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Transport and deposition of injected hydrocarbons in plasma generator PSI-2

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Abstract

The transport and deposition of hydrocarbons were studied in the stationary plasma of plasma generator PSI-2. CH_4 or C_2H_4 were injected into the plasma at different positions in the target chamber. After an interaction between the plasma and the hydrocarbons, different species are produced, some of them having high sticking probabilities and forming a:CH films on a temperature controlled collector. The film growth is studied in situ for different plasma parameters. The 3D Monte Carlo code ERO including three different sets of atomic data is used to describe the formation of hydrocarbon films.

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1. Introduction

It is well known that in all fusion experiments which use carbon as wall materials, long term hydrogen (tritium) retention occurs which would not be acceptable for ITER [1].

An extrapolation from existing facilities is necessary as well as modelling of the processes which occur. In PSI-2, a stationary high current arc discharge, experiments were performed to obtain the relevant information about transport and sticking of hydrocarbons [2]. Well defined amounts of CH_4 or C_2H_4 were injected into the plasma (hydrogen, deuterium or argon discharges) and the deposition patterns were measured in situ for different plasma parameters. The growing rates detected for the a:CH films were compared with ERO-code calculations carried out for our particular conditions.

2. Experimental set up

The experimental set up is explained in [2]. In the middle of the target chamber a temperature controlled collector is fixed 0.06 m away from the plasma (see Fig. 1). There are two possibilities for hydrocarbon injection: (1) via the nozzle which is located opposite the collector and near to the plasma edge having an inner diameter of 1 mm, and (2) via the valve which is located on the same side 0.40 m upstream and close to the vessel wall (distance

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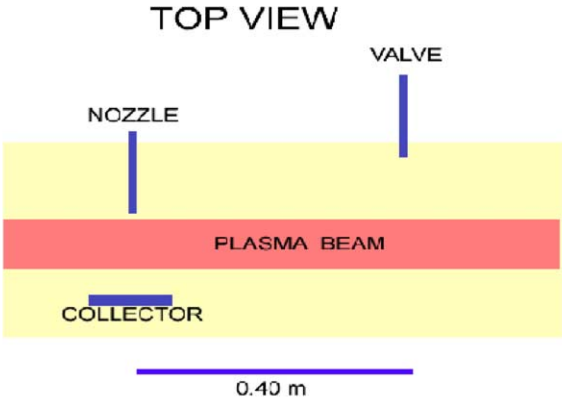

Fig. 1. Target chamber: arrangement of nozzle, valve and collector.

Table 1
Plasma parameters and discharge current for different working gases

Working gas	Electron density (m^{-3})	Electron temp. (eV)	Discharge current (A)
Argon	$(2\ldots50)\times10^{17}$	4…8	50…200
Hydrogen	$(1.5\ldots14)\times10^{17}$	4…8	50…300
Deuterium	90×10^{17}	1…2	400

to the plasma 0.15 m). The radial profiles of the electron density and temperature were determined using a scanning Langmuir probe (see Table 1).

The thickness of the a:CH films was measured in situ by reflection spectroscopy (see [2]).

3. Experimental results and discussion

The same amount of hydrocarbons is injected through the nozzle or the valve. For low density plasma, the majority of injected molecules passes the plasma beam without suffering disintegrating collisions. After reflection at the chamber walls, they enter the plasma beam repeatedly until being converted to a species with high sticking probability which then contributes to the formation of a:CH films on the collector and the inner surface of the target chamber. In this case we expect a more or less uniform distribution of a:CH films along the target chamber and therefore only a small change in the deposition rate at the collector when switching the gas inlet from nozzle to valve. When C_2H_4 is injected into a low density plasma ($n_e = 0.2\times10^{18}\,m^{-3}$), the nozzle and valve rates are found to be nearly equal (0.57 nm/min and 0.48 nm/min) (see Fig. 2).

With increasing plasma density, a larger amount of the injected molecules is converted to high sticking radicals during the first passage through the plasma. This behaviour is demonstrated in Fig. 3. The same amount of C_2H_4 is injected into an Ar discharge. The ratio of the growth rates (nozzle/valve) rises with increasing density. In contrast to Fig. 2, for an electron density of $5\times10^{18}\,m^{-3}$ there is a clear difference between the two positions of injection. For nozzle injection the growth rate is about 20 times higher than for valve injection. The decomposition of hydrocarbons for such conditions is a local process, that means the mean free path (mfp) for decomposition is smaller than the plasma diameter.

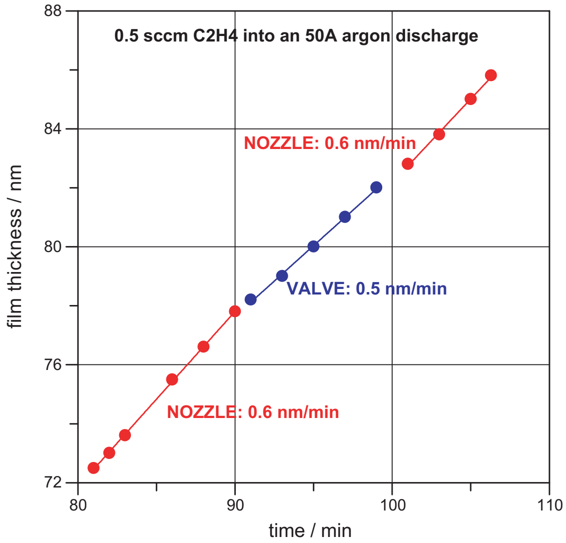

Fig. 2. Film thickness versus time for an argon discharge ($n_e = 2\times10^{17}\,m^{-3}$, $T_e = 2.5\,eV$). Injection of 0.5 sccm ethylene.

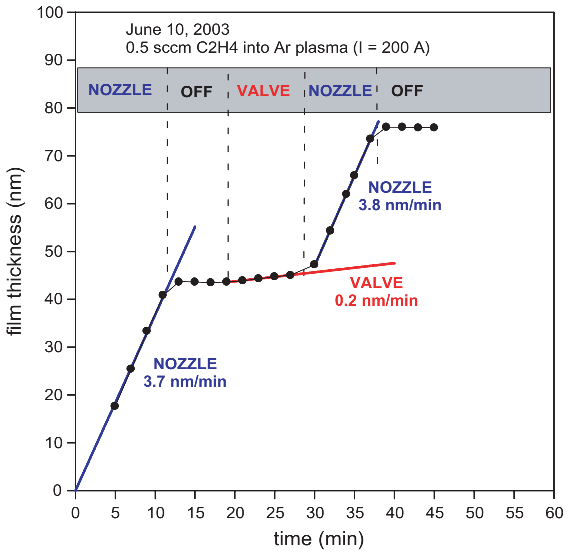

Fig. 3. Film thickness versus time for an argon discharge ($n_e = 5\times10^{18}\,m^{-3}$, $T_e = 5\,eV$). Injection of 0.5 sccm ethylene.