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Quantitative diagnostics of atomic O and O_3 molecules in O_2 mixed non-thermal plasmas

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Atomic oxygen is one of the key reactive species in plasma chemistry and involved plasma treatments. Quantification of atomic O is essential and often accomplished by the method of two-photon absorption laser-induced fluorescence (TALIF) spectroscopy benefiting from its high resolution in time and space. However, photo-dissociation of ozone (O_3), another active molecule formed commonly in O_2-added plasmas, by the same UV laser often disturbs the TALIF measurement through *in situ* additional production of atomic O fragment. This interference of O_3 fragmentation needs to be considered and separated from the plasma produced O atoms in the TALIF measurement. In this work a novel conception benefiting from the photo-fragmentation effect of O_3, is proposed for calibrating the TALIF signal of atomic oxygen in studied media. It is realized by TALIF detection of ground-state $O(2p^4\ ^3P)$ fragment produced by fully photolyzing O_3 by another synchronized 266 nm pulse laser. A robust 1:1 concentration ratio between the $O(2p^4\ ^3P)$ fragment and photolyzed O_3 is achieved, and therefore the known O_3 density, *e.g.* from an ozonizer, can be utilized as a calibration reference for the TALIF signal of unknown-quantity O atoms in gaseous media of interested. This calibration method is straightforward to implement and simpler if same gas conditions are used in calibration source (*e.g.* ozonizer) and diagnosed gaseous media, and no need of noble Xe gas. Furthermore, the O_3 interference is able to be separated from atomic O originated from studied media, and the concentrations of O and O_3 are able to be determined simultaneously. A successful exemplified diagnose by the proposed method is applied to a typical atmospheric-pressure pulsed-driven He/O_2 DBD, where the time behaviours of O and O_3 productions are quantified simultaneously in the post-discharge.

Figure 1 presents the line-to-plate DBD as a diagnostic example by the full photo-fragmentation TALIF approach. TALIF laser and photolytic laser were entering the plastic enclosure against each other through two quartz Brewster windows at both ends. 10% O_2 gas was mixed as the precursor source of atomic O and O_3 in the studied He discharge.

The detected fluorescence signals of atomic O in the post-discharges by the 226 nm TALIF laser alone and the dual lasers, are showed in Figure 2. The O_3 disturbance is significantly evident in the TALIF measurements of the 700 Hz post-discharge, as presented in Figure 2. An apparent deviation of fluorescence signal is observed between measurements by the single 226 nm laser and the dual-laser (266 nm & 226 nm), even at initial moments immediately after the discharge pulse. This is ascribed to the residual O_3 molecules from previous discharges. By the proposed dual-laser TALIF approach, the densities of O and O_3 are able to determined separately by combining a kinetic model of O and O_3 in the pulsed He+10%O_2 post-discharge[1-2].

This adverse interference of O_3 photolysis is inevitable and commonly occurring in TALIF detection of O atoms in O_2-mixed discharges. However, by the help of O_3 full photo-dissociation with another laser beam, this O_3 interference is able to be separated and quantification.

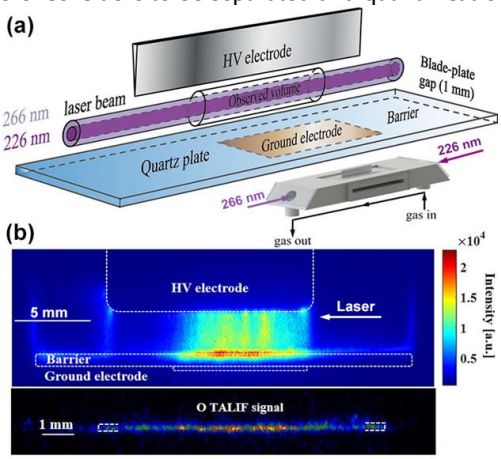

Figure 1 (a)Schematic of the studied line-to-plate DBD. (b) Discharge image, under He+10%O_2 gas condition and 10 Hz pulse frequency.

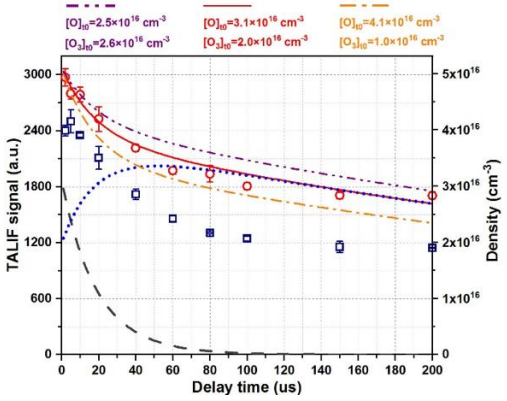

Figure 2 Time behaviors of O and O_3 densities in the post-discharge, under 700 Hz pulse frequencie.

References

[1] Zhan Shu, Junjie Qiao, Chuanqi Wang, Qing Xiong, Simultaneous quantification of atomic oxygen and ozone by full photo-fragmentation two-photon absorption laser-induced fluorescence spectroscopy, *Plasma Sources Science & Technology*, 30, 055001 (2021).

[2] Junjie Qiao, Zhan Shu, Chuanqi Wang, Qing Xiong, O_3 interference on TALIF measurements of atomic oxygen in O_2-mixed non-thermal plasmas: quantification and separation, *Plasma Sources Science & Technology*, *under review* (2021).