Be COATINGS OF CFC AND W EU TARGETS FOR EXPOSURE TO ITER-RELEVANT TYPE I ELM, AND MITIGATED DISRUPTION LOADS IN PLASMA-GUN FACILITIES TW6-TPP-BECOAT

C. P. Lungu, I. Mustata, A. Anghel, A. M. Lungu, P. Chiru, C. C. Surdu Bob, O. Pompilian

National Institute of Laser, Plasma and Radiation Physics, Magurele

1. Objectives

Production of Be coatings for the 4 W and 4 CFC EU targets to be exposed to ITER-like transient loads on the Russian plasma-gun facilities with the following specifications:

(i) The coating thicknesses to be in the range of 0.05 to 50 µm. This range covers the two extreme cases for Be coverage of the target in ITER. Some elements of the target (~10 mm x 10 mm) may be left uncoated so that they can be used as reference in the experiments.

(ii) The Be coatings of the targets have to be carried out at temperatures in the range of 200-500^{o}C to explore the effect of surface temperature on mixed material formation and its subsequent influence on the behaviour of the coatings under transient loads.

2. Beryllium coatings

Based on the results obtained on the preliminary coatings of thick Be film performed during 2006 at the National Institute for Lasers, Plasma and Radiation Physics (NILPRP) using the existent TVA technology and taking count of the fact that until now the largest thickness of the Be film was 10 µm, it was decided to improve the coating device and the process. In order to assess the main issues of the project's tasks a new evaporation system, suitable for deposition thicknesses in the range of 50 – 100 µm, was designed. A new rotating system for heating the substrates, using molybdenum active elements, to a maximum temperature of 500 ˚C was designed and realized in order to improve the uniformity of the coatings. An automatic control panel of the deposition system was installed in collaboration with experts from NFP.

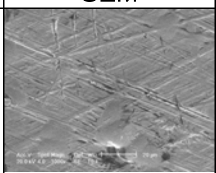
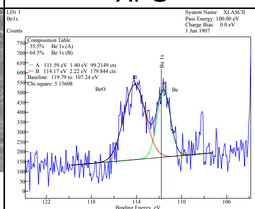
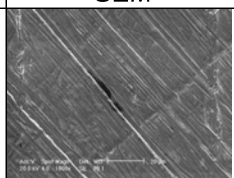
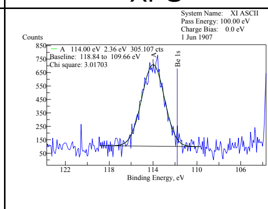
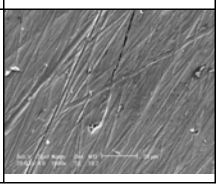
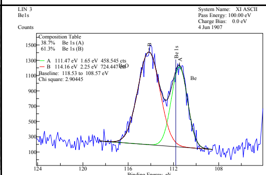
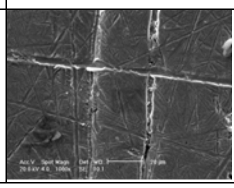
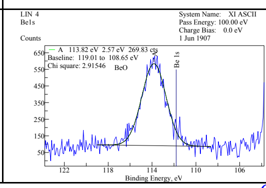
Be film Thick-ness	200^{o}C		500^{o}C	
	SEM	XPS	SEM	XPS
15nm				
54nm				

Figure 1. SEM and XPS analysis of the beryllium films deposited on stainless steel substrates at 200^O C and 500^{o}C, respectively.

According to the time schedule of the project, preliminary Be depositions of 15 nm, 50 nm, 25 and 50µm thickness were prepared on stainless steel and glass substrates at the minimum and maximum temperatures of the 200-500°C interval.

Figure 1 show the Scanning Electron Microscope (SEM) images and Be1s X-ray Photoelectron Spectra (XPS) of the beryllium films deposited at 200°C and 500°C, respectively.

The SEM images showed no significant differences of the surface morphologies of the films prepared at different temperatures. The XPS spectra showed drastic change of the Be1s peak from two Be1s peaks to a single one. Connected with the fact that the film adherence, evaluated by a pulling-test and after discussion with the FZJ Juelich collaborators, it was decided that all beryllium film coatings to be performed at 500°C, the maximum temperature provided by the heating element.

The stainless steel substrates were smooth (2 samples - grinded with #1000 grit paper) and rough (2 samples - sandblasted with ZrO_2 powder of 15-20 µm) and the glass substrates were smooth glass of 0.5 mm in thickness.

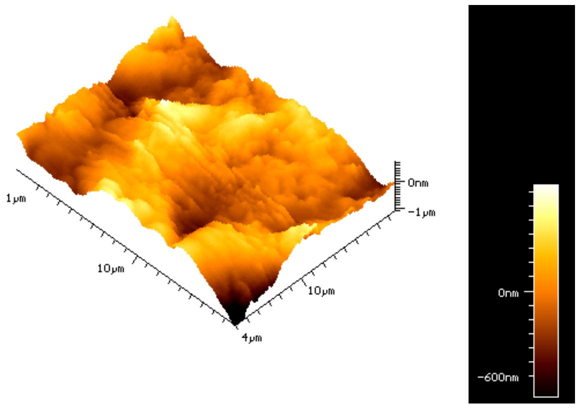


Figure 2. AFM image of Be film deposited on sand blasted stainless steel: R_{rms} = 255,7 nm, R_{abs}=200,4nm

In order to study the morphology of the 25 µm deposited films, AFM measurements were carried out. These measurements revealed the importance of the substrate's smoothness as shown in Fig.2 and Fig. 3.

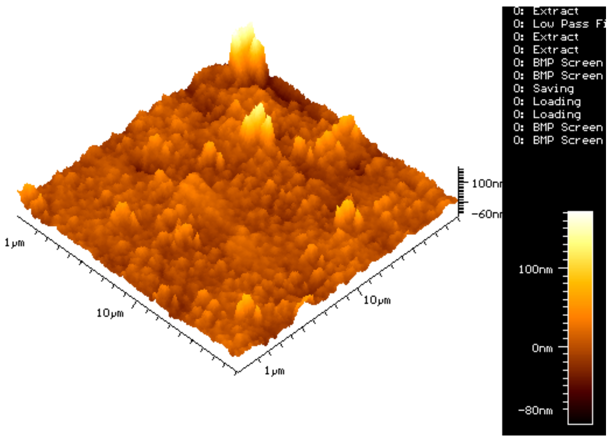


Figure 3. AFM image of Be film deposited on smooth stainless steel: Rrms=19,18nm, Rabs=12,7nm

A comparison of the roughness of Be deposited films obtained by AFM measurements, between the smooth stainless steel substrate and the rough one reveals that even at such thicknesses (25 µm) the substrate roughness influences the roughness of the deposited films.

The adherence of Be films were tested by adhesive tape and pulling test. The stainless steel substrates coated with Be passed the test (Detaching load: 10 N; no delamination under adhesive tape test).

The film thickness was measured by a Mitutoyo stylus profiler and confirmed the measurements performed using an "in situ" quartz balance: Be coatings were in the range of 25+/- 2 µm and 50+/-5 µm.

Disc substrates made of tungsten (30 mm in diameter, 3 mm thickness) were received from FZJ Juelich, Germany and sandblasted at NFP Pitesti. Small test W and CFC samples (30-50) with typical surface dimensions of (10-20) mm x (10-20) mm were coated with Be spanning the range of conditions above. These samples were characterized at FZJ Julich by e-beam loads and will be the basis of the final specifications for the coatings of the EU W and CFC targets.

W discs of 30mm in diameter and 5 mm in thickness (received from FZJ Juelich) were used as substrates for thick Be coatings (50-100 µm). In Fig.4 the heating element and the W substrate holder are presented.

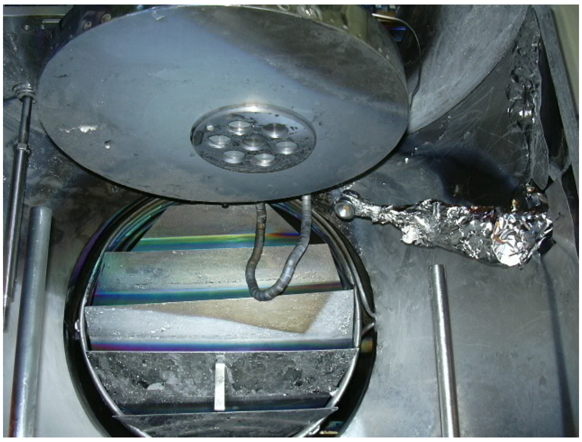


Figure 4. Set-up of the W discs substrate holder and the heating element.

The evaporation of beryllium, using thermionic vacuum arc deposition equipment was performed using the following parameters:

The intensity of the heated cathode filament: 60 A; the potential applied on the anode: 1200 ±50 V; the intensity of the discharge current: 1500 ± 100 mA; Thick Be films were deposited on the W discs, as shown in Fig. 5. The thick Be film deposited on sandblasted W disc presented higher adherence compared with polished W discs.

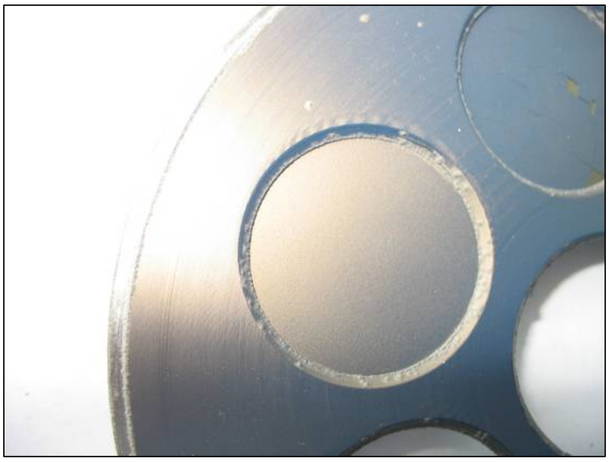


Figure 5. W discs coated with Beryllium.

After discussion with the specialists of the Close Support Unit-Garching, it was decided to perform Be coatings of 10 µm and 100 µm on W and CFC substrates sent by FZJ specialists as follows:

2 Be-coated (10 µm & 100 µm) CFC TARCAR target plate parts (Fig. 6)

2 Be-coated (10 µm & 100 µm) W TARCAR target plate parts (Fig.7)

2 Be-coated (10 µm) CFC coupons

2 Be-coated (100 µm) CFC coupons

2 Be-coated (100 µm) W disk samples

4 Be-coated (10 µm) W disk samples

Fig. 6. Be film (100 µm) deposited on CFC TARCAR target plate parts

Figure 7. Be film (100 µm) deposited on W TARCAR target plate parts

The 100 µm thickness Be films and the bulk Be used as evaporation target were analyzed by XRD (X-ray diffraction). Fig. 7 shows the X-ray diffraction spectra of the bulk Be target used as evaporation material (black curve) and the spectrum of the Be film prepared by TVA method. The XRD spectrum of the bulk Be material shows the characteristic peaks of Be but these peaks are broadened suggesting a disordered structure; On contrary, XRD spectrum of the Be film shows sharp peaks, suggesting a preferred orientation on the Be (002) crystallographic plane. Some peaks of the second phase of BeO also were identified on the bulk Be target spectrum.

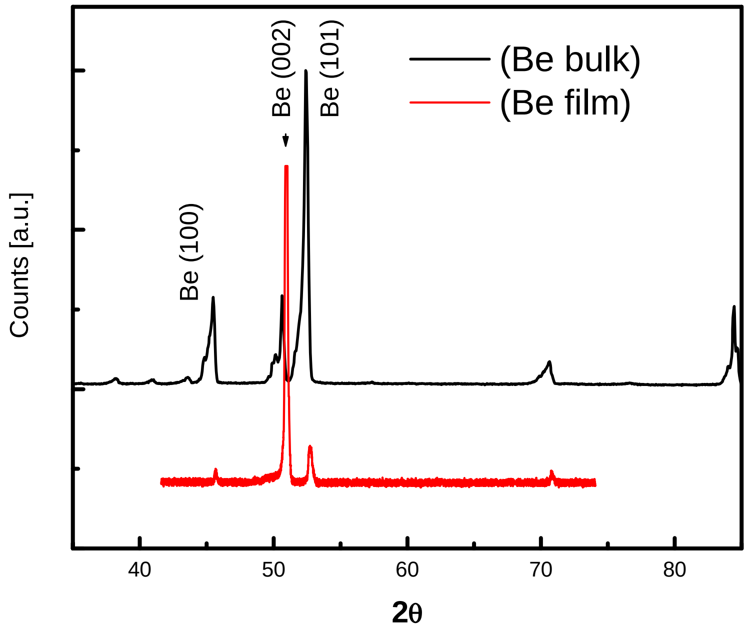


Figure 8. XRD patterns of the thick Be films prepared by TVA methos (red curve) and Bulk Be target used for evaporation (black curve)

Finally the CFC and W TARCAR substrates, CFC coupons and W discs coated with 10 µm and 100 µm Be films were thermally sealed into double polyethylene bags and sent to FZJ Juelich for thermal load tests.

Collaborative actions:

During the project a close cooperation was established between NILPR and FZJ Juelich (Dr. J. Linke and Dr T. Hirai)

3. Conclusions

Based on the results obtained on the beryllium film preparation in the range of 200nm to 8 µm using thermionic vacuum arc method, the coating system was improved by designing and realization of a new evaporation system, suitable for deposition thicknesses in the range of 50 – 100 µm. A new rotating system for heating the substrates to a maximum temperature of 500 ˚C was designed and realized in order to improve the uniformity of the coatings.

Be coatings of 10 µm & 100 µm were performed on: CFC and W TARCAR target plate parts, CFC coupons and W disk samples. The samples were sent to FZJ Juelich for termal load tests.