International Journal of
Science and Engineering Investigations vol. 8, issue 94, November 2019
Received on October 30, 2019 ISSN: 2251-8843

Improve the Physical and Mechanical Properties of the Structures by Using the Coating Ti, Al, Zr, Si, N

Emad Toma Karash
Northern Technical University
(emadbane2007@yahoo.com)

Abstract- The main results of the study are the introduction of pulsed RF potential in the deposition process can reduce the size of the nan crystals for TiN of 80 nm to 10 - 15 nm to 60 nm ZrN of 25 nm. Coatings based on Zr, Si and N and Ti, Si and N crystallites formation of two phases of ZrN and TiN. TiN crystallite size is 25 nm, and the crystallites ZrN - not more than 10 nm.

The features of structural-phase state based coatings of Zr, Ti, Al, Si, and N, obtained by vacuum arc deposition using RF pulse stimulation. Increased on-HF strip from -100 to -200 in B leads to more efficient capture nitrogen atoms in the surface region formed coating that stimulates an intensive course of chemical reactions of nitrides. In the resulting ballistic dispersion of light atoms is substantial depletion of their synthesized coating. Conditions for the formation of Nan composite coatings based on Zr, Ti, Si and N causes increasing lattice strain crystallites, which determines the development of films squeezing voltages of up to 9 GPa. Increasing the capacity of pulsed RF bias of -100 V to -200 causes formation texture in the (111) plane of deposition. It has been proved that the use of RF pulse stimulation is an effective method that enhances the adhesion strength of coatings to the substrate. The hardness of Nano crystalline coatings nc-TiN have a hardness H = 32.6 GPa, modulus E ≈ 300 GPa, and the coating based solid solution Ti-Si-N, Ti-Zr-Si-N high hardness: for Ti-Si-N (N = 35 GPa, E = 286 GPa) for Ti-Zr-Si-N (H = 40.8 GPa, E = 392 GPa). Established that refractory compounds based on multi-coatings in terms of friction in the air at elevated temperatures almost not deformed (low structural activity) without cracking and crumbling of kontrtilom not seize.

Keywords- *Nano Composite Coatings, Aluminum, Vacuum-Arc Deposition Method, Metals of Transitional Group, Solid Solution*

I. INTRODUCTION

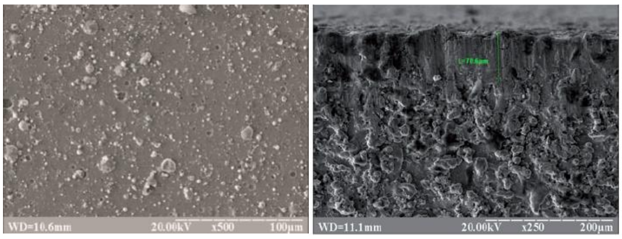
Components like valves, tappets, rings, crankshafts and camshaft used in automotive industry, as well as tools for advanced machining processes (e.g., high-speed and dry cutting) are exposed to severe tribological and thermal conditions. Protective coatings are an effective means of increasing the productivity and reliability of functional materials. Due to the high mechanical properties and thermal stability, the protective layer can maintain the functionality of tools in severe operating conditions for a long time. Protective coatings were designed for providing high hardness of material on its surface, low friction coefficient, oxidation resistance and wear resistance [1-3]. One of the most called-for materials among those which are widely used for the formation of protective coatings, are nitrides of transition metals which perform one of the best complexes of their properties. Among the binary systems of the nitrides, titanium nitride (TiN) is the most widely used material due to its high mechanical properties and corrosion resistance [4]. In the last decade the titanium-aluminum nitride (Ti1-xAlxN) has got the wide application. It increases hardness and durability of the cutting tool in high-speed machining. Besides, the addition of aluminum in the coating composition leads to the increased oxidation resistance in the temperature interval of 500 °C to 800 °C, due to formation of resistant layer of aluminum oxide on the surface [5]. Adding such elements as chromium or zirconium in order to form a ternary system, leads to the positive effects in improving the functional properties of the coatings [6, 7]. Thus, the transition from the two-element coatings to the more complex ones by means of doping by the elements of the transition metals is the effective way to significantly change the functional properties of the coating. The most frequently used vacuumplasma methods, used for obtaining the mentioned systems of coatings are the following: vacuum-arc deposition, magnetron sputtering [8 - 11]. The aim of this paper is to study to develop physical and technological foundations of obtaining solid nanocomposite coatings based on TiN doped Al, Si and Zr, exploring their physical and mechanical properties and tribotechnical.

II. EQUIPMENT AND METHODES OF INVESTIGATION

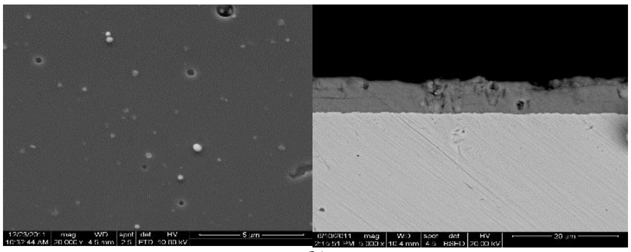
As a method of obtaining coatings of (**Ti, Al, Zr, Si, N**) system, the Vacuum-arc deposition, vacuum-arc deposition of a high-frequency stimulation and coating deposition by magnetron sputtering, scanning electron-ion microscopy with microanalysis, transmission electron microscopy diffraction, atomic force microscopy, X-ray backscatter and the elastic response, micro beam of protons, the method of analysis using the scratch test (scarring of the pyramid), photoelectron spectroscopy, X-ray phase analysis, measurement of nano- and micro-hardness, wear, abrasion, corrosion resistance.

III. RESULTS AND DISCUSSION

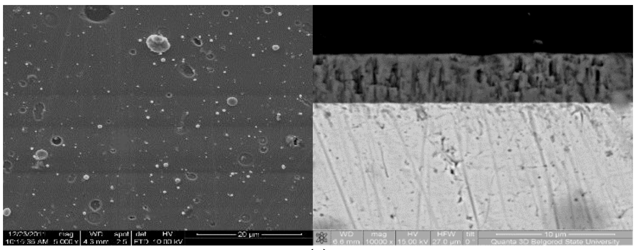
Analyzed and results of experimental studies of the morphology, elemental and phase composition of coatings based on TiN; Ti-Al-N; Ti-Si-N and Ti-Zr-Si-N, obtained by vacuum-arc deposition with continuous and pulsed RF using deposition. Section 3.1 investigated the morphology and elemental composition of the surface coating TiN, Ti-Al-N; Ti-Si-N, obtained by vacuum-arc. Sketch 1 shows portion of the surface coating TiN and Ti-Al-N.



(a)



(b)



(c)

Figure 1. Micro stock sites coatings: a - general view cross section and surface coating TiN, obtained by continuous deposition; B - general view cross section and surface coating TiN, obtained by pulsed RF deposition; a - general view cross section and surface coating Ti-Al-N, obtained by pulsed RF deposition.

Surface Morphology and transverse structure condensates have studied general patterns regardless of the materials evaporated (cathode). However, the size of crystallites in transverse fracture of condensate in the case of the alloy significantly smaller. The use of pulsed RF stimulation in the method of vacuum-arc deposition of coatings in the synthesis leads to changes in the prevailing levels to the substructure crystallites.

The elemental composition of the coating TiN, obtained through continuous deposition of a composition: N – 33.24 am. %; O2 – 31.38 am. %; Ti -35.37 at. %. The use of pulsed RF deposition leads to changes in the coating: Ti – 44.6 at. %, N – 53.5 at. %, O_2 – 1.3 at. %, C – 0.6 at. %. Growth content of nitrogen atoms associated with HF ionization, which stimulates the flow of chemical reaction of titanium nitride.

Coatings based on Ti-Al-N formed by vacuum-arc cathode by spraying this composition: Ti - 85 at. % and Al - 15 at. %. The concentration of elements in the coating was: nitrogen - 43.36 am. %, Aluminum - 3.84 am. % Titanium - 52.80 am. %. When a pulsed RF potential concentration of elements changed as follows: N – 47.12 am. %; Al – 0.84 at. %; Ti–51.96 am. %.

Results of the study elemental composition of coatings based on Ti, Si and N are shown in Fig. 2. From microanalysis conducted on the surface coating, it follows that the concentration of titanium is about 74 at. % Concentration of nitrogen ≈ 21 atm. % Si at a concentration of about 2.5 at. %.

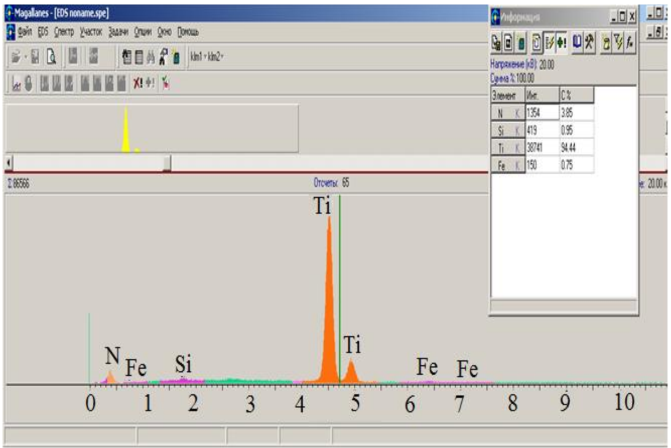


Figure 2. Energy dispersive range of coatings based on Ti, Si and N, obtained by vacuum arc deposition using high frequency stimulation: Uzs = -200 V, P = 0.3 Pa.

Study of elemental composition and surface morphology of nanocomposite coatings based on Zr, Ti, Si and N is dedicated unit 3.2. To study the features of formation of structure and phase state of multicomponent coatings based on Zr, Ti, Si and N were made two cathodes. The first cathode contains elements composed of Ti - 78 at. %; Zr - 10 at. %; Si - 12 at. % And the other composed of cathode - Zr - 65 at. %; Ti - 25 at. %; Si - 10 at. %. The first series was obtained by evaporation of the cathode determining the content of zirconium atoms during deposition parameters Uzs = -200 V, P = 0.7 Pa. According to elemental microanalysis covering the first series containing an average of 2.1 - 2.3 at. % Of silicon, 4.4 - 4.7 at. % Titanium, 56 - 59 at. % Zirconium atoms. Compared with the composition of target elements relative impoverishment for most atoms, forming a coating characteristic of silicon atoms. The content of nitrogen atoms in a pulsed potential bias = -200 Uzs in slightly increased, reaching 6.4 - 7.8 wt. %, Corresponding to 35 - 41 at%. For the second series of samples relative impoverishment of silicon atoms is even greater, resulting in the average composition of 1.5 - 1.7 at. % Silica, 7.5 - 8.8 at. % Titanium, 89.5 - 91 at. % Zirconium atoms. Also increased and the average value of the nitrogen atoms that fall from the atmosphere sprayed with content in the condensate is close in stoichiometric XN (whereX-Zr+Si+Ti) composition. This is, of effective interaction of titanium atoms with nitrogen atoms in the near-surface region, due to an increase in the content of titanium atoms in silicon than in the second series of condensates obtained at higher pressure N_2. Analysis of nanocomposite coatings based on Ti, Si and N, and Zr, Ti, Si and N, containing silicon as an alloying element obtained by vacuum arc deposition using RF pulse stimulation indicates significant depletion silicon coating. Section 3.3 studied composition phase nanocomposite coatings based on TiN; Ti-Al-N; Ti-Si-N and Ti-Zr-Si-N. The results of X-ray analysis of coatings based on titanium nitride shown in Table 1.

TABLE I. PHYSICAL PARAMETERS TIN COATINGS

Parameter	Vacuum arc deposition	Pulse RF deposition
The crystal lattice, nm	0.42603 ±0.0141	0.42599 ±0.0173
Δa/a, %	0.38	0.24
Size of coherent scattering, nm	10.5 ÷ 12	9 ÷ 10

Mode of deposition of RF pulse stimulation provides a fine crystalline structure, average size of about nanocrystals (9 - 10) nm. Compounds formed on the surface coating TiN (10 nm depth) were determined by XPS. Sketch. 3 given range of XPS peaks for Ti 2p, N 1s and O 1s.

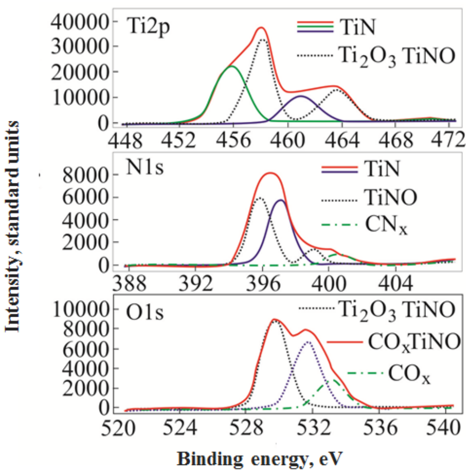


Figure 3. FES spectra taken from the surface of TiN coatings.

To interpret the spectral data used approximation XPS photoelectron lines and may Gauss-Lorentz functions. Determined peak width, intensity and integrated intensity. For all the samples the state of nitrogen 1s binding energy 399.0 - 400.6 eV can be attributed to adsorbed atomic nitrogen (398.3 - 399.4 eV) molecules adsorbed or NO (400.0 - 401.6 eV). Oxygen 1s line has three components with energies communication within 531.6 - 535.4 eV which may relate to O and OH (531.7 eV) and to adsorbed water (533.3 eV). Analysis of the diffraction coatings Ti-Al-N, obtained by sputtering cathode Solid shows that cover the main phases consist of Ti1-xAlxN of cubic lattice type B1 NaCl. Studies indicate that the deposition process using the pulsed RF processing nanocrystalline structure formed of crystallites with size 12 - 15 nm. When potential shift Uzs = - 200 V shaped texture (111) plane in the formation of the coating, and the lattice parameter of 0.4273 nm.

For coatings based on Ti-Zr-Si-N (coating thickness of ~ 3.2 micron) deposited on a steel substrate, as for the first series of samples, and for the second series (Fig. 4) throughout the investigated range of pressures and potential displacement, determined by radiographs clearly diffraction reflexes related to solid solution (Zr, Ti) N-based ZrN type of cubic lattice NaCl.

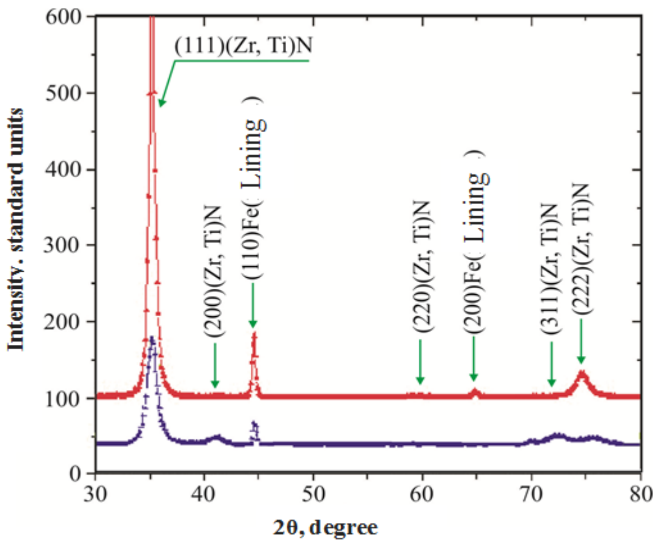


Figure 4. Fragments radiographs of specimens coated Ti-Zr-Si-N, obtained at P = 0.7 Pa; Uzs = 200 V

IV. CONCLUSION

The paper study physical, mechanical and tribotechnical properties of nanocomposite coatings based on Zr, Ti, Al, Si and N, synthesized by vacuum-arc method using high frequency stimulation. The effect of physical and technological parameters of deposition on the properties of nanocrystal line coatings was analyzed. It was found that the sizes of crystallites of synthesized nanocomposite coatings based on Ti-Al-N, Ti-Si-N and Ti-Zr-Si-N vary in the range of 10-25 nm. The correlation between ultimate composition, microstructure and mechanical properties of coatings was determined. The structure of the obtained coatings is essential for their mechanical characteristics. The maximum hardness for Ti-Al-N synthesized coatings is 35.8 GPa, for Ti-Si-N – 35.0 GPa, and for Ti-Zr-Si-N system– 40.8 GPa. The elasticity modulus for these coatings is determined within 392÷456 GPa. The increase of module of impulse HF shear potential from 100 V to 200 V for coatings of Ti-Zr-Si-N system causes the formation of texture (111) in the plane of coating deposition. The improvement of tribotechnical characteristics for coatings Ti-Al-N, Ti-Si-N and Ti-Zr-Si-N was established as compared with coatings based on TiN. It was found that high-melting compounds on the basis of multicomponent coatings in terms of friction in air at elevated temperatures are characterized by a low level of structural activity.

ACKNOWLEDGMENT

This research was supported by the Engineering Science Research Program through the *Northern Technical University* / Ministry of Higher Education and Scientific / Research / Republic of Iraq. (No. 2019-00366).

REFERENCES

[1] W.C. Oliver, G.M. Pharr, 'Measurement of hardness and elastic modulus by instrumented indentation': Advances in understanding and refinements to methodology, J. Mater. Res. 19 (2011) 3–20.

[2] A.D. Pogrebnjak, A.A. Muhammed, E.T. Karash, N.Y. Jamil, J. Partyka, Przegląd Elektrotech. 89, 315 (2013).

[3] Chen L., Moser M., Du Y., Mayrhofer P.H. 'Thin Solid Film'. 2009;517:6635.

[4] Hiroyuki H., Ayako K., Tetsuya S. 'Surf. Coat'. Technol. 2000;132:76.

[5] M.V. Goltsev, S.V. Gusakova. 'Ion-plasma coatings based on triple nitrides of refractory compounds' // Newsletter BelGU. 2008, v. 1, N 2, p. 15-18.

[6] B. Bhushan, X. Li, Nanomechanical characterisation of solid surfaces and thin films, Int. Mater. Rev. 48 (2003) 125–164.

[7] A. D. Pogrebnyak, A. M. Mahmud, E. T. Karasha, G. V. Kirik, R. Y. Tkachenko and A. P. Sypylenko, "Structure and Physical-Mechanical Properties of Nc-TiN Coatings Obtained by Vacuum-Arc Deposition and Deposition of HF Discharge," Journal of Nano- and Electronic Physics, Vol. 3, No. 4, 2011, pp. 97-105.

[8] N.A. Azarenkov, O.V. Sobol, A.D. Pogrebnyak, V.M. Beresnev. 'Vacuum-plasma coatings engineering'. Kharkiv: Karazin Kharkiv National University, 2011, 344 p.

[9] Musil J. 'Hard nanocomposite coatings: thermal stability, oxidation resistance and toughness. Surface and Coatings Technology'. 2012; 207:50-65.

[10] A. D. Pogrebnyak, A. M. Mahmud, E. T. Karasha, " Structural properties of nanocrystalline tin film," International Journal Of Structronics & Mechatronics, May 27, 2012.

[11] D.V. Shtansky, M.I. Petrzhik, I.A. Bashkova, F.V. Kiryukhantsev-Korneev, A.N. Sheveyko, E.A. Levashov. 'Adhesion, friction and deformation characteristics of the coatings Ti-(Ca, Zr)-(C, N, O, P) for orthopedic and teeth implants' // Solid State Physics. 2006, v. 46, issue 7, p. 1231-1238.

Dr. Emad T. B. Karash was born on March 2th, 1962 in Mosul, Iraq. He received the Bachelor degree in Mechanical Engineering from Mosul University, Mosul, Iraq, in 1985. Master degree in Appliea mechanics from Mosul University, Mosul, Iraq, in 2002. Master degree in Dynamic and strength of Machines from Sumy State University, Sumy, Ukraine, in 2012. He has been working on the Northern Technical University.

How to Cite this Article:

Karash, E. T. (2019) Improve the Physical and Mechanical Properties of the Structures by Using the Coating Ti, Al, Zr, Si, N. International Journal of Science and Engineering Investigations (IJSEI), 8(94), 21-24. http://www.ijsei.com/papers/ijsei-89419-04.pdf