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TRIBOLOGICAL BAHAVIOUR OF COATINGS DEPOSITED BY REACTIVE MAGNETRON SPUTTERING METHOD

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ABSTRACT
Monolithic nitride coatings and multilayer metallic/ceramic coatings were deposited onto brass (CuZn40Pb2) substrates by dc magnetron sputtering. The ceramic coatings or layers are Cr-, Ti-, TiAl-, Zr-nitrides. The mechanical properties, tribological behaviour were studied. To improve adhesion, a thin metallic layer was deposited prior to deposition of ceramic monolithic coatings. Two sets of multilayer coatings for each nitride family were produced. One of the sets with 15 monolayers and the other with 150 monolayers. The results show that all coatings demonstrate good adhesion. The optimum mechanical properties, tribological behaviour and wear resistance were obtained for the monolithic coatings with a thin intermediate metallic layer.
Keywords: PVD coatings, tribology, erosion test

1. INTRODUCTION
The progress in the area of manufacturing and extending the life expectancy of the constructional elements and tools, used in various domains of life, is taking place mostly thanks to the more and more common employment of the thin coatings deposition, made from hard, wear resistant ceramic materials. Big selection of coatings available actually and their deposition technologies are the effects of the growing, in the last years, demand for the contemporary modification methods and materials' surface protection [1-4]. Currently, the CVD (Chemical Vapour Deposition), and PVD (Physical Vapour Deposition) methods play an important role in the industrial practice among many techniques improving the materials' life. The PVD techniques are currently commonly used for improving the mechanical and functional properties of a wide range of engineering materials. Thanks to the relatively low PVD process temperature, other than the CVD processes there is no risk of losing the properties acquired during the heat treatment of the coated materials. Extension of life of elements coated with the wear resistant coatings poses additional requirements pertaining to the tribological properties of the coatings deposited and their contact with the hard materials. The hard coatings made in the PVD processes increase significantly the abrasive wear resistance of materials covered with them [5-6]. Friction reduction, resulting from a lower friction coefficient of coatings alone, increases the economical benefits connected with using the products covered with the protective coatings [7-8]. Tribology, dealing with investigation of phenomena occurring between the interacting surfaces in their relative motion, plays an important role in studying materials wear mechanisms and in search of methods to counteract this adverse phenomenon [9-10]. Various tribological tests exist carried out in many scientific laboratories. The pin-on-disc test is the one used most often from all of them for determining the wear abrasion resistance. Another popular method, which makes it possible – in a relatively simple way - to determine durability of materials, their functional properties, and to differentiate them, is the erosion test using the powder abradant. The goal of this work is investigation of the erosion resistance and tribological properties of coatings deposited by reactive magnetron sputtering (PVD method) onto the CuZn40Pb2 brass substrate.

2. EXPERIMENTS

The coatings were produced by reactive dc magnetron sputtering using metallic pure targets. They were deposited on CuZn40Pb2 brass substrates. The nitride coatings or nitride layers were deposited when the substrates were static in front of the target in an Ar and N_2 atmosphere. The metallic layers were deposited when the substrates were static in front of the target in an Ar atmosphere. Some deposition conditions are summarized in table 1. Disks containing pure metals (Ti, Cr, Mo, Zr) and the 50% Ti - 50% Al alloy, featuring the substrates of phases deposited on the charge, were used for deposition the coatings. The coatings were deposited in the inert gas atmosphere (argon) and/or reactive gas (nitrogen) delivered continuously to the furnace chamber. Experimental methodology was presented in [11].

Table 1. Coating types, their deposition parameter and summary results of the mechanical properties tests.

Coating type	Substrate bias voltage, V	Furnace pressure, Pa	Hardness DHV0,005	Critical load L_{C2}, N	Friction distance, m
Ti/CrN×1	-50	0,39	2450	50	100
Ti/CrN×15		0,46	2350	48	98
Ti/CrN×150		0,34	1800	47	24
Ti/ZrN×1	-50	0,29	3100	45	16
Ti/ZrN×15		0,31	2700	41	10
Ti/ZrN×150		0,40	2200	40	7
Ti/TiAlN×1	-40	0,41	240	41	10
Ti/TiAlN×15		0,41	2100	40	5
Ti/TiAlN×150		0,49	1850	38	2,5
TiAlN/Mo×1	-60	0,46	2400	48	75
TiAlN/Mo×15		0,50	2200	45	16
TiAlN/Mo×150		0,39	2000	40	3

3. DISCUSSION OF RESULTS

The dynamical hardness tests were made with the 0,05 N load, to eliminate the influence of the substrate on the obtained results. A clear effect was revealed of the number of layers deposited onto the brass substrate on the obtained values of the dynamical hardness (table 1). The monolayer coatings demonstrate the highest hardness.

Erosion tests were carried out to evaluate the working and operation properties of coatings. Because of the specific properties of the substrate material (being relatively soft compared to coatings), the standard in such case, analysis of the crater profile developed during erosion tests is not possible due to driving the erodent into the soft brass base at the bottom of the developed crater. This results in a change of the profile of the developing failure, which makes it impossible to evaluate the coating failure degree. However, taking advantage of the differentiated tint of the substrate and coating, the colour metallographic methods were used, employing the computer image analysis in the scanning electron microscope for evaluation of the failure degree for the examined coatings (fig. 1). Observations of the coatings damaged due to the erosion test in the scanning electron microscope make it also possible to determine the percentage portion of the damaged surface in reference to the total area of the observation field, set up so that the maximum area of the developed crater is visible, using the stereological methods for that. As it turns out from the data included in fig. 2, monolayers, and especially the Ti/CrN×1 one, exhibit the best resistance to the abradant operation. In this case only 1,1% of the substrate is uncovered after 1 sec of test duration by the hitting abradant particles; whereas, the percentage coating damage is about 11,5% (percentage portion of the uncovered substrate + abradant particles stuck in the coating and substrate materials), meaning that 88,5% of the coating surface does not reveal damages. In case of the same layer consisting of 15 layers, the percentage portion of the coating surface that does not exhibit any damages connected with the destructive abradant operation after 1 sec is 53%; whereas, in case of 150 layers – 17,5%, which means that 82,5% of the coating surface is damaged and its erosion resistance is more than four times lower that in case of the monolayer after the same test duration time.

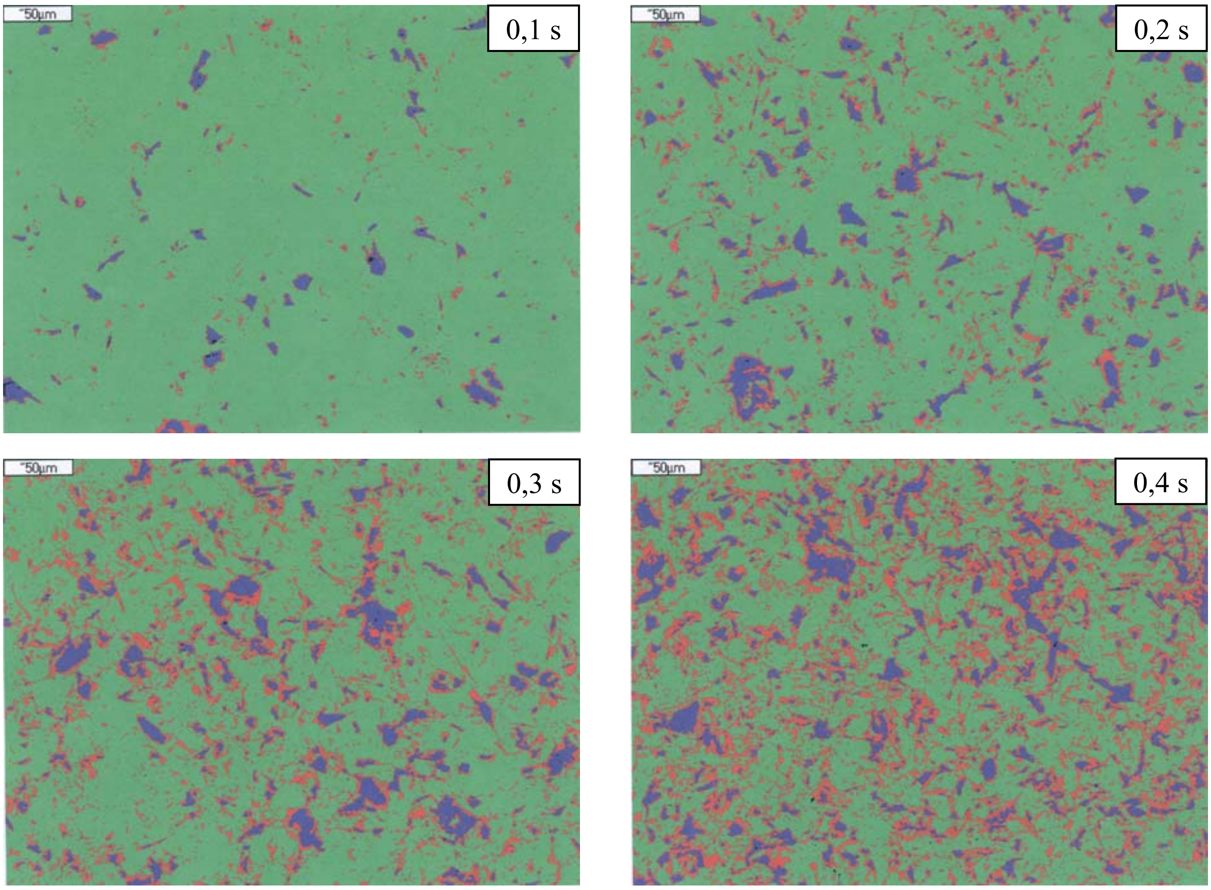

Figure 1. Surface of the Ti/ZrN×1 coating in various of the erosion test stages, depending on the SEM test duration.

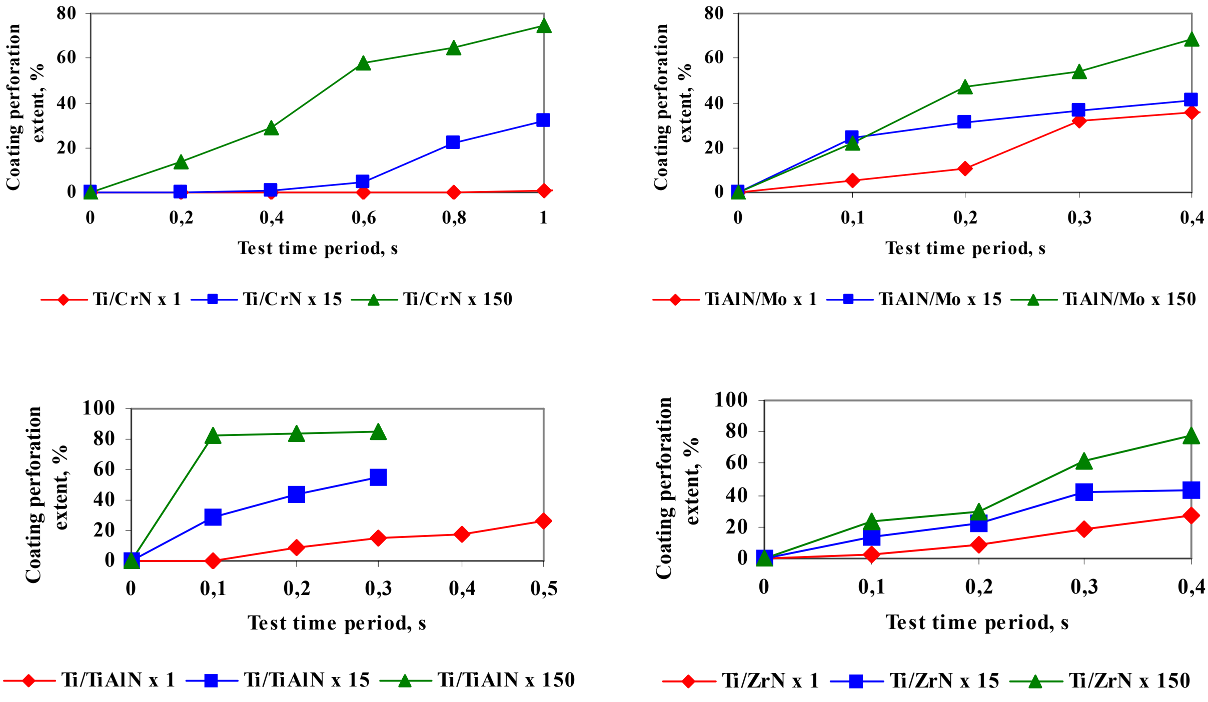

Figure 2. Extent of perforation of the multilayer coatings deposited onto the CuZn40Pb2 substrate depending on the erosion test time period.

In case of the remaining multilayer coatings their perforation extent was much bigger, which results in their worse erosion resistance. Analysis of the surfaces of coatings (fig. 1) makes it possible to point out to the successive stages of the coating failure process, developing due to abradant particles action. In the beginning phase of the erosion test, the abradant being driven into the coating material causes development of small coating failures, due to friction or chipping occurring in various spots. There are places where the coating is intact and small areas in which, first of all, hard abradant particles have been driven into the coating material. The next stage is connected with development of new centres of failure and continuing process of growth of the area in which coating failure had occurred. Locations in which the abradant particles are driven into the coating material should be also treated as the area in which failure has occurred. As the time goes on, erosion process intensifies, resulting in connecting the damaged coating areas into big zones, thanks to which full crater develops, gets deeper, and finally big areas of the substrate surface get uncovered, which is connected with total destruction of the coating material by the abradant particles. The pin-on-disc abrasion resistance tests were carried out to determine fully the functional and working characteristics of coatings deposited onto the brass substrate by PVD process. It was found out in the course of investigations, that the longest distance after which coatings failure occurs due to friction of the counter-specimen is characteristic for the Ti/CrN×1 (table 1) monolayers, which corresponds with the results obtained after carrying out the erosion test. The critical load L_{C2} values, characterizing adhesion of the investigated coatings to the CuZn40Pb2 brass substrate caused mostly by adhesion and diffusion forces, at the linearly increasing load, were determined with the scratch test. Good adhesion of the deposited coatings to the substrate should be connected with the existence of the transition layer. This may be attested by the critical load L_{C2}, being in the range of 50-38 N (table 1), depending on the coating type.

4. SUMMARY

Basing on the investigation results the following conclusions were arrived at:

- the optimum mechanical properties and abrasion wear resistance were obtained for monolayers with a thin interlayer from pure metal, whereas increase of the number of layers to 15 or 150 results in reducing their life four times. These are connected with the higher hardness and wear abrasion resistance of a single nitride layer than those of the multilayer system, where the hardness and tribological properties of the alternating layers put down from pure metals are lower.
- the investigated coatings demonstrate good adherence to brass substrate, which is decided not only by adhesion but also the interlayer between the coating and the substrate, developed as a result of diffusion and because of action of high energy ions causing mixing of elements in the interface zone.

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