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**Laser Diagnostics for Nanosecond Pulse and Hybrid Plasmas: Electrical and Chemical Properties**

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Applications of nonequilibrium plasmas to chemical syntheses, such as plasma-assisted combustion, fuel reforming, and catalysis require efficient generation of excited species and radicals. Self-sustained electric discharges allow only a limited degree of control over the reduced electric field (E/N) and therefore the range of species generated in the plasma. The use of "hybrid" electric discharges, sustained by two independent voltage waveforms, helps circumvent this constraint. Hybrid plasmas are sustained by a combination of two overlapping discharges, (i) high peak voltage, high repetition rate, ns pulse discharge producing electron impact ionization, and (ii) sub-breakdown quasi-steady-state (DC or RF) discharge, which does not generate ionization by itself but couples additional energy to the pre-ionized flow. This approach improves the discharge stability, while generation of desired excited species and radicals is optimized by combining a high peak E/N ns pulse waveform with a "tailored" E/N value in the quasi-steady-state discharge. In the present work, the plasma is sustained by a ns pulse discharge train combined with a capacitively coupled RF voltage waveform, which enables selective generation of vibrationally and electronically excited molecules. The advantages of this method include the use of a single pair of electrodes external to the plasma chemical reactor, which provides better stability at high pressures and input powers, since the RF discharge remains non-self-sustained in the entire gap. Electrical and chemical properties of the plasma, such as the electric field distribution, gas temperature, vibrational level populations of diatomic molecules, and number densities of excited metastable electronic states are measured using laser diagnostic techniques such as Electric Field Induced Second Harmonic (EFISH) generation, Coherent Anti-Stokes Raman Scattering (CARS), Cavity Ring Down Spectroscopy (CRDS), and Tunable Diode Laser Absorption Spectroscopy (TDLAS). These data provide detailed insight into kinetics of ionization, vibrational relaxation, quenching of excited electronic states, molecular dissociation, and plasma chemical reactions.