Effects of irradiation of stainless steel and TiMoN coatings on stainless with low-energy Alpha-particles, Krypton and Xenon ions

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One of the directions for development of new structural materials for nuclear installations is deposition of protective coatings with high stability of physical and mechanical properties to ionizing irradiation on the existing structural materials. In particular, this applies to the nuclear reactors of generation IV, among which are considered as promising reactors with liquid metal and gas coolant. Materials in such reactors in addition to the neutron flux will undergo to high temperatures and corrosive environments. Ternary transition metal nitrides (TiZrN, TiCrN and others) have high strength, corrosion resistance and can be regarded as promising. However, the properties stability of these materials under irradiation not investigated. In this paper we study the effect of irradiation with low-energy alpha particles, krypton and xenon ions, on the stability of the physical and mechanical properties of coatings TiMoN. Alpha particles simulate accumulation transmutant helium, krypton and xenon ions simulate nuclear fuel fission fragments.

TiMoN coating formed by deposition a substance from the plasma phase under ion bombardment. The coatings were deposited in an atmosphere of N2 gas at a pressure of 1.10 Pa in the chamber, the substrate potential is 120 V and currents of the cathodes of the arcs of molybdenum and titanium is 100 and 180 A.

Irradiation with low-energy ions He, Kr, and Xe was carried out on the low-energy channel of heavy-ion accelerator DC-60 in the Astana branch of the INP. The ion energy was 20 keV/ charge. Selected irradiation fluences ranged from $5\cdot10^{16}$ to $5\cdot10^{17}$ ions/cm^2, the area of the irradiated surface – 1 cm^2, irradiation temperature does not exceed 150 °C.

Study of the structure and properties of Cr18Ni10Ti steel and TiMoN coating before irradiation and after were conducted by X-ray difractometry, atomic force and scanning electron microscopy, nanohardness measurements and corrosion resistance measurements.

1. Studies have shown that the physical and mechanical properties of the non-irradiated coating greatly exceed the properties of steel Cr18Ni10Ti, see **Table 1**.

Table 1. Nanohardness and the corrosion rate of the unirradiated coating TiMoN and steel

Material	nanohardness, GPa	Vcorr, mm/year
TiMoN	35	$6\cdot10^{-6}$
steel	3,3	$9\cdot10^{-3}$

2. Irradiation by alpha particles, starting from fluence $1\cdot10^{17}$ cm^{-2}, results in the surface blistering and flaking. For TiMoN coating blistering's not fixed, even at the maximum fluence $5\cdot10^{17}$ cm^{-2}.
3. Irradiation by Kr ions with energy 280 keV and by Xe ions with energy 360 keV leads to strong surface sputtering both steel and TiMoN coating. The surfaces of coating remain sufficiently smooth with no obvious signs of ion etching. The surface of the steel has obvious traces of ion etching.
4. Physical and mechanical properties of both steel and coating TiMoN degraded under ion irradiation, see Table 2, where presented data of physical and mechanical properties for coating irradiate by He, Kr and Xe ions up to fluence $5\cdot10^{16}$ cm^{-2}.

Table 1. Nanohardness and the corrosion rate of the irradiated coating TiMoN by He, Kr and Xe ions

Fluence, $5\cdot10^{16}$cm^{-2}	nanohardness, GPa	Vcorr, mm/year
TiMoN, irr. He	5	$3\cdot10^{-3}$
TiMoN, irr. Kr	25	$17\cdot10^{-6}$
TiMoN, irr. Xe	32	$534\cdot10^{-6}$

In spite of degradation, the mechanical properties of the coatings significantly exceeds the mechanical properties even unirradiated steel Cr18Ni10Ti.