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Ultra-short, repetitively pulsed atmospheric-pressure microplasmas

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Low-temperature atmospheric-pressure plasmas are of great importance in many emerging biomedical and materials processing applications; in recent years there has been a growing interest in short-pulsed excitation of such plasmas as a gateway to access highly non-equilibrium discharge chemistry. This contribution employs time-resolved electrical and optical diagnostics in combination with a time-hybrid computational model to uncover the physics behind repetitive short pulsed excitation of atmospheric pressure plasma. It is shown that during the applied voltage pulse the peak dissipated power can exceed $1\text{GW}/\text{cm}^3$ resulting in electron densities approaching 10^{17} cm^{-3} (~6 orders of magnitude larger than conventional low-temperature atmospheric discharges) while the gas temperature remains close to room temperature.

Using discharges ignited in neon, helium and argon the temporal evolution of excited species in a nanosecond pulsed microplasma are examined experimentally. Over the applied voltage pulse the emission intensity of all excited states grow rapidly. After the applied voltage pulse, electrons rapidly cool below the excitation threshold suggesting emission from excited neutrals should also diminish rapidly. However, in all gases it is clear that emissions are observed for several microseconds after each applied pulse, far in excess of their radiative lifetimes. In addition, line ratio measurements indicate considerable reheating in discharges ignited in neon and helium; potential reheating mechanisms are explored.

Finally, the influence of pulse width on the discharge chemistry is considered. It is observed that as pulse duration is decreased from several hundred nanoseconds to less than ten nanoseconds the discharge chemistry changes considerably. This finding suggests that pulse width may be a route to tailor the discharge chemistry to suit a given application; a finding that could have far reaching consequences.