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Multiple Pulse Effects on Decomposition of Hydrocarbons for Hydrogen Production

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Hydrogen production on vehicle is under development by using plasma discharges working in high pressure condition (> 1.5 atm). In this system, no production of COx is expected. The original fuel for the system is methane (CH_4) or propane (C_3H_8). For those purposes mainly dielectric barrier discharge (DBD) non-thermal plasma system is employed with high voltage pulse of width 5-30 μs and maximum amplitude 13 kV. The decomposition rate depends on the input pulse width. At present 5~30 μsec width square shaped pulse is tried, but each pulse is decomposed into multiples of fundamental 5 μs pulse, because of machine problem. As a result, up to 20 μs width, the decomposition efficiency increases, but over that values it decreases. The physical phenomena of the pulse width dependence are discussed with use of multiple pulse decomposition model.

We consider the ion density continuity equation with a source term $n_i H(t-\tau_i)e^{-\alpha(t-\tau_i)}$ for i = 0, 1, 2, etc., where the Heaviside function *H(t)* is defined by *H(t)* = 0 for t < 0 and *H(t)* = 1 for $t \geq 0$. The continuity equation is expressed as follows:

$$\begin{aligned}\frac{d}{dt}n_i + \nabla\cdot(n_i v) &= n_0 H(t-\tau_0)(1+\beta_0 e^{-\alpha(t-\tau_0)}) \\ &+ H(t-\tau_1)\{n_1 + \beta_1(n_0+n_1)e^{-\alpha(t-\tau_1)}\} \\ &+ H(t-\tau_2)\{n_2 + \beta_2(n_0+n_1+n_2)e^{-\alpha(t-\tau_2)}\} \\ &+\cdots \\ &\cdots\cdots\cdots \quad (1)\end{aligned}$$

where $\alpha = 1/\tau_d$, τ_d is the plasma decay time of about 10 - 50 μs, β_i is the ionization rate of hydrogen molecules, n_i is the hydrogen density determined by the plasma source, and thus $n_0, n_1, n_2 \cdots$ due to production rate of H_2 after decomposition from a hydrocarbon, and τ_n corresponds to the birth time of hydrogen. Here, we can assume that the produced H_2 molecule density is almost constant during the pulse decay time, but a small amount of which, β_i %, may be ionized by accelerated electrons to higher energies. The ionized hydrogen atom H_2^+ will decay into neutral H_2 after some decay time, say, about 10~50 μs. Through these process, however, total amount of H_2 molecules does not change. In other words, each pulse decomposes hydrocarbon to make H_2 molecules, but once H_2 molecules are produced, the total number of which is kept constant even if some of H_2 was ionized.

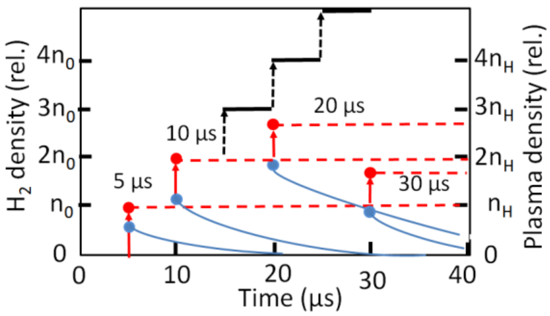

Fig. 1. The dependence of decomposition rate on pulse width calculated with using Eq.(1) at different pulse width .Black solid lines correspond to expected production amount of H_2.

Reference

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