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DOPPLER SPECTROSCOPY OF THE HYDROGEN BALMER BETA LINE IN A WATER VAPOUR HOLLOW CATHODE GLOW DISCHARGE

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Abstract. The Doppler broadened H_β line profiles are recorded from a hollow cathode glow discharge (HCGD) operated with water vapour. The results revealed the existence of two components of the line profile, i.e. the narrow component and the broad one. The average kinetic energy (temperature) of excited hydrogen atoms in the center of the discharge are around 0.3 eV for the narrow component, and 3 eV for the broad one, respectively.The radial distribution shows slight monotonic increase of H^* temperature, from the center towards cathode wall.

1. INTRODUCTION

The electron impact disociative excitation of the H_α water vapor molecule was studied using Doppler profile measurements of the hydrogen Balmer alpha line shapes emitted in electron $\rightarrow$ H_2O molecule (Kouchi et al. 1979). The Doppler profiles consisted of two components, the narrow component and the broader one. This result indicates that there are two kinds of precursors leading to excited hydrogen atoms, H^*(n=3) contributing to the H_α emission. The average kinetic energies of H^*(n=3) are (0.4 $\pm$ 0.2) eV and (4 $\pm$ 1) eV for the narrow and broad component respectively. The authors analyzed numerous dissociation processes responsible for the production of the H_α emission (see Table 2 in Kouchi et al. 1979) and selected two responsible for narrow and broad component:

$$H_2O^{**}(\approx 18eV) \rightarrow H^*(n=3)(Ek = 0.4eV) + OH(X^2\Pi)$$

$$H_2O^{***}(\approx 25-30eV) \rightarrow H^*(n=3)(Ek \approx 4eV) + (O(2p^4)H(n=1)$$

or

$$H_2O^{***}(\approx 25-30eV) \rightarrow H^*(n=3)(Ek \approx 4eV) + OH^*(B^2\Sigma^+)$$

The values in the parantheses after H_2O^{**} and H_2O^{***} are their internal energies, respectively. Since the first adiabatic ionization potential of H_2O is 12.6 eV, both H_2O^{**} and H_2O^{***} are superexcited states. The detailed study of $e \rightarrow H_2O$ interaction and the major processes responsible for the formation of excited hydrogen atoms

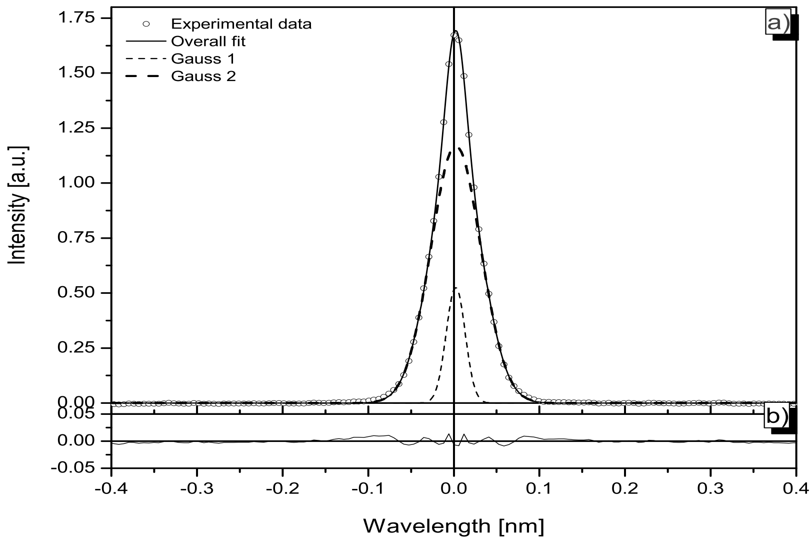

Figure 1: a) The typical H_β line profile recorded in a center of the hollow cathode glow discharge with a stainless steel cathode fitted with two Gaussians; b) residual plot.

from water, can be found elsewhere (see Kurawaki et al. 1983). Here, we report results of the hydrogen Balmer beta line shapes study in a stainless steel and copper hollow cathode glow discharge operated in water vapour.

2. EXPERIMENTAL

In experiments with water vapour we used the HCGD source with cylindrical stainless steel (SS) or copper (Cu) cathode and with two symmetrically positioned molybdenum anodes. The hollow cathode (HC) was 100 mm long with 6 mm internal diameter and 1 mm wall thickness. The construction details of the HCGD source are presented elsewhere (Šišović et al. 2005). The glassy container filled with bidistillated water was used as a water vapour generator. The spectral line shape recordings were realized with 2 m spectrometer (equipped with 651 g/mm reflection grating) having 0.74 nm/mm reciprocal dispersion in first diffraction order. The instrumental profile is Gaussian, with full half-width of approximately 0.018 nm. The discharge image, 1:1 magnification, was projected with an achromatic lens (focal length 75.8 mm), onto the entrance slit of the spectrometer. Signals from the CCD detector (3648 channels, pixel size 8 μm) are A/D converted, collected and processed by PC.

3. RESULTS AND DISCUSSION

The experiments were realized under the following discharge conditions: the pressure of 0.74 mbar, current 60 mA and voltage of 378 V and 327 V with SS and Cu hollow

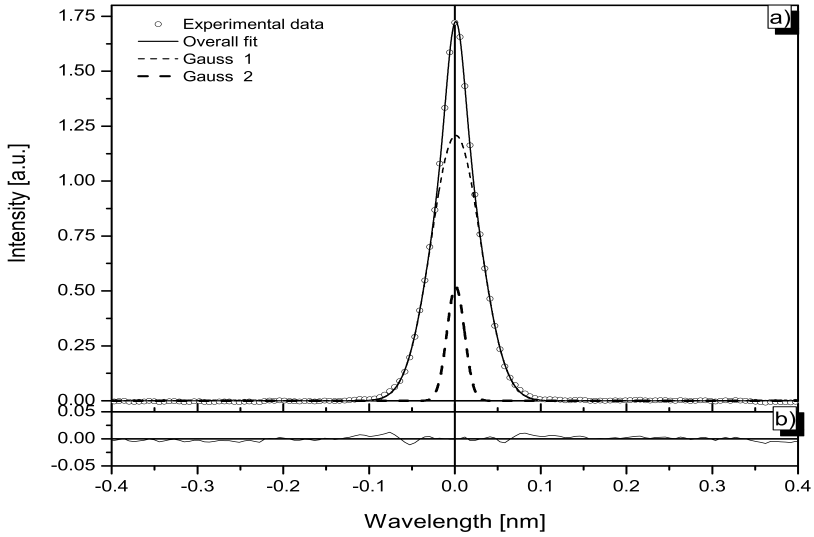

Figure 2: Same as Figure 1, but for Cu cathode. (a) Typical H_β line profile recorded in a center of the hollow cathode glow discharge with a copper cathode fitted with two Gaussians; b) residual plot.

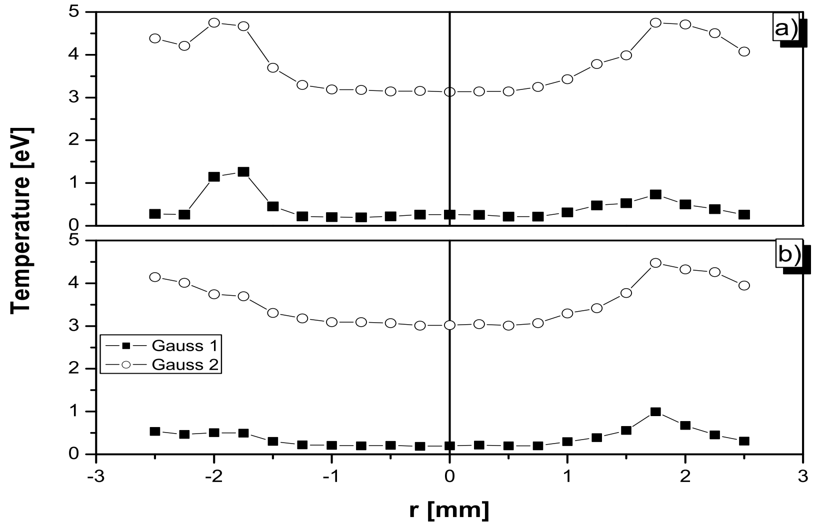

Figure 3: Temperature distribution of the H^* atoms derived from Gauss 1 and Gauss 2 component in a glow discharge with a) SS and b) Cu hollow cathode.

cathode, respectively. The typical H_β profile with SS and Cu cathode is presented in Fig. 1 and Fig. 2, respectively, together with best fit curve composed of two Gaussians. This result differs from earlier profiles with these two HC operated with hydrogen isotopes or hydrogen-inert gas mixtures where three Gaussians were needed (see Figs. 2-7 and Tables 1 and 2 in Šišović et al. 2005 and Šišović et al. 2007). This time largest width Gaussian related to anomalous Doppler broadening is missing. This is in agreement with the recent radio frequency (RF) excited experiment in water vapour flow (Mills et al. 2005). The full half-width of Gaussian components of the overall fit presented in Figure 1 are 0.026 nm and 0.068 nm, and 0.024 nm and 0.067 nm for those presented in Figure 2. Temperature of excited hydrogen atoms, derived from above values are 0.26 eV and 3.1 eV, and 0.2 eV and 3 eV for the discharge operated with SS and Cu cathode, respectively. The comparison of temperature radial distribution of H^* atoms originating from both excitation processes in HCGD for these two cathodes are presented in Figure 3. One should notice the linear increase in temperature from the center towards HC wall. Such behavior is a consequence of electric field radial distribution in HCGD, which is largest close to the HC wall (see Hirose and Masaki 1988). The maximum temperature value lies between 1.75 and 2 mm from the HC center and has the value in the range (0.75 $\div$ 1 eV) for the first, and (4 $\div$ 4.5 eV) for the second excitation process. The radial distributions in Figure 3 shows marginal difference in values in tendency of H^* atoms temperature change between SS and Cu HCGD.

Acknwoledgements

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