THE METHOD FOR IN SITU MONITORING OF THE QUALITY OF IN-VESSEL MIRRORS IN A FUSION REACTOR

V.G. Konovalov, M.N. Makhov, A.N. Shapoval, I.V. Ryzhkov, A.F. Shtan', S.I. Solodovchenko, V.S. Voitsenya

Institute of Plasma Physics, NSC "Kharkov Institute of Physics and Technology", Kharkov, Ukraine

In laser and optical methods of plasma diagnostics in ITER the most critical components of the measurement schemes will be the First Mirrors (FM) facing the burning plasma and located rather close to plasma volume. It is very important to check regularly the working condition of FM surface ***in situ***, e.g., to control the Quality of transmitted Image (IQ) or signal. In the present work we compare the results of measurements of IQ made ***in situ***, directly on the plasma device DSM-2 during mirror exposure to ion bombardment, with a compact optical scheme in use, and the results of ***ex situ*** measurements (on the DIQ stand) – with two times longer distance to mirror (~2.5 meters).
PACS: 52.40.Hf; 76.68.+m; 79.20.Rf

1. INTRODUCTION

The main object of this work is the further development of the scheme [1] on investigation of effects of mirror surface roughness on IQ.

The dynamics of specular and diffusive reflectance was traced. The registration of an image of the light source with sharp edges was carried out by means of a digital camera (in situ) and/or by scanning device placed rather far from the mirror under investigation (ex situ). In ITER conditions, the distance between mirror and the image quality analyzer will be many meters.

For the tests the mirror samples with various degree of surface roughness were chosen. Polycrystalline: copper coarse-grained (C-G) 100-1500 μm, Be - sheet and hot pressed (TGP-200), and mirrors fabricated of amorphous alloy known in literature as Vitreloy-1 [2].

2. RESULTS

The optical scheme for ***in situ*** measurements of IQ in DSM-2 (Fig. 1) contains: 1– light source (λ=540 nm); 2 – spectral slit; 3 – collimating optics; 4 - deflecting mirror; 5 – CCD camera which registers a profile of the image.

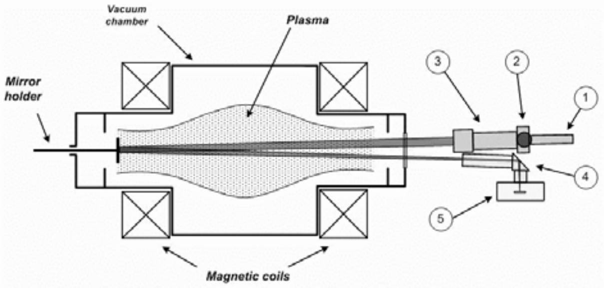


Fig.1. Scheme of the DSM-2 stand

2.1. COPPER SAMPLES

Fig. 2 shows the dynamic of an edge fuzziness of initially sharp image of the light aperture depending on sputtered layer thickness *h* (indicated in μm near every curve) by ions of deuterium plasma with energy 1000 eV.

Further processing of these profiles was made on the basis of next criterion: the area within the limits of width of the initial profile is considered as a Specular Part (SP), and the area outside the limits of the initial profile is a Diffusive Part (DP) of a reflected light flux.

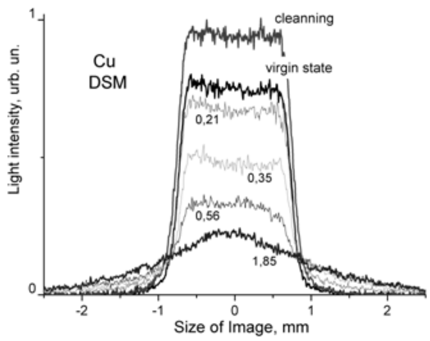


Fig.2. Results of measurements at the DSM-2 stand

In Fig. 3 the results of processing of measured profiles are presented. A sharp deterioration of IQ for the C-G sample is clearly seen.

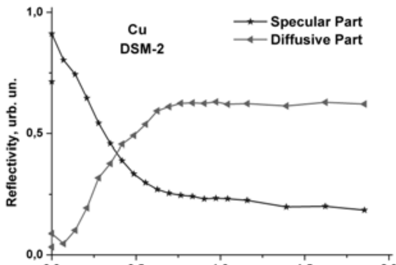


Fig.3. Dependence on h of specular and diffusively scattered parts of light reflected from Cu mirror

The dynamics of degradation of IQ of the same copper mirror was studied also ***in situ*** with He-Ne laser probing beam. Fig.4 shows: a) - the laser beam spot reflected from an ideal Al-on-quartz mirror, b) - the spot of laser beam reflected from the Cu mirror in initial state, c) - after bombardment with deuterium plasma ions during 5 min (h=0.12 μm) and d) - 40 min (h=0.93 μm).

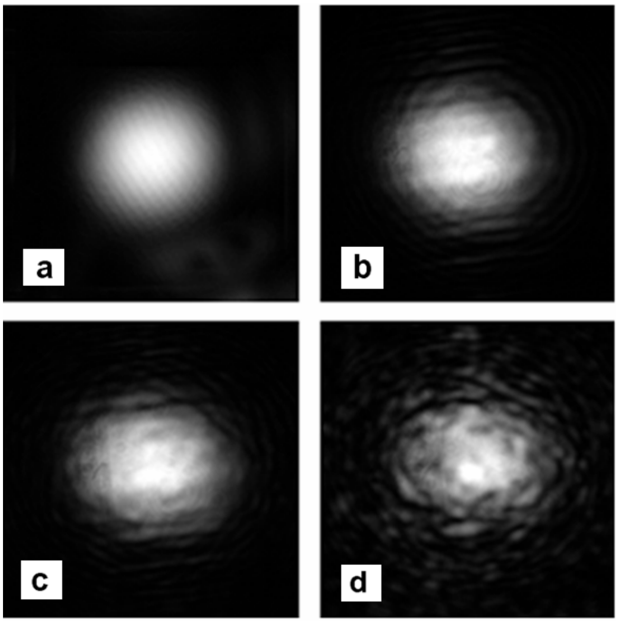


Fig.4

The photos of Fig. 4 demonstrate the feature of this method: the reflected beam carries the information about the granular structure of the mirror surface as the face of each grain is a small independent mirror.

2.2. *SS* SAMPLES ON STAND *DIQ*

Results of measurements of IQ before placing in DSM-2 and after last exposure are shown in Fig.5. Appreciable superiority of SS-mirror over Cu samples is evident if to compare Fig.2 on the one hand and Fig.5 on the other hand.

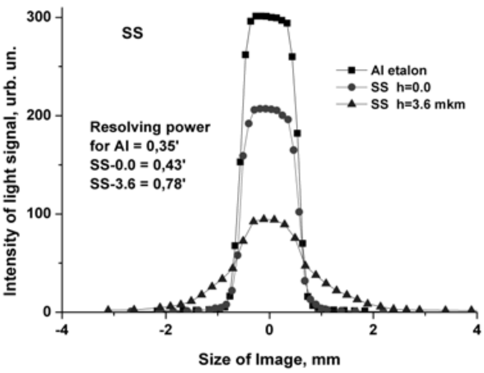


Fig.5. Change of IQ-profile for the SS after sputtering the layer of 3.6 µm in thickness, as measured on the stand DIQ. Reflectivity and resolving power in angular minutes are shown

2.3. Be SAMPLES ON STAND *DIQ*

Be mirrors are of interest because beryllium can be a possible candidate of the FM material for ITER.

Two kinds of Be mirrors were chosen for the experiments: one sample of the sheet material and another – of a hot pressed TGP-200. These samples were many times exposed in deuterium discharges with energy of ions from 60 up to 1500 eV. Total time of experiment - near 60 hours. The IQ profiles of Al etalon and Be mirror were found to have an ideal coincidence, as Fig. 6 shows.

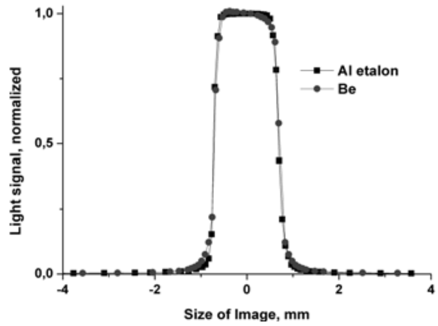


Fig.6. Normalized profiles IQ for Al etalon and the Be mirror sample after numerous exposures to deuterium plasma ions

2.4. AMORPHOUS MIRROR SAMPLES

Mirrors of metal glasses are of a special interest because of: 1) expected absence of roughness growth when such mirror is being long-term sputtered [3], and 2) opportunities of manufacturing mirrors of spherical or any other form.

For studying the behavior of IQ under ion bombardment a pair of amorphous mirrors was selected: AMA-3 and AMK-3. The difference between samples is: the AMA-3 – is amorphous, and AMK – is its twin crystallized due to annealing at T=500 C during one hour. Thus there was chance to compare behavior of such twin in similar experimental conditions. The composition of samples (Vitreloy-1) was similar to samples studied in [4]: Zr(41.2)Ti(13.8)Cu(12.5)Ni(10)Be(22.5).

The AMA-3 and AMK-3 samples were subjected to noticeable sputtering by Ar^+ ions with energy variable between 100 and 1350 eV. The ***in situ*** IQ profiles for them turned out to be close by shape, however the reflectance of the crystallized AMK-3 sample decreased significantly faster than for its amorphous counterpart. The dynamics of IQ for AMK-3 during sputtering from h=13.3 by 19.8 µm with Ar^+ ions is presented in Fig.7.

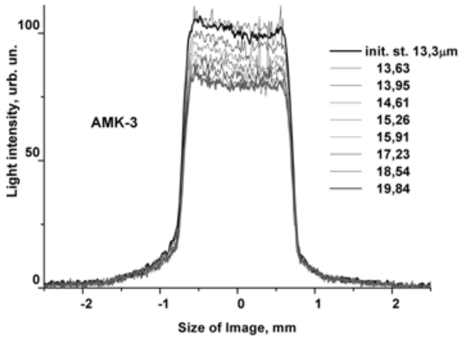


Fig.7. Dynamics of IQ for AMK-3 under sputtering with Ar^+ ions of 1 keV energy ***in situ*** *measurements*

The results of IQ profiles (on DIQ stand) after layers of indicated thickness were sputtered are shown in Fig. 8. The values of resolving power in angular minutes are indicated on the insertion.

One can see that the AMA-3 is much more resistant to sputtering with Ar^+ ions. Its integral rate of mass loss was noticeably less (~10%) than for AMK-3 after identical sets of exposures to ion bombardment.

These results were supported by photos made in situ in the DSM-2 stand with He-Ne laser, Fig. 9.

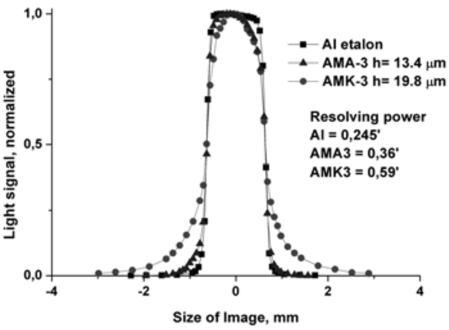
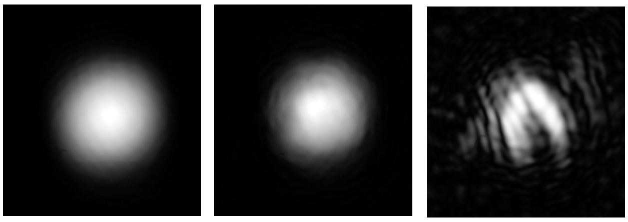


Fig.8. The comparison of IQ for AMA-3 and AMK-3 after sputtering the layers with thickness 13.4 and 19.8 μm correspondingly



a) *b* *c*

Fig.9. Photos of the laser beam spot reflected from a) Al etalon, b) AMA-3 (h=6.8 μm) and c) AMK-3 (h=8.9 μm) after similar series of exposures to ions of Ar plasma

3. CONCLUSIONS

1. The compact optical stand attached to DSM-2 device allows to control ***in situ*** the dynamics of degradation of mirrors subjected to sputtering with ions of deuterium or argon plasmas. Both, the reflectance and IQ profiles are measured simultaneously. The use of a digital photo-camera simplifies noticeably the accumulation of experimental information.

2. The imitating long-distance system DIQ, where ***ex situ*** measurements were provided, may be a prototype of the system for ***in situ*** measurements on large fusion devices. With this system the reflectance (what is useful when deposit of contaminants is important) as well as a resolving power of the optical system (when the determining factor of mirror degradation is the surface roughness) of the FMs can be measured.

3. The laser probing of mirrors in both ***in situ*** and ***ex situ*** versions, were found useful for observation of the dynamics of surface roughness when mirror is subject to ion sputtering. The character of reflected light directly correlates with the granular structure of the surface subjected to sputtering. The technique is quite mobile and easy to operate, but at the moment it looks as a source for obtaining the demonstrational material. The continuation of the work will possibly results in a more universal scheme for ***in situ*** characterization of in-vessel mirrors.

4. As follows from obtained results, the optical properties of remote mirrors can be successfully controlled by application of above-mentioned methods of probing of the mirrors disposed in a vacuum chamber.

REFERENCES

1. V.G. Konovalov, M.N. Makhov, A.N. Shapoval et al // *Problems of Atomic Science and Technology. Series "Plasma Phisics"(12).* 2006, N6, p. 244.
2. M. Telford // *Materialstoday*. March 2004, p. 36.
3. V.S. Voitsenya, A.F. Bardamid, M.F. Becker et al // *Rev. Scient. Instrum.* 1999, v. 70**,** p. 790.
4. A.F. Bardamid, A.I. Belyaeva, V.N. Bondarenko et al// *Physica Scripta*. 2006, v. T123, p.89.

Article received 16.11.08

МЕТОД IN SITU- МОНИТОРИНГА КАЧЕСТВА ЗЕРКАЛ, РАЗМЕЩЁННЫХ ВНУТРИ КАМЕРЫ ТЕРМОЯДЕРНОГО РЕАКТОРА

В.Г. Коновалов, М.Н. Махов, А.Н. Шаповал, И.В. Рыжков, А.Ф. Штань, С.И. Солодовченко, В.С. Войценя

В лазерных и оптических методах диагностики плазмы в ITER'е критичным элементом схемы измерений является первое зеркало (FM), размещённое в непосредственной близости к плазменному шнуру. Поэтому очень важно отслеживать состояние поверхности ***in situ***, например, контролируя качество передаваемого изображения (IQ). Мы сравниваем результаты измерений IQ, сделанных с использованием компактной оптической схемой ***in situ,*** непосредственно во время экспонирования зеркала на плазменной установке DSM-2, с результатами ***ex situ***- измерений (на DIQ стенде) – с более удалённым положением зеркала.

МЕТОД IN SITU- МОНІТОРИНГУ ЯКОСТІ ДЗЕРКАЛ РОЗМІЩЕНИХ ВСЕРЕДИНІ КАМЕРИ ТЕРМОЯДЕРНОГО РЕАКТОРА

В.Г. Коновалов, М.М. Махов, А.М. Шаповал, І.В. Рижков, А.Ф. Штань С.І. Солодовченко, В.С. Войценя

В лазерних та оптичних методах діагностики плазми в ITER'і критичним елементом схеми вимірювань є перше дзеркало (FM), розміщене в безпосередній близькості до плазмового шнура. Тому дуже важливо відстежувати стан поверхні ***in situ***, наприклад, контролюючи якість переданого зображення (IQ). У даній роботі ми порівнюємо результати вимірювань IQ зроблених за допомогою компактної оптичної схеми ***in situ,*** безпосередньо під час експонування дзеркала на плазмовій установці DSM-2, з результатами ***ex situ***- вимірювань (на DIQ стенді) – з більш віддаленим положенням дзеркала.