Energy distributions of neutrals and ions in H_2 low temperature plasmas: a study of fast H atoms.

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In this work we study by visible emission spectroscopy, energy resolved ion mass spectrometry and electric probes, H_2 plasmas generated in low pressure hollow cathode glow discharges. The study allows the determination of the energy distributions of the different plasma constituents (ions, electrons and neutrals), which span five orders of magnitude. 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 ionizations and dissociations, display mean kinetic energies of 3-6 eV; whereas ions (H^+, H_2^+, H_3^+) and a part of H atoms reach the highest energies (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 behaviour.

Three different Doppler broadenings are found in the atomic lines: the narrow peak, the plateau, and the far wings, with FWHM of ~ 0.3, 6 and up to 80 eV, respectively [1]. Besides, a directional and asymmetric behaviour in the line shifts up to some 300 eV is observed when ions are directed preferentially towards the observation window through a grounded grid. 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 also explained by electronic excitations, in this case to pre-dissociative levels and levels giving rise to dissociative ionization. Their effectiveness depends primarily on electron temperature. In contrast, the far wings are assumed to be mainly due to charge transfer processes and dissociative reactions of H_2 with the H^+, H_2^+ and H_3^+ ions accelerated in the plasma sheath. The latter processes depend strongly on collision frequency and increase appreciably with pressure. The ion energy distributions obtained by mass spectrometry [2, 3] and the electron temperatures measured with the electric probe support the validity of the proposed mechanisms.

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References

[1] M. Jiménez-Redondo, E. Carrasco, V. J. Herrero, I. Tanarro, Plasma Sources Sci. Technol., 22, 025022 (2013).
[2] I. Méndez, F. J. Gordillo-Vázquez, V. J. Herrero, I. Tanarro, J. Phys. Chem. A, 110, 6060 (2007).
[3] M. Jiménez-Redondo, E. Carrasco, V. J. Herrero, I. Tanarro, PCCP, 13, 9655 (2011).