Electrochemical and mechanical properties of low friction nc-CrC/a-C:H and nc-WC/a-C:H coatings on construction materials deposited by magnetron sputtering.

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The increased focus on the natural environment protection, the increasing fuel prices and the will to reduce the costs of machines' maintenance - all that obliges us to search for innovative engineering solutions that would both limit the use of conventional lubricants and enhance the machines' efficiency. To fulfil this challenging goal, the parts of machines are coated with special low friction and high wear resistant materials more and more often. The PVD methods play a great role in this field. As the examples of coatings deposited by a PVD method and assuring the above mentioned goals may serve the nc-CrC/a-C:H and nc-WC/a-C:H.

This research focuses on the electrochemical and mechanical studies of low friction nc-CrC/a-C:H and nc-WC/a-C:H coatings deposited by magnetron sputtering on two kind of construction materials: Vanadis 23 steel and oxygen hardened Ti-6Al-4V alloy.

The obtained coatings were investigated using various electrochemical and mechanical methods. The following parameters of coatings were determines: electrochemical (corrosion resistance), micro-mechanical (nanohardness, Young's modulus) and tribological (wear resistance, friction coefficient).

The results presented in this paper have been obtained within the project "KomCerMet" (contract no. POIG.01.03.01-00-013/08 with the Polish Ministry of Science and Higher Education) in the framework of the Innovative Economy Operational Programme 2007-2013.

Keywords*: nanocoatings, electrochemical properties, corrosion, mechanical properties*

Materials and testing

Coatings were deposited using magnetron sputtering of three graphite targets (Ø 107x10 mm) and one of pure metal Cr or W (Ø 107x10 mm) for nc-CrC/a-C:H or nc-WC/a-C:H, respectively in atmosphere of $Ar+H_2$. The coatings were deposited onto bulk hardened HS steel Vanadis 23 (Ø25x6mm), diffusion hardened Ti6Al4V alloy (Ø25x6mm), silicon wafers (10x10x0,55 mm) and 0H18N9 steel plates (10x10x1 mm).

Metal substrates were grinded using abrasive papers with fraction from 80 to 1200 and polished using diamond powder (1µm) with lubricant. After polishing substrates were washed in mixture of water and detergent, after that using acetone in sonic bath. Silicon substrates were cleaned using only water mixture with detergent and acetone. After cleaning substrates were mounted on holder inside vacuum chamber of B-90 deposition unit. The exact preparation of samples, processes of deposition and schema of B-90 unit were presented in [1-2].

Tribological properties were measured using ball-on-disc method using High Temperature Tribotester CSM with use fi1/4" 100Cr6 counterbodies under load of 10 N with linear speed 0.1 m/s on radius of friction path 10 mm, friction path was 1000 m. Humidity during tribological test was 25±6%. The friction force, temperature, humidity and vertical displacement were measured during tribological tests. Mechanical properties like nanohardness and Young modulus were measured using Nanoindenter G-200 based on CSM (Continuous Stiffness Measurement). Chemical composition and thickness were measured using Hitachi S-3000N with EDS module. Quality of adhesion of coating to steel and hardened titanium alloy was measured using Daimler-Benz test.

The impedance (electrochemical impedance spectroscopy - EIS) data was obtained at the open circuit potential with a Princeton Applied Research model VersaStat 3 system. The frequency range analysed, went from 10^6 Hz up to 10^{-3} Hz, with the frequency values spaced logarithmically (ten per decade). The amplitude of sinusoidal voltage signal applied to the system was 10 mV rms (root-mean-square). Prior to the beginning of the measurements, the specimens were maintained for 1.5 h in 0.5 M/l NaCl for stabilisation of an open – circuit potential.

The investigation of the coated oxygen hardened Ti-6Al-4V alloy and VANADIS 23 steel nano/microstructure was carried out by scanning- and transmission electron microscopy (SEM, TEM) and high resolution TEM (HRTEM). Phase identification was performed by means of selected area electron diffraction (SAED), XRD and GIXRD measurements. The SAED and fast Fourier transformation FFT patterns were interpreted with the help of Java Electron Microscopy Software (JEMS) [3].

Results

Electrochemical properties

a) **b)**

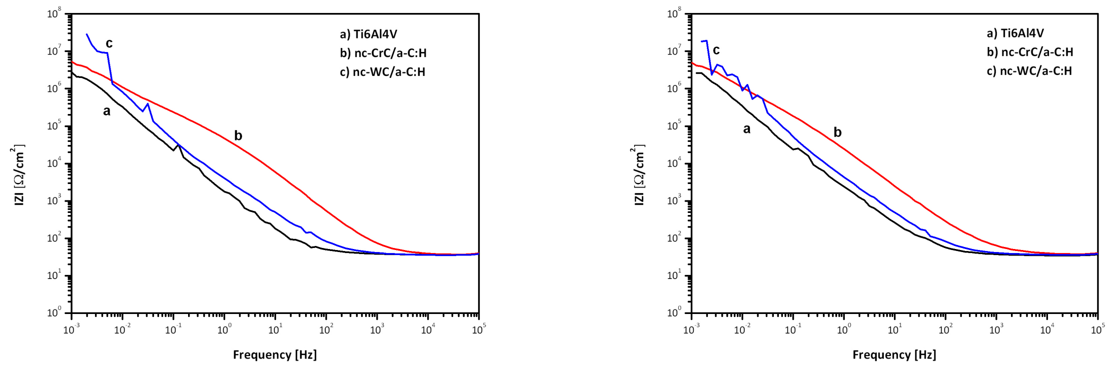

Fig. 1. Impedance modulus for Ti6Al4V with and without nanocomposite coatings after 1h (a) and 48h (b) immersion in 0.5 M NaCl.

a) **b)**

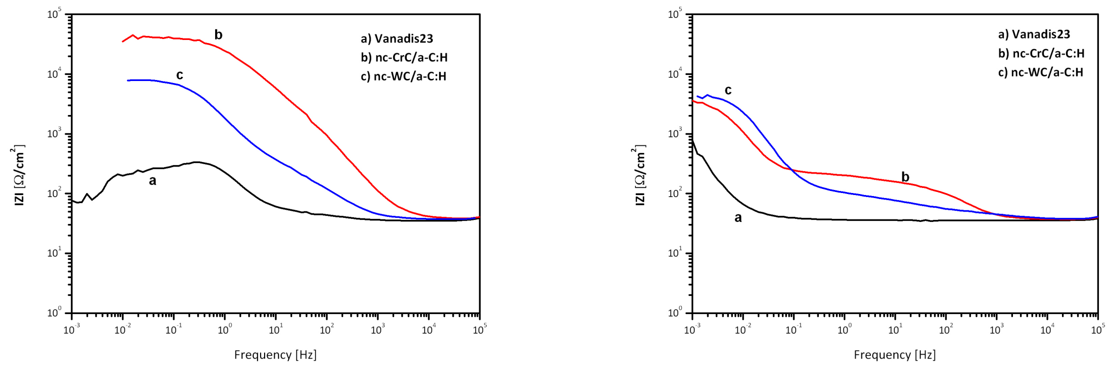

Fig. 2. Impedance modulus for Vanadis 23 steel with and without nanocomposite coatings after 1h (a) and 48h (b) immersion in 0.5 M NaCl.

a) **b)**

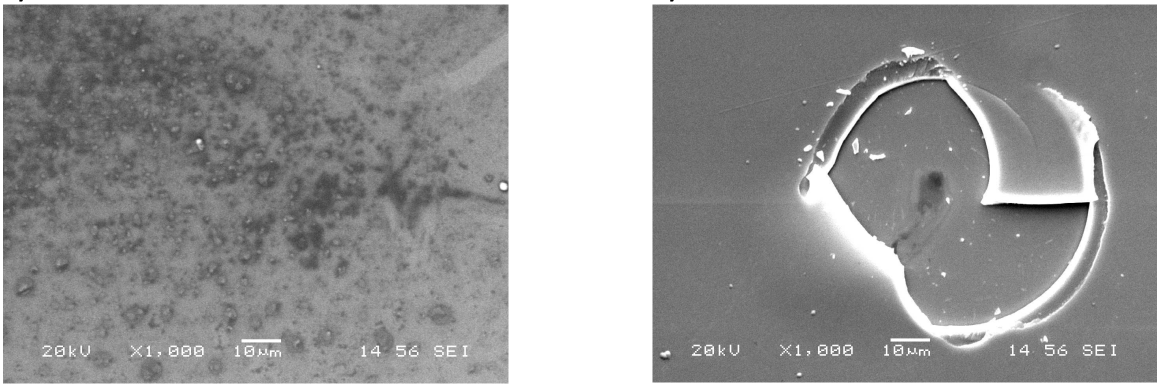

Fig. 3. SEM images of Ti6Al4V with nc-CrC/a-C:H (a) and nc-WC/a-C:H (b) coating after 48h immersion in 0.5M NaCl.

a) **b)**

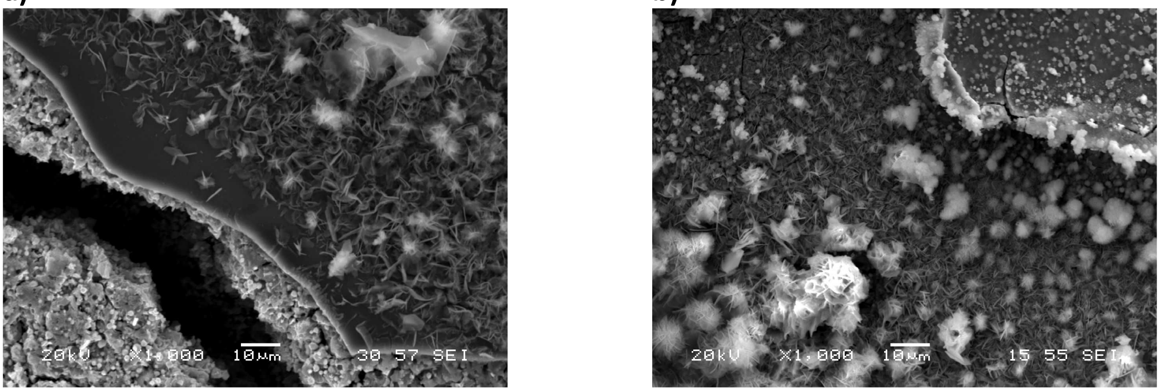

Fig. 4. SEM images of Vanadis 32 with nc-CrC/a-C:H (a) and nc-WC/a-C:H (b) coating after 48h immersion in 0.5M NaCl.

Mechanical properties

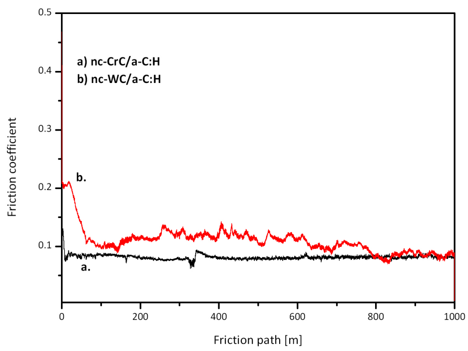

Fig. 5. Friction coefficient in function of friction distance for a) nc-CrC/a-C:H and b) nc-WC/a-C:H deposited onto Vanadis 23.

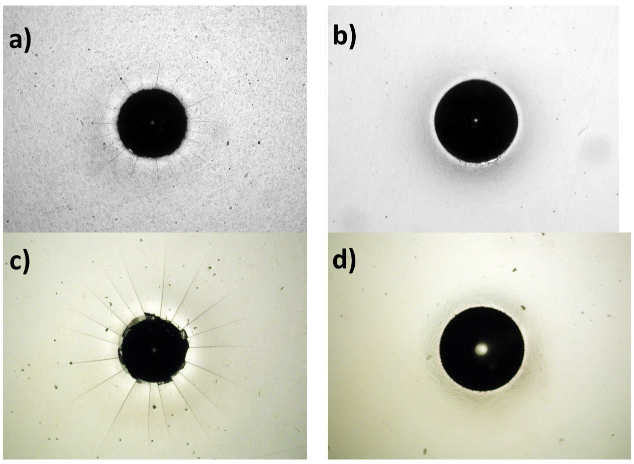

Fig. 6. View of coatings surface after Daimler-Benz test of a)nc-WC/a-C:H on Ti6Al4V, b) nc-WC/a-C:Hon Vanadis 23, c) nc-CrC/a-C:H Ti6Al4V d) nc-CrC/a-C:H Vanadis 23.

Microstructure

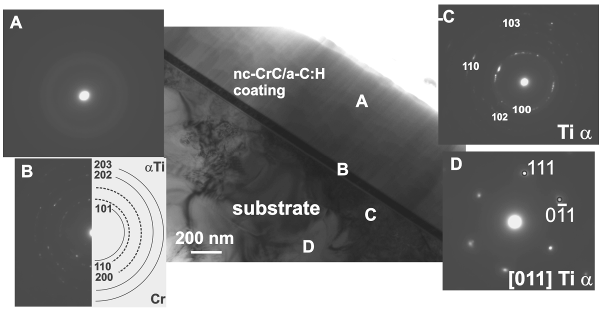

Fig. 7. Microstructure of the nc-CrC/a-C:H coating on oxygen hardened Ti-6Al-4V alloy as well as SAED patterns taken from the areas A-D marked in the figure and their identification; TEM cross-section thin foil.

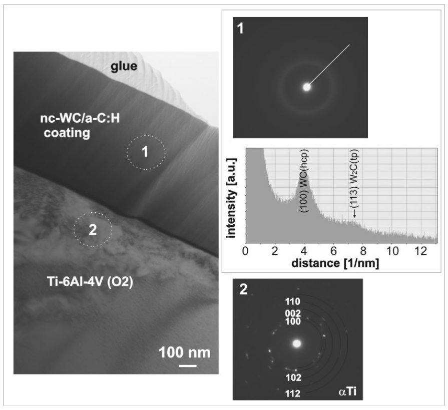

Fig. 8. Microstructure of the nc-WC/a-C:H coating on oxygen hardened Ti-6Al-4V alloy as well as SAED patterns taken from the areas marked on the figure and their identification; an intensity profile of the SAED patterns taken from the coatings are presented; TEM cross-section thin foil.

Conclusions

Obtained nc-CrC/a-C:H and WC/a-C:H coatings have very good adhesion also to bulk hardened and tempered steel substrates and to diffusion hardened Ti6Al4V alloy. Mean values of friction coefficients between coatings on steel substrates and hardened titanium alloy was 0.08 for nc-CrC/a-C:H and 0.1 for nc-WC/a-C:H. This is a very good result and in connection with good quality of adhesion to those substrates, allows to use low friction nanocomposite coatings based on amorphous matrix and nanocrystalites of transition metals to enhance tribological properties of elements made of steel or titanium alloys working as friction couples in temperatures up to 200 ºC. Especially in aviation and car industry as parts of engines and power transmissions and as a coating on machining tools, also for hard-to-machining materials like Ni, Ti and Co. In spite of low values of hardness and Young modules the coatings have very good wear resistant which are most important for low friction coatings than mechanical properties.

Corrosion properties of nanocomposite coatings mainly depend on the substrate material. In the case of steel Vanadis 23 coatings caused a significant increase of corrosion resistance, even after 48 hours in a chloride solution.

However, in the case of titanium alloy tested coatings also increased corrosion resistance. However, this increase was not as significant as in the case of steel Vanadis 23.

References

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