Surface mechanisms investigation for negative ion production.

S. Béchu [(*)1], A. Soum-Glaude [2], A. Bès [1], P. Svarnas [3], M. Bacal [4], A. Lacoste [1]

[1] LPSC, Univ. J. Fourier Grenoble 1, CNRS/IN2P3,Institut Polytechnique de Grenoble, 38026 Grenoble, France
[2] PROMES-CNRS, 7 rue du Four Solaire, 66120 Odeillo, France
[3] High Voltage Laboratory, Electrical and Computer Eng. Depart., Univ. of Patras, 26504 Rion-Patras, Greece
[4] LPP, UMR CNRS 7648, Ecole Polytechnique, 91128 Palaiseau, France

[(*)] stephane.bechu@ujf-grenoble.fr

In parallel to the ITER tokamak construction is raising the question of the next step toward a real Fusion power plant (called DEMO reactor), which should be a full ignition and high power fusion machine. It is highly desirable for new reactor to find alternatives to the use of caesium (Cs) due to several important drawbacks like a very high Cs consumption rate for long shot duration (or steady state) operation, the diffusion of this material which yields to a stray Cs coating on the injector components (accelerating electrodes, metal shields, insulators) and a decrease of the high voltage holding capability. For this purpose, an alternative surface mechanism that could enhance the H- formation under a hydrogen atoms flux has been investigated by using different materials.

Seven dipolar sources [1] have been settled just above a Pyrex cylinder ($\varnothing$ 200 mm, 200 mm in height). The Pyrex cylinder is settled in the center of the Camembert III reactor [2] that provides the pumping unit and gas intake regulation. Its temperature is not regulated. Hydrogen atoms that have been produced in the Electronic Cyclotronic Resonance (ECR) volumes of each source partly diffuse in the Pyrex cylinder that limits their diffusion to the reactor's walls. This arrangement is presented in Fig. 1a). The aim of this cylinder is the creation of a smaller volume than the Camembert III one's to promote surface reactions with samples of limited size ($\varnothing$ 50 mm) presented in Fig. 1b).

Dipolar plasma sources (×7)

a)

Pyrex cylinder

ECR coupling volumes

b)

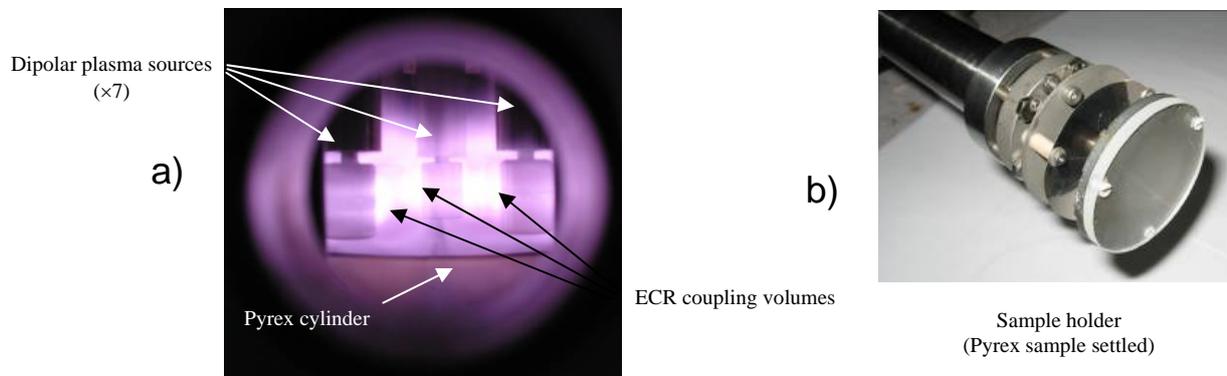Sample holder
(Pyrex sample settled)

Fig. 1   a) Picture of seven plasma sources in functioning above the Pyrex cylinder; b) Sample holder holding a Pyrex disk of 48 mm in diameter. The sample can be heated up to 750 °C, cooled down to -180 °C and biased to +/- 500 V.

With this arrangement, the sample is settled at the inner wall of the Pyrex cylinder and samples are changed via a lock chamber. Hence, vacuum remains undisturbed in the plasma chamber. The reference sample is a disk of Pyrex. If this material is set on the sample holder, plasma produced by the seven sources faces only Pyrex surfaces. We have investigated material effect in the following order: Pyrex $\rightarrow$ graphite (HOPG) $\rightarrow$ tantalum $\rightarrow$ Pyrex at the same micro-wave power input (1000 W) and the same pressure (5 mtorr). Photodetachment signal (cf. Fig. 2a) has been amplified with a wide band pulse amplifier (Lecroy VV100 BTB) for better accuracy. Fig. 2b represents obtained results for $\Delta I/I_{DC}$, which is proportional to n_i^-/n_e. ΔI is the peak amplitude as represented in Fig. 2a and I_{DC} is the electron current collected by the probe biased to 25 V above the plasma potential. We can stress the good reproducibility of these results: results obtained with Pyrex are extremely similar over 2 days and 2 samples change. Errors bars are obtained over 5 five measurements for each temperature setting.
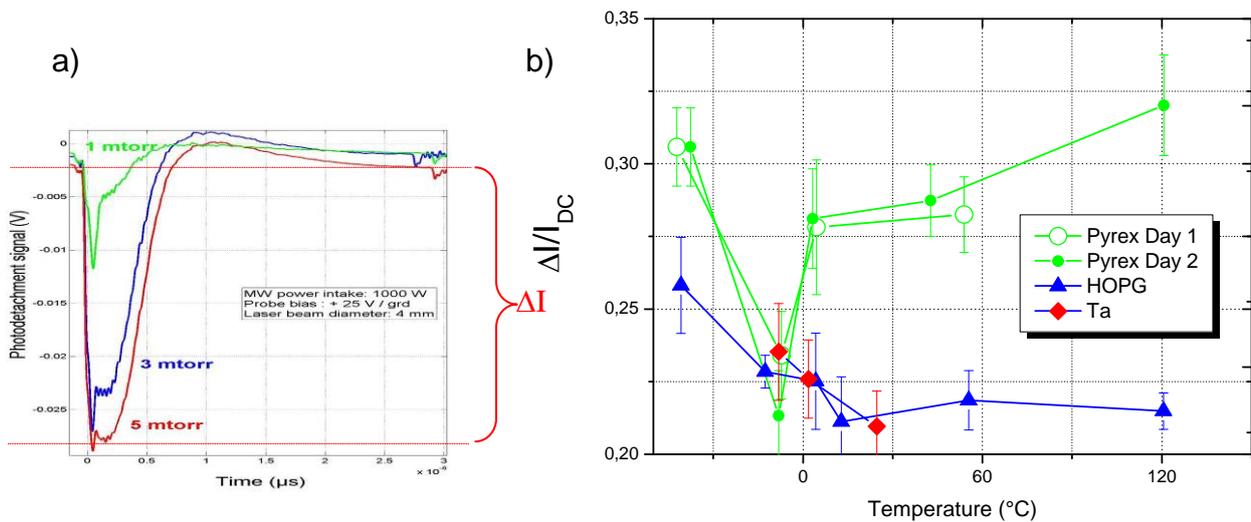
Fig. 2   a) Photodetachment signal obtained at three different pressures (1, 2 and 3 mtorr). ΔI is measured between the baseline and the plateau observed just after the signal overshoot; b) Variations of the $\Delta I/I_{DC}$ ratio with respect to the temperature of the considered sample (Pyrex, Ta or HOPG).

No significant increase of the ratio $\Delta I/I_{DC}$ with respect to temperature or bias have been obtained for HOPG or Ta samples. HOPG is said to be potentially the best candidate to produce excited molecules $H_2(X^1\Sigma_g^+, v'')$ via recombinative desorption mechanisms [3]. However, sticking (of H atoms on the surface) and impinging with low energy atoms (0.5 eV) coming from the plasma have to be achieved prior to the recombinative process. In a second step, excited molecules have to be converted into negative ions via dissociative attachment (*D-A*) with cold electrons. At different potentials (-70 V to +10 V) no significant modification of the ratio $\Delta I/I_{DC}$ occurs as mentioned by Schiesko *et al.* [4]. Tantalum sample does not produce a variation of this ratio as indicated by Bacal *et al.* [5] for Ta evaporation inside Camembert III reactor when operated with filaments. Behaviour of Pyrex sample is much more interesting. For this sample, even for the small surface considered (0.007 m² with respect to 0.16 m² for the whole Pyrex surface facing plasma) we have recorded an increase of 45 % (between 0.22 and 0.32) when its temperature increases from -10 °C up to + 120 °C. Results presented in Fig. 2b could be interpreted by a variation of the recombination coefficient of H atoms (γ_H) on Pyrex surface that is totally different for metals. For Pyrex and quartz, results obtained by Wood *et al.* [6] indicate a huge variation of the γ_H coefficient with respect to the surface temperature. γ_H decreases to a factor 5×10^3 if temperature decreases from 500 K to 125 K and increases to a factor 100 if temperature still decreases. On the contrary, recombination coefficient γ_H is not modified with respect to the temperature within a range of 700 ° (300 K – 1000 K) for metals except for Au and Pt [6]. In our experimental conditions, even though the production of negative ions requires a two step mechanism (production of $H_2(X^1\Sigma_g^+, v'')$ molecules followed by D-A reaction), the production of excited molecules of high quantum number as stressed by Amorim *et al.* [7] is large enough to increase the negative ion density of the plasma contained inside the Pyrex cylinder.

References:
[1] A. Lacoste, T. Lagarde, S. Béchu, Y. Arnal, and J. Pelletier, *Plasma Sources Sci. Technol.* 11, (2002) 407
[2] C. Courteille, J. Bruneteau, F. P. G. Valckx, Z. Sledziewski, M. Bacal, *Rev. Sci. Instrum.* 64, (1993) 3265
[3] X. Sha, B. Jackson, D. Lemoine *J. Chem. Phys*. **116**, (2002) 7158-7169
[4] L. Schiesko, M. Carrere, G. Cartry, and J. M. Layet, *AIP Conference Proceedings* **1097** (2009) 84.
[5] M. Bacal, A. A. Ivanov Jr, M. Glass-Maujean, Y. Matsumoto, M. Nishiura, M. Sasao, M. Wada, *Rev. Sci. Instrum.* **75** (2004) 1699-1703
[6] B. J. Wood, H. Wise, Interaction of atoms with solid surfaces, Edit. Talbot: Rarefied gas Dynamics.
[7] J. Amorim, L. Loueiro, D. Schram, *Chemical Physics Letters* **346** (2001) 443-448