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Study of deuterium retention in Be-W coatings with distinct roughness profiles

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HIGHLIGHTS

- Development of a deposition technique to produce coatings with distinct roughness profiles within the same composition.
- AFM, SEM and IBA measurements confirm the change of the roughness profiles in pure Be, pure W and mixed Be:W (50:50) coatings.
- The samples were simultaneously implanted by 15 keV deuterium ions up to a fluence of 5e17 ion/cm^2.
- It was not observed a trend caused by the change of the superficial topography. The retained amounts follows the Be content in the coatings.

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ABSTRACT

Three batches of pure beryllium (Be), pure tungsten (W) and mixed Be:W (50:50) coatings were deposited by using the thermionic vacuum arc (TVA) technique. Different superficial roughness and morphologies were obtained by adjusting the bias voltages in the substrate holder. The coatings were irradiated afterwards with 15 keV $^2H^+$ ions up to a fluence of 5e17 ion/cm^2 with the purpose to investigate the influence of the roughness parameters on the retention of deuterium in Be-W deposits in the absence of other co-deposited impurities. Current densities lower than 0.2 W/cm^2 were used to avoid the release of deuterium induced by heating loads. The results of the experiment point to the negligible effect of rugosity on the retention behaviour under energetic ion bombardment.

1. Introduction

The erosion of plasma facing components (PFC) and the migration of impurities during the operation of the International Thermonuclear Experimental Reactor (ITER) will result in the formation of co-deposits on the exposed surfaces with properties distinct from those ones of the original materials. These issues have motivated the research community to investigate the properties of co-deposited Be:W coatings, since in ITER the deposits will present a mixture of beryllium (Be) and tungsten (W). Recent investigations of tiles exposed in the Joint European Torus ITER-like wall (JET-ILW) have shown that the fuel retention in co-deposits highly depend on their roughness and morphologies [1]. Beyond beryllium and tungsten, other impurities as carbon are commonly identified, and this chemical effect can hinders the individual role of the superficial morphologies in mixed Be:W layers on the fuel retention mechanisms.

The tailoring of the topography of Be and W coatings will be a demand in the next future retention experiments. The goal of the present document is to report the activity and investigate the influence of the superficial topography on the retention behaviour of Be:W coatings in the absence of other impurities. The presence of small amounts of oxygen (O) is unavoidable due to the affinity of O to react with Be.

2. Experiment

Three different batches composed by pure Be, pure W and mixed Be:W (50:50) coatings were deposited on mirror quality Si plates by using the thermionic vacuum arc (TVA) method, a plasma deposition technique that avoids the use of any buffer gas [2,3]. The TVA electric diagram used for multi-elemental depositions is described

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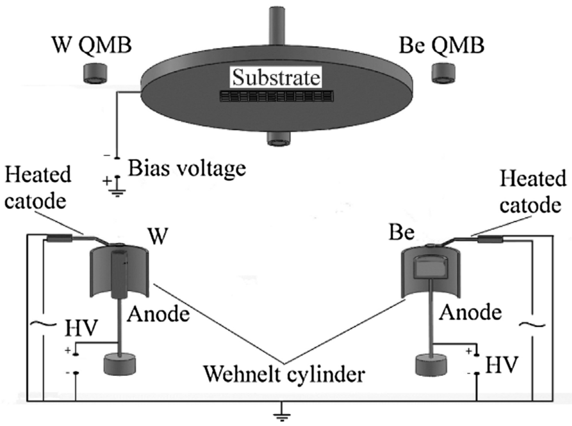

Fig. 1. Electric diagram of the TVA facility.

in Fig. 1. The container of each elemental source is biased with a positive voltage to accelerate negative charged particles and surrounded by a Wehnelt cylinder that focuses an electron beam produced by a circular heating cathode (a tungsten filament). A brief description of the discharge parameters useful to assure plasma ignition are presented elsewhere [2,3]. The elemental deposition rates imposed by plasma exposure on the sampler holder are controlled with quartz balance monitors (QBM). The deposition process is obviously enhanced by biasing the substrate holder with a negative voltage, which increases the energy of incident ions, leading to more compact topographies. In opposition, a positive voltage will reject most of the negative ions and the growth of the deposited layers will be carried out preferentially by neutral atoms. Earlier experiments revealed changes in the final superficial morphology of pure Be coatings by simply adjusting the bias voltage of the sampler holder and by maintaining simultaneously all the other deposition parameters [2]. The calibration of the final morphologies involving Be and other elements is under development. In this experiment three bias voltages were used to deposit Be, W and mixed Be:W coatings: −700 V, 0 V and +400 V.

At the end, the morphologies of nine different surfaces (three within each batch) were evaluated by atomic force (AFM) and scanning electron (SEM) microscopes. All the initial AFM maps revealed granular morphologies homogeneously distributed along the film's surface, being the same trend and topography features confirmed by the SEM images. Finally, four different AFM scans were carried out in each sample with the same tip (probe) and imaging conditions over different areas with dimensions of 10×10, 5×5, 3×3, and $1 \times 1\ \mu m^2$. AFM images with larger scan sizes tend to give higher roughness values due to features related with the detection of both short and long spatial lengths.

The elemental in-depth compositions of the as-deposited and as-implanted coatings were quantified with ion beam analysis (IBA), namely by using elastic (EBS) and Rutherford backscattering (RBS) spectroscopies with incident 1600 keV H^+ and 2000 keV $^4He^+$ ion beams, respectively. Irradiation experiments involving the use of energetic ions are important in fusion research since abnormal plasma instabilities will easily accelerate hydrogen ions towards the divertor [5]. In the present experiment, the retention behaviour of deuterium on the surfaces was investigated by implanting 15 keV $^2H^+$ ions with fluences of 1e17 ion/cm^2 and 5e17 ion/cm^2. The depth range (R_p) and straggling (ΔR_p) of the incident ions on pure Be, mixed Be:W (50:50) and pure W layers were evaluated with the SRIM code [4] to be about 255 ± 47 nm, 140 ± 66 nm and 87 ± 44 nm, respectively, pointing to the final retention of ^2H within the coating's depth. The impinging ionic power densities were maintained lower than 0.2 W/cm^2 in order to avoid heating events. The retained ^2H amounts were evaluated up until 48 h after implantation by nuclear reaction analysis (NRA) using incident 1000 keV and 1500 keV $^3He^+$ ion beams and an NRA detector placed at an angle of 140° relative to the impinging beam direction. The analytical procedure used for IBA was described previously [6–10].

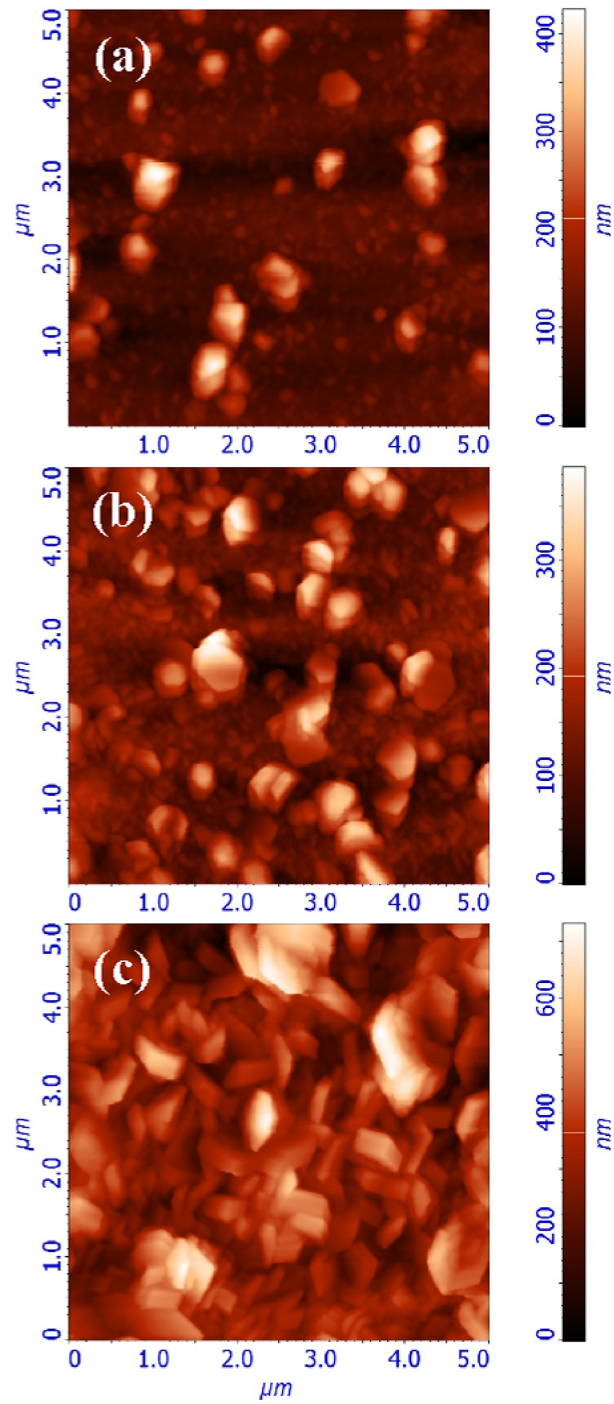

Fig. 2. Two-dimensional AFM maps and topography of the as-deposited Be/−700 V (a), Be/0 V (b) and Be/+400 V coatings (c).

3. Results and discussion

The estimated roughness values were almost the same in each individual surface, whatever the dimension of the scanned