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Injection of hydrogen and ethylene at the plasma edge of TJ-II: A comparative study.

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Introduction

In a previous work[1], carbon fuelling experiments were performed in ECRH TJ-II plasmas by injecting C_2H_4 (ethylene) at several radial positions through a gas injection port located on a poloidal limiter. The experiments were then focussed on the screening by the plasma of carbon impurities under "normal" and divertor-type magnetic configurations. In the present work, complementary studies on the effect of the injection on the total particle content are described. For that purpose, injection of hydrogen and ethylene under the same geometry as that previously used has been performed. Experiments under divertor-type magnetic configurations are again compared to the standard-configuration case. Due to the much higher electron/molecule ratio in ethylene, a larger increase in electron density would be expected if the products of the cracking by the plasma of this species had a large recycling probability. Even if this is not the case, the H atoms released in such cracking, and characterised by a strong Ha emission associated to the ethylene puffing, could effectively fuel the plasma. However, the observed lower fuelling efficiency of ethylene compared to hydrogen indicates that little of the H contained into the molecule is actually available as plasma fuel. Evidence of strong H retention associated to the injection of ethylene, possibly through the formation of local carbon layer, is also provided by the release of carbon impurities from the limiter carrying the gas inlet and the H balance during the injection.

Experimental

The TJ-II stellarator has been described elsewhere[2]. For the experiments here reported, ECH plasmas (2 gyrotrons, 2nd harmonic, 250 kW each) were produced and several magnetic configurations, some of them with island structures at the edge (island divertor configurations) were used[1]. Hydrogen and He plasmas were used as the background for the injection of ethylene and hydrogen through a hole located in the middle of a poloidal limiter that can be inserted into the plasma and is controlled remotely. Gas flows through the inlet are calibrated by expansion into the vacuum vessel. Another limiter, located at 180 toroidally from the gas inlet, is instrumented with Langmuir probes. Two Ha monitors look at the limiters under an identical geometry and they are calibrated with respect to each other. A CCD camera from a toroidal window (time resolution of ~20 ms/frame) allows for the direct observation of the injection through the limiter. Other edge diagnostics include different types of impurity and particle monitors, a thermal lithium beam and a supersonic He beam[3]. Outgassing of hydrogen after the discharge is evaluated by a differentially pumped mass spectrometer[4]. Passive CX detectors are used for the evaluation of Ti and neutral density.

Results

Pulses of 15 ms of ethylene and hydrogen were injected at a fixed time of the discharge, corresponding to the injection of ~ 8.10^{18} particles. The response of some plasma parameters to the injection is shown in figure 1 for both species, H_2 (top) and C_2H_4 (bottom). Also shown (fig.2) are the corresponding CCD images (Ha filter). The location of the limiters corresponds to the nominal LCFS for these shots. As seen, plasma density, local Ha emission and central carbon density (CV) show a more or less significant increase as the species is injected. For the shots displayed in the figure, no significant changes in the ion temperature or in the edge electron temperature (not shown) were recorded. Also apparent from the figure is the higher increase in local Ha emission for the hydrogen case and the higher relative increase of the central carbon emission for ethylene injection. Also, a highly localized emission near the inlet at the limiter is observed for both cases in figure 2, which is again more intense in the H_2 case. Table I displays the comparison of density and neutral hydrogen rise upon the injection of either molecule. As seen, a much lower fuelling efficiency for ethylene is deduced, in spite of its much higher electron/molecule content. This is also true for the increase of local Ha emission, in spite of the higher H/molecule ratio of ethylene. The outgassing of hydrogen after the discharge, when compared between fuelled and non-fuelled shots, also points to a lower release of free H atoms upon the cracking of the hydrocarbon in the plasma. All this information can be analysed under the view of the prompt deposition of carbon layers with high H content when ethylene is fed into the plasma.

The topic of local contamination by the injection of hydrocarbons is specifically addressed in the experiments of limiter insertion shown in figure 3. Ethylene was injected as 15 ms pulses during a radial scan of the limiter position in two different configurations. In each scan, the symmetric limiter was kept at the location of the nominal LCFS. Thus, limiter C (the one that carries the gas inlet) was gradually inserted from the normalized minor radius r=1 up to 25 mm inside the LCFS (r~ 0.8) in discharges < 13575. From 13576 to 13582, the reverse was made, i.e., limiter A was inserted while limiter C remains at the LCFS position. Finally, a configuration with island-divertor characteristics was established, and limiter C was again inserted. Data shown in parts a) and b) of the figure refer to the parameter value before the pulse is produced (t < 1120, fig. 1). As seen in the figures, local enhancement of recycling at the limiter that is inserted is observed, as expected. However, only a small decrease of particle fluxes in the opposite location is simultaneously recorded. It must be kept in mind that the total displacement of the limiter is more than twice the corresponding density decay length of the SOL (~1 cm) of this type of plasmas. The behaviour of the A limiter signals (Ha and Isat) during the radial scan of limiter C is different however in divertor configurations. In that case, some increase of particle fluxes to limiter A is simultaneously seen. The short connections lengths for the iota =2 (Lc=2.5 m) cases between both limiters could be responsible for this feature. As ethylene is being puffed during the whole scan, chances of creating a local amorphous carbon layer near the injection point exist. Evidence of this is shown in the systematic increase of the plasma carbon content as limiter C is inserted shot by shot (figure 3b).

Conversely, a constant value (although higher than the initial one) of this plasma impurity is found when the carbon limiter A is moved inside the LSFS, thus indicating that simple erosion of the graphite limiter is not responsible for the enhancement. Finally, a lower contamination by limiter C is achieved in the divertor configuration, comparatively, even when the associated displacement into the plasma is higher (28 mm). At this point, elucidation between lower fluxes to the limiter, higher screening of worse confinement of the released impurities in the plasmas is still in progress. Figure 3 bottom shown the fuelling effect of the injected ethylene. As seen, a fairly constant value is reached for all configurations and only for the innermost locations of the limiter (>2 cm in) an enhanced effect takes place. The value of this, however, represents only a 2% of the available electrons in the pulse. The same type of experiments in hydrogen indicates that a significant enhancement of central neutral density ($n_0/ne=1.10^{-5}$) is achieved for deep insertion of the source.

Summary and conclusions:

- Injection of H_2 and C_2H_4 through mobile limiter and into different magnetic configurations has been performed in TJ-II ECH plasmas.
- Little plasma contamination by ethylene is seen under most conditions.
- A factor of 7 less Ha emission than in H_2 puffing is produced from ethylene cracking.
- Locally deposited carbon layers drive enhanced contamination when limiter is inserted at the plasma edge.
- Small fuelling efficiency is consistent with previous reported data for other hydrocarbons[5].
- Strong hydrogen built up in deposited layers associated with ethylene injection has been deduced.
- All these observations agree with prompt cracking and ionization of injected hydrocarbon, leading to local carbon layer deposition.

Acknowledgments

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References

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	ethylene	hydrogen
Electron/molecule	14	2
Molec/pulse	$7\ 10^{18}$	$8.7\ 10^{18}$
Densityincrease/pulse (total electrons)	$1.2\ 10^{18}$	$1.5\ 10^{18}$
H/molecule	4	2
Halph. increase/pulse (a.u.)	3	10
H outgas/H in	0.10	0.25

Figures

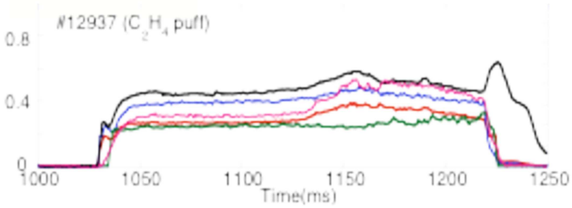

Fig.1a

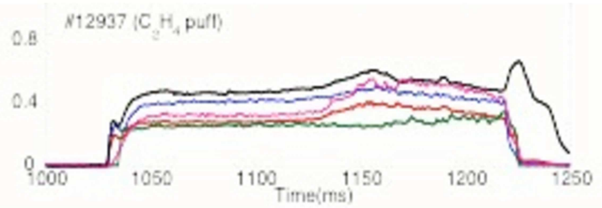

Fig.1b

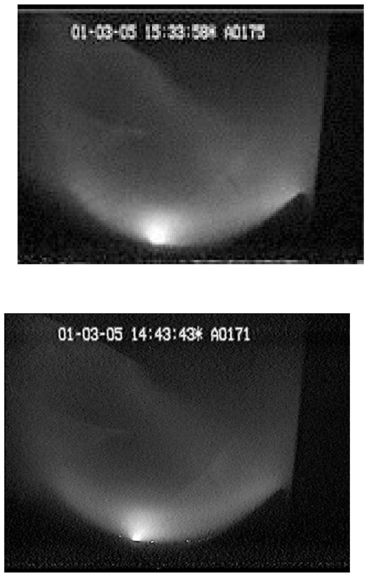

Fig.2 a) b)

Fig.3