Tungsten erosion in the JET divertor
EFDA Task Agreement Code: JW8-FT-JET (MEdC Contribution)

Cristian Ruset, Eduard Grigore, Ion Munteanu, Nicolae Budica
National Institute for Lasers, Plasma and Radiation Physics, Magurele

1. INTRODUCTION

The objective of the project is to measure the net erosion of tungsten on the divertor tiles. Tiles G6, G7, G8, LBSRP and the lamellas of the load-bearing septum replacement plate (LBSRP) have been chosen for this investigation. The method which will be used is that of W markers. The marker layers consist of a tungsten layer at the surface with a thickness of about 5 μm and a molybdenum interlayer with a thickness of about 7 μm. The layers will be deposited at MEdC and then they will be analyzed with ion beam analysis methods at IPP Garching before and after exposure at JET. By this way the erosion of the divertor tiles will be measured in various positions. Sixteen tiles and six W lamellas will be coated with W markers and then they will be installed in JET at different positions.

2. OBJECTIVES

The W/Mo markers had to be applied on CFC tiles coated with 200 μm W by a European company using Vacuum Plasma Spray technology. Due to the serious technical problems with this technology the strategy concerning the W coating of CFC tiles for JET has been changed. It was accepted that a W coating with a thickness of 20 – 25 μm would be enough for divertor. As a result of the High Heat Flux (HHF) tests carried out at IPP Garching in GLADIS ion beam test facility, in March 2009 it was decided that the divertor tiles will be coated by Combined Magnetron Sputtering and Ion Implantation (CMSII) technology.
This change of strategy in the W coating of divertor tiles led to a change of strategy of the Mo/W markers as well. The markers will be applied together with the base coating in the same cycle.
Specific objectives for 2009 were as follows:
a) to identify exactly which tiles to be coated with W markers
b) to establish the appropriate configuration of the Mo/W markers and to optimize the coating parameters in order to get this configuration
c) application of Mo/W markers on G6, G7, G1, G8 tiles

3. RESULTS AND DISCUSSION

a) The decision was taken to apply W/Mo markers on the entire surface of particular G6, G7, G1, G8 and LBSRP tiles. A number of 20 tiles (4 Off of each type) were identified to be coated with W/Mo markers. These tiles are:
G1A W620 51 101 / 2IWG1A 17
G1A W620 51 101 / 25IWG1A 15
G1C W620 51 301 / 14ING1C 19
G1C W620 51 301 / 1 17
G6C W620 56 301 / 2BNG6C 10 / B
G6C W620 56 301 / 3 10 / C
G6D W620 56 401 / 14BNG6D 11 / A
G6D W620 56 401 / 1 10 / B

G7A W620 57 101 / 2ONG7A 2 / B
G7A W620 57 101 / 14ONG7A 2 / B
G7A W620 57 101 / 2 3 / A
G7A W620 57 101 / 3 2 / C
G8A W620 58 101 / 14ONG8A 25
G8A W620 58 101 / 1 21
G8B W620 58 201 / 2ONG8B 21
G8B W620 58 201 / 1 22
LBSRP (RHN) F620 00 001 / LBT01RN 38
LBSRP (RHW) F620 00 001 / LBT04RW 36
LBSRP (LHN) F620 00 002 / LBT14LN 37
LBSRP (LHN) F620 00 002 / LBT02LN 37

In accordance with JET priorities only G6, G7, G1 and G8 tiles had to be coated in 2009.

b) As a result of many discussions the following configuration for Mo/W markers was chosen: 2-3 μm Mo + 12-14 μm W + 3-4 μm Mo + 3-4 μm W. This configuration can be seen in Fig.1 where a SEM fracture of the coating is shown. Both W and Mo coatings are very compact, extremely dense and free of any pores or cracks. This structure can be seen at high magnification in Fig. 2. It is important to notice that the thicknesses of Mo and W layers from Fig. 1 are in a good agreement with the GDOS depth profiles of Mo and W shown in Fig. 3.

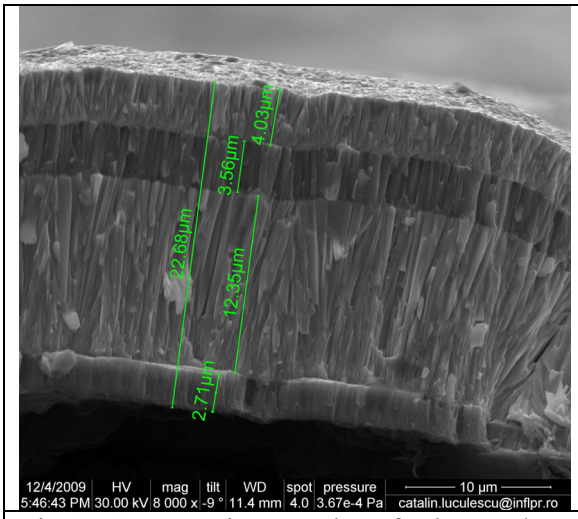

Fig.1 SEM micrograph of the W/Mo markerss

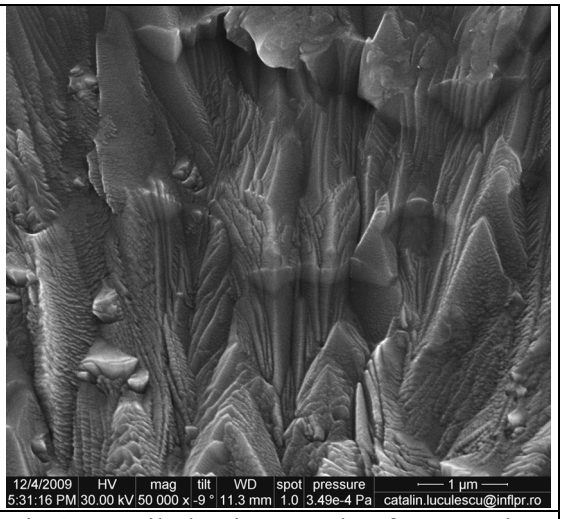

Fig.2 Detailed micrograph of W coating structure

A small surface contamination with O and C can be seen, but this is typical for any sample. A carbon concentration of ~ 1.2 at% appears at the Ti-Mo interface. This is due to the deposition on the titanium sample of some carbon sputtered from CFC in the initial phase of the coating process. The carbon concentration in this area depends on the position of the Ti samples with respect of CFC tiles. The maximum carbon concentration accepted into the coating in accordance with the Specification is 10 at.%.

c) Fifteen tiles (G1, G6, G7 and G8) have been coated with Mo/W markers and delivered to IPP for Nuclear Reaction Analyses. By this method the W and Mo profiles have been measured in a non-destructive mode. The same tiles will be analyzed after the first campaign with the new wall and the erosion rate will be determined. A G1 tile coated with Mo/W marker was successfully tested at HHF in GLADIS ion beam facility at IPP Garching. Two pictures of the G6, G7 G8 and G1 divertor tiles coated with Mo/W markers are shown in Fig.4. The biggest tile G7 has 370 mm in height and 170 mm in width.

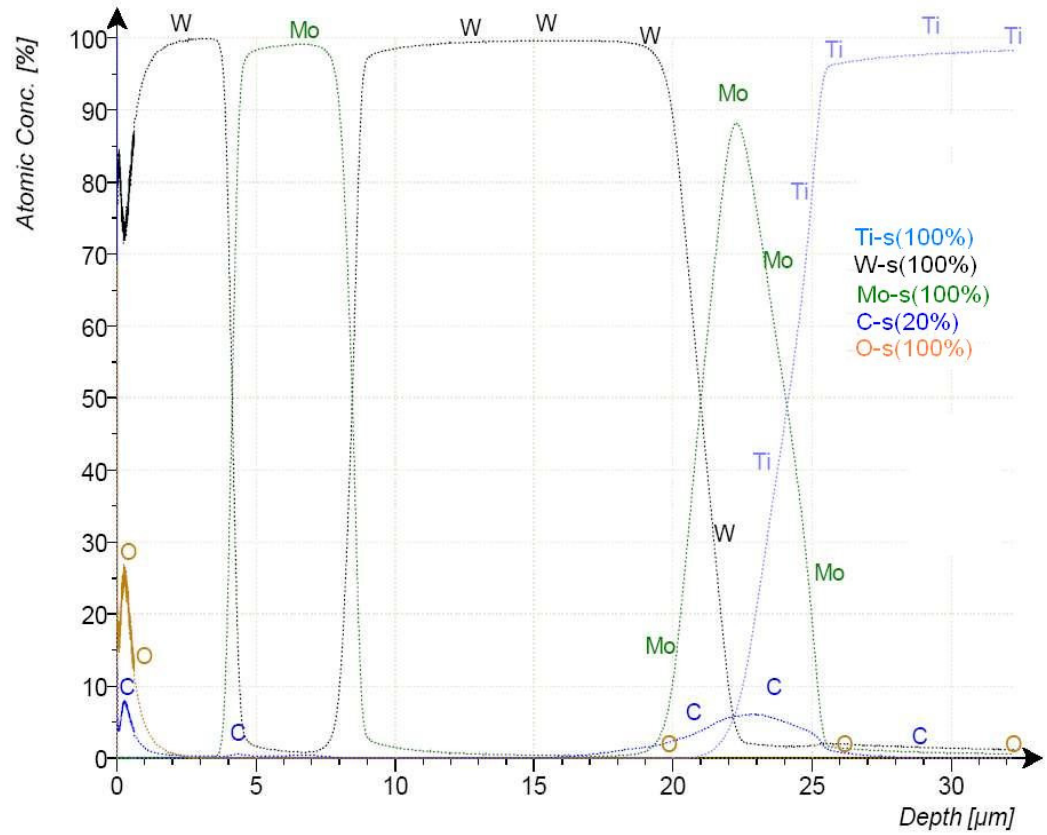

Fig. 3 GDOS depth profiles for W, Mo, C, O and Ti measured for the run IU-147

(a)

(b)

Fig.4 G6, G7 (a) and G8, G1 divertor tiles coated with W/Mo markers.

4. DISSEMINATION OF RESULTS

The structure and the characteristics of the W/Mo markers have been shown in the presentation entitled "Status of W coatings techniques" which Cristian Ruset has given at the 17th European Fusion Physics Workshop which was held at Velence, Hungary on 7 – 9 December 2009. The results concerning the W erosion in JET divertor will be published after the first JET campaign with the new wall.

[1] C.Ruset, E.Grigore, H.Maier, H.Greuner, R.Neu, M.Mayer and G.Matthews, Status of W coatings techniques, 17th European Fusion Physics Workshop, Velence, Hungary on 7 – 9 December 2009.

5. CONCLUSIONS

- W/Mo markers have been applied on tiles G6, G7, G8 and G1. These tiles have been sent to IPP Garching for analyses and then further to JET.
- LBSRP tiles will be coated with Mo/W markers at a latter time in 2010 in accordance with JET priorities.
- No W lamellas have been received yet.

6. COLLABORATIVE ACTIONS

A close cooperation between JET, IPP and MEdC occurred in connection with production and characterization of Mo/W markers.