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Plasma-Assisted Flame Ignition and Stabilization using Nanosecond Repetitively Pulsed Discharges[1]

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Ever more stringent environmental regulations are providing impetus for reducing pollutant emissions, in particular nitric oxides and soot, in internal combustion and aircraft engines. Lean or diluted combustible mixtures are of particular interest because they burn at lower flame temperatures than stoichiometric mixtures and thus produce lesser amounts of thermal nitric oxides. Over the past decade, high voltage nanosecond pulsed discharges have been demonstrated as energy efficient way to ignite such mixtures. However, the practical application of these discharges for ignition purposes is limited by the very high electric fields required, especially in high pressure combustion chambers. Moreover, stabilization requires a steady-state addition of energy that cannot be achieved with single or low repetition frequency pulses. In the present work, we investigate the applicability and effectiveness of high voltage nanosecond discharges with high pulse repetition frequencies, typically up to 100 kHz. The high repetition frequencies are chosen to exceed the recombination rate of chemically active species. In this way, the concentration of active species can build up between consecutive pulses, thus yielding significantly higher concentrations than with low frequency pulses. These discharges are investigated for two applications, the ignition of diluted air/propane mixtures at pressures up to several bars in a constant volume chamber, and the stabilization of atmospheric pressure lean premixed air/propane flames. Time-resolved electric and spectroscopic measurements are presented to analyze the discharge regimes, the energy deposition, the gas temperature evolution, the electron number density, and the production of excited species. The results show that nanosecond repetitive pulses produce ultrafast gas heating and atomic oxygen generation, both on nanosecond time scales, via excitation of molecular nitrogen followed by dissociative quenching of molecular oxygen. These effects result in a significant reduction of the lower flammability limit and in the subsequent extension of the domain of flame stability, for a power consumption typically less than 1% of the heat released by the flame.

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