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Dielectric windows as front-end diagnostic elements in ITER

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The performance of front-end elements of optical diagnostics in ITER under long-term operation and with limited access for their maintenance is in the focus of extensive R&D program involving laboratory study and testing in working tokamaks. The requirements to the front-end element design are driven by high-energy neutron and gamma radiation, intense particle fluxes and thermal loads at the element location on the one hand and necessity to provide periodic or continuous surface recovery on another. The insulating diagnostic window as an alternative to commonly accepted first mirror option is discussed in the presentation. The approach implementation is illustrated for the divertor Thomson scattering (DTS) optical scheme using front-end windows for injection of laser beam and collecting of scattered light. Surface recovery techniques based on plasma cleaning and laser ablation are described with the focus on the performance of the windows under laser and plasma treatment. The windows made from fused silica glass KU-1 and Al2O3 were tested. Plasma cleaning experiments have been performed for clean windows and windows coated with Al films. As was shown by the means of optical microscopy, XPS and AFM the dominant mechanism of window optical degradation is surface roughening. The development of surface relief becomes more intensive after deposition and removal of Al. The clear indication of the dependence of surface degradation rate on the initial polishing quality was also obtained for the windows with and without Al deposition. Laser experiments reveal the decrease in laser-induced damage threshold by the factor of~ 3 for both window materials under continuous tungsten deposition. In the case of Al droplets spraying, damage threshold is about 6 times as low as that of pure KU-1 window. The experiments on the long-term laser cleaning under continuous contamination showed that the evolution of tungsten film stops over the first hundreds of pulses and further exposition has no effect on the film thickness. The steady-state thickness of tungsten deposit in the beam spot was found to be ~ 5 nm for the deposition rate of ~10nm/min and laser (3 ns) energy density of ~ 2 J/cm2, forming almost transparent coating in visible and near-IR regions. Radiation-induced effects in silica glass and sapphire and corresponding limitations are also discussed.

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