Determination of He(2^3S) concentration in a surface barrier discharge: 2D distributions

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The two-dimensional distributions of metastable excited helium atom He(2^3S) concentration are measured in a surface barrier discharge by use of diode laser absorption technique. The transition $2^3S \rightarrow 3^3P^0$ absorbing the light with wavelength 388.9 nm is used. The discharge is operated with excitation frequency from 4 to 8 kHz, voltage from 0.5 to 1.5 kV and helium flow of 400 sccm. The pressure range from 20 mbar to 1 bar is investigated. The obtained metastables concentration profiles are compared with CCD pictures of the discharge emission. Depending on pressure two types of concentration and emission intensity profiles over the discharge electrode are observed: with single maximum (<150 mbar), and with two maxima (>150 mbar).

1. Introduction

Due to its long time stability and simplicity, the surface barrier discharge (SBD) electrodes are very promising tool for technological applications under atmospheric pressure such as ozone generation [1], gaseous pollutant removal [2], fine particle generation [3] or chemical analysis [4]. Recently an efficient generation of atmospheric pressure glow discharge (APGD) [5] by use of SBD electrodes was demonstrated [6]. APGD allows broad range of applications because of its homogeneity. For such applications as surface treatment, etching or film deposition, the geometrical properties of the discharge are critical. It is known, that the metastable excited species are crucial for sustaining the APGD [5]. In this work the two-dimensional distributions of He(2^3S) concentration measured by use of diode laser atomic absorption spectroscopy (DLAAS) are presented.

2. Experimental technique

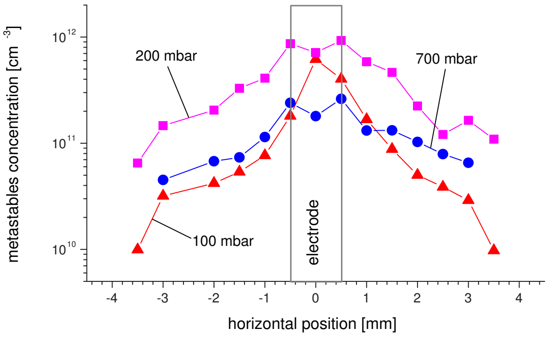

Figure 1: Horizontal distributions of metastables concentration for three pressures, collected by PMT.

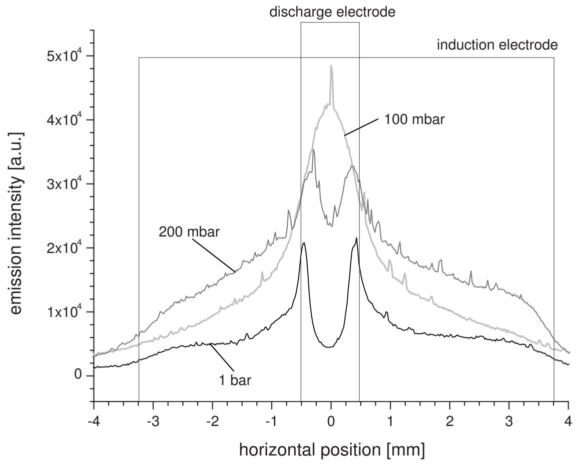

Figure 2: Emission intensity profiles for three pressures.

The DLAAS applied for determination of metastables concentration in this work is described in detail in [7]. For pressures lower than 200 mbar plasma densities are sufficient for direct measurment of absorption. The plasma modulation technique (PMT) with lock-in-amplifier are performed from 50 mbar to 1 bar.

The SBD electrode as specified in [7] is placed horizontally with discharge electrode on the top in a cubic vacuum chamber with dimensions of 6 × 6 × 6 cm^3 and with two quartz windows across the laser beam. For collection of the two dimensional distributions the chamber is moved vertically and horizontally, in the plane perpendicular to the laser

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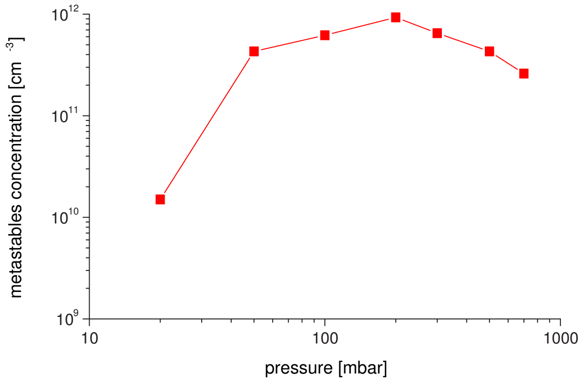

Figure 3: Max. metastables concentration vs. pressure.

beam. Helium flow of typically 400 sccm is applied. The discharge is operated with excitation frequency from 4 to 8 kHz, voltage from 0.5 to 1.5 kV. For time resolved characteristics of the high voltage signal supplied to the discharge electrode refer to [8].

2. Horizontal metastables distributions

The laser beam was swept over the SBD plate surface to obtain the horizontal metastables distributions (see Fig. 1). The shapes of these distributions are similar to these of the corresponding emission intensity profiles extracted from the 2D images taken by ICCD camera (see Fig. 2). Two different types of concentration profiles can be observed. The curves for pressure below 150 mbar have a single maximum over the discharge electrode. The curves for pressures higher than 150 mbar have local minimum over the discharge electrode and two maxima at the right and left side of the discharge electrode. The reason of such transition is discussed on the base of temporal discharge development in [8]. The distinct difference is the much sharper shape of emission curves. The reason for much smoother metastables concentration profiles is the integrating influence of the laser beam with intensity distribution as described in [7].

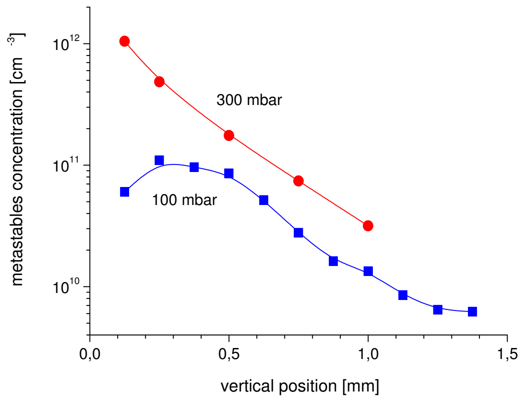

Figure 4: Vertical distributions of metastables concentration measured at horizontal position $x = -0.5$ mm for two pressures.

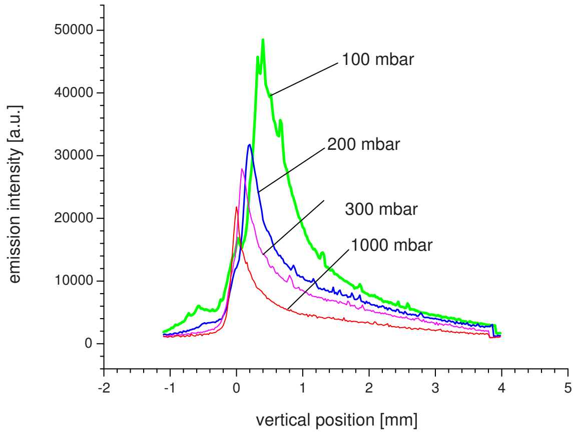

Figure 5: Vertical profiles of emission intensity measured at horizontal position $x = -0.5$ mm for pressures from 100 to 1000 mbar.

The maximum value of the metastables concentration increases with pressure up to 200 mbar due to the decrease of the diffusional loses and than drops due to decreasing lifetime of the metastables, as shown in Fig. 3.

3. Vertical metastables distributions

In Fig. 4 the vertical distributions of metastables concentration measured by direct absorption technique for 100 and 300 mbar are displayed. A much stronger influence of the metastables losses at the electrode surface on the profile for 100 mbar than for 300 mbar can be observed due to much higher diffusion constant. For comparison in Fig. 5 the vertical distributions of light emission for pressures between 100 and 1000 mbar are displayed.

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