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Experimental Results on the Irradiation of a Number of the Nuclear Fusion Relevant Materials at the Dense Plasma Focus “Bora” Device

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Samples of materials counted as perspective ones for use in the first-wall and construction elements in fusion reactors (W, Ti, Al, low-activated ferritic steel “Eurofer” and some alloys) were irradiated in the Dense Plasma Focus (DPF) device “Bora” having bank energy of ≤ 5 kJ. The device can generate powerful streams of hot dense ($T \sim 1$ keV, $n \sim 10^{24}$ m⁻³) deuterium plasma streams ($v \sim 105$ m/s) and fast ($E \sim 0.1 \dots 1.0$ MeV) deuterons of power flux densities P up to 1010 and 1012 W/cm² correspondingly. A so-called “damage factor” $F = P \times \tau \times 0.5$ ensures an opportunity to simulate radiation loads (predictable for both reactors types) by the plasma/ion streams generated in DPF, which have namely those parameters as expected in the fusion reactor (FR) modules. Before and after irradiation we provided investigations of our samples by means of a number of analytical techniques. Among them we used optical and scanning electron microscopy to understand character and parameters of damageability of the surface layers of the samples. Atomic force microscopy was applied to measure roughness of the surface after irradiation. These characteristics are quite important for understanding of mechanisms and values of dust production in FR that may relate to tritium retention and emergency situations in FR facilities. We also applied two new techniques. For surface we elaborated the portable X-ray diffractometer that combines X-ray single photon detection with high spectroscopic and angular resolutions. A laser-based remote distance sensor allows positioning the material point of analysis with a precision of about 30 micrometers. For bulk damageability investigations we applied an X-ray microCT system where X-rays were produced by a Hamamatsu microfocus source (150 kV, 500 μ A, 5 μ m minimum focal spot size). The detector was a Hamamatsu CMOS flat panel coupled to a fiber optic plate under the GOS scintillator. The reconstruction of 3D data was run with Cobra 7.4 and DIGIX CT software while VG Studio Max 2.1 and Amira 5.3 were used for segmentation and rendering. We also provided microhardness measurements. The report contains results of the investigations of modifications of the elemental contents, structure and properties of the materials.

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