

Atmospheric pressure plasmas as sources of reactive oxygen and hydrogen species for biomedical applications

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Cold atmospheric pressure plasmas (APPs) are known sources of reactive oxygen, nitrogen and hydrogen species^(1,2), and therefore offer a great potential to be used for biomedical applications, where these species play an important role. The electrons and heavy particles in these plasmas are not in a thermal equilibrium, allowing for high electron temperatures (around a few eV), leading to the very active chemistries necessary for the production of reactive species. The gas temperature stays around room temperature, which is favourable for the treatment of biological samples. However, in order for APPs to achieve widespread usage in therapeutics, controlled production of the species of interest is essential. At atmospheric pressure, diagnostics on these reactive species are challenging, due to short particle lifetimes and significant spatial inhomogeneity, especially in the plasma effluent region, which is usually where the interaction with biological samples takes place. Additionally, impurities in the plasma source coming from ambient air can significantly change the plasma chemistry.

In this work we investigate a radio-frequency (RF) atmospheric pressure plasma jet (APPJ) running in Helium (He). By introducing different levels of humidity (H₂O), we can significantly change the production of several reactive species such as atomic oxygen (O), atomic hydrogen (H) and hydroxyl radicals (OH). A 0-dimensional chemical kinetics model⁽³⁾ is used in order to investigate the plasma chemistry, giving insight into the plasma kinetics involving 65 species, including electrons, positive and negative ions, and ground state and excited neutral species. We also carry out experimental investigations using picosecond Two-photon Absorption Laser-Induced Fluorescence⁽⁴⁾, vacuum ultra-violet high-resolution Fourier-Transform Absorption Spectroscopy⁽⁵⁾, and ultra-violet Broad-Band Absorption Spectroscopy⁽⁶⁾ to quantify O, H and OH in the plasma and compare with simulation results. We find that H and OH increase non-linearly when the H₂O content of the feed gas is increased. The trend for O is strongly dependent on the concentration of air impurities present in the APPJ.

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References

- (1) M. G. Kong et al., *New J. Phys.* **2009**, 11, 115012.
- (2) D. B. Graves, *J. Phys. D: Appl. Phys.* **2012**, 45, 263001.
- (3) S. D. Stafford et al., *J. Appl. Phys.* **2004**, 96, 2451.
- (4) J. Bredin et al., “Picosecond-TALIF measurements of atomic oxygen in RF driven atmospheric pressure plasma jets”, 67th Gaseous Electronics Conference, Raleigh, NC (Nov 2014)
- (5) K. Niemi et al., *Appl. Phys. Lett.* **2013**, 103, 034102.
- (6) M. Foucher et al., *Plasma Sources Sci. Technol.* **2015**, 24, 042001.