Comparison of spectroscopic and catalytic probe characterization of afterglow oxygen and hydrogen plasma

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Inductively coupled plasma modification of surface is a well-established technique used in a wide variety of applications [1, 2]. Reactive and fast interaction between the plasma and sample show the need for real-time plasma diagnostics. Optical emission spectroscopy and actinometry combined with the measurement of oxygen atom concentrations by the catalytic probe offer a relatively simple and efficient solution for that need. The combination of these methods was used for characterization of low pressure inductively coupled oxygen plasma in an afterglow chamber. The chamber enables real-time monitoring of modification of samples (via 12 windows/inputs).

Plasma was created in a linear borosilicate glass tube by a 6 turn coil with an EM field oscillating at 13.56 MHz at the distance of 30 cm from the center of the afterglow chamber. Various plasma conditions were used: oxygen and hydrogen gas pressure (20-90 Pa), and discharge powers (up to 260 W of applied power). Real-time spectral analysis was performed by a LIBS2000+ spectrometer system from Ocean Optics, which consists of seven miniature spectrometers (resolution 0.1 nm in the range 200-980 nm). The spectrometer is calibrated for the spectral response. Ni-plated catalytic probe was used for measuring neutral oxygen atom concentrations, while Au probe was used for neutral hydrogen atoms.

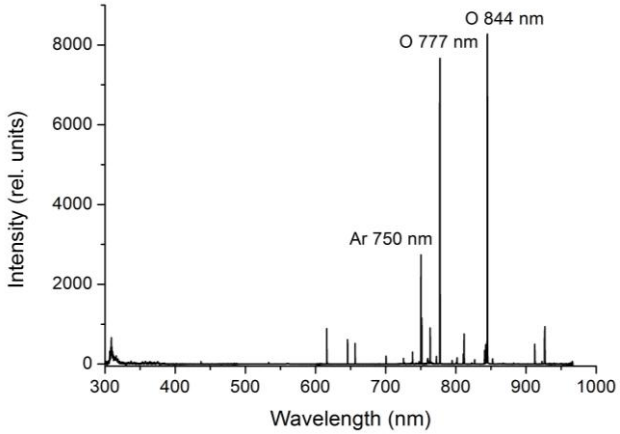

Fig. 1: *Spectrum of oxygen-argon plasma mixture (for actinometry) at 29 Pa and 260 W.*

Both the spectral features and the O and H atom concentrations are spatially resolved. Oxygen spectrum (with the 2% of added argon for actinometry) is shown on Fig. 1. It is characterized by oxygen lines (stronger ones are 777 and 844 nm), as well as with the argon line at 750 nm.

Oxygen atom concentrations were measured to be in the range from $5 \cdot 10^{18}$ m^{-3} (lowest pressure, furthest position) to $2 \cdot 10^{21}$ m^{-3} (70 Pa, near the coil). Significant concentrations of oxygen atoms were measured even in the "dark" parts of the afterglow chamber. Spatial distribution of concentration (Fig. 2) shows two distinct areas: inside the afterglow chamber (from -4 cm to 8 cm), and near the coil in the tube (10 cm to 27 cm).

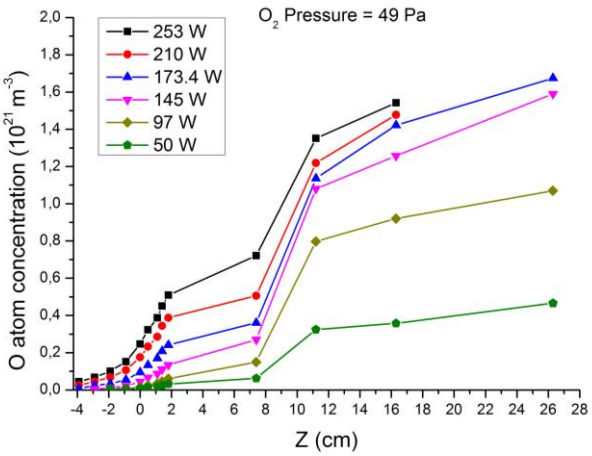

Fig. 2: *O atom concentration as a function of position and applied power inside the chamber and the tube.*

Actinometric concentrations will be compared with the catalytic probe measurements (for all positions in the chamber) which will allow a complete picture for the future material processing.

References

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[2] O. Grulich, Z. Kregar, M. Modic, A. Vesel, U. Cvelbar, A. Mraček, P. Ponizil, Plasma Chem. Plasma P. **32**, pp 1075 (2012)