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Tailoring reactive species production in atmospheric pressure plasmas: measurement & simulation

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Atmospheric pressure plasmas are versatile and efficient sources for reactive species at ambient room temperature. The non-equilibrium chemical kinetics is initiated and determined by the electron dynamics. Due to the strongly collisional environment and associated short electron energy relaxation times the electron dynamics can be tailored using multi-frequency power coupling techniques, enabling separate control of key parameters like electron density and electron mean energy. Details of the chemical kinetics depend on the feed-gas composition and desired application. Measurements and predictive simulations of key reactive species are equally challenging due to the strongly collisional environment and their multi-scale nature in space and time. The most promising approach is the exploitation of complementary advantages in direct measurements combined with specifically designed numerical simulations. The employed diagnostic techniques include picosecond laser spectroscopy (O, N, H, CO measurements), synchrotron VUV spectroscopy (O, N measurements), UV & IR absorption spectroscopy (OH, O_3, CO_2, CO measurements) and nanosecond optical imaging spectroscopy (electron dynamics). Picosecond two-photon absorption laser induced fluorescence (TALIF) spectroscopy allows us to measure absolute densities of atomic oxygen (O), nitrogen (N) and hydrogen (H), even in chemical environments with complex reaction kinetics and associated collisional quenching processes, through directly resolving the effective lifetime with sub-nanosecond resolution. This is particularly important in realistic situations for technological applications with plasma operation and species penetration into ambient air. The picosecond TALIF measurements are compared with direct VUV synchrotron absorption spectroscopy under well-defined gas compositions showing very good agreement. Further insight into the chemical kinetics is obtained through additional UV & IR absorption spectroscopy (OH, O_3, CO_2, CO) measurements and synergistic combination with multi-scale numerical simulations of the chemical kinetics. The presentation will focus on examples of He-O_2-N_2-H_20 mixtures for bio-medical applications and He/Ar-CO_2 mixtures for CO_2 conversion into value-added chemicals.

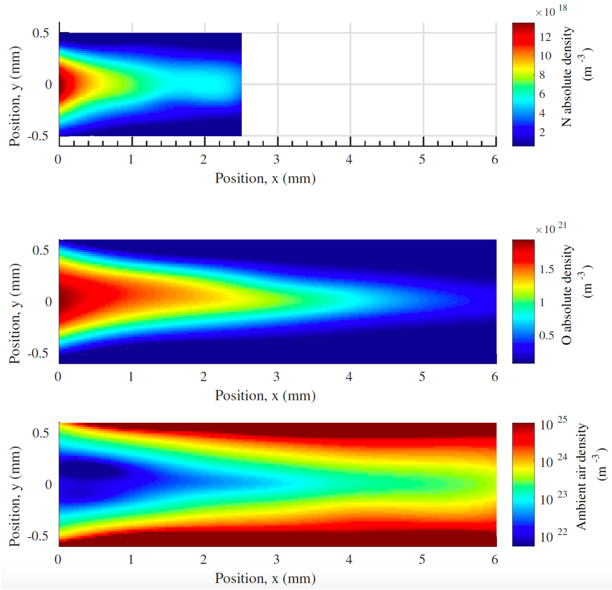

Figure 1: Spatially resolved ps-TALIF measurements on a radio-frequency driven atmospheric pressure plasma jet operated in helium with a 0.4% synthetic air admixture (N_2:O_2 ratio of 4:1). The plasma was operated in a COST reference jet [1] for an applied rf power of 5 W (700 V_{pp}). The measurements show the plasma plume diffusing into ambient air representing atomic nitrogen and atomic oxygen densities [a) & b)] and the ambient air density [c)] calculated from the measured lifetime of the laser-excited state of atomic oxygen.

References

[1] Concepts and characteristics of the 'COST Reference Microplasma Jet'
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