Quantitative diagnostics of atomic O and O₃ molecules in O₂ mixed non-thermal plasmas

Junjie Qiao¹, Zhan Shu¹, Chuanqi Wang¹, Qing Xiong¹

¹ State Key Laboratory of Power Transmission Equipment and System Security and New Technology, Chongqing University, Chongqing 400044, PR China

e-mail (speaker):qingxiong@cqu.edu.cn

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 (O₃), another active molecule formed commonly in O₂-added plasmas, by the same UV laser often disturbs the TALIF measurement through in situ additional production of atomic O fragment. This interference of O₃ 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 O₃, is proposed for calibrating the TALIF signal of atomic oxygen in studied media. It is realized by TALIF detection of ground-state O(2p⁢³ ³P) fragment produced by fully photolyzing O₃ by another synchronized 266 nm pulse laser. A robust 1:1 concentration ratio between the O(2p⁢³ ³P) fragment and photolyzed O₃ is achieved, and therefore the known O₃ 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 O₃ interference is able to be separated from atomic O originated from studied media, and the concentrations of O and O₃ are able to be determined simultaneously. A successful exemplified diagnose by the proposed method is applied to a typical atmospheric-pressure pulsed-driven He/O₂ DBD, where the time behaviours of O and O₃ 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% O₂ gas was mixed as the precursor source of atomic O and O₃ 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 O₃ 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 (226 nm & 226 nm), even at initial moments immediately after the discharge pulse. This is ascribed to the residual O₃ molecules from previous discharges. By the proposed dual-laser TALIF approach, the densities of O and O₃ are able to determined separately by combining a kinetic model of O and O₃ in the pulsed He+10%O₂ post-discharge¹².

This adverse interference of O₃ photolysis is inevitable and commonly occurring in TALIF detection of O atoms in O₂-mixed discharges. However, by the help of O₃ full photo-dissociation with another laser beam, this O₃ 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% O₂ gas condition and 10 Hz pulse frequency.

Figure 2 Time behaviors of O and O₃ densities in the post-discharge, under 700 Hz pulse frequency.

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, O₃ interference on TALIF measurements of atomic oxygen in O₂-mixed non-thermal plasmas: quantification and separation, Plasma Sources Science & Technology, under review (2021).