Measurement of the radial density profile of Ar metastables by self-absorption method with an optical probe

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1. Introduction

The self-absorption method is usually adopted to determine the metastable species density in a large number of low-temperature plasmas. In previous works this method only gives an average density in the radial direction, after assuming a uniform density profile. However, as found in [1], the density of Ar($1s_5$) given by this method may be inaccurate in a capacitive plasma due to inhomogeneity. For similar reason, the given metastable density is changing if different emission lines are selected to study an inductive plasma [2].

In order to overcome the above limitations, this work develops a self-absorption method to work in combination with an optical probe [3]. The probe is immersed in the plasma and moved along the radial direction. It can study the radial variation of the plasma emission intensity and the branching ratio. The information on the inhomogeneous metastable density can be extracted from these data using a certain procedure.

2. Experiment

The inductive plasma is generated by a 2.5-turn four-fold antenna (driving frequency 13.56 MHz) at pressures 0.1, 0.3 and 1 Pa and power 200 W. Plasma emissions are collected by a ceramic tube and focused to a fiber by a small achromatic lens at the end of the optical probe. A home-made prism spectrometer records the 2p-1s emission lines of Ar with a thermoelectrically cooled CCD camera.

3. Results

In figure 1, the radial density of Ar($1s_5$) is given by the above OES method using the line-ratio of 922 nm and 763 nm (from $2p_6$). The plasma is optically thin for the former line, but the latter one becomes weaker due to absorption by the Ar($1s_5$) state.

The above line-ratio depends on the photon transmission coefficient and thus also on the gas temperature, which needs to be known in advance. We use values of 300, 400 and 500 K to investigate the possible influence. In general a higher density is obtained at a higher temperature, due to a broader line profile (Doppler broadening).

The gas temperature at 1 Pa and 200 W is ~ 400 K as measured in [4]. The prediction of a collisional-radiative model (CRM) [5] agrees best with the OES curve at 400 K. At 0.1 Pa and 200 W, the electron density is much lower and the gas temperature is ~ 300 K. So the curve at 300 K gives the best fit.

In conclusion, we find: (i) The radial metastable density given by the self-absorption method with an optical probe is in good agreement with the model; (ii) When the gas temperature is known, absolute density can also be accurately determined.

References

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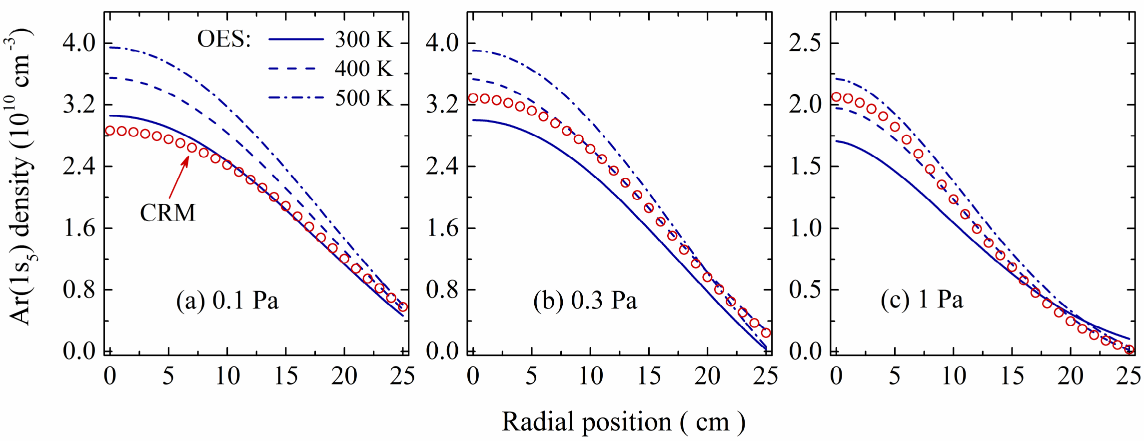

Fig. 1: *Comparison of the radial density of Ar($1s_5$) at (a) 0.1 Pa, (b) 0.3 Pa and (c) 1 Pa. The OES curves are obtained by the self-absorption method with gas temperatures 300, 400 and 500 K. The circles show predictions of the CRM [5].*