IMAGE QUALITY AS A POSSIBLE METHOD OF IN SITU MONITORING THE IN-VESSEL MIRRORS

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The plasma facing mirrors (FM) in ITER will be subjected to sputtering and / or contamination with the rates depending on mirror locations. The result of influence of both these factors will be reduce of mirror reflectance (R) and worsen the quality of transmitted image (IQ). This implies that control of the mirror quality *in- situ* is an actual problem, and this work is an attempt to approach to its solution. The method suggested for evaluation of IQ was applied to mirrors exposed in LHD, TRIAM-1M, TS and in the DSM-2 stand (IPP NSC KIPT).

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INTRODUCTION

The degree of impact of sputtering and deposition will depend on locations of elements of optical system in a vacuum vessel. The sputtering of mirror results in irreversible changes of its optical properties (OP). However, if contaminated, e.g., with a carbon film, the mirror can be recovered to the initial OP, using some efficient method of cleaning.

The goal of this work: to investigate, to what degree the specular component of reflected light survives in the course of mirror degradation due to deposition of contaminating film and long-term sputtering.

The structure of paper is as follows: in section 1) the results of *ex- situ* measurements of OP (R, IQ) of mirrors exposed in fusion devices LHD, TRIAM-1M, and Tore Supra (TS) are presented; in section 2) the results of laboratory experiments carried out in IPP NSC KIPT are described. The stand for measurement of R over the range of wavelengths 220…650 nm was assembled using the optical scheme described in [1]. The optical scheme of IQ stand is shown in Fig.1.

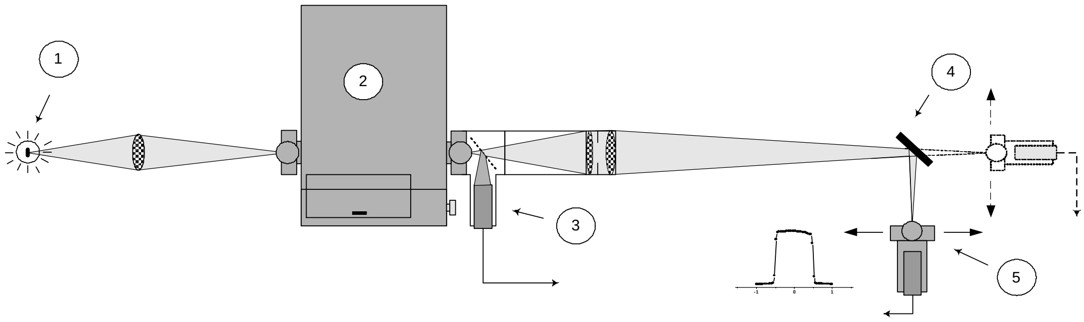


Fig. 1. The optical scheme for measuring IQ: (1) - light source, (2) - monochromator, (3) – reference signal, (4)- test mirror, (5) - scanner of the enlarged image of the monochromator exit slit

1. OPTICAL RESEARCHES OF MIRRORS EXPOSED IN LHD, TRIAM-1M, TS

1.1 LHD. In the 7-th (2003-2004) experimental campaign three stainless steel mirrors (SS316) were exposed in locations, shown in Fig.2.

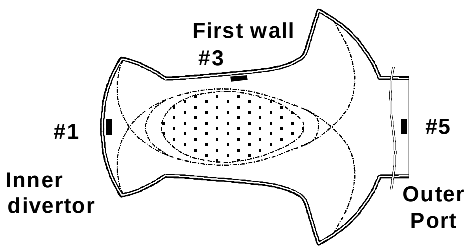


Fig. 2. Lay-out of samples in vessel LHD

All samples were not protected from impact of glow-discharge plasma during conditioning and boronization procedures with total duration many times exceeded the total duration of working discharges. The observed IQ data are presented in Fig.3.

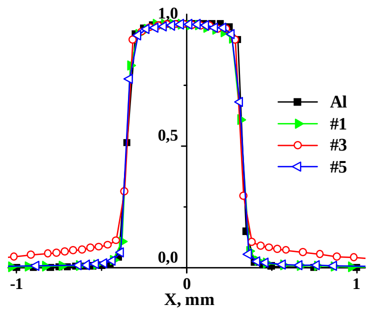


Fig. 3. IQ normalized for LHD-samples

The presented distributions characterize the quality of the obtained information in the case that such mirror would be used for a diagnostic aim. It is seen that IQ for sample #3 does not completely coincide with that of an ideal (Al / quartz) mirror. The wings of distributions correspond to the diffusive component of R, and are connected with structural changes of the mirror surface. The analysis of the state of samples with the help of an optical microscope has shown the presence of feebly marked grain structure on the mirror #3 surface, without any trace of deposition. Therefore, the appearance of wings has to be attributed to the light scattering on the arisen surface roughness. The samples #1 and #5 with the deposited film of not known yet chemical composition, did not show any apparent deviations from IQ for an ideal mirror.

1.2.TRIAM-1M. In the vessel of this tokamak five mirror samples were installed: one monocrystalline Mo (mc-Mo) and polycrystalline samples. After exposure, some deposited film on all samples was detected resulting in decrease of reflectance. The procedure of studying the samples comprised in multi-step cleaning of their surface in a deuterium ECR discharge plasma. After every single exposure, the measurements of R and IQ were carried out. In Fig.4 the IQ data are presented.

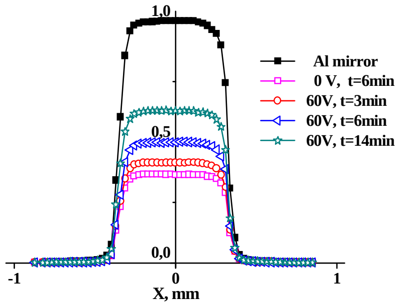


Fig. 4. Recovery of reflectivity (IQ method)

The normalized data of IQ for Mo and SS samples have shown the complete accordance with an ideal mirror.

1.3. Tore Supra. The experiment at TS was provided with two mirror samples of every of three metals: (mc-Mo), pc- samples SS and oxygen free Cu. The mirror samples were installed on the high field side of the vessel for long-term exposure (2003-2004). The detail description of TS experimental conditions is in [2, 3].

Total exposure a cumulated pulse length of working discharges (D_2) reached ~7.2 h. Wall conditioning was provided by glow discharges in He (362 h) and D_2 (606 h) and also ~13 h of boronization.

1. Mc-Mo. Erosion depth (ED) ~ 0.12 µm. The decrease of reflectance was connected with appearance of contaminating film (C, B, O, H, D) of ~12 nm thick.

2. SS. ED ~ 0.22 µm. Slightly noticeable surface roughness and corresponding diffusive component in reflected light appeared.

3. Cu. ED ~2.5 µm and the topography was drastically changed.

The observed data on IQ of the listed above mirrors are given in Fig.5.

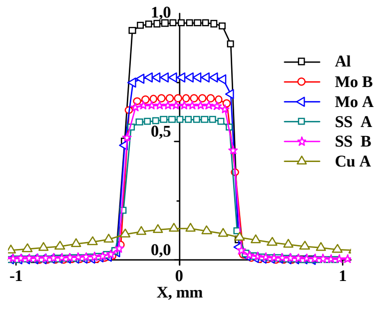
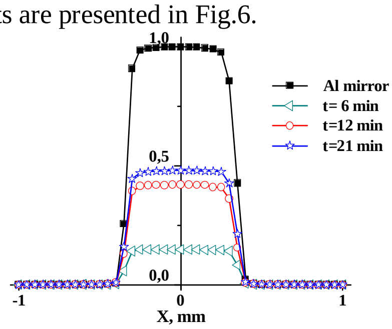


Fig. 5. IQ for TS samples

2. LABORATORY STUDY OF FILM-COATED AND SPUTTER-ERODED MIRRORS

2.1 Film-coated mirror. One factor of reflectivity degradation of the in-vessel mirrors is the deposition of contaminating films, e.g., carbon. For clearing up their role, we investigated the effects of such films deposited in an arc discharge with graphite electrodes on the surface of mc-Mo (110) and SS samples. The thickness of films varied from 30 to 50 nm. After cleaning the sample surface by plasma of an ECR discharge in deuterium, during several short (3-5 minutes) exposures without supplying any potential, the sample was taken out and the measurements of R (in the range λ=250…650 nm) and IQ (at λ=550 nm) were carried out. The results of these measurements are presented in Fig.6.



Fig, 6. Evolution of IQ by cleaning procedure

The normalization of this initial distributions, demonstrates a quite good coincidence with a control Al mirror.

2.2 Sputter-eroded mirrors. For FMs of some diagnostics in ITER will be important not only how they transmit the amplitude of signal but also what quality is the image of plasma or the surface of inner components transmitted by given mirror system. Without high IQ, there is a problem of adequate interpretation of optical measurements, e.g., the radial distributions of plasma radiation because the effect of diffusive part of R should result in losses of an image contrast. That is why, important is to investigate IQ depending on the rate of sputter erosion of mirror and deposition of contaminants. For experiments the pc Cu and SS mirrors were chosen.

The single step sputtering mirrors was carried out in series, using an ECR discharge in a simple double-mirror magnetic trap (DSM-2). The time varying negative potential was supplied to the sample holder what provided a wide energy distribution of ions bombarded the mirror surface in the range 30-1500 eV.

2.2.1. Copper samples. For clearing up of effect of grain size of a surface mirror on optical properties copper samples have been selected with small-grain (S-G)~ 50…120 µm and large-grain (L-G) ~ 500…1500 µm. Observed data for Cu S-G, as example, are shown on Fig.7.

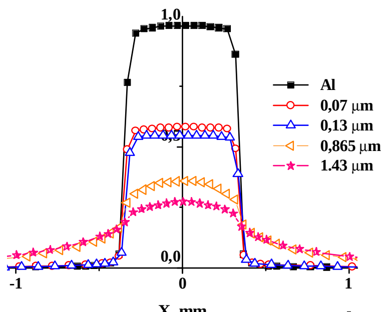


Fig. 7. IQ at sputtering Cu S-G sample

It is obvious, that the diffusive part of a reflected light increases and the specular part decreases with increasing the thickness of sputtered layer. A crude calculation of the specular (SR) and diffusive (DR) parts of reflectivity is possible by comparison of the areas under the distribution curve in a central part and in wings.

The dynamics of ratio of SR and DR parts in depending on the sputtered layer thickness is shown in Fig.8.

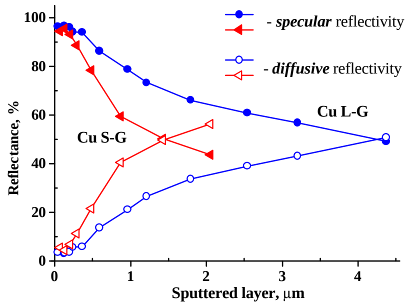


Fig. 8.The ratio of SR and DR components of a reflectivity under sputtering Cu-SG and Cu-SG samples

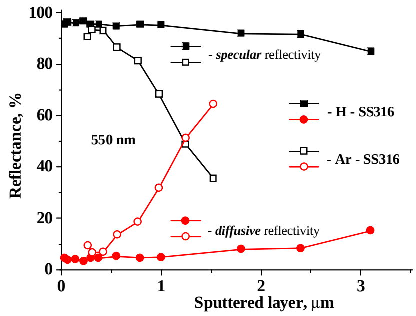


Fig. 9. The ratio of a SR and DR components of reflectivity under sputtering SS samples

2.2.2. Stainless steel samples (SS316). As it is known, for conditioning of vacuum chamber a glow discharge with different gases is used. Therefore, it is interesting to compare the effects of different gases on IQ at equal values of sputtered layer thickness. In our experiments the comparison was made for hydrogen and argon working gases. Results are given in Fig.9.

One can see a very surprising fact of not equal behaviour of IQ on sputtered layer thickness for the same material of a mirror for ions of H and Ar plasmas.

3. CONCLUSIONS

1. The optical properties of mirrors long-term exposed in LHD, TRIAM-1M, Tore Supra and mirrors advisedly coated with a carbon film or sputtered in a laboratory stand were measured. It is shown, that the contaminating film (≤ 50nm) practically does not influence the IQ properties, but results in decrease of R only.

2. Under sputtering of polycrystalline materials, accordingly, the IQ characteristics fall down. With that, dynamics of ratio of specular and diffusive parts of the total reflectivity was investigated.

3. The procedure of measurement of IQ principally enables to distinguish between the reasons of deterioration of mirror quality. In all cases investigated, the deterioration of IQ occurred due to development of a surface roughness but not due to contaminating film.

4. By modernization of suggested scheme of IQ measuring, it would be possible to make an *in-situ* remote monitoring of the quality of in-vessel mirrors in fusion devices of the ITER scale.

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КАЧЕСТВО ПЕРЕДАВАЕМОГО ИЗОБРАЖЕНИЯ КАК ВОЗМОЖНЫЙ МЕТОД МОНИТОРИНГА IN SITU ЗЕРКАЛ, НАХОДЯЩИХСЯ В ВАКУУМНОМ ОБЪЁМЕ

В.Г. Коновалов, М.Н. Махов, А.Н. Шаповал, Н. Ашикава, С. Масузаки, А. Сагара, Д.И. Найденкова, И.В. Рыжков, А.Ф. Штань, С.И. Солодовченко, В.С. Войценя

Первые зеркала в установке ITER будут подвергаться распылению и / или загрязнению. Это приведёт как к снижению отражательной способности (R), так и к ухудшению качества передаваемого изображения (IQ). Это означает, что контроль качества зеркала *in- situ* – актуальная проблема. Данная работа является попыткой приблизиться к её решению. Представлены результаты измерений R и IQ для зеркал, проэкспонированных в термоядерных установках LHD, TRIAM-1M, TS и после ионной бомбардировки на стенде ДСМ-2 (ИФП ННЦ ХФТИ).

ЯКІСТЬ ПЕРЕДАНОГО ЗОБРАЖЕННЯ ЯК МОЖЛИВИЙ МЕТОД МОНІТОРИНГУ IN SITU ДЗЕРКАЛ, ЩО ПЕРЕБУВАЮТЬ У ВАКУУМНОМУ ОБ'ЄМІ

В.Г. Коновалов, М.М. Махов, А.М. Шаповал, Н. Ашикава, С. Масузакі, А. Сагара, Д.І. Найденкова, І.В. Рижков, А.Ф. Штань, С.І. Солодовченко, В.С. Войценя

Перші дзеркала в установці ITER будуть розпилятись й / або забруднюватись. Це призведе як до зниження відбивної здатності (R), так і до погіршення якості переданого зображення (IQ). Це означае, що контроль якості дзеркала *in- situ* – актуальна проблема. Ця робота є спробою наближення до її вирішення. Представлено результати вимірів R і IQ для дзеркал, проекспонованих в термоядерних установках LHD, TRIAM - 1M, TS та після іонного бомбардування на стенді ДСМ-2 (ІФП ННЦ ХФТІ).