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High-electron-density microplasmas generated inside capillaries

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The miniature of the plasma jets is very much desired for root canal treatment, single-cell-precision cancer treatment, micro-patterning functionalized surface, and inner tube surface modification [1, 2]. An effective and simple approach to realize microplasma jets is the reduction of the tube diameter. However, the plasma properties may be changed as the tube diameter decreases.

In this work, non-thermal high-aspect-ratio atmospheric-pressure Ar microplasmas are generated inside capillaries of inner diameter 4-100 μm. First, with the assistant of the air DBD, the ignition voltage of the microplasma plume inside a capillary is significantly reduced. Second, as the tube diameter decreases from 100 μm to 9 μm, the current density increases from 2.5×10^7 A/m^2 to 3.5×10^9 A/m^2, and the electron density measured from the Stark broadening of H_α line increases from 2×10^{16} cm^{-3} to 11×10^{16} cm^{-3}. The electron density measurement is further confirmed by the electron density calculation of the current-velocity method. Therefore, The electron density of the microplasmas is 2-4 orders of magnitude greater than that of the regular plasma jets. The high degree of ionization is related to the increase of the electric field in the ionization front. In addition, ICCD images show that the propagation of the microplasma plume is a continuous plasma column, instead of the well-known discrete "plasma bullets". This study gives insights of the effects of the tube diameter on the ignition and the plasma properties of the microplasmas confined inside capillaries, which may be useful in plasma medicine, UV radiation sources, and the inner surface modification of microtubes.

References

[1] Ye D, Wu S, Yu Y, et al., *Applied Physics Letters*, 2014,104(10310510).
[2] Wu, Shuqun, Wu Fei, et al., *Plasma Processes and Polymers,* 16.3 (2019): 1800176.

Figure 1. The electron density and the current density of the microplasmas as a function of inner diameter of the capillary.