Nanosecond repetitively pulsed microplasmas and perspectives on the synthesis of carbon nanomaterials

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Both nanosecond repetitively pulsed (NRP) plasmas and microplasmas have been studied for applications in nanoscience. The non-equilibrium chemistry of microplasmas has been exploited for the synthesis of nanomaterials, including graphene, nanodiamonds, and carbon nanotubes [1]. Promising work has also begun on the use of NRP plasmas for synthesis [2]. Particularly high mean electron energies can be achieved either by temporal control of the applied field in the case of NRP plasmas, or by spatial confinement in the case of microplasmas. By combining the above discharges into NRP microplasmas, it is possible to reach electron number densities in noble gas mixtures exceeding those observed by either type alone [3, 4]. If the pulse repetition period is made shorter than the recombination time, then chemical species can accumulate up to high steady-state densities. Also, the high surface-to-volume ratio can be exploited to enhance surface processes and increase energy exchange with surfaces.

The present work concerns NRP microplasmas generated in air at atmospheric pressure and their effects on flows and surfaces. Using particle image velocimetry and Schlieren imaging to characterize the flow, we observe the generation of an electro-thermal plume when a DC electric field is applied to a metal plate placed near the microplasma. The character of the flow is both thermal and electrohydrodynamic, and the relative importance of each property can be adjusted. To study surface interactions, we focus on the case of NRP microplasmas and surface discharges generated at metal-silicon-air triple junctions. The plasma-silicon interface provides a wide range of current transport mechanisms [5] due to a different energy band structure from plasma-dielectric interfaces [6]. This enables the triple junction discharge to achieve a wider dynamic range of current density than is possible with other nanosecond discharges generated with [7] or without dielectric barriers [8, 9]. The discharge regime and structure can be modified by changing Si doping levels and adding Al_2O_3 thin film. In-situ Raman spectroscopy points toward transient surface changes induced by plasma activity, but only when the thin film is present.

Finally, we will discuss perspectives on the potential use of NRP microplasmas for the synthesis of carbon nanomaterials.

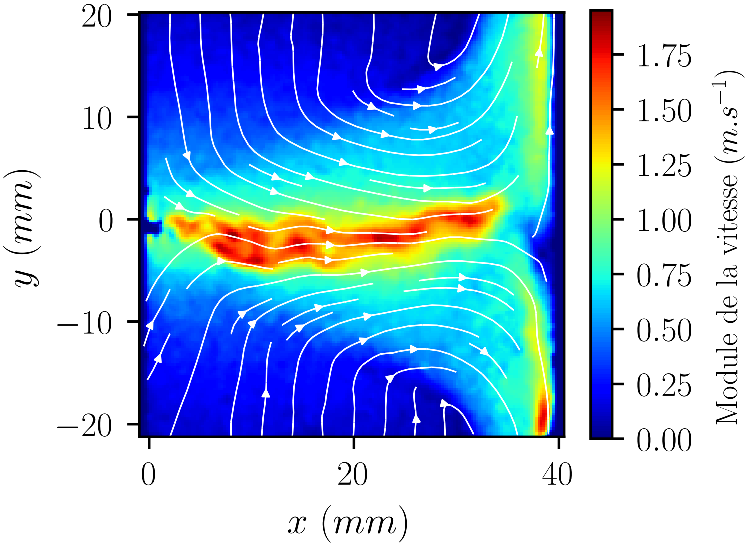

Figure 1: Velocity field (color map) and flow streamlines (white lines) of the electro-thermal plume generated by a NRP microplasma placed at *x* = 0 mm, with a metal plate placed at *x* = 40 mm that is biased to a negative DC potential.

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