https://doi.org/10.69646/aob241122

Spatio-temporal dynamics of a microsecond pulsed glow discharge

Krstić, I.B.,[1] Obradović, B.M.[1] and Kuraica, M.M.[1]

[1]*University of Belgrade – Faculty of Physics, Belgrade, Serbia*
E-mail: obrat@ff.bg.ac.rs

As a type of pulsed discharges, microsecond pulsed glow discharges (µs-PGD) brought an improvement of the analytical characteristics of the GD sources for several optical and mass spectrometric methods. Advantages of µs-PGD are increasing signal outputs and the temporal resolution of analytical species from concomitant species in the discharge plasma. Another benefit of µs-PGD is that even though instantaneous power is higher, the average power can be significantly lower than in millisecond PGD, resulting in reduced thermal stress of the analyzing sample. The higher instantaneous power of the µs-PGD is closely related to the so-called "pre-peak", a spike in the electrical current and a spike of plasma radiation at the leading edge of the discharge pulse. The radiation pre-peak, together with an increased radiation in afterglow for some spectral lines (after-peak) are responsible for the improvement of the analytical characteristics of the PGD in optical emission spectrometry. Here we present results of measurement of spatio-temporal distributions of several atomic spectral lines of copper in a Grimm-type µs-PGD.

To run discharge, a laboratory made pulsed voltage power supply were used, with capability to ensure up to 300 W per pulse. For a space resolved emission measurements we used optical system contained of quartz lens and 1m-Spectrometer equipped with ICCD camera. Following the suggestion (Alberts et al al, 2010) measurements have done by using the frequency of 5 kHz and the pulse width of 30 µs. 170 µs off-time allows to investigate near afterglow of the discharge.

At the line intensity distribution, three characteristic phases (or the discharge regimes) can be resolved: the pre-peak (0 – 5 µs) caused by fast increase of the applied voltage; steady-state (5 – 30 µs) during it the voltage has a constant value, and the afterglow when the voltage is switched off, see Fig. 1. There are the two space regions, characteristic for the discharge: the CF which border is marked as L, and the NG beyond the CF region.

The distributions of Cu I 510.55 nm (4s – 4p, 1.39 – 3.82 eV) and Cu I 515.32 nm (4p – 4d, 3.79 – 6.19 eV) lines, as example for the two typical representative copper lines are presented at Fig. 1. The distributions of Cu I 510.55 nm line clearly shows the manifestation of three characteristic phase of the µs-PGD operation: pre-peak, steady-state and afterglow. In the pre-peak phase, at the moment of the V_{max}, line intensity distribution has a strong broad maximum positioned at 2.7 mm from the cathode. During the pre-peak phase almost entire line emission comes from the NG region. The Cu I line intensity depends on the sputtered copper atoms and as well as on the EEDF. According to the Monte Carlo analysis made for the discharge similar to ours, during the first several microseconds after the discharge is ignited, the EEDFs in the NG are characterized by a high peak corresponding to a few eV (Martín et al., 2008). Electron energy of several eV is sufficient for excitation of many copper atom's low energy levels, so intensity of such Cu I lines in the pre-peak phase can be much higher in the NG than in the CF region, even the copper atoms density in much lower in the first one.

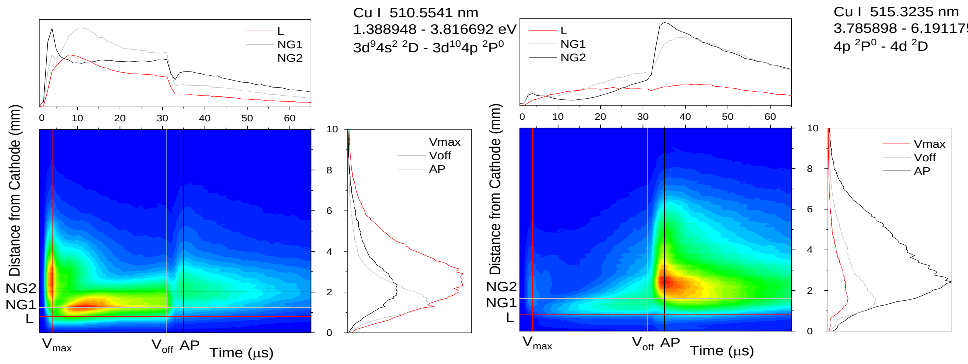

Fig. 2. Spatio-temporal distribution of Cu I lines intensities.

The observed maximum of the line intensity during the time development appears as the consequence of several simultaneous processes that influence on copper atom number: sputtering, redeposition and Pennig ionization of the copper atoms. Analyzing Fig. 1 one can see that the Cu I 515.32 nm line intensity is much higher during the afterglow than during the pulse phase of the discharge. As the self-absorption is excluded for this line, increasing of the line intensity with time is evidence of increasing of the copper atom number during the steady-state phase. During the afterglow phase the line intensity greatly increases at the distances that belongs to the NG region; farther from the cathode, the increasing is higher.

Acknowledgments: This work was supported by the Ministry of Education and Science of the Republic of Serbia (Contract Number 451-03-68/2022-14/200162) and by the Science Fund of the Republic of Serbia through the Project ATTOPLASMAS # 7750277.

References

Alberts D. et al, 2010, Spectrochim. Acta - Part B 65, 533–541.
Martín A. et al, 2008, Spectrochim. Acta - Part B, 63 1274–1282.