Measurement of Metastable Helium Density in Radio Frequency Dielectric Barrier Discharge in Helium at Atmospheric Pressure

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1. Introduction

Vastly studied in the low frequency range (LF, typically under 300 kHz) dielectric barrier discharges (DBD) are nowadays one of the main atmospheric pressure diffuse discharge source [1]. In order to increase the power injected in the discharge, the use of high frequency (HF, typically above 3 MHz) excitation waveform is often considered. In this paper, metastable density of an atmospheric pressure discharge generated by a DBD excited by a 13.56 MHz waveform is evaluated via absorption measurement from a spectral lamp [2, 3, 4, 5]. The results are compared with an helium collisional radiative model.

2. Method

In atmospheric pressure plasmas with high charge densities, the absorption line width can be dominated by Stark broadening, hence yielding a Voigt profile, which must be taken into account for determining the absorption coefficient k_0. In our case, considering that the charge density in DBD is rather low, one can expect that Stark broadening is negligible as compared to Doppler broadening. Therefore, the metastable density can be calculated by

$$n_1 = \frac{4\pi^{3/2}}{\sqrt{\ln 2}} \frac{g_1}{g_2} \frac{\Delta\nu_D}{\lambda_{21}^2 A_{21}} \frac{k_0 L}{L}. \qquad (1)$$

where g_1 and g_2 are the degeneracies of the lower and upper levels of the transition, $\Delta\nu_D$ is the FWHM of the Gaussian profile associated with the Doppler broadening, λ_{12} is the wavelength of the transition, k_0 is the absorption coefficient, L is the length of the discharge in the line of sight. In this situation $k_0 L$ can be obtained via the global absorption coefficient A_L which can be measured experimentally. The global absorption coefficient as a function of $k_0 L$ is a function that depends on the FWHM of the Doppler broadening. In order to consolidate the experimental results, an helium 0D model is used to calculate the metastable density in similar conditions [6].

3. Results

The volume of the discharge is around 1 cm^3 while the injected power is roughly $P_{inj} = P_{inc} - P_{ref}$ where P_{inc} is the incident power and P_{ref} is the reflected power indicated by the power generator. An Andor DH520 ICCD mounted on a Jobin Yvon Triax550 spectrometer are used to record the spectra.

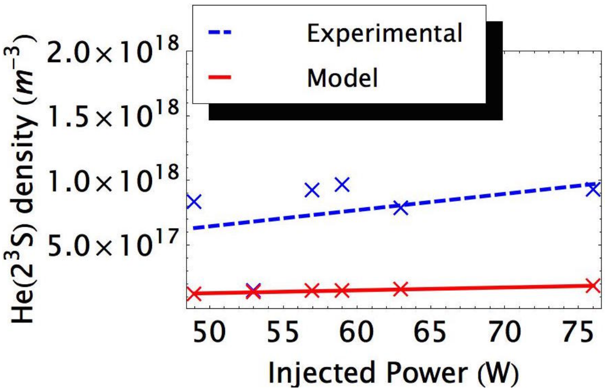

Fig. 1: *He(2^3S) density as a function of the power density.*

The measured density of the triplet state (2^3S) of helium atom is of the order of magnitude 10^{17} m^{-3}. This is in good agreement with the model, considering that the effective field used for model calculations might be underestimated due to the inhomogeneity of the sheath region. According to the model, this density is of the same order of magnitude as the electron in the discharge. With respect to the power, the metastable density is rather constant. The small density augmentation is probably due to the discharge volume enlargement as the power increases.

References

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