Atomic surface loss coefficients studied by a pulsed induced fluorescence technique

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1. Introduction

Plasma surface interactions (PSI) are of great interest to researchers because of the wide use of plasma technologies in many industrial processes. Ions and atoms are created during the plasma discharge. The surface loss coefficient (γ) is a key point in PSI studies. It can give information on the species inventory and is also an important input for modeling and theoretical work [1]. The aim of this project is to determine the atomic hydrogen and deuterium (H/D) surface loss coefficient on tungsten sample in a low-pressure radio-frequency inductively coupled plasma (ICP) reactor to address the plasma-wall interaction issues in magnetically confined fusion issues. Pulsed induced fluorescence technique (PIF), which is a non-intrusive and time-resolved optical emission spectroscopy method, is employed to measure surface loss coefficient.

2. Experimental set-up and results

2.1. Experimental set-up

A 4 inches tungsten sample is introduced horizontally inside an ICP plasma chamber. The pulsed plasma with 1 Hz, 5% duty cycle is employed. The H atom decay in the afterglow is correlated with the loss on all the surfaces surrounding the plasma. Therefore, one needs to have a low loss background material to make sure atoms are mainly lost on tungsten sample. The present study is focused on the choice of such material for the surrounding walls. A Pyrex tube has been introduced in the plasma chamber. The tube is closed with a Pyrex disc at the bottom and with a quartz window at the top. The optical fiber for the line-of-sight measurements of the light intensity is located 0.5 cm above the sample, so that the H_α emission decay is correlated with H atom loss on Pyrex. It is necessary to measure γ value on Pyrex under different plasma conditions, since there is little literature data available on it.

The PIF signal, H_α line intensity (I_H), is proportional to electron density n_e, to the excitation coefficient which depends on the electron temperature T_e, and to the atomic density ($I_H \propto n_e \times k[T_e] \times [H]$). In this technique, a long main pulse generates a steady-state plasma, and a secondary shorter probe pulse re-excites the discharge with an adjustable delay with respect to the main pulse. The H_α line intensity at the beginning of the probing pulse is proportional to the remaining atomic density. By varying the delay between the main pulse and the probing pulse, the atomic decay in the afterglow can be obtained, provided that n_e and T_e are constant in the probing pulse for each delay time. The decay is exponential with a time constant τ that is used to calculate surface loss coefficient γ. A 26.5 GHz Microwave Interferometer is used to determine the time resolved electron density during the probing pulse. A Langmuir probe is installed to obtain the spatial profile of n_e for correcting interferometer measurements and to measure T_e versus time.

2.3. Results

Interferometry measurements show that n_e is varying with time during the probe pulse, and this variation depends on the probe pulse delay. To cancel n_e variation effects, PIF signal is normalized by n_e so that I_H is proportional to H atomic density and to the excitation coefficient. To eliminate any overshoot of the electron temperature at the breakdown, a quite long probing pulse is used (5 ms), and the normalized PIF signal is extrapolated at the beginning of the probing pulse.

A two-stage exponential decay in the plasma afterglow was observed in the measurements of γ, including a fast decay (γ_{fast}) in the early afterglow and a slow decay (γ_{slow}) afterwards. The atom surface loss coefficient on Pyrex for H atom (γ_H) and D atom (γ_D) are found to be on the order of 10^{-2} at 5 Pa and 10 Pa, with γ_D being higher than γ_H for both pressures.

The H atom surface loss coefficient on tungsten is expected to be on the order of 10^{-2} [2]. Therefore, under our experimental conditions Pyrex is not a proper choice for the surrounding walls. A lower surface loss coefficient material such as quartz would be preferable for the γ measurements on tungsten.

The detailed information about PIF technique and the results on Pyrex will be shown in the presentation.

References

[1] Y. Feng, F. Sardei and J. Kisslinger 1999 Journal of Nuclear Materials **266-269** pp 812

[2] C. M. Samuell and C. S. Corr 2014 Journal of Nuclear Materials **451** pp 211