Publ. Astron. Obs. Belgrade No. 84 (2008), 309 - 312 *Contributed Paper*

SPECTROSCOPIC STUDY OF HIGH ENERGY EXCITED HYDROGEN ATOMS IN A HOLLOW CATHODE GLOW DISCHARGE

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Abstract. Presented results are concerned with the shape of Balmer alpha line emitted from a low pressure DC glow discharge with aluminum (Al) and copper (Cu) hollow cathode (HC) in pure hydrogen and in Ar-H_2 gas mixture. The analysis indicates that the line profile represents a convolution of Gaussian profiles resulting from different collision excitation processes.

1. INTRODUCTION

Recently recorded Balmer line shapes along the axis of a hollow cathode discharge and side-on to the Grimm discharge are found to be symmetric in H_2 and in hydrogen-inert gas mixtures (Šišović et al. 2005, Cvetanović et al. 2005). These profiles exhibit multicomponent behaviour that can be analyzed with great precision by fitting with several Gaussians.

The narrowest part of profile with the Doppler temperature not exceeding 1 eV, and middle part of line profile, with Doppler temperature smaller then 10 eV, are related to excited H^* atoms generated in collision of high-energy electrons with H_2 molecules (see e.g. Majstorović et al. 2007 and references therein). The pedestal of line profile is anomalously broad, indicating the presence of energetic H^* atoms, having energies larger than hundred eV, see Fig. 1.

The explanation of the phenomena of anomalous Doppler broadening (ADB) of hydrogen Balmer lines is based on a sheath-collision model (Petrović et al. 1992, Radovanov et al. 1995, Gemišić-Adamov et al. 2003). According to this model, the anomalously broaden part of hydrogen line profile is related to the hydrogen atomic and molecular ions (H^+, H_2^+ and H_3^+) present in discharge under the typical discharge conditions. In the cathode sheath region the accelerated ions exchange electric charge with hydrogen molecules and, as a result, fast neutrals and slow ions appear:

$$(H^+)_f + (H_2)_s \rightarrow H_f^* + (H_2^+)_s$$

$$(H_2^+)_f + (H_2)_s \rightarrow H_f^* + H_f + (H_2^+)_s$$

$$(H_3^+)_f + (H_2)_s \rightarrow H_f^* + (H_2)_f + (H_2^+)_s$$

where f and s denote fast and slow particles, respectively. It is shown that the particles (H^+, H_2^+ and H_3^+, H_2 and H) having energies of the order of magnitude of 10^2 eV are back scattered from metals in the form of fast hydrogen atoms H (Eckstein et al. 1976). The number and the energy of back-scattered atoms depend upon the material, while their spatial distribution follows cosine law.

The main sources of fast excited hydrogen atoms are H^+ and H_3^+ ions (exhibit an asymmetrical charge-exchange reaction in collisions with H_2), which are, as a consequence of relatively low cross-sections for collisions, efficiently accelerated towards cathode. On their way to cathode, some of these ions collide with the matrix gas H_2, producing fast exited neutrals H^*. The rest of accelerated ions reach the cathode where they neutralize, or neutralize and fragmentize. The back-reflected particles from the cathode are fast H atoms directed back to discharge. After collisions of these fast H atoms with H_2 and/or with other discharge constituents, fast excited hydrogen atoms H^*, are produced also. Thus, the fast excited hydrogen atoms moving towards and from the cathode are detected in different discharges by means of Doppler spectroscopy of Balmer lines.

In argon-hydrogen mixtures, the ADB Balmer line profile looks different from those in pure hydrogen isotopes (see Šišović et al. 2007 and the references therein). The line shape with strong line wings, see below, Fig. 2, is the result of dominant role of H_3^+ ion that is efficiently produced in Ar-H_2 mixture. The excited H atoms after fragmentation of H_3^+ ion in collision with H_2 or back-scattered H atoms from cathode have smaller energy (total ion energy is shared between three particles) than in the case of H^+.

The aim of this work is to study the H_α line shape in aluminum (Al)and copper (Cu) HC glow discharge operated in H_2 and Ar-H_2 gas mixture. Special attention will be devoted to the correlation between line shape and cathode material.

2. EXPERIMENTAL

In this experiment, the H_α line shapes were observed in aluminum and copper hollow cathode discharges operated in pure hydrogen and in inert gas-hydrogen mixture (Ar + 0.8% vol. H_2) at a pressure of 2 mbar. The HC tubes were 100 mm long with 6 mm internal diameter. The discharge source is described elsewhere (Šišović et al. 2005). Here, we shall mention only few important details relevant to the optical setup for line shape recordings. The light along the axis of hollow cathode glow discharge is focused by an achromat quartz lens onto the entrance slit of spectrometer (2 m focal length; reciprocal dispersion 0.74 nm/mm in the first order with a 651 grooves/mm reflection grating). Spectral line shape measurements are performed with an instrumental profile having Gaussian shape with 0.018 nm full half-width. Signals from CCD detector (3648 pixels, 8 μm) are collected and processed by PC. During the discharge operation, cathode was air cooled while HC wall temperature is controlled with a K-type thermocouple.

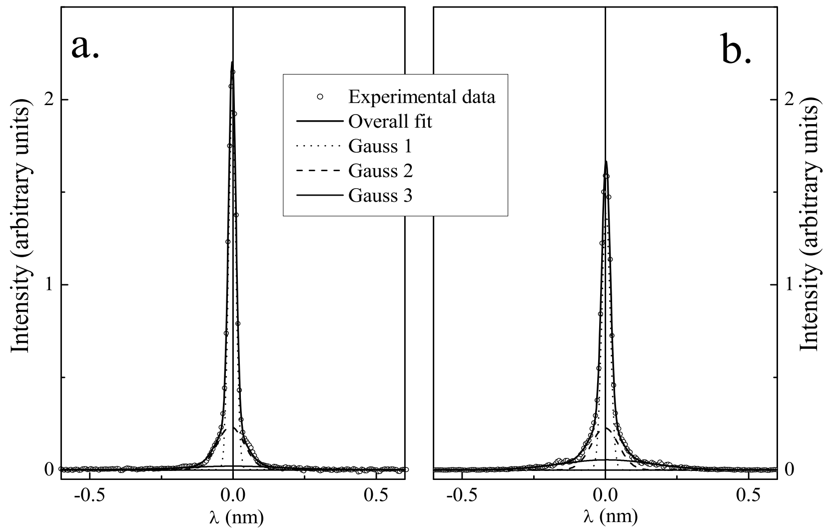

Figure 1: The H_α line profiles recorded in the center of an hollow cathode glow discharge in H_2 and their best fits: (a) Aluminum, U=385V; I=90 mA and p=2mbar; and (b) Copper, U=405V; I=90 mA and p=2 mbar.

3. RESULTS AND DISCUSSION

Typical examples of the H_α line shape recording from the central region of aluminum and copper HC operated with hydrogen in low-voltage glow discharge regime are given in Fig. 1. For the fitting of experimental profiles three Gaussian (Gauss 1, 2 and 3) are successfully used in most cases. Here, it should be noticed that an exception occurs when the extremely large contribution of the ADB part masks the middle component. An illustrative example is the shape of H_α line recorded from the copper HC discharge in Ar-H_2 mixture, see Fig. 2b.

The results for energies of fast excited hydrogen atoms derived from the width of Gauss 3, about 56eV, prove that the anomalous H_α line broadening is present in both discharges under studied experimental conditions. The Gauss 3 contribution to the profile is considerably lower for aluminum (7.7%) than for copper (18.0%) HC. This difference can be explained qualitatively by lower number reflection coefficient R_N of H^+ ions on aluminum (Tabata et al. 1983).

In the HC experiment with Ar-H_2 gas mixture, this difference is detected as well (46.9% and 29 eV for Al versus 95.1% and 44 eV for Cu). Here, it should be pointed out that the reflection coefficients of H and H^+ are of marginal importance in Ar-H_2 gas mixture where the dominant interacting ion with cathode is H_3^+. Unfortunately, the reflection coefficients of H_3^+ from polycrystalline metals are not available.

The results in Figures 1 and 2 indicate that the concentration and energy of fast excited hydrogen atoms depend upon cathode material through its back scattering coefficient.

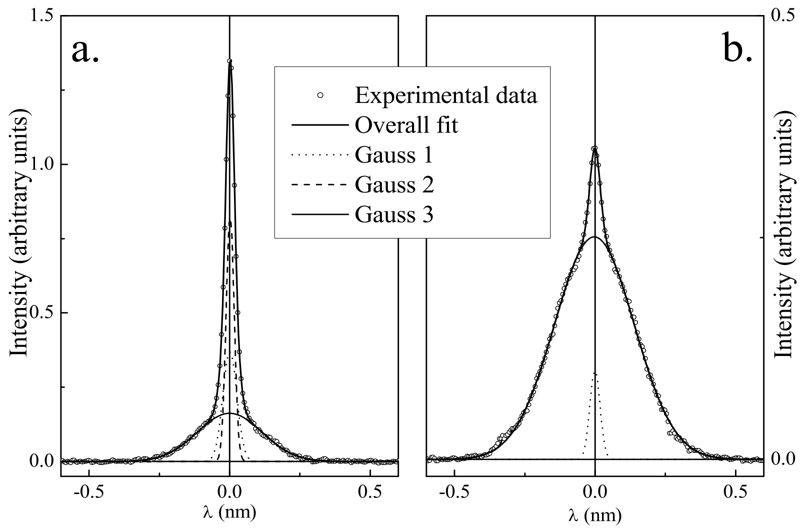

Figure 2: The H_α line profiles recorded in the center of an hollow cathode glow discharge in H_2 and their best fits: (a) Aluminum, U=324V; I=90 mA and p=2 mbar; and (b) Copper, U=326V; I=90 mA and p=2mbar.

The surface composition like the presence of metalic hydrades at cathode surface is of importance also (Šišović et al. 2007).

Acknwoledgements

This work is supported by the Ministry of Science of the Republic of Serbia (Project 141032B).

References

Cvetanović, N., Kuraica, M. M., Konjević, N.: 2005, *J. Appl. Phys.*, **97**, 033302.

Eckstein, W., Matschke, F. E. P., Verbeek, H.: 1976, *J. Nucl. Mater.*, **63**, 199.

Gemišić-Adamov, M. R., Obradović, B. M., Kuraica M. M., Konjević N.: 2003, *IEEE Trans. Plasma Sci.*, **31**, 444.

Majstorović, G. Lj., Šišović, N. M., Konjević, N.: 2007, *Phys. Plasmas*, **14**, 043504.

Petrović, Z. Lj., Jelenković, B. M., Phelps, A. V.: 1992, *Phys. Rev. Lett.*, **68**, 325.

Radovanov, S. B., Dzierzega, K., Roberts, J. R., Olthoff, J. K.: 1995, *Appl. Phys. Lett.*, **66**, 2637.

Šišović, N. M., Majstorović, G. Lj., Konjević, N.: 2005, *Eur. Phys. J. D*, **32**, 347.

Šišović, N. M., Majstorović, G. Lj., Konjević, N.: 2007, *Eur. Phys. J. D*, **41**, 143.

Tabata, T., Ito, R., Itikawa, Y., Itoh, N., Morita, K.: 1983, *At. Data Nucl. Data Tables*, **28**, 493.