Energy Distributions of Neutrals and Ions in H_2 Low Temperature Plasmas

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In this work, we analyse the results obtained by visible emission spectroscopy, energy resolved ion mass spectrometry and electric probes on H_2 plasmas generated in low pressure hollow cathode glow discharges. The study allows determining the energy distributions shown by the different plasma constituents, which span five orders of magnitude. So, the rotational H_2 temperature, assumed to be close to the translational one, scarcely exceeds the room temperature (0.03 eV); free electrons, responsible of primary ionization and dissociation processes, display mean kinetic energies of 3-6 eV; whereas ions (H^+, H_2^+, H_3^+) and even a part of the H atoms are found at the highest energy limit (¿300 eV). Our present study focuses on the line-shape analysis of the H Balmer series emitted by the plasma, whose spectral profiles evince its remarkable deviation from thermal equilibrium, and on the dependence of these profiles with H_2 pressure. The aim is to get a deeper understanding of the processes responsible of this behavior, presently an issue under some controversy. The technique has been proposed to detect nanoparticles formation in plasmas. The results may be also of interest for the spectral diagnostics of the atmospheres of the outer planets. Three different Doppler broadenings are found in the atomic lines (fig.1): the narrow peak (a), the plateau (b) and the far wings (c), with FWHM of some 0.3, 6 and up to 80 eV, respectively. Besides, a directional and asymmetric behavior in the line shifts up to some 300 eV is observed when ions are directed towards the observation window. The narrow line peak can be explained by direct electron impact excitation of the free H atoms and by Frank-Condon transitions to Rydberg levels. The plateau is explained by excitations to pre-dissociative levels and levels giving rise to dissociative ionization. Their effectiveness depends on electron temperature. On the contrary, the far wings are assumed to be due mainly to charge transfer reactions and dissociative reactions of the H^+, H_2^+ and H_3^+ ions with H_2, as well as to backscattering of H atoms after ionic neutralizations in the walls. These latest processes depend on the collision frequency and pressure. The ion energy distributions obtained by mass spectrometry and the electron temperatures measured with the electric probe support the validity of the proposed processes.

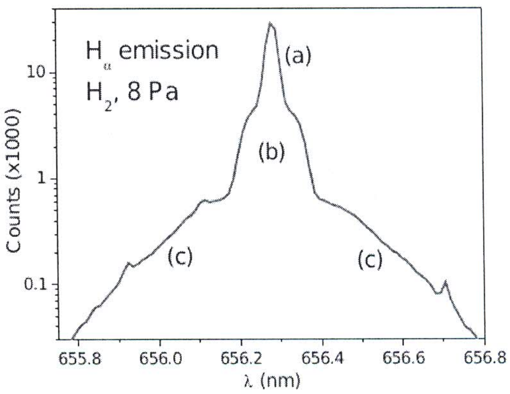

Figure 1: Spectral profile of the emitted Hα Balmer line from a 8 Pa, 150 mA, 450 V, hollow cathode discharge, detected with a visible spectrometer. Spectral resolution: 0.02 nm.