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Direct comparative test of single crystal and polycrystalline diagnostic mirrors exposed in TEXTOR in erosion conditions

A. Litnovsky[1], G. De Temmerman[2], P. Wienhold[1], V. Philipps[1], O. Schmitz[1], U. Samm[1], G. Sergienko[1], P. Oelhafen[2], M. Rubel[3], B. Emmoth[4]

[1]*Institut für Plasmaphysik, Ass. EURATOM, TEC, Forschungszentrum Jülich, Germany*

[2]*Institut für Physik, University of Basel, Switzerland*

[3]*Alfvén Laboratory, Royal Institute of Technology, Ass. EURATOM-VR, Stockholm, Sweden*

[4]*Dept. of Microelectronics, Royal Institute of Technology, Ass. EURATOM-VR, Kista, Sweden*

Introduction

Metal mirrors are foreseen for ITER optical diagnostics [1]. There are concerns that erosion, deposition and particle implantation can change mirror performance in ITER. The choice of mirror materials is presently of crucial importance. Single crystal candidate materials, such as molybdenum and tungsten are believed to preserve their optical properties under erosion conditions unlike the polycrystalline ones. This was confirmed in laboratory tests [2]. The dedicated experiment was needed to allow the direct comparison of single crystal and polycrystalline mirrors in the tokamak environment. Such an experiment was made in TEXTOR. The parameters in the SOL plasma of TEXTOR are such that ion energy corresponds to the CX neutral energies that are expected to cause erosion of mirrors in ITER [3]. The same time, ion flux densities in the SOL plasma of TEXTOR are much higher than CX neutral flux densities on the first wall of ITER. Therefore, there is an advantage in one day exposure to simulate the effect of several hundreds of ITER discharges.

The experiment consisted of three stages. At the first stage, the optical and surface pre-characterization of mirrors was made in the University of Basel (Switzerland) and in the Institute of Plasma Physics, Research Centre in Jülich (Germany). After pre-characterization the mirrors were exposed in the erosion dominated conditions in the SOL plasma of TEXTOR tokamak in the same plasma environment for series of identical shots. After the exposure, the complete surface and optical characterization was made again.

Mirror pre-characterization.

Three mirrors were used in the experiment: mirror made from polycrystalline molybdenum (PC Mo), mirror made from single crystal molybdenum [110] (SC Mo) and mirror made from single crystal tungsten [111] (SC W). Single crystal mirrors were supplied by Kurchatov Institute, Moscow. In this paper we will focus on the analysis of molybdenum mirrors.

During pre-characterization it was detected, that the SC molybdenum mirror was oxidized during storage in the air. This oxidation caused a drop in the total reflectivity in the UV region down to 35% against 65% described in the literature [4]. Hydrogen discharge cleaning was applied and after 2 exposures for 15 minutes each, the reflectivity of mirror was successfully recovered. Detailed description of cleaning procedure will be given elsewhere.

The optical pre-characterization included measurements of total and diffuse reflectivity in the wavelength range of 250-2500 nm and polarization measurements at several angles of incidence: 45^o, 55^o, 65^o. Polarization measurements were made in the range of 300-800 nm. Surface pre-characterization comprised the X-Ray Photoelectron Spectroscopy (XPS) measurements for elemental analysis of the mirrors and stylus profiling for assessing the planarity and surface curvature of mirrors.

Exposure in TEXTOR

For the exposure all three mirrors were placed in a row on the specially instrumented limiter. The limiter with mirrors was exposed in the SOL plasma of TEXTOR under erosion-dominated conditions in the same plasma environment. 36 NBI-heated plasma discharges were carried out with total duration of 210 seconds. Optical pyrometers were used to monitor the temperature of mirrors. The temperature of the limiter was measured with thermocouples and was varying between 200^oC and 270^oC degrees during the exposure. Electron density and temperature were measured with He beam diagnostic. The energy of D^+ ions impinging the surface of mirrors was in the range of 200 - 250 eV. Ion flux density was $2.4*10^{18}$ion/(cm^2*sec) which is approximately 25000 times larger than expected for flux of CX neutrals on the first wall in ITER [5]. Total fluence averaged over mirror surface was $1.7*10^{20}$ ion/cm^2, which corresponds to more than 1000 ITER discharges. The limiter with mirrors after the exposure is shown on Fig. 1.

Effect of erosion on single crystal and polycrystalline mirrors

The total reflectivity of mirrors was measured after exposure on the same locations as before it. The results are shown in Fig. 2. The total reflectivity of both mirrors didn’t change much under erosion conditions. In turn, the effect of erosion on diffuse reflectivity was dramatic. The dependence of diffuse reflectivity on wavelength is plotted on Fig. 3. For the

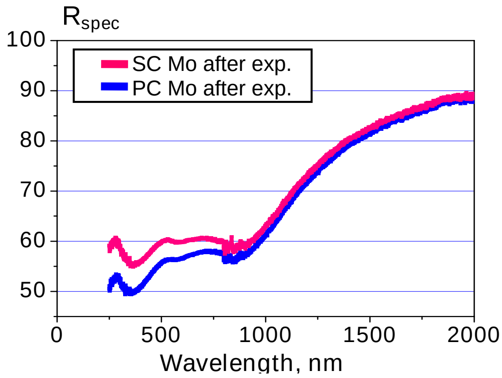

Fig.4. Specular reflectivity of molybdenum mirrors after exposure

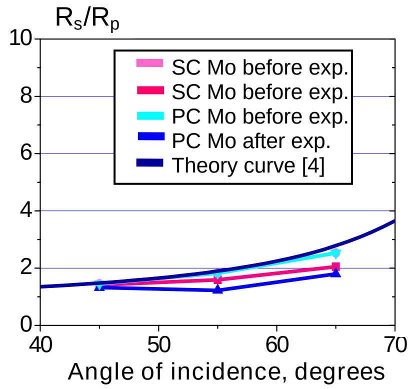

Fig.5. Polarization at different angles of incidence. R_p and R_s are parallel and perpendicular components of light vector respectively.

Summary

First direct comparative test of single crystal and polycrystalline diagnostic mirror materials under erosion conditions has been made in TEXTOR. Before exposure in TEXTOR, glow discharge cleaning has efficiently restored the reflectivity of initially oxidized mirrors. After the exposure, no significant changes in total reflectivity were observed. Drastic increase of diffuse reflectivity was measured for polycrystalline molybdenum mirror, but not for the single crystal. Thus, specular reflectivity of single crystal is significantly higher than of polycrystalline one. The most affected wavelength range is 250-1000 nm, no significant changes of reflectivity was noticed in the range 1000-2000 nm. No or negligible effect of erosion on polarization characteristics of mirrors was measured.

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