DEVELOPMENT OF *IN-SITU* CLEANING TECHNIQUES FOR DIAGNOSTIC MIRRORS IN ITER

A. Litnovsky[1], M. Laengner[1], M. Matveeva[1], Ch. Schulz[1], L. Marot[2], V. S. Voitsenya[3], V. Philipps[1], W. Biel[1] and U. Samm[1].

[1] *Institute for Energy Research IEF-4 (Plasma Physics), Forschungszentrum Jülich, Association EURATOM-FZJ, Trilateral Euregio Cluster, D-52425 Jülich, Germany, www.fz-juelich.de/ief/ief-4*
[2] *Department of Physics, University of Basel, CH-4056 Basel, Switzerland;*
[3] *IPP, NSC Kharkov Institute of Physics and Technology, Kharkov 61108, Ukraine.*

Corresponding author: a.litnovsky@fz-juelich.de

In all optical and laser diagnostics in ITER mirrors will be used to directly observe plasma radiation. In the severe ITER environment mirrors will primarily suffer from erosion and impurity deposition. These processes will deteriorate optical properties of mirrors hampering an overall operation of the affected diagnostics. Experiments made in fusion devices and laboratory facilities demonstrate that the strongest deterioration of the reflectivity will be caused by deposition. The formation of carbon or beryllium deposits with a thickness of only ~20 nm will cause the drastic (tens of percent) decrease in the reflectivity. Recent modeling results show that deposits with such a thickness will be formed on the mirrors already after several weeks of ITER operation, clearly outlining an urgent need in development of *in-situ* mirror recovery techniques for ITER.

Cleaning of mirrors using plasma represents an attractive option for mirror recovery. To assess the feasibility of plasma cleaning for a possible implementation in ITER, investigations are underway in Forschungszentrum Jülich. Low-temperature electron cyclotron resonance-generated plasmas are currently used for cleaning of ITER-candidate molybdenum mirrors. For investigations, mirrors were pre-coated under well-defined laboratory conditions with a carbon film of known physical and optical properties. The mirrors were successfully cleaned in hydrogen plasmas by the chemical erosion of carbon by hydrogen with the maximum erosion yield $Y\sim10^{-2}\ C_{at}/H_{ion}$. The deposit removal rate under experimental conditions was about 4.7 nm/min. The optical reflectivity in the range of 250-2500 nm was restored completely without any damage of the substrate material.

Subsequently, studies were made with a mirror exposed in the DIII-D divertor along with mirrors exposed in TEXTOR. After exposure in tokamaks, the DIII-D mirror was coated with a softer amorphous carbon film, whereas mirrors from TEXTOR became contaminated with a hard carbon film. After treatment in hydrogen plasmas the mirror with a softer film was successfully cleaned with an erosion yield $Y\sim10^{-2}\ C_{at}/H_{ion}$ corresponded to a removal rate of ~4.2 nm/min. On a contrary, the mirrors with a hard film could be recovered neither in hydrogen nor in deuterium plasmas. An additional biasing (-50V) was required to completely recover the reflectivity in the visible and UV ranges and to attain the ~90% recovery in NIR. For these mirrors, surface analyses revealed the presence of molybdenum carbides partially implanted into the mirror substrate due to higher temperature of mirrors during exposure and higher energies of impinging carbon ions in TEXTOR. The presence of carbides decreased the cleaning efficiency by an order of magnitude preventing the mirror recovery using only non-destructive chemical erosion.

Current studies have clearly demonstrated the necessity of the physical sputtering of the contaminated mirror surface when applied for *in-situ* plasma cleaning in ITER. Future efforts will be concentrated on the recovery of mirrors having beryllium-like and mixed deposits. An overview of experiments will be presented in this contribution along with an assessment of applicability of plasma/ion techniques for mirror cleaning in ITER.