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SPATIAL DISTRIBUTION OF ArI LINE INTENSITY IN A LOW-PRESSURE MICROWAVE DISCHARGE IN ARGON AND ARGON-MOLECULAR GAS MIXTURES

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Abstract. Spatial distribution of the ArI 415.8 nm line intensity in low-pressure microwave induced discharge in argon, argon-hydrogen (0.9% H_2), argon-oxygen (0.9% O_2) and hydrogen-argon (5% Ar) mixtures in the pressure range from 1 to 6 mbar is presented in this paper. In the same pressure range, the H_β line intensity distribution is observed in hydrogen-argon mixture.

1. INTRODUCTION

The simplicity of generating stable and reproducible discharge makes microwave induced plasmas an interesting light source for atomic and molecular spectrometry, see e.g. Broekart and Siemens (2004). Another common property of microwave induced plasmas is good coupling of electromagnetic waves with free electrons in plasma. The electron energy, gained through interaction with electromagnetic wave, is further transferred to heavy particles through elastic and inelastic collisions. Well known principles of microwave energy transfer into plasma, were incorporated in different source designs, see e.g. Tendero et al. (2006).

Our low-pressure microwave plasma source is an Electrode Microwave Discharge (EMD) source (Lebedev et al. 2006, 2008), operating at the frequency of 2.45 GHz. A non-uniform character of this discharge is its main feature. The discharge consists of self-sustained near electrode region (sheath), with overcritical electron density ($n>n_c$; $n_c=7.45\times10^{10}$ cm^{-3}), non-self-sustained ball-like plasma ($n < n_c$) and dark external space. The radius of ball-like plasma is smaller than radius of the discharge chamber over broad range of absorbed power and gas pressure (Lebedev et al. 2006). Due to negligible role of electrode surface in generation of charged particles, the absence of electrode erosion makes this source suitable for plasma-solid state interaction experiments, see Lebedev et al. (2006) and references therein. The investigation of plasma-chemical processes and interaction between plasma structure and gas flow are also possible applications of EMD.

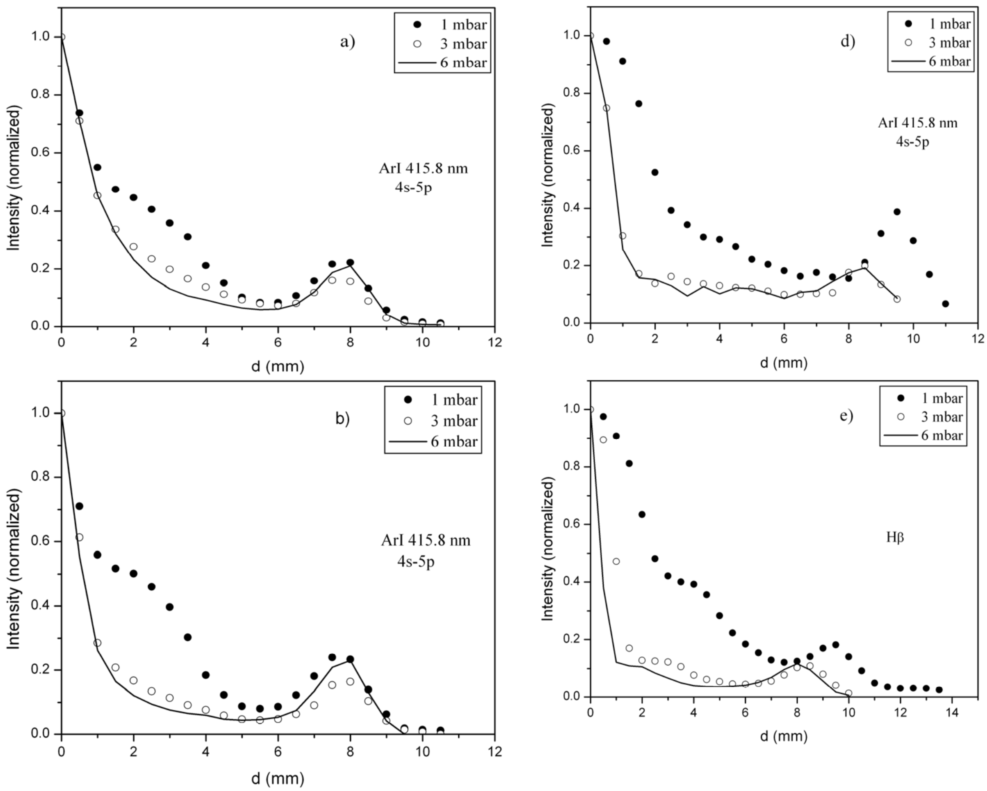
Here, we report the results of an optical emission spectroscopy study of the spatial distribution of ArI 415.8 nm line intensity in argon, argon-hydrogen (0.9% H_2), argon-oxygen (0.9% O_2) and hydrogen-argon (5% Ar) mixture at three different pressures. In addition, the spatial distribution of the H_β line intensity in hydrogen-argon mixture is reported also.

2. EXPERIMENTAL

The experiments were realized in argon (99.999%), argon-hydrogen (0.9% H_2 by volume like all other gas mixtures), argon-oxygen (0.9% O_2) and in hydrogen-argon mixture (5% Ar) in a pressure range (1 – 6) mbar. The incident microwave power was ≈ 250 W. Spectroscopic measurements were performed with 0.67 m focal length monochromator (light power f/4.7, reciprocal dispersion 0.83 nm/mm in the first diffraction order with 1800 grooves/mm reflection grating). The discharge image was projected onto the entrance slit of monochromator by system of optical components (Dove prism, achromat lens, flat and spherical mirrors). The Dove prism was used to rotate plasma image for 90° (vertical into horizontal plasma image in respect to monochromator slit) while an achromat lens is used to focus light on flat mirror. The achromat lens (focal length 80 mm) was used to translate image in perpendicular direction to the discharge axis with a spatial resolution of 0.5 mm. The combination of Dove prism and achromat lens enabled observation of required spatial position in plasma starting from electrode tip. The arrangement of two flat mirrors and one spherical mirror (focal length 305 mm) was used to transfer and focus discharge image onto the entrance slit of monochromator. The air cooled CCD (2048x506 pixels, pixel width 12 μm) is used as radiation detector. Signals from CCD detector are A/D converted, collected and processed by PC.

3. RESULTS AND DISCUSSION

The optical emission spectroscopic technique is applied to determine spatial distributions of the ArI 415.8 nm line (4s-5p transition) in argon, argon-hydrogen, argon-oxygen and hydrogen-argon and the H_β line in hydrogen-argon discharge, in the pressure range from 1 to 6 mbar, see Fig. 1. Here, in order to achieve higher sensitivity instead of the photographic technique usually applied for spatial intensity distribution monitoring, the Ar I and H I line intensity is used. In Fig. 1 all spatial distributions of light intensity are normalized to the light intensity at the electrode tip. In this study the spatial intensity distribution of spectral line represents the distribution of plasma light emission *versus* distance along the axis of discharge extending from electrode tip. By comparing spatial distributions of ArI 415.8 nm line intensity in Figs. 1a)-1d), one can notice that the local maximum of light intensity, which corresponds to a boundary between plasma and dark outer space, is well defined and exist in a whole pressure range. Further, the results in Figs. 1a)-1d) illustrate the difference in spatial structure of plasma light emission in the non-self-sustained plasma central region (between 1 mm and 6



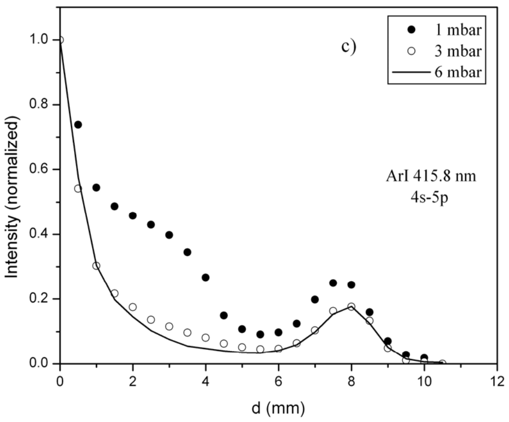


Figure 1: Spatial distribution of the ArI 415.8 nm line intensity in pure argon (a); argon-hydrogen (b); argon-oxygen and (c) hydrogen-argon mixture (d); and the H_β line spatial distribution in hydrogen-argon mixture (e) at gas pressure of 1 mbar [—], 3 mbar [---] and 6 mbar [···]. The line intensity is always normalized to its maximum value. Discharge conditions: absorbed power 20-30% of incident microwave power in Ar, Ar+0.9%H_2 and Ar+0.9% O_2 and between 60% and 70 % of incident microwave power in H_2+5% Ar.

mm), at low and high pressures. At low pressures, the ArI 415.8 nm line intensity distribution reveals a plateau in the central region of argon plasma, see Fig. 1a). In argon-hydrogen and argon-oxygen mixture, this plateau is more pronounced, see Fig. 1b) and 1c). At higher pressures, in argon, argon-hydrogen and argon-oxygen discharges, the intensity of the ArI 415.8 nm line decreases with the distance from electrode tip in a nearly exponential manner. The modeling of argon microwave discharges in cylindrical configuration shows that the electric field spatial distribution has decreasing exponential character from microwave launcher (Sa et al. 2001, Alves et al. 2009). In hydrogen-argon mixture, spatial distributions of the ArI 415.8 nm line intensity in near electrode and non-self-sustained plasma region are different from spatial distributions in argon and argon-hydrogen discharges in same regions, see Fig. 1d). In addition, the spatial distribution of the H_β line intensity in hydrogen-argon discharges is presented in Fig. 1e). The observed shape of spatial structure of EMD in hydrogen-argon mixture has been studied and discussed in details elsewhere (Lebedev and Mokeev 2003).

For all studied cases, presented in Fig. 1, the contribution of the central part of non-self-sustained plasma to overall intensity decreases with pressure.

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