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Spectroscopic study of argon microwave induced discharge

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Abstract. The results of an optical emission spectroscopy study of an electrode low-pressure microwave induced discharge in pure argon are reported. The Boltzman plot of relative ArI line intensities is used for both, measurements of electron excitation temperature and for characterization of equilibrium state of argon atoms in pure argon discharge.

1. INTRODUCTION

The well known collision-radiative (CR) analytical and numerical model [1,2] is used to describe atomic states population distribution function of bounded electrons. The model offers relationship between the shape of Boltzman plot and dominant elementary processes (collision and radiative) responsible for energy levels population. According to CR model the nonequilibrium plasma is "ionizing" if density of lower energy levels is overpopulated in respect to thermodynamic equilibrium values, and the plasma is recognized as "recombining" when an underpopulation of low energy excited levels occurs. In this paper, we report the results of electron excitation temperature determination from the Boltzman plot of relative ArI line intensities and the results of characterization of equilibrium state of argon atoms in pure argon discharge.

2. EXPERIMENTAL

The used microwave plasma source is an electrode microwave discharge (EMD) [3], operating at the frequency of 2.45 GHz. The experiments were realized in argon (99.999%) in a pressure range (1 – 6) mbar. The incident microwave power was ≈ 250 W and absorbed microwave power of 45 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). 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 Boltzman plot of relative ArI line intensities in argon plasma at 1 mbar is presented in Fig. 1a. The shape of relative population distribution indicates presence of two groups of excited levels. Higher levels (5p and above) may be well fitted with a straight line while population of lower levels (4p group) is located below this line, which is frequently used for electron excitation temperature T_e measurement. For the studied pressure range T_e was around 3000 K. In order to investigate equilibrium state of argon plasma, the b(p) coefficient *versus* principal quantum number of excited energy levels p for three different pressures is set, see Fig. 1b. The coefficient *b*(p) represents the relative population density of excited levels *η*(p) normalized to Saha-Boltzman equilibrium density η^{SB}(p). With an increase of pressure, the *b*(p) for lower levels (4p group) approaches unity, i.e. their population density increases towards equilibrium value. The fact that *b*(p)<1 holds for 4p argon levels, indicates that argon plasma is in *partial local thermodynamic equilibrium* (pLTE) of recombining mode. According to CR model of recombining plasma [1,2], lower levels belong to *capture-radiative-cascade* (CRC) phase, and they are populated by electron capture and cascade and depopulated by radiative decay. The collision transitions (stepwise character) are responsible for the population of high energy levels (5p and above), which are close to local thermodynamic equilibrium.

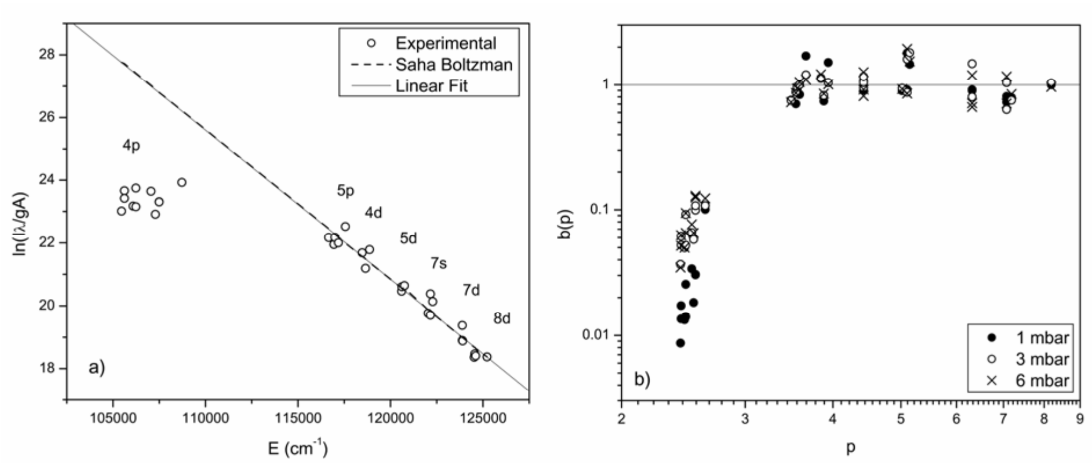

Figure 1. (a) Boltzman plot of ArI lines and (b) Relative population of excited argon energy levels normalized to the Saha-Boltzman equilibrium density, *b*(p)=*η*(p) /η^{SB}(p), as a function of principal quantum number p. Saha-Boltzman equilibrium density and linear fit through high energy data points are also shown in Fig 1a. Discharge conditions: pure argon discharge at (a) 1 mbar and (b) 1 mbar, 3 mbar and 6 mbar. Absorbed microwave power 45 W.

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