STRUCTURE AND MECHANICAL PROPERTIES OF TiN COATINGS DEPOSITED BY VACUUM-ARC METHOD UNDER HIGH NITROGEN PRESSURE

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Introduction:

The vacuum arc method allows obtaining a wide range of hard nanostructured coatings on the surface of tools and parts for various industries. Most of the developed processes are based on the deposition of plasma flows at low gas pressure in a vacuum chamber (< 1 Pa). The deposition of nitride coatings in the area of higher nitrogen pressures appears promising, as it allows reducing the content of defects in the form of macroparticles of cathode material in the coatings.

The goal of this study was to investigate the structure and mechanical properties of vacuum arc TiN coatings deposited at a nitrogen pressure of 2 Pa and a negative bias potential on the substrate ranging from 50 to 300 V.

Experimental details:

The TiN coatings were deposited using unfiltered vacuum arc plasma method in a "Bulat" system equipped with a Ti (99.9%) cathodes of 60 mm diameter. The coatings were deposited under nitrogen pressure ~ 2 Pa for 60 min. The negative bias voltage on the samples was changing from -50 to -300 V. The substrate temperature was maintained at a level of ~ 500 °C.

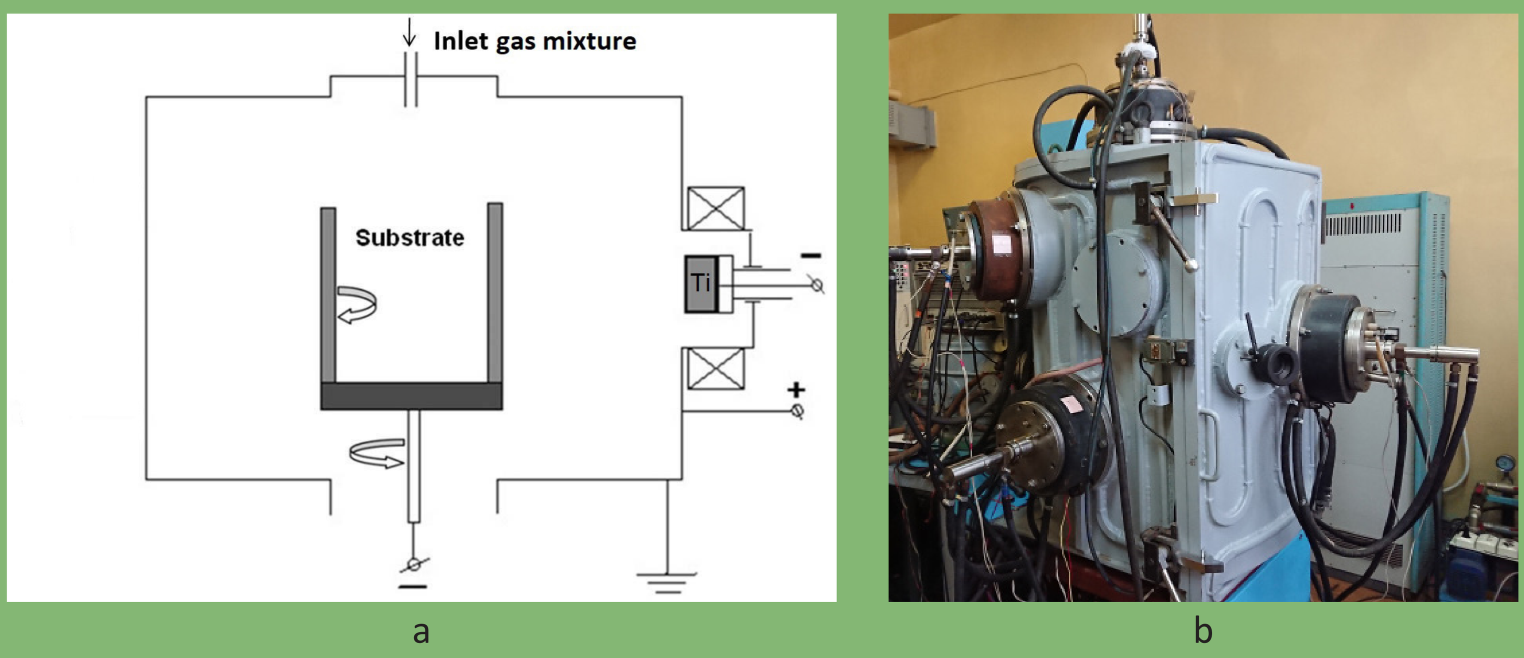

Fig.1. Scheme (a) and photo (b) of experimental setup

The surface morphology, microstructure and chemical composition of TiN coatings were investigated using Dimension FastScan atomic force microscope, PeakForce QNM, X-ray Diffraction (XRD) and Energy Dispersive X-ray Spectroscopy (EDS).
The mechanical properties of coatings were characterized using nanoindentation by Nanoindenter G200.

Results:

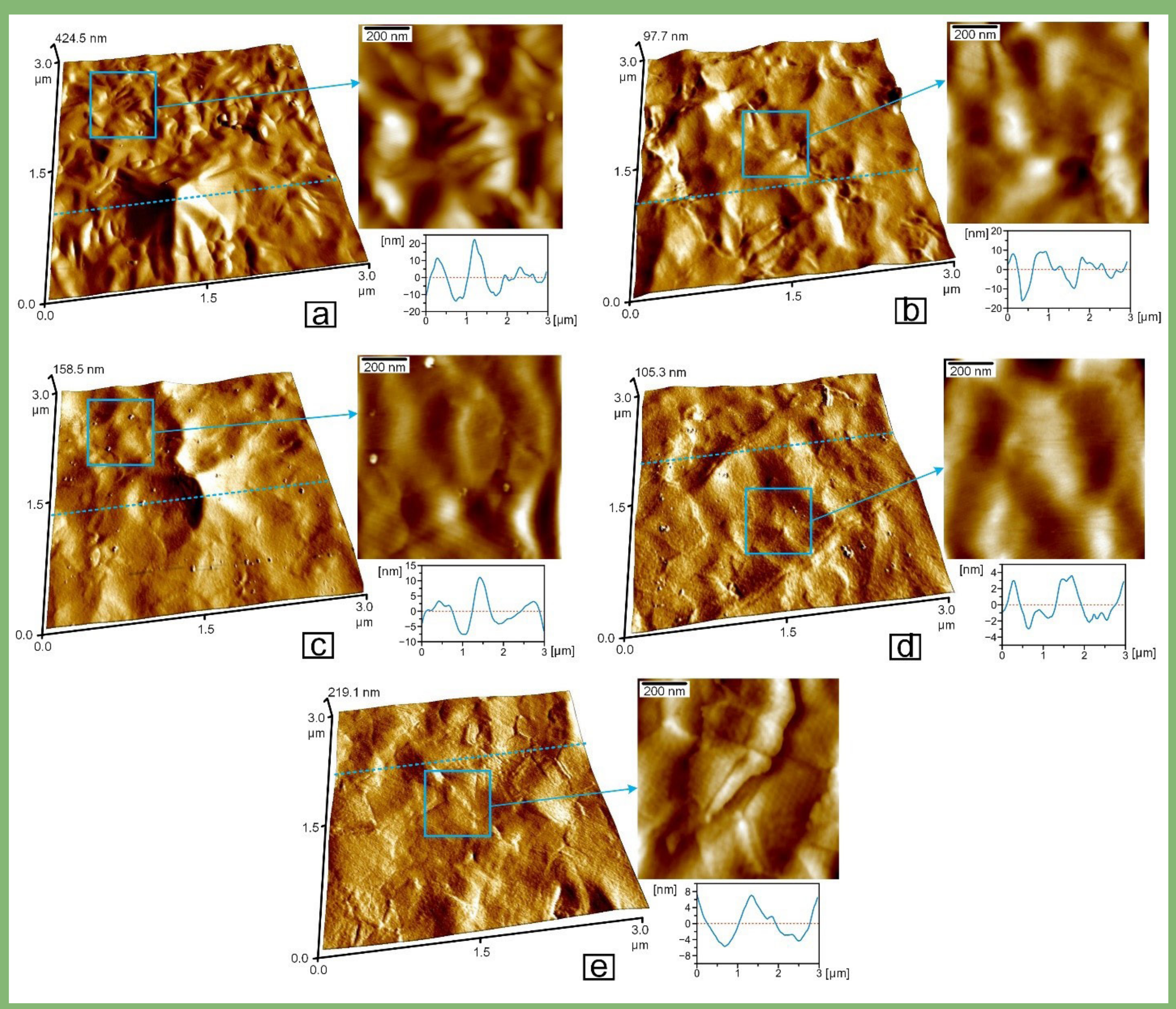

Fig.2. AFM-images (3d, 3 × 3 μm²) of surface morphology of TiN coatings: a – -50 V; b – -100 V; c – -150 V; d – -200 V; e – -300 V

Mechanical properetis of TiN coatings				
Bias potential	H, GPa	E, GPa	H/E	H^3/E^2
-50	27.7	574	0.048	0.065
-100	29.6	496	0.06	0.1
-150	32.1	524	0.06	0.12
-200	30.8	526	0.059	0.106
-300	25	442	0.057	0.08

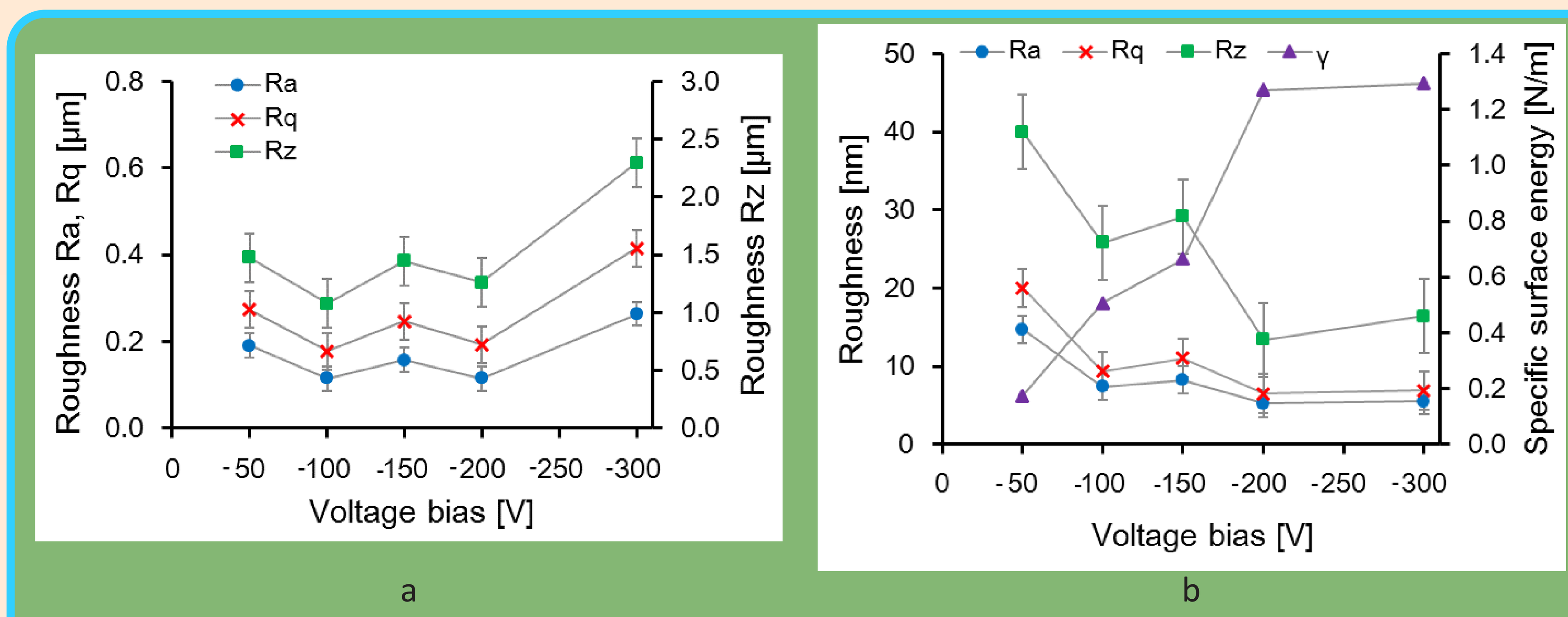

Fig. 3 – The dependence of the roughness parameters (Ra, Rq, Rz) and specific surface energy of TiN coatings on the voltage bias: a) measured distance – 2.5 mm (profilometer); b) on the area 3 × 3 μm² (AFM)

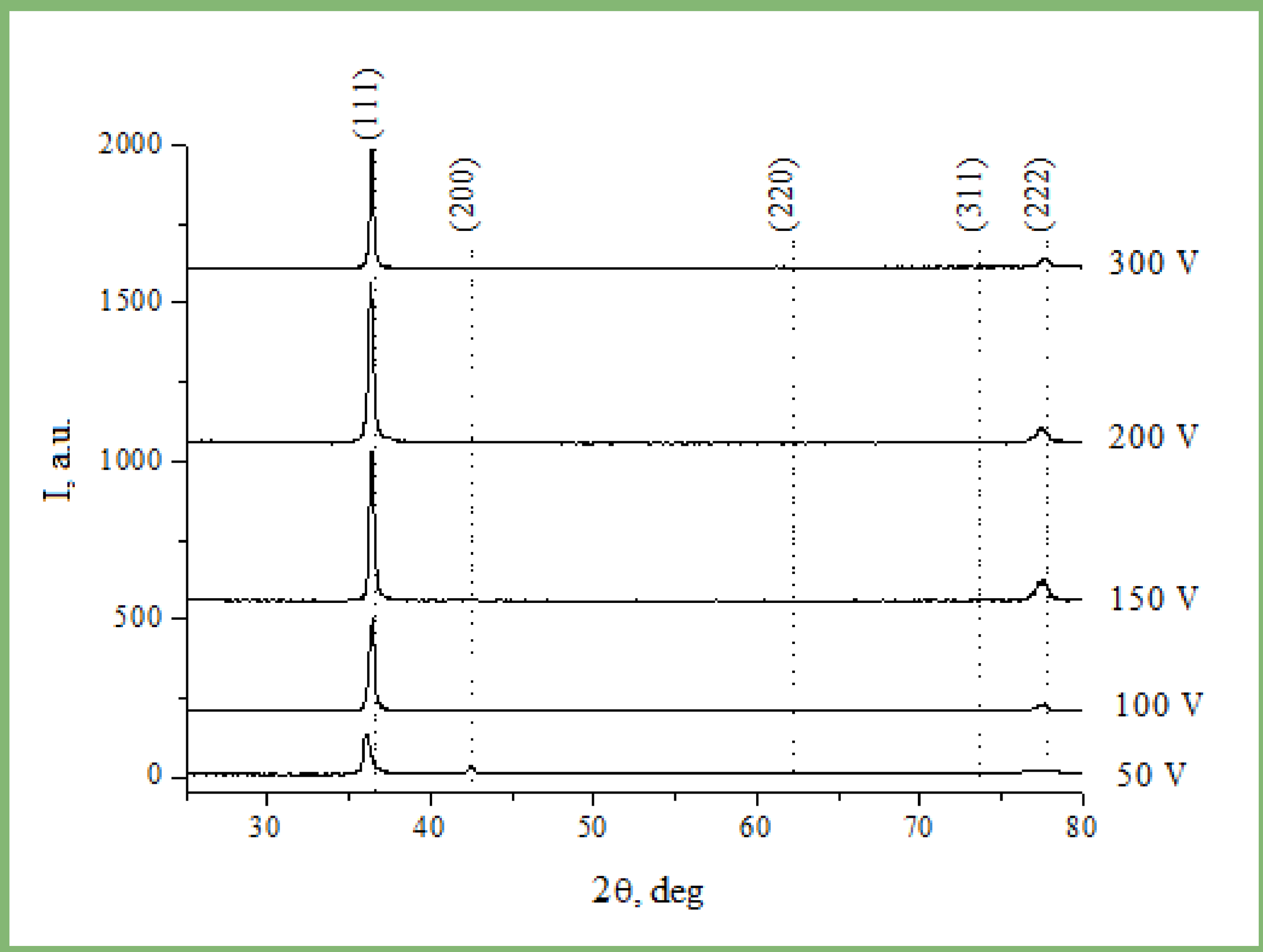

Fig. 4. X-ray diffractograms of TiN coatings

The intensity ratios of the diffraction peaks of TiN in the diffractograms deviate from the values given in the International Center for Diffraction Data powder diffraction database (JCPDS No. 38-1420), according to which the diffraction line (200) has the highest intensity. The diffractograms of the obtained coatings show sufficiently intense lines (111) and (222). Other TiN reflections at the ϴ-2ϴ scanning are not detected at all. The exception is the diffractogram of the sample deposited at a displacement potential of 50 V, which shows a weak line (200).

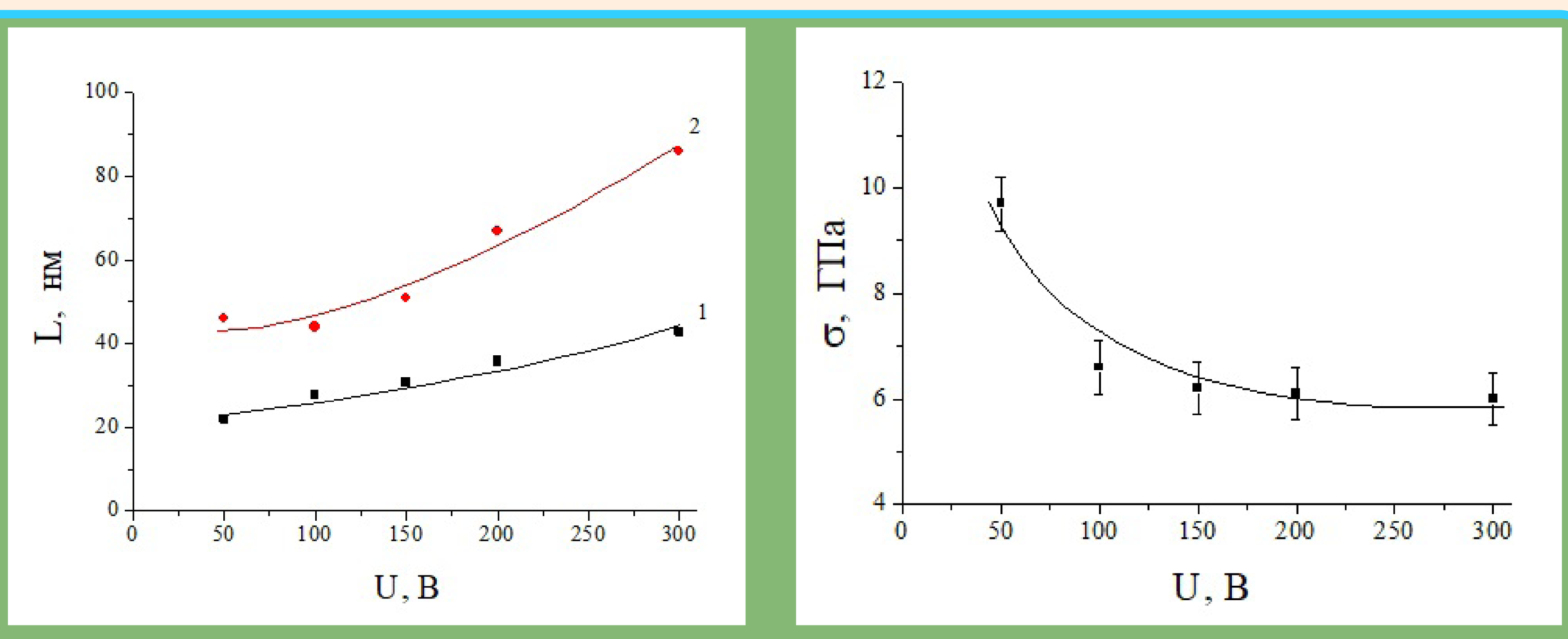

Fig.5. The impact of displacement potential on the substrate during the deposition of TiN coatings on the size of crystallites (a) and the level of compressive macrostresses (b). The size of the crystallites was determined by different methods: 1 - Scherrer method; 2 - Hall method.

The maximum level of macrostresses, 9.7 GPa, was found in coatings deposited at a potential of 50 V. With an increase in potential from 50 to 100 V, the level of macrostresses sharply decreases to 6.6 GPa. With a further increase in potential, the level of compressive stress in the coatings decreases more smoothly to 6.0 GPa at 300 V.

Conclusions:

1. The surface morphology of the coatings is nanosized cellular with low roughness, which decreases from 15 to 6 nm as the potential increases.
2. X-ray analysis identified a cubic TiN nitride phase in the coatings, showing improved texture, increased crystallite size from 46 to 86 nm, and reduced microdeformations and macrostresses with potential increase.
3. According to the results of nanoindentation, all coatings are characterized by high mechanical performance. The most promising in terms of wear resistance is the TiN coating obtained at a potential of 150 V, which has an optimal combination of a relatively low stress level (6 GPa) and maximum values of hardness (32 GPa) and index of resistance to plastic deformation (H^3/E^2 = 0.12)

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