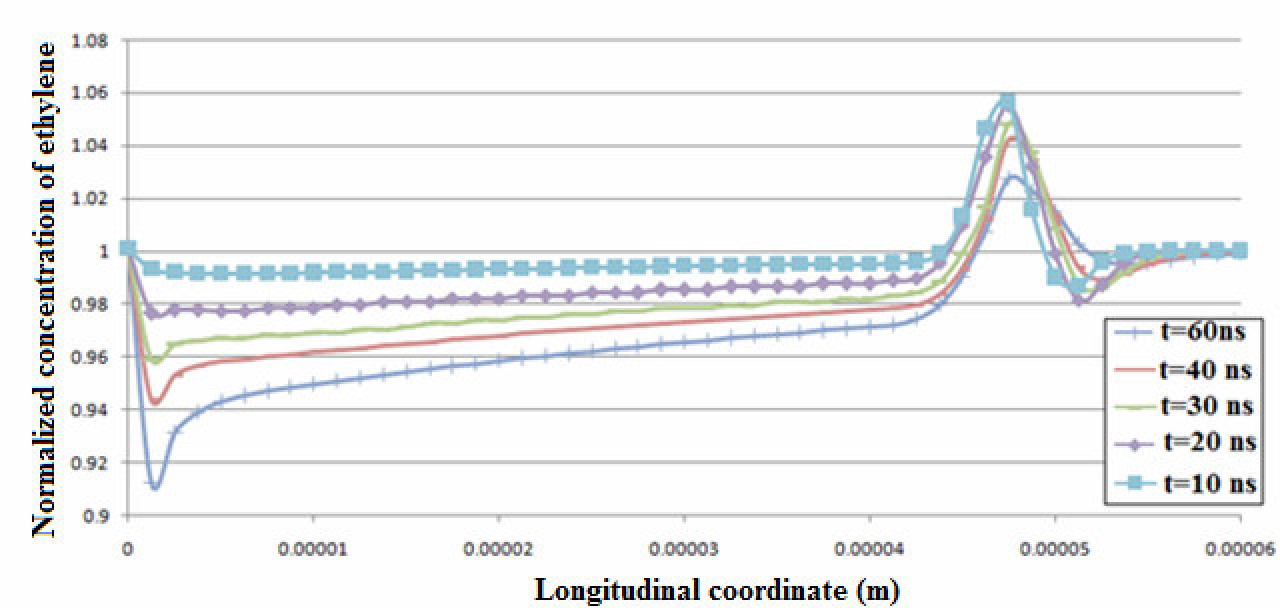


Figure 2 - $C_2H_4$ distribution across the channel for the ethylene-air mixture with $\Phi$=0.5 at different moments

We considered plasma decay started with the maximal initial concentration of electrons in the plasma channel $n_{e0} = 1.25 \cdot 10^{16}\ \mathrm{cm}^{-3}$. According to the calculation results for the lean mixture after 10 ns concentration of electrons is twice lower compared with the initial value, after 20 ns it is in 5 times lower and after 50-60 ns concentration of electrons is lower than 5%. This data forms initial conditions for the second discharge with the controllable energy input depending on the conditions at the ignition point.