Fusion Engineering and Design xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

# Exposure of liquid lithium confined in a capillary structure to high plasma fluxes in PILOT-PSI—Influence of temperature on D retention

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ARTICLE INFO

*Article history:*
Received 30 December 2015
Accepted 9 August 2016
Available online xxx

*Keywords:*
Hydrogen retention
Deuterium retention
Liquid lithium
Capillary porous system
CPS
Fusion energy
Liquid metal

ABSTRACT

Experiments on deuterium retention on liquid lithium confined in a capillary structure followed by *ex-situ* thermal desorption spectrometry (TDS) at high plasma fluxes ($\sim 10^{23}$ m$^2$ s$^{-1}$) and high temperatures (440 °C and 580 °C) have been performed. Deuterium plasmas were generated at the PILOT-PSI linear plasma device and the targets were a 30 mm diameter stainless steel disc, 5 mm thick, covered with a porous mesh and filled with lithium. The settings (current) of the plasma source were varied in order to get different sample surface temperatures during irradiation. The targets were kept at floating potential during the exposure. Hydrogen and Li emission signals were monitored during the plasma exposure and TDS analysis was made afterwards in a separated system.

Decreased retention at high exposure temperatures was deduced from the analysis of the hydrogen emission signals. Nevertheless, the results from TDS signal analysis were not conclusive.



## 1. Introduction

The use of liquid metals as plasma facing materials for fusion reactors has several advantages with respect to other proposals based on solid materials, as it is the absence of permanent damage by neutron and plasma irradiation among others.

Liquid lithium, due to its high vapor pressure (which means high capacity of cooling the plasma edge by irradiation) and its large heat capacity, seems to be a suitable option in order to achieve a fast removal of the power impinging on the divertor. Also, the contamination of the plasma is expected to be low due to the low Z value of lithium. Moreover, the confinement of liquid lithium in a metallic porous structure, called Capillary Porous System (CPS), would prevent the liquid from splashing in the presence of MHD induced forces and disruptions in Fusion devices. But concerns about tritium retention and elevated vapor pressure still exist.

Extensive work at Ciemat on exposure of hot lithium (200–400 °C) to $H_2$ and $D_2$ atmospheres has proved that under the low pressures existing in the divertor chamber, no irreversible hydride formation takes place [1]. Moreover, no uptake of H in any of its possible chemical states (solved, trapped, bonded) was seen at exposure temperatures above 500 °C [2]. For plasma exposures in TJ-II, precluding D retention on CPS LL limiters requires temperatures between 400 and 500 °C [3], as found in other devices [4]. This relatively low temperature may be associated to unavoidable surface oxidation leading to an enhanced retention but a lower binding energy of trapped hydrogen on Li surfaces [5].

In relation to this, plasma exposures are required to check for any possible temperature dependence of retention. Baldwin et al. get a full uptake of all the incident deuterium ions of the lithium liquid surface, independently of the temperature [6], although the maximum temperature value reached in that experiments was 400 °C.

In this contribution we present the experiments performed in PILOT PSI with liquid lithium confined in a capillary structure, using higher temperatures: 440 °C and 580 °C.

## 2. Experimental

Deuterium plasmas (fluxes $\sim 10^{23}$ m$^2$ s$^{-1}$) were generated at the PILOT-PSI. The plasma-exposed target was a 5 mm thick 30 mm diameter stainless steel disc, covered with a porous mesh. The deposition of lithium on the samples was done *in situ* inside the PILOT-PSI, exposing them to an oven containing 0.53 g of lithium that was heated up to 650 °C. The time evolution of the surface

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http://dx.doi.org/10.1016/j.fusengdes.2016.08.008
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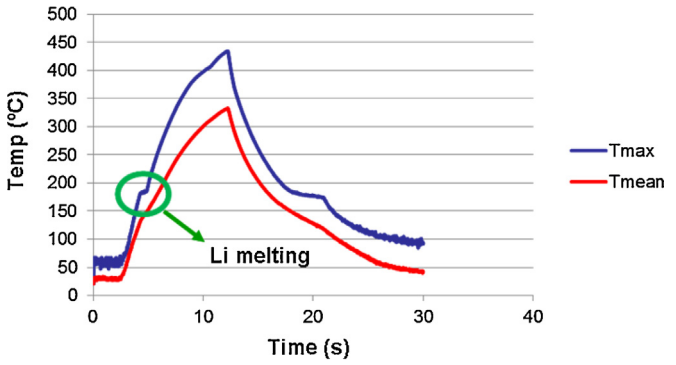


**Fig. 1.** Maximum and mean temperature over time on the surface of one of the plasma exposed lithiated targets. The small plateau observed corresponds to the lithium melting point.

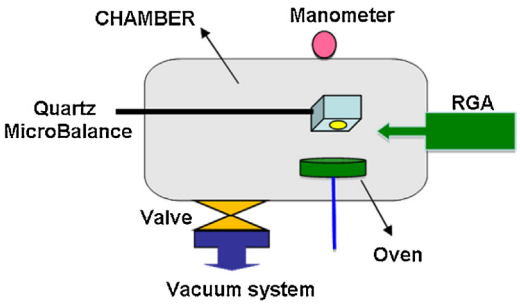


**Fig. 2.** Schematic experimental set-up used in the determination of Li filling conditions of the targets and in TDS experiments.

temperature during the pulse was monitored by a fast infrared camera. The surface temperature of the sample rises with time until reaching a *plateau* around 440 °C and 580 °C respectively during the 5–10 s pulses with a total exposure time of 38 s. The targets were kept at floating potential during the exposure. Hydrogen and Li emission signals (656 and 671 nm respectively) were monitored during the plasma exposure and TDS analysis was made afterwards.

Details of the PILOT-PSI facility have been presented elsewhere [7]. The full-width at half maximum (FWHM) of the plasma beam was 12 mm. From the profiles of $n_e$ and $T_e$ measured with a Thomson scattering system the fluxes at the targets were determined, asuming the ions were accelerated to the sound speed at the sheath entrance (Bohm criterion). The settings (current) of the plasma source were varied in order to get different sample surface temperatures during irradiation. In our case, the balance between the incoming power flux from the plasma and the cooling efficiency of the water cooling system from the back side of the samples, was not enough to control the surface temperature of the target, (see Section 3.1) thus, the 2nd pump was switched off. This way, the increased pressure raised the ratio of the neutral to ionized particles in the plasma, producing a decrease in the flux reaching the sample, and hence, a decrease of the target temperature. The targets were exposed to plasmas during 5–10 s per pulses with a total exposure time of 38 s. The time evolution of the surface temperature during the pulse was monitored by a fast infrared camera (Thermosensorik GmbH, Model CMT 256MHS), which measures IR radiation in the wavelength range 3–5 mm. The frame rate of the camera was set to 14 kHz. The emissivity used for the temperature conversion is found in Ref. [8]. In our experiments, when lithium is present in the sample, a slight delay in the rising of the temperature with time was observed (see Fig. 1), and it was attributed to the Li melting process. That temperature was used in order to set the emissivity of the lithium surface, so the emissivity parameter of the IR camera was adjusted as to measure at that point the value of the lithium melting point, 180.5 °C. The accuracy of IR temperature measurements was corroborated by the lithium evaporation signal obtained in the experiments as it is explained below.

The peak surface temperature was also measured in situ with a multi-wavelength spectroscopic pyrometer (FAR SpectroPyrometer model FMPI) that measures a spectrum from 1000 to 1700 nm, with a resolution of 1.56 nm.

Plasma exposed targets: Different targets were used in the experiments; all of them were kept at floating potential during the exposure:

1. Wtarget: 30 mm diameter pollycrystalline tungsten disc, 5 mm thick.
2. PorousTarget: 30 mm diameter TZM disc, 5 mm thick, covered with a SS porous mesh with pore sizes of 200–800 μm.
3. LiWtarget: Lithium deposited in Wtarget.
4. LiPorousTarget: Lithium deposited in PorousTarget.

The deposition of lithium was done *in situ* inside the PILOT-PSI, exposing Wtarget and PorousTarget for 30 min to an oven (3 cm SS cylinder heated by a thermocoax) containing 0.53 g of lithium that was heated up to 650 °C and completely evaporated in order to get a complete filling of the sample with 0.33 g of Lithium.

The time of evaporation and the temperature of the oven were determined in a previous laboratory test at CIEMAT, using a Quarz Microbalance (QMB) to measure the thickness of the lithium deposited layer. The QMB was placed facing the oven containing an excess of lithium (not all the lithium evaporated condenses on the target) at the same distance as the oven-target distance in PILOT-

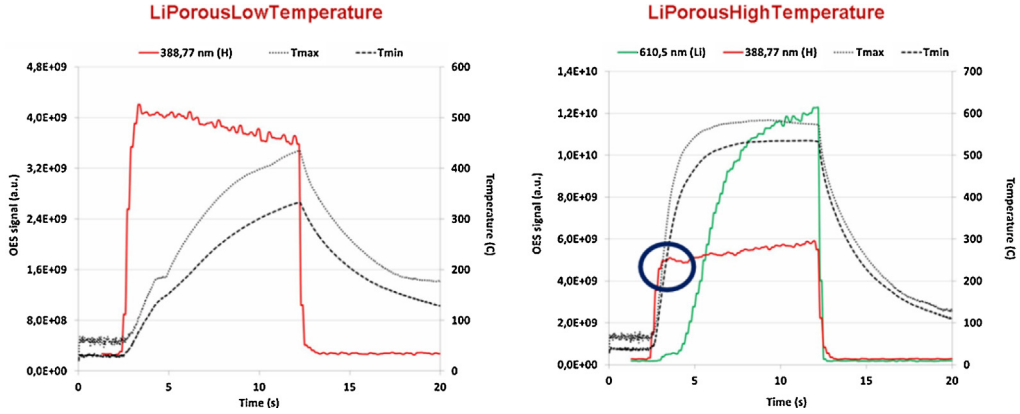


**Fig. 3.** Evolution of target temperature and emission intensities during the exposure.

Please cite this article in press as: A.B. Martin-Rojo, et al., Exposure of liquid lithium confined in a capillary structure to high plasma fluxes in PILOT-PSI—Influence of temperature on D retention, Fusion Eng. Des. (2016), http://dx.doi.org/10.1016/j.fusengdes.2016.08.008