Space Resolved Optical Emission Spectroscopy of Inductively Coupled RF Water Plasma

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Low temperature plasmas have a broad area of applications for treatment of various materials which points to the need of real time plasma characterization during processing [1,2]. Inductively coupled plasmas are of particular interest since details of the inductive coil design and its surrounding can be used to influence plasma content. Water plasma is of special interest since it could be used for sterilization [3]. In the present work we characterize a discharge vessel used for studying gas plasma interactions with water vapours by means of an optical emission spectroscopy (OES) [4] and a fiber optics catalytic probe (FOCP) [5].

The discharge vessel was a linear tube with outer diameter of 40 mm made of a borosilicate glass which has a good transparency from 300 nm to IR. The tube was connected to the vacuum system, which provides the pumping speed of 35 m^3/h and the base pressure of 1 Pa. The pressure in the system was measured with a Baratron gauge. The flow of the gas was controlled by a needle valve and measured by a mechanical flow meter (about 50 ml/min). Plasma was created within 8 turn coil connected through a matching network to a RF amplifier (RIZ SW Amp.). The amplifier was fed by oscillation from a frequency generator (Hameg HM8131-2) at frequency of 13.56 MHz. The power was adjustable up to 300 W. Forward and reflected power component were monitored at the amplifier. The coil was placed closer to the left edge of the glass tube (5 cm) and its length was 14 cm. The discharge vessel contains also a capillary glass tube (outer diameter 0.6 cm, inner 0.1 cm). Diameter of capillary tube exit was about 0.03 cm. The tube could be used for introducing various vapours into plasma. The spectra were measured by means of a LIBS2000+ spectrometer system from Ocean Optics which consists of seven miniature spectrometers (2048 pixels and 12 bit A/D conversion). The nominal spectral resolution was 0.1 nm in the spectral range from 200-980 nm. Each spectrometer is equipped with Sony CCD array (2048 pixels and 12 bit A/D conversion) used as a detector. The spectral response was determined by means of a reference light source (LS-1-CAL, Ocean Optics). Spectrometers were controlled, and saved spectra analyzed by homemade software developed within the LabVIEW. Simultaneously plasma images were recorded by a standard CCD camera for each set of gas pressures and discharge power parameter. The catalytic probes (Ni, Au) were placed in downstream region of the plasma tube, and controlled on the separate PC.

The light was collected by means of an optical fiber (solar resistant) perpendicularly to the plasma tube. The distance from the collecting lens to the tube wall was 4 mm. The fiber was moved in steps of one centimetre along the tube (45 cm effective length). At each position spectra were recorded for 10 seconds with integration times up to 2 seconds. In this way stepwise profiles were obtained. Three distinct zones along the tube were identified, as indicated

in Fig. 1 by vertical dash lines, left to the coil, within the coil and right from the coil (downstream). Spectral signatures of O, H, and OH were observed. As an example, Fig. 1 shows set of spectral intensities at 309 nm (OH radical) at different water vapour pressures (rows) at three different discharge powers (columns). As discharge power is increased (above 200 W) or water vapour pressure decreased the transition from mode sustained by the static electric field (E-mode) to the mode sustained by the induced electromagnetic field (H-mode) is observed.

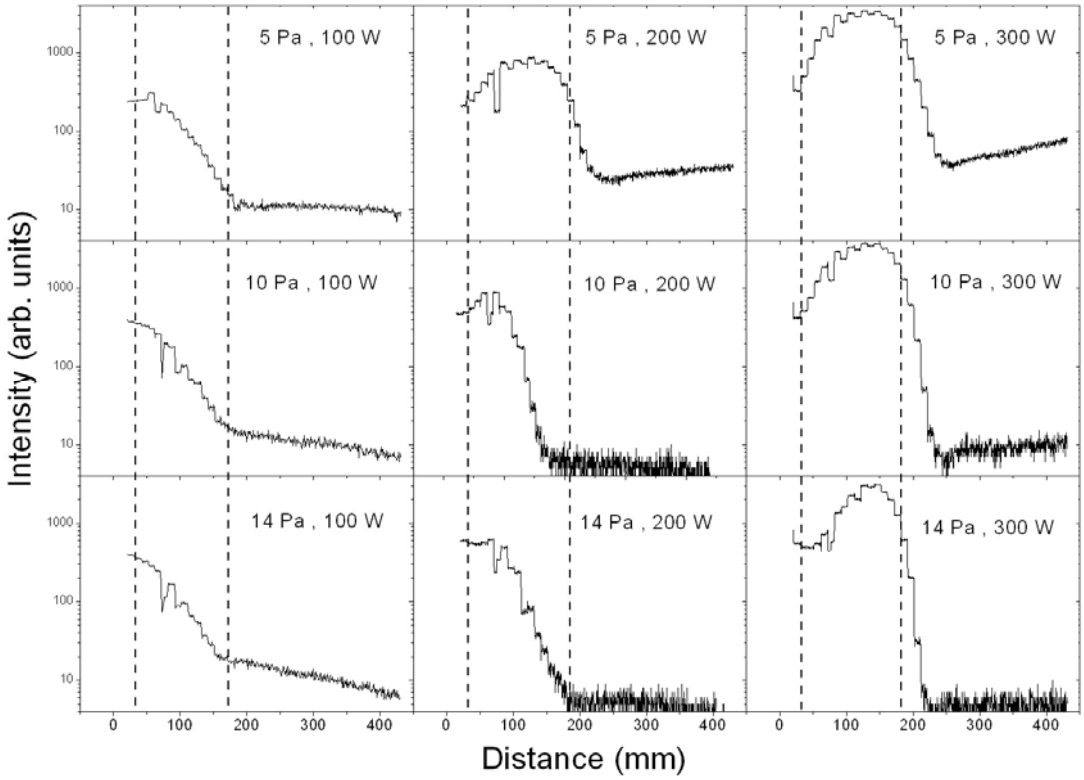

Figure 1: Spectral intensities along plasma vessel tube of the OH emission at 309 nm. Vapour flow is from the left to right. Vertical dashed lines indicate position of the coil.

For comparison of OES and FOCP techniques emission spectra were recorded at a particular point in downstream region versus discharge power for different pressures of water vapour, pure oxygen and hydrogen within the E-mode. The onset of the mode transition will be discussed in the framework of spectral line spatial profiles dependences and changes of the OH molecular band rotational structure (rotational temperature).

Reference

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