LIF spectroscopy of OH radicals and the electron temperature in the effluent of atmospheric RF JET in Ar-H_2O mixtures

L Li[1], A Nikiforov[(*)1, 2], Q Xiong[1, 3], N Britun[4] , R. Snyder[4] , X Lu[3] and C Leys[1]

[1] *Department of Applied Physics, Research Unit Plasma Technology, Ghent University, Jozef Plateaustraat 22, Ghent B-9000, Belgium*
[2] *Institute of Solution Chemistry of the Russian Academy of Science, Academicheskaya St., 1, Ivanono, 153045, Russia*
[3] *College of Electrical and Electronic Engineering, HuaZhong University of Science and Technology, WuHan, Hubei 430074, China*
[4]*Chimie des Interactions Plasma-Surface (ChIPS), CIRMAP, Universite de Mons, 20 Place du Parc, B-7000 Mons, Belgium*
[(*)]anton.nikiforov@ugent.be

The measurements of the spatial distribution of OH radicals and electon temperature in an atmospheric RF Ar-H_2O plasma jet is carried out by means of laser induce flourescence (LIF) and absolute line intensity (ALI) measurements. Plasma with 0.3% H_2O is characterized by highest LIF signal where, accordingly, the second peak of Te appears around the same water content. The dominant radical production mechanism is dissociation electron-ion recombination in the atmospheric RF plasma jet.

Atmospheric pressure plasma jets (APPJs) characterized by high concentration of radicals and low gas temperatures are suitable for many applications [1,2] particularly for the localized modification of sensitive surface[3] where treatment can be implemented without the requirement of complicated and expensive vacuum systems. The increasing interest in the application of APPJs heightened the need for quantification and mechanistic studies of the plasma species in APPJs. The experiments can be based on several different diagnostic techniques that can be further divided into active and passive spectroscopy. This paper focuses on the LIF measurements of an absolute densities of OH, electron temperature derived from absolute line intensity (ALI) measurements and the effect of H_2O content on the formation process of excited species in the atmospheric radio frequency jet.

A schematic diagram of the system used for laser spectroscopic diagnostics is presented in Fig. 1 a)- b). The capacitively coupled plasma jet with L-matching impedance box was sustained in open air. Discharge was operated in diffuse α-mode at low input power (13.46 MHz, typically 10 W). The image on the right-up corner shows a contiguous, stable and noiseless plasma jet measuring 8 mm long and 2 mm wide. The gas flow through the glass tube is kept constant at 2 SLM with pure argon and a small admixture of water (0%~1%).

A 10 Hz Nd:yttrium aluminum garnet pumped dye laser was used to generate the nanosecond laser pulses at around λ =284 nm for excitation of OH radicals from ground state ($X^2\Pi$, v'=0) to ($A^2\Sigma^2$, v''=1) state with three different transition $P_1(4)$, $P_2(3)$ and $P_2(6)$ in the excited volume. The LIF signal is accumulated by a SR430 photon counter at the frequency of the YAG:Nd laser during 1000 pulses and the space resolved two-dimensional cross section of OH fluorescence was detected by an ICCD camera synchronized with the laser pulse. For the spectroscopic diagnostics, several Argon 4p lines were recorded in the range of 700~780 nm. The optical system is calibrated by replacing the RF jet with a standard tungsten ribbon lamp, operated at an accurately known electric current.

Fig. 1 c) shows the uncalibrated spacial distribution of OH concentration in the x-y-plane with $P_2(3)$ transition while the jet is operated with 0.1%, 0.3% and 0.5% H_2O admixture. The cross-section images are recorded with in the gate time of 300 ns after the accumulation of 50 laser pulses. The highest density was observed in closest distance to the plasma core at position of (0, 0, 1) and steeply decreases within a range of 1mm in the x-y plane. Moreover, even at the distance of 8 mm away from the nozzle, there are still the detectable LIF signal. Futhermore, the discharge with 0.3% H_2O has the strongest LIF signal and the most contracted plasma.

The sum intensity of the measured LIF signal, reduced by the unit laser energy, of OH radicals as a function of the water content is shown in Fig. 2 a). For all excited transitions, the maximum LIF intensity always appears when the admixture of water is around 0.3%. Meanwhile, the conbination of

absolute line intensity (ALI) measurements and a colisional radiative model (CRM) give the electron

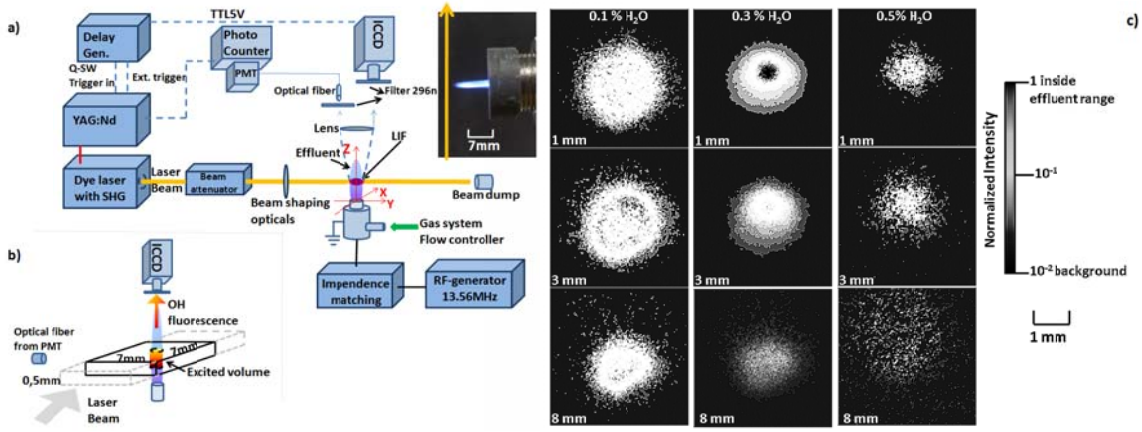

Fig. 1: a) Schematics of the OH radicals LIF diagnostic system of the atmospheric pressure RF-JET. b) Optical arrangement for OH radical cross-section measurements. c) Space variation along Z direction of OH radicals LIF signal of the jet effluent excited on $P_2(3)$ transition with different water content.

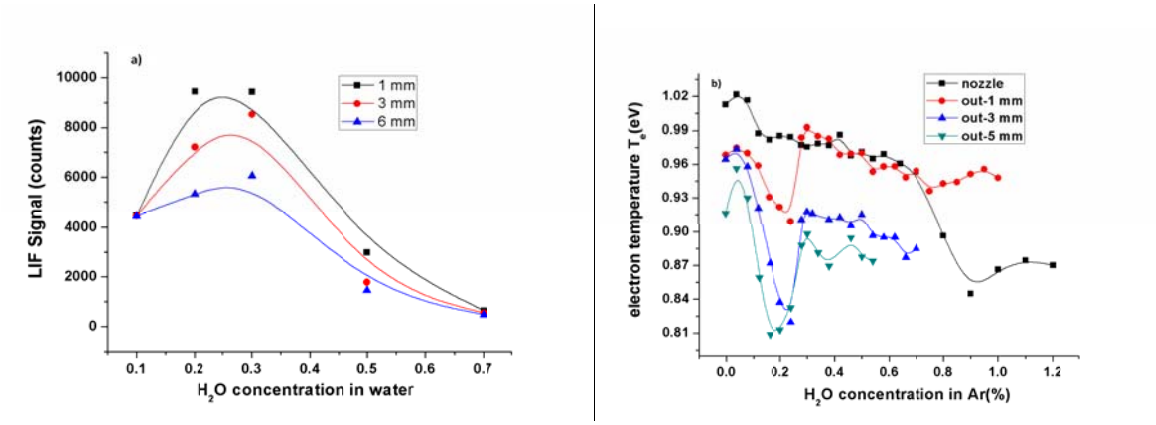

Fig. 2: a)The reduced LIF signal and b) the electron temperature as a function of water conten at different position along Z direction.

temperature of ~1 eV with a margin of 10%. Fig. 2 b) shows the results of T_e as a function of water content. It can be seen that substantial difference of H_2O effect on Te between inside nozzle and in the atmospheric air. Inside the glass tube, a nearly linear decrease of the electron temperature with increasing water is observed. The effect of H_2O content on T_e inside nozzle supports that the discharge was operated in diffuse α-mode. However, out of the nozzle, after the steep decreasing of electron temperature until ~0.2% H_2O, the second peak of Te appears around 0.3% H_2O where the reaction between N_2 from air and metastable Ar should be taken in to account as well. Due to the comparably low gas temperature of 500±50 K in RF plasma jet estimated by optical emission spectroscopy of OH band and according to the relevant reaction rates [4], the dominant radical production mechanism is electron-ion recombination in the atmospheric RF plasma jet and the diminishment of LIF signal above 0.3% water content due to water quench .

The authors thank the financial supports of the China Scholarship Council (CSC) and the Belgian Government through the IAP program (P06/08). N.B. is a postdoc researcher of the FNRS, Belgium

References

[1] X. Lu, Z. Jiang, Q. Xiong, Z. Tang, and Y. Pan, *Appl. Phys. Lett.* **92** (2008) 151504.
[2] A. Shashurin, M. Keidar, S. Bronnikov, R. A. Jurjus, and M. A.Stepp, *Appl. Phys. Lett.* **93** (2008) 181501.
[3] S.Paulussen, R. Rego, O. Goossens, D. Vangeneugden and K.Rose, *J. Phys. D: Appl. Phys.* **38** (2005) 568.
[4] P. Bruggeman and D. C Schram, *Plasma Sources Sci. Technol.* **19** (2010) 045025.