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Nanosecond Pulse Discharges and Fast Ionization Wave Discharges: Fundamental Kinetic Processes and Applications

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Over the last two decades, nanosecond pulse discharges and Fast Ionization Wave (FIW) discharges have been studied extensively, both theoretically and experimentally. Current interest in characterization of these discharges is driven mainly by their potential for applications such as plasma chemical fuel reforming, plasma-assisted combustion, high-speed flow control, pumping of electric discharge excited lasers, and generation of high-energy electrons. A unique capability of FIW discharges to generate significant ionization and high concentrations of excited species at high pressures and over large distances, before ionization instabilities have time to develop, is very attractive for these applications. Recent advances in laser optical diagnostics offer an opportunity of making non-intrusive, spatially and time-resolved measurements of electron density and electric field distributions in high-speed ionization wave discharges, on nanosecond time scale. Insight into FIW formation and propagation dynamics also requires development of predictive kinetic models, and their experimental validation. Although numerical kinetic models may incorporate detailed kinetics of charged and neutral species in the propagating ionization wave front (including non-local electron kinetics), analytic models are also attractive due to their capability of elucidating fundamental trends of discharge development. The talk gives an overview of recent progress in experimental characterization and kinetic modeling of nanosecond pulse and fast ionization wave discharges in nitrogen and air over a wide range of pulse repetition rates, 0.1-40 kHz. FIW discharge plasmas sustained at high pulse repetition rates are diffuse and volume filling, with most of the power coupled to the plasma behind the wave, at E/N=200-300 Td and energy loading of 1-2 meV/molecule/pulse. The results demonstrate significant potential of large volume, diffuse, high pulse repetition rate FIW discharges for novel plasma chemical applications.