Project no: PN-II-ID-PCE-2011-3-0522: « Giga and terra-watt laser interaction with carbon, tungsten and beryllium films »

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Scientific report (Abstract)

5 December 2014

OBJECTIVES

1. Study the binary composite films of Be-C and Be-W interactions with the plasma produced by plasma ignited in air due to the high power laser irradiation (TEWALAS)
2. Study the binary composite films of Be-C and Be-W interactions with the plasma produced by plasma ignited in deuterium due to the high power laser irradiation (TEWALAS)
3. Results disemination: presentations to International conferences (2 works) and publications in scientific journals (2 papers)

Introduction

Following some experimental measurements correlated with the reference studies we chosen the optimum conditions for preparation of simultaneous depositions of Be-C and Be-W mixed layers.

We settled the working conditions in order to obtain a relative atomic concentration if the pair components of 50/50.

We realized composite Be-C and Be-W films on fine grain graphite plates of 12 mm x 15 mm x 1 mm. The peak to valley roughness of the substrates was less than 50 nm. We used dedicated TVA evaporators for every material: graphite rods of 10 mm diameter and 100 mm length, while for Be and W evaporators were used rods of 25 mm diameter, 40 mm length for Be, and 10 mm diameter and 100 mm length for W.

The lower part of the rods were kept to low temperature by a water cooling system, while the upper part was bombarded and melted by the focused electron beam.

The principle scheme of the evaporation system using 2 TVA guns is shown in Fig. 1.

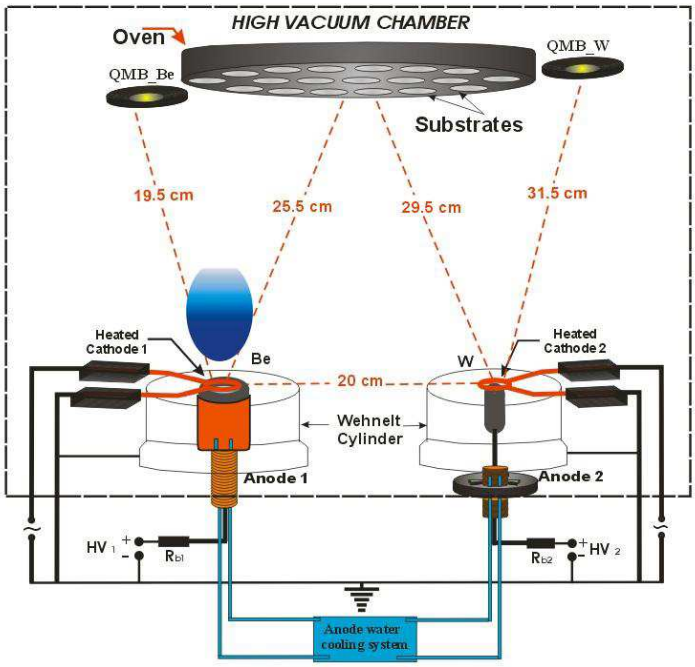


Fig.1 The draw of the evaporation system for simultaneous Be-C and Be-W depositions.

During the year 2014 were performed the following activities:

Preparations of Be-C and Be-W films were performed using the following parameters:

Material	Distance to quartz balance, mm	Distnace to substrates	Discharge voltage, V	Discharge current, A	Deposition rate, nm/s	Residual pressure, torr x 10^{-5}
Carbon	250	240	890	1.8	1.6	1.4
Tungsten	365	230	2300	1.9	0.51	0.5
Beryllium	250	220	1250	1	2.72	0.5

AFM characterization of the prepared films

A typical 3D image of a Be-W mixed films is shown in Fig.2, while in fig 3 is shown the Rq (mean square root) roughness of the prepared films as function of the Be/W ratio. One can be observed a decrease of the roughness when the relative

concentration of W increases in the range of 85 to 25 nm. The same tendency is observed in the case of the Be-C mixed layer, when the Rq decrease from 50 to 41 nm when the C concentration increases, (Figs. 5-6). We conclude that the Be high concentration leads to the roughness increase. Be crystal is growing as oriented crystals perpendicular to the substrate or under a determined angle by the positive ion energy.

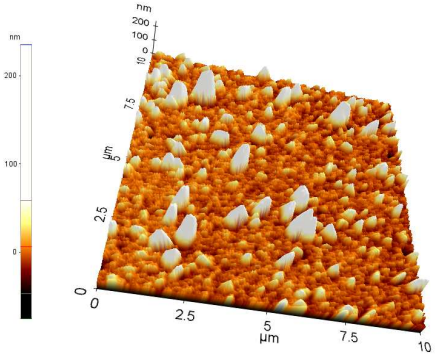


Fig.3 Typical AFM 3D image of Be-W film

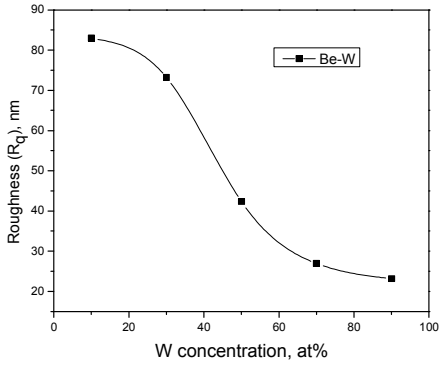


Fig.4 Roughness of the Be-W films as function of W at% concentration

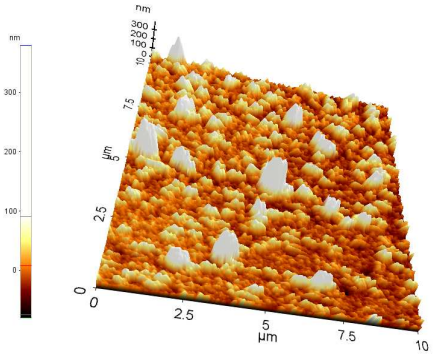


Fig.5Typical AFM 3D image of Be-C film

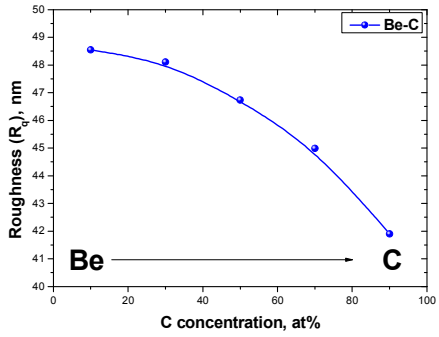
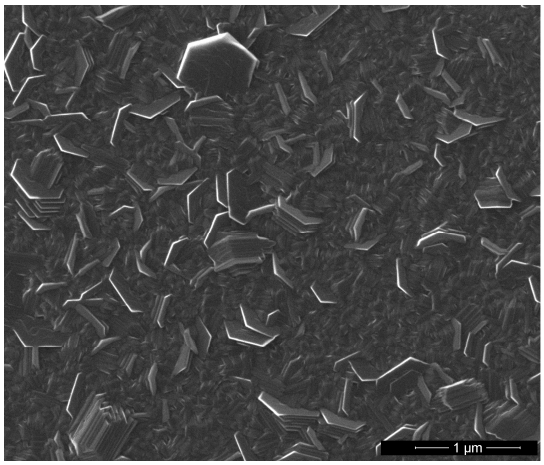


Fig.6 Roughness of the Be-C films as function of C at% concentration

Morphological investigations were performed by Scanning-Electron-Microscopy (SEM) using a “FEI - INSPECT S” microscope. The surface morphology is shown in Fig 7 and Fig. 8.



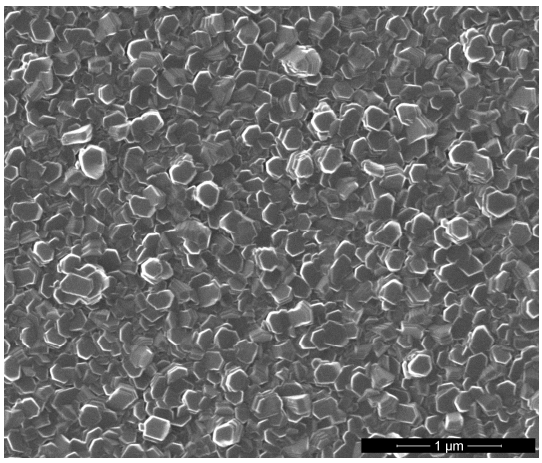


Fig.7 Be-W film morphology analized by SEM Fig.8 Be-c film morphology analized by SEM

Laser irradiation

A femtosecond high power laser at 800 nm wavelength and 100 fs pulse duration was used for a direct irradiation of a Be-C and Be-W targets (Fig. 9). The laser energy per pulse was about 120 mJ, the focused spot size on the target was about 2.8 mm x 150 µm with a Gaussian profile on both 'X' and 'Y' axes.

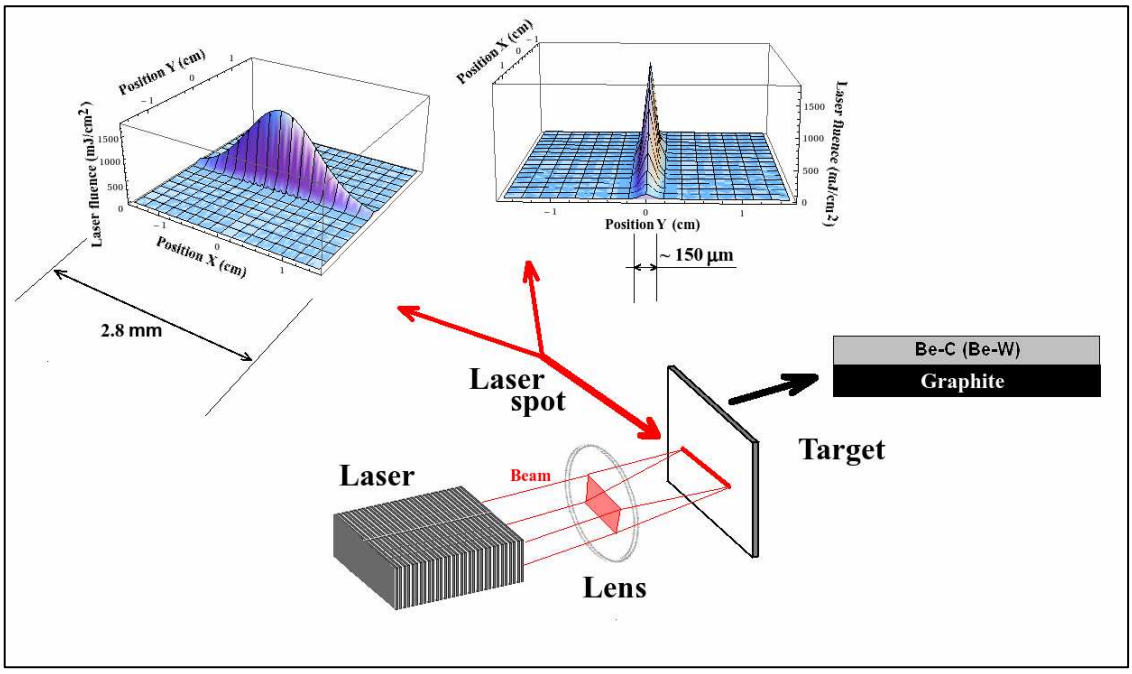


Fig. 9 Schematic draw of the laser irradiation.

The Be-W and Be-C coatings were irradiated by dense plasma formed in deuterium and air by focusing the high power ultra-short laser pulses. The gas breakdown was possible due to the high laser intensity obtained in the focal spot. The laser beam was approximately parallel to the surface, as shown in Fig. 10 (a). The craters created by the plasma on the surfaces are shown in Fig. 10 (b). Their shape is elongated, in accordance with the propagation direction of the beam.

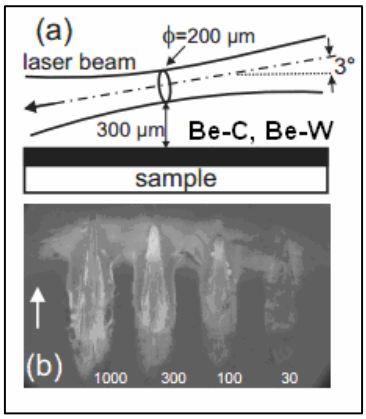


FIG. 10. (a) The laser beam is focused in a spot with diameter φ near the samples coated with Be-C and Be-W mixed films.

Be-C mixed films characterization

Fig. 11 (a) shows the RBS spectra. The energies corresponding to Be, Cand O at the surface are identified by rows, in order to facilitate the interpretation of the RBS spectra. A reduced amount of Be is already quantified in the superficial film. However, the backscattered profiles for Be, C and O did not change too. Nevertheess, the backscattered yields are already compatible with the presence of the Be_2C composition at the Be-C. Afterwards, the Be and C yields evolve very fast. The formation of the car- bide component is clear that the carbide reaction is accomplished by a strong oxidation of the surface, as it is observed from the large increase of the O signal. Most probably Be diffuses through the carbide layer and oxidizes at the surface. This is indicated by the recoil of the carbon peak and movement of the beryllium barrier towards the surface.The

diffusion of C in the substrate is difficult to quantify and hinders the quantification of the elemental profiles.

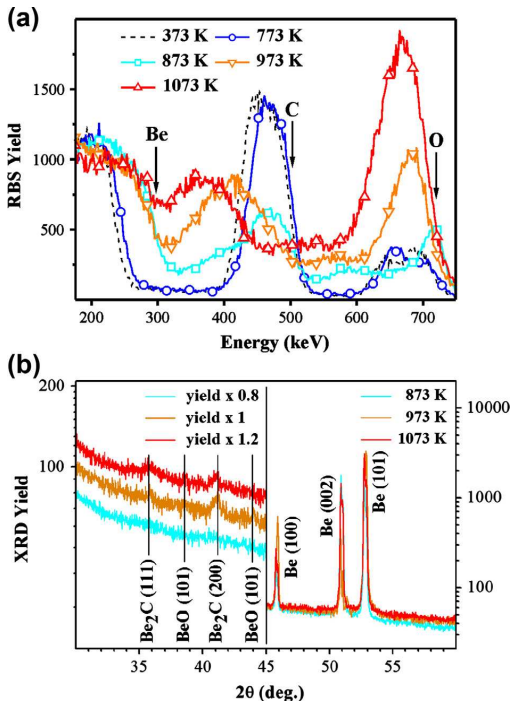


Fig.11.RBS spectra profiles. (a)Be_2C and BeO identification in the XRD patterns (b).

CONCLUSION

From the present results in the Be-C system, it is evident that the formation of Be_2C and BeO phases in the layers will promote by itself the emission of dust particles to the plasma during reactor operation. At the same time, the mechanism could be advantageous for cleaning purposes in PFCs. It is foreseen the use of carbon parts in divertor modules in future tokamaks and a full description of the outcomes arising from a beryllium deposition on the carbon surfaces should be presented in the near future. The possible occurrence of delamination events in the Be/C/O system is also relevant to the fusion community due to the implications for the ITER project.

Disemination

The work performed in 2014 year were disseminated by presentations at the International conferences and publications in ISI ranked journals:

ISI Papers

1	High repetition Rate Laser Ablation for Vapor Liquid Solid Nanowire Growth	2014	CURRENT APPLIED PHYSICS Volume: 14 Issue: 4 Pages: 614-620 (2014)	A. Marcu, F. Stokker, R.R. Zamani, C.P. Lungu, C. Grigoriu
2	Laser beam interaction with carbon-tungsten materials	2014	Journal of Physics: D Applied Physics, Vol. 47, Issue. 35, (2014)	A Marcu, L Avotina, A Marin, C P Lungu, C E A Grigorescu,N Demitri, D Ursescu, C Porosnicu, P Osiceanu, G Kizane, C Grigoriu
3	Mixed film coatings analyzed by micro X-ray fluorescence	2014	Digest Journal of Nanomaterials and Biostructures	M. Lungu, C. Dobrea, T. Craciunescu, I. Tiseanu, C. Porosnicu, I. Jepu, I. Mustata
4	Periodic striations on tungsten and beryllium surfaces by high-power femtosecond laser irradiation of the ambient gas	2014	APPLIED PHYSICS LETTERS Volume: 104 Issue: 10 Article Number: 101604 (2014)	C. P. Lungu, C. M. Ticos, C. Porosnicu, I. Jepu, M. Lungu, A. Marcu, C. Luculescu, G. Cojocaru, D. Ursescu, R. B_anici, and G. R. Ungureanu
5	The behavior of W, Be and C layers in interaction with plasma produced by terawatt laser beam pulses	2014	Vacuum Volume 110, December 2014, Pages 207–212	C.P. Lungu, C. Porosnicu, I. Jepu, M. Lungu, A. Marcu, C. Luculescu, C. Ticos , A. Marin , C.E.A. Grigorescu

Conferences

No.	Title	Year	Type	Conference
1	Femtosecond laser pulse influence on binary mixed Be, W and C layers	2014	Poster	EMRS 2014 Spring Meeting, Lille, France
2	MnGeSb: (Fe, Co) films deposited by PLD on various substrates	2014	Poster	EMRS 2014 Spring Meeting, Lille, France
3	The effect of the substrate temperature and the acceleration potential drop on the structural and physical properties of sic thin films deposed by TVA method	2014	Lecture	14th International Balkan Workshop on Applied Physics, 2-4 July, Constanta, Romania
4	W-Mg alloy films deposited by tva on hydrogenated eurofer substrates for plasma facing components	2014	Oral	14th International Balkan Workshop on Applied Physics, 2-4 July, Constanta, Romania
5	Thermally treated cucofe thin films obtained by TVA method	2014	Poster	14th International Balkan Workshop on Applied Physics, 2-4 July, Constanta, Romania
6	Periodic structures formation on beryllium, carbon, tungsten films mixed films by tw laser irradiation	2014	Lecture	14th International Balkan Workshop on Applied Physics , 2-4 July, Constanta, Romania
7	Preparation and analysis of functional materials	2014	Poster	14th International Balkan Workshop on Applied Physics, 2-4 July, Constanta, Romania
8	Laser influence on multilayer Ag/Ni and Ag/Ce magnetic thin film structures prepared by Thermionic Vacuum Arc technology	2014	Oral	Advanced workshop in nanophysics and solar energy conversion, September 1-3, 2014, Magurele – Bucuresti