ION BEAM STUDIES OF DEUTERIUM RETENTION IN HIGH ENTROPY ALLOYS AND W TARGETS IN THE PF-1000U FACILITY

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The demands of materials proposed for nuclear fusion applications are based on high radiation hardness and low activation. Actually, W is being used as plasma facing material [1] and High Entropy Alloys (HEAs) were proposed as thermal barriers interlayers between W and heat sink parts [2]. It is a demand to study the chemical and morphological modifications induced by plasma discharges in fusion grade materials to evaluate their behaviour under operational or accidental scenarios. In the IAEA research contract with IST under the frame of the CRP F13020 project [3], target samples with mirror quality surfaces are being irradiated in the plasma focus PF-1000 U at the IFPiLM institute in Warsaw, Poland [4], with intense deuterium plasma stream discharges. Virgin and as-irradiated samples are characterized before and after exposition by electron microscopy, namely by scanning electron microscopy (SEM) and, particularly, by ion beam analysis (IBA) at IST, Bobadela, Portugal [5], involving proton induced X-ray emission (PIXE) to investigate any possible heavy or semi-heavy elemental contamination apart the plasma species, elastic backscattering spectrometry (EBS) for other light elemental inspection, and a simultaneous Rutherford backscattering spectrometry (EBS) and nuclear reaction analysis (NRA) to quantify the retained deuterium contents from the NRA protons yields induced by the $^{2}H(^{3}He,p)^{4}He$ reaction [6].

The first irradiation campaign was carried out with two batches of $W_{30}Ta_{17.5}Cr_{17.5}Nb_{17.5}V_{17.5}$ and $W_{20}Ta_{20}Cr_{20}Nb_{20}V_{20}$ HEA alloys produced at IST. Three pairs of samples with mirror quality surfaces (0.8 mm thick, ~1 cm^2) were irradiated simultaneously with 1, 3 and 5 deuterium plasmas discharges of similar power densities and plasma parameters. After five discharges the $W_{20}Ta_{20}Cr_{20}Nb_{20}V_{20}$ target collapsed. The remaining irradiated targets were analysed by SEM, by EBS with a 1750 keV $^{1}H^{+}$ ion beam, and simultaneously by RBS-NRA with 1000 keV and 2300 keV $^{3}He^{+}$ ion beams. SEM images evidenced some blisters, most of them detached from the fully cracked surface in the $W_{20}Ta_{20}Cr_{20}Nb_{20}V_{20}$ alloy after 1 and 3 discharges, with no visible morphological evolution. The $W_{30}Ta_{17.5}Cr_{17.5}Nb_{17.5}V_{17.5}$ surfaces present blistering and superficial swelling after 1 discharge with additional fracture and zoned melting afterwards (see Fig. 1). In opposition to SEM, RBS-NRA quantifications evidenced an extremely low deuterium retention in the irradiated surfaces (see the example of NRA $^{2}H(^{3}He,p)$ yields with corresponding fit lines achieved from quantification in Fig. 2a and 2b). Despite a huge increment of deuterium after successive discharges, maximum superficial deuterium areal amounts are similar and lower than 9.0×10^{15} at/cm^2 in both alloys along a depth range of ~1.5 μm. Other elemental contaminations were not quantified in the same surfaces by PIXE and EBS. The results point to a low retention behaviour in the bulk of the HEA alloys under extreme deuterium plasma exposure.

A second irradiation campaign on 8 W plates with mirror quality surfaces (99.95 at.%, 10x10x2 mm^2) is being carried out at PF-1000U comprising: (a) 3 plates exposed to 1, 3 and 5 deuterium plasma discharges at the same power density used for the HEA alloys, (b) 3 plates exposed to 1, 3 and 5 deuterium plasma discharges at a distinct power density, and (c) 2 plates exposed to 1 and 3 discharges

at the same power density used for the HEA alloys using a mixture of deuterium and helium gases (75 % ^{2}H + 25 % ^{4}He). The results will signalize the role of the individual plasma discharges in the W irradiated surfaces.

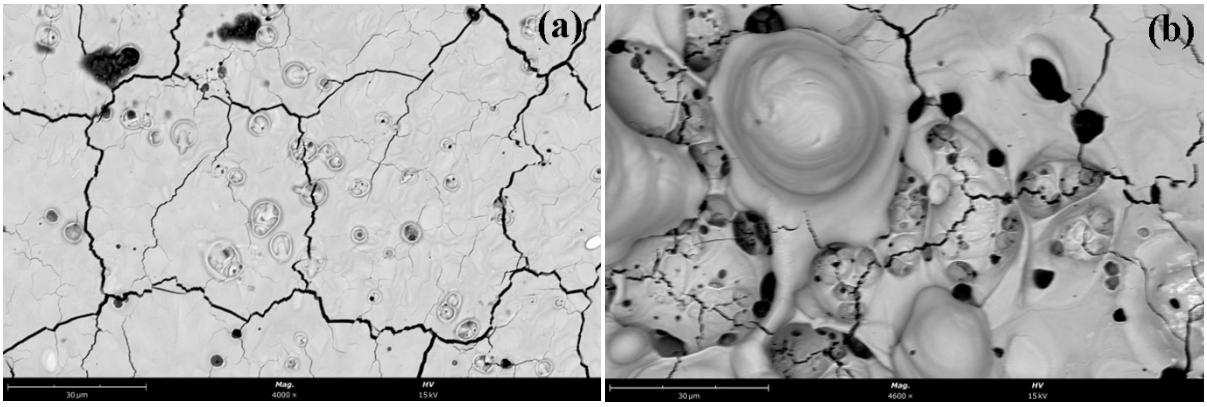

FIG. 1: SEM images of (a) $W_{20}Ta_{20}Cr_{20}Nb_{20}V_{20}$ and (b) $W_{30}Ta_{17.5}Cr_{17.5}Nb_{17.5}V_{17.5}$ after 3 discharges.

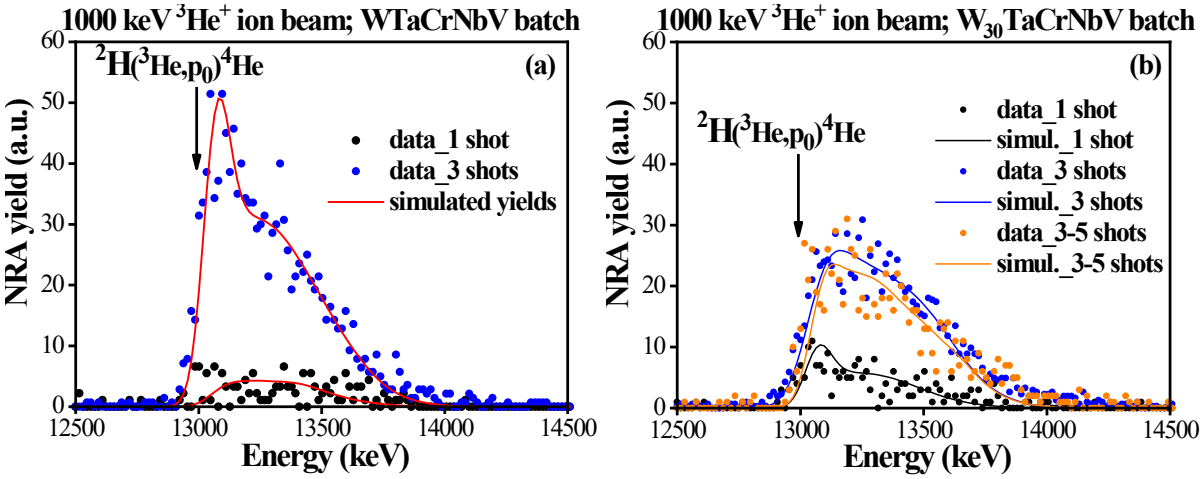

FIG. 2: NRA spectra and corresponding fit lines achieved from the elemental quantification using the NDF code [6]: (a) $W_{20}Ta_{20}Cr_{20}Nb_{20}V_{20}$ and (b) $W_{30}Ta_{17.5}Cr_{17.5}Nb_{17.5}V_{17.5}$ alloy.

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