Kinetics of nanosecond discharges at high specific energy release

Svetlana Starikovskaia

Laboratory of Plasma Physics (CNRS, Ecole Polytechnique, Sorbonne Universities, University of Pierre and Marie Curie-Paris 6, University Paris-Sud, Observatoire de Paris), Ecole Polytechnique, route de Saclay, 91128 Palaiseau, France

Recent progress in solid-state high power electronics was a reason for increased, during last decades, interest to nanosecond discharges: modern companies suggest compact and reliable high voltage nanosecond generators allowing operation both in laboratories and in the extreme conditions of industrial applications. High-voltage pulses 5-10 kV in amplitude and a few tens of nanoseconds in duration are capable to produce highly nonequilibrium low temperature plasma in a wide pressure range, from 0.1 Torr to 15 bar. High electric fields, up to kTd, are typical for discharge front, a few nanoseconds in duration. Behind the front the electric field stays high, hundreds of Td, providing high densities of electronically excited states, high dissociation degree and so high efficiency of nanosecond discharge as a trigger for various chemically active systems. The fact that nanosecond discharges are uniform at low and moderate gas densities, and are naturally synchronized within 0.1 ns in time in the case of a multi-streamer configuration at high gas densities, is extremely attractive for laboratory-scale research. Concentration, in space and time, of energy transmitted from external electrical circuit to gas, causes significant influence on parameters of resulting plasma. At specific deposited energies 0.5-1 eV/molecule high rate of energy relaxation from electronically excited molecules or so-called fast gas heating provides increase of gas temperature for thousands of K during tens of nanoseconds; excitation degree becomes so high that the collisions of excited species with charged, other excited and dissociated species become important, changing "classical" low temperature plasma kinetics developed in the assumption of a small chemical perturbation of the system. A review of plasma parameters in nanosecond discharges, from fast ionization waves (FIWs) at low pressure to filamentary nanosecond surface dielectric barrier discharges (nSDBDs) at tens of bars will be given. Possible modifications of discharge leading to high energy release will be discussed. Consequences of developed chemistry of excited species for plasma diagnostics and necessary precautions when treating the data will be presented. Potentials of nanosecond plasmas for applications will be briefly reviewed.