EFFECT OF He^+ ION IRRADIATION ON STRUCTURE AND WEAR RESISTANCE OF TiAlN COATINGS DEPOSITED BY MAGNETRON SPUTTERING

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Hard and super-hard coatings have a lot of applications in modern physics and technique /1/. One of the most promising applications of these coatings is tribological sphere. TiAlN coatings are widely spread in many different machine building applications as they are hard, resistant to corrosion and relatively easy in production. There are a lot of methods of vacuum coating depositions: vacuum arc deposition, chemical vapor deposition, plating and others, but the method of reactive magnetron sputtering gives an opportunity to obtain coatings with a very dense structure and without a drop fraction /2/.

It is of great interest to investigate the influence of ion irradiation on structure and properties of the TiAlN coatings.

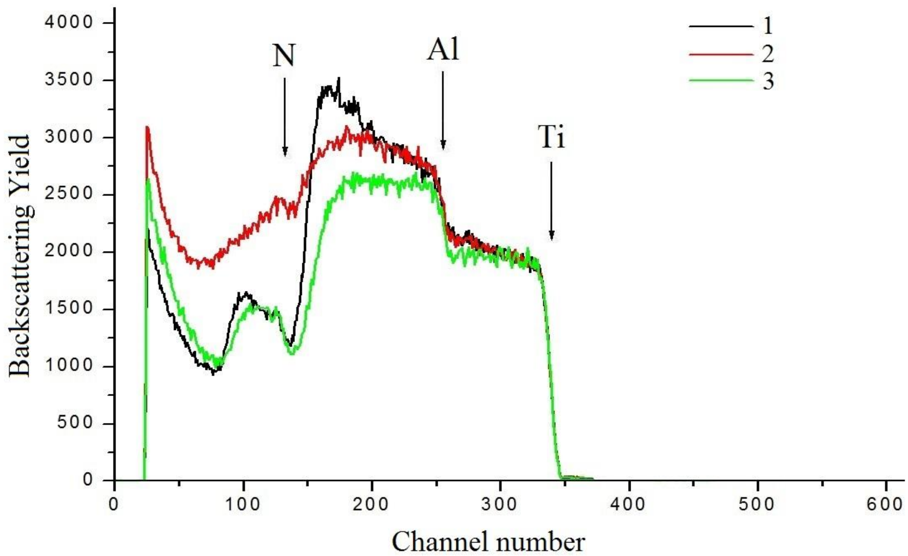
Investigations were conducted on the TiAlN coating prepared by reactive magnetron sputtering using a URM 327 vacuum setup equipped with a system for the automatic control of the supply of argon and nitrogen based on a S100 portable spectrometer. Gas pressure of $Ar+N_2$ was fixed at 0.7 Pa. During deposition of the TiAlN coatings, the substrate temperature was kept constant at 250 °C. Other conditions such as supply voltage, discharge current and bias on the substrate were fixed to 300-320 V, 1.4-1.75 A, -90 V, respectively. The deposition rate was ~1.5 nm/s. The thickness of the TiAlN coatings was 2.5 μm. The deposition of the TiAlN coatings was carried out using the three following regimes: with a deficiency ($TiAlN_{1-x}$), at a stoichiometric concentration (TiAlN), and with an excess ($TiAlN_{1+x}$) of the reactive gas N_2.

Elemental composition was examined by the Rutherford backscattering method (RBS) with 1.5 MeV helium ions and a resolution of the detector of 15 keV. Structural properties have been studied by x-ray diffraction method (XRD) using a DRON-3 diffractometer operating in Bragg-Brentano configuration using 1.79021 Å wavelength and scanning electron microscopy (SEM), using electron microscope Hitachi SU3400. Tribological tests were conducted using the tribometr ATVP equipment.

Irradiation of the TiAlN coatings was performed at the ion accelerator «High Voltage Engineering Europa B.V.» using He^+ ions with energy of

500 keV and fluences in the range of $5x10^{16}$ to $3x10^{17}$ ions/sm^2. The coating were annealed at temperature of 773 K during 15 min after the He^+ ion irradiation to simulate the usage of TiAlN coatings in nuclear reactor.

Figure 1 shows the RBS spectra of TiAlN coating after deposition. Curves 1, 2, and 3 in Fig. 2 correspond to the following conditions of the coating deposition: (1) deposition with a deficiency of nitrogen; (2) deposition at the stoichiometric concentration of nitrogen; and (3) deposition with an excess of nitrogen.



1 – deposition with a deficiency of nitrogen; 2 – deposition at the stoichiometric concentration of nitrogen; and 3 – deposition with an excess of nitrogen.
Fig. 1. RBS spectra of TiAlN coatings

Titanium and aluminum present in the TiAlN coatings in approximately equal concentrations (0.5 ± 0.02), but their concentrations are not homogeneous in the depth of the coating in the case of deposition with a deficiency of nitrogen and at the stoichiometric concentration of nitrogen (Fig. 1, curves 1, 2). In the case of deposition with an excess of nitrogen, the concentrations of Ti and Al are homogeneous (Fig. 1, curve 3). The concentration of N is not homogeneous in all cases of coating deposition. There is a strong gradient in element concentrations in TiAlN coating, as it can be seen from RBS spectra (Fig. 1), which indicates that coatings deposition process is highly nonequilibrium.

Figure 2 shows XRD spectra of deposited and irradiated TiAlN coatings. There are observed reflexes from λ-Fe (steel substrate) and from complex nitride (Ti, Al)N, which is a substitutional solid solution. The lattice parameter of (Ti, Al)N is 4.226 Å. It can be seen, that there is no changes in structure, phase composition and lattice parameter of TiAlN coating after He^+ irradiation.

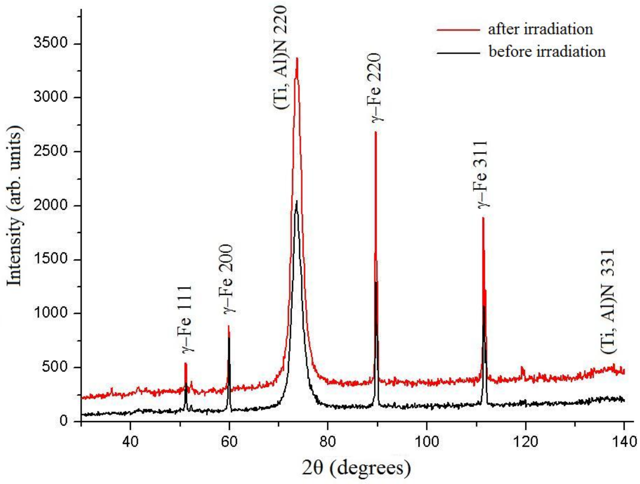
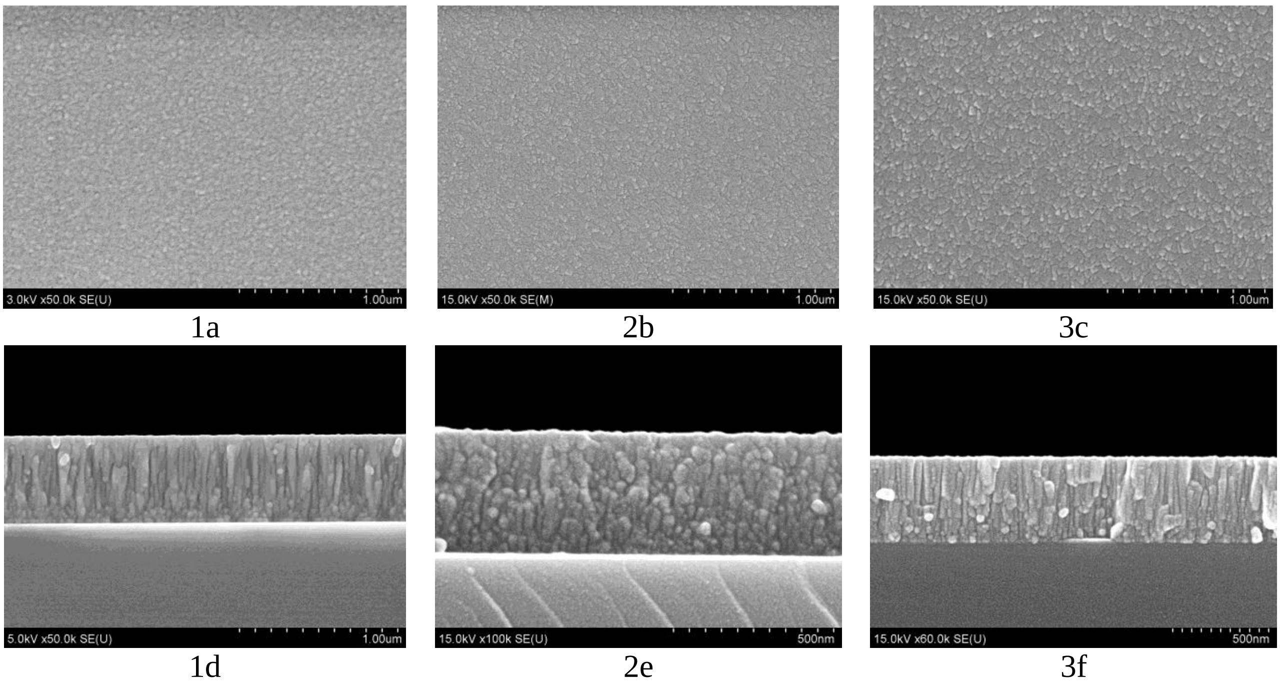


Fig. 2. XRD spectra of as-deposited TiAlN coating (black curve) and of irradiated by He^+ ions with an energy 500 keV and fluence $2x10^{17}$ ion/cm^2 TiAlN coating (red curve)

Figure 3 shows the microphotographs of TiAlN coatings structure obtained by SEM.

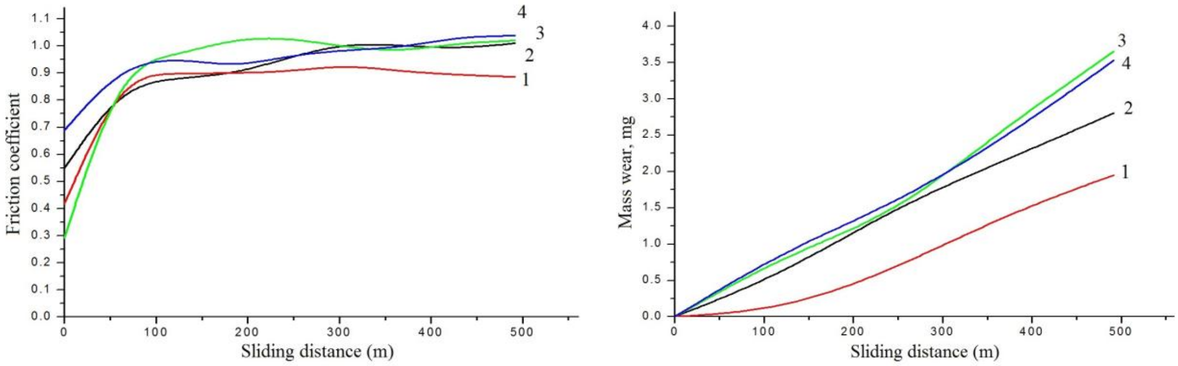


1 – deposition with a deficiency of nitrogen; 2 – deposition at the stoichiometric concentration of nitrogen; 3 – deposition with an excess of nitrogen.

Fig. 3. SEM microphotographs of TiAlN coatings: 1a, 2b, 3c – plan view images, 1d, 2e, 3f – a cross-section images

In all cases of coating deposition, we have a fine nanocrystalline structure with an average crystalline size of 10-20 nm. In the case of TiAlN coating deposition with a deficiency of nitrogen and with an excess of nitrogen, there is observed a columnar crystalline structure of coatings (Fig. 3. 1d, 3f). In the case of TiAlN coating deposition at the stoichiometric concentration of nitrogen, a globular crystalline structure is formed (Fig. 3. 2e).

The lowest friction coefficient and mass wear of TiAlN coatings were obtained in the case of the deposition with a deficiency of nitrogen (Fig. 4. Curve 1). Also, the TiAlN coating shows a good tribological performance in the case of deposition at the stoichiometric concentration of nitrogen, where a globular crystalline structure was formed (Fig. 3. 2e.).



a b

1 – deposition with a deficiency of nitrogen; 2 – deposition at the stoichiometric concentration of nitrogen; and 3 – deposition with an excess of nitrogen; 4 – steel substrate.
Fig. 4. Friction coefficient of TiAlN coatings and steel substrate (a), mass wear of TiAlN coatings and steel substrate (b)

Tribological investigations of irradiated TiAlN coatings were also performed. Presently, the obtained results are under consideration, but we can announce, that the irradiation influences a nonlinear behaviour of the friction coefficient of TiAlN coatings on ion fluence, as we have observed that earlier in our study of hardness /3/.

References

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