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Gas temperature from line broadening in a neon microwave plasma at atmospheric pressure

A. Sáinz[1], M. D. Calzada[1], M. C. García[2]

[1] Grupo de Espectroscopía de Plasmas, Dpto. de Física, Edificio C-2, Campus de Rabanales. Universidad de Córdoba, 14071 Córdoba, Spain
[2] Dpto. de Física Aplicada Edificio C-2, Campus de Rabanales. Universidad de Córdoba, 14071 Córdoba, Spain

Abstract. We have used the collisional broadening of neutral neon lines to determine the gas temperature of a microwave discharge at atmospheric pressure. The gas temperature can be obtained from the van der Waals broadening, provided that the Stark broadening is negligible. Thus, the variation of the Stark broadening of the H_β, H_α, H_γ lines has been compared with the Lorentzian width of several prominent neutral neon lines from low-lying levels (close to the ground state). The values of gas temperature obtained have been compared with those provided by OH radicals with an excellent agreement.

Key words. Microwave discharges-Atmospheric pressure-Atomic emission spectroscopy-Spectral line broadening-Gas temperature

1. Introduction

Plasma parameters such as electron density (n_e) and gas temperature (T_{gas}) can be readily determined from the intensity, broadening, and shift of spectral lines (Konjevíc 1999). The Stark broadening of the hydrogen Balmer series lines, H_β, H_α, H_γ, is classically used to determine electron density while the gas temperature is obtained from the ro-vibrational spectra of the thermometric molecules such as the OH radical when, for instance, water vapor is already present in the carrier gas. When emission intensities of H_β, H_α, H_γ and OH spectral lines are too weak, aditional H atoms and OH radicals are provided, for example, by adding water vapor to the gas. Such additions result in changes of the discharge properties, which in some cases may be considered unacceptable. A straightforward solution to this problem, whenever applicable, is to determine n_e from Stark (quadratic) broadening and T_g from Doppler and Van der Waals broadenings of spectral lines emitted by the discharge gas itself. However, at high pressures, Doppler contribution is overlapped by the optical broadening.

In this work, we use emission spectroscopy to determine T_g from neutral neon line broadening in a surface-wave sustained discharge at atmospheric pressure. The applied method is based on the analysis of the dependence of the Stark and Van der Waals broadening on an appropriate set of NeI lines. This technique has been previously used in the spectroscopic diagnosis of an argon plasma by Christova et al. (2004) successfully. We compared the values of gas temperature inferred from these lines

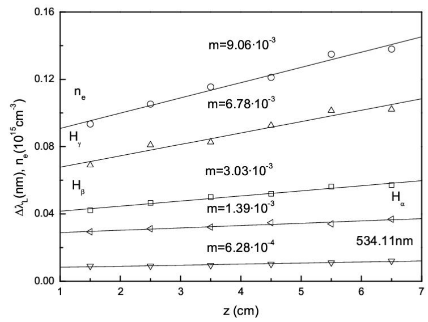

Fig. 1. Experimental values of Lorentzian FWHM and electron density

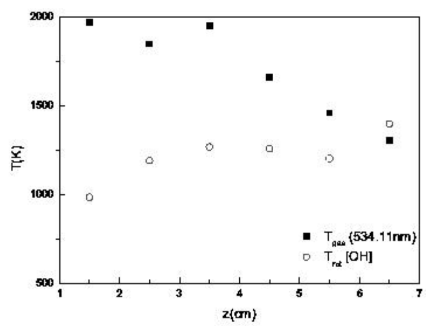

Fig. 2. Axial variation of the T_{gas} and T_{rot} obtained with the 534.11 nm and the OH radical band spectra respectively

with those obtained from the rotational temperature of the OH radical.

2. Results and discussion

Van der Waals full width at half-maximum (FWHM) of a spectral line, is only a function of T_g while Stark FWHM depends on both the electron density, n_e, and the electron temperature, T_e. Details about the corresponding expression can be consulted in Konjevíc (1999), and Christova et al. (2004). In plasmas at atmospheric pressure, the shape of the intensity lines obtained is approximated to a Voigt function resulting from the convolution of a Lorentzian (Stark and Van der Waals effects) and Gaussian (Doppler effect and instrumental broadening). Thus, the Lorentzian contribution is obtained by deconvolution. In Fig. 1 it is represented the Lorentzian Half widths of the Balmer series lines and the 534 nm line as well as the electron density along the plasma column. The electron density has been obtained with the Stark FWHM of the H_β with the diagnostic tables of Gigosos & Cardeñoso (1996). As can be seen, the FWHM of the hydrogen lines and the electron density present a non-negligible gradient along the plasma column while the NeI line does not. Since the Lorentzian broadening of the NeI line is almost constant along the plasma column, we can assume that the line is mainly broadened by the Van der Waals effect. The rotational temperature is practically constant (see Fig. 2), thus the Van der Waals broadening is expected to be constant too. The values of T_g and T_{rot} are represented in Fig. 2. As can be seen, the agreement at high axial positions is good while at low z positions the difference is significant. This can be explained if it is taken into account the small values of the Lorentzian FWHM of the 534.11 nm NeI line. Nonetheless, the van der Waals broadening of this line provides a good estimation of the T_{gas}.

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