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Properties of the mono-layer ceramic coatings deposited by PVD process

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The paper presents investigation results of the structure, mechanical and functional properties of hard ceramic monolithic nitride PVD coatings produced by reactive dc magnetron sputtering method on the brass substrate.

1. INTRODUCTION

Progress in the area of manufacturing and extending the life of structural elements and tools, being used in various fields is being attained mostly because the more and more common employment of techniques for deposition thin coatings from hard, wear resistant ceramic materials. Wide selection of the coating types and technologies of their deposition available currently is an effect of the growing in the last years demand for the modern methods of modification and protection of material surface [1,2]. The PVD techniques as ones of many methods modifying the properties of the surface layer make it possible to develop coatings from phases called ceramic materials, characterized by the low friction coefficient and high wear resistance [3]. Examining properties of coatings made in the PVD processes one should pay particular attention to issues connected with their mechanical properties (adhesion, hardness, internal stresses, etc.), physical properties (thermal conductivity, friction coefficient, etc.), abrasion resistance, their corrosion, diffusion, and thermal protection, as well as with the structure, chemical composition and thickness of coatings [4,5].

The goal of this work was to investigate the structure, as well as mechanical and working properties of the mono-layer ceramic coatings deposited by PVD technique onto the brass substrate.

2. EXPERIMENTS

The coatings were produced by reactive dc magnetron sputtering using metallic pure targets. They were deposited on CuZn40Pb2 brass substrates. Some deposition conditions are summarized in table 1.

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Table 1. Coating types and their deposition parameter: *during metallic layers deposition; ** during ceramic layers deposition.

Coating type	Substrate bias voltage, [V]	Partial Pressure, [Pa]		Thickness [μm]	Temperature, [^{o}C]
		Nitrogen	Argon		
Ti/CrN	–50	0* 0,15**	0,31	4,8	300
Ti/ZrN	– 50	0* 0,10**	0,29	2,1	
Ti/TiAlN	– 40	0* 0,10**	0,38	2,3	
Cr/CrN	– 50	0* 0,15**	0,30	3,6	
Ti/TiN	– 60	0* 0,07**	0,25	2,4	
Zr/ZrN	– 60	0* 0,10**	0,29	2,0	
TiAl/TiAlN	– 60	0* 0,11**	0,45	2,3	

The coatings were deposited onto the polished brass specimens by the reactive magnetron sputtering. Water cooled disks of the 200 x 100 x 6 mm size, containing pure metals (Cr, Ti, Zr) and the 50% Ti - 50% Al alloy, featuring substrates of the compound deposited on the charge, were used to deposition the coatings. The coatings were deposited in the atmosphere of the inert gas (argon) or/and reactive gas (nitrogen). In order to improve corrosion resistance and adhesion, a thin layer (about 100 nm) from pure Cr, Ti, and TiAl alloy was deposited onto the brass substrate, before coating it with the CrN, TiN,and TiAlN layers respectively. The distance between each of the disks and the coated brass specimens is 65 mm. Experimental methodology was presented in [6].

3. DISCUSSION OF RESULTS

The examination of cross section of the coatings by SEM reveals a compact structure, without any visible delamination or defects. In case of the single-layer coatings their columnar structure is clearly visible, which may be recognized as consistent with the Thornton model (I zone) (fig.1).

Summary results of mechanical tests and of examinations of the working properties of the coatings are presented in Table 2. Using the scratch test with the linearly increasing load the critical load L_{C2} values were found, characterizing adhesion of the investigated coatings to the CuZn40Pb2 brass substrate caused mainly by the adhesion and diffusion forces. The critical load L_{C2} value is in the range of 57÷41 N, depending on coating type (Table 2). Employment of an additional thin intermediate (Ti, Zr, Cr, TiAl) layer in single layer coatings improves adhesion of the nitride coating to the substrate, as the it counteracts propagation of cracks and reduces stresses in the coating-substrate zone. Hardness for the mono-layer coatings is 2400÷3100 DHV0.0025, which has also the decisive effect on their higher erosion resistance.

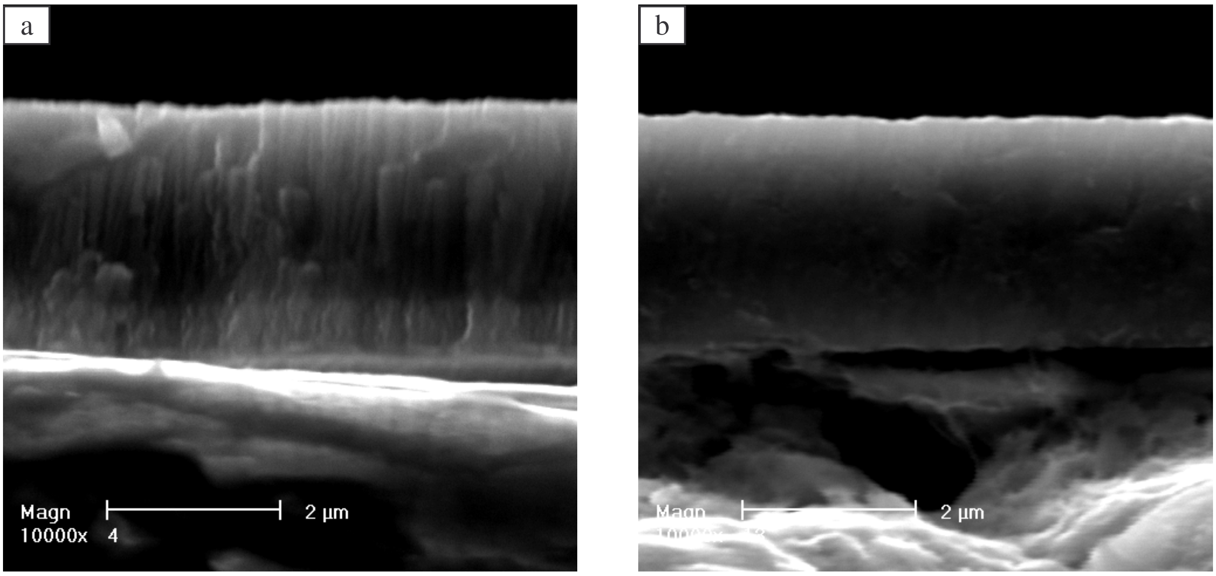

Fig. 1. Fracture of the: a)Ti/TiAlN, b)Ti/TiN coating deposited onto the CuZn40Pb2 substrate

Table 2. Summary results of the mechanical and functional properties tests

Coating type	Critical load L_{C2}, N	Friction distance, m (pin-on-disc)	Hardness, DHV	Corrosion rate, mm/year
Ti/CrN	50	100	2450	0,027
Ti/ZrN	45	16	3100	0,008
Ti/TiAlN	41	10	2400	0,063
Cr/CrN	48	25	2400	0,045
Ti/TiN	50	140	2800	0,012
Zr/ZrN	48	60	3100	0,006
TiAl/TiAlN	50	90	2200	0,007

To determine the working and operational properties of the coatings, the erosion, tribological, and corrosion tests were made. A high erosion resistance is demonstrated by mono-layer coatings with a thin interlayer, and especially Ti/TiN and Zr/ZrN for which the coating perforation extent is within 15÷20% range after 0.4 sec of the test duration (Fig. 2). To obtain a comprehensive working and operational characteristics of coatings deposited in the PVD process onto the brass substrate, the coating abrasion test was made with the pin-on-disc method. The tests revealed that the longest path after which the coating is damaged due to friction by a counter-specimen is characteristic for the mono-layer Ti/TiN and Ti/CrN coatings (Table 2), which corresponds to results obtained in the erosion test.

It was found out in case of the corrosion tests that the corrosion rate of the mono-layer coatings is much higher than obtained for the multi-layer ones [6]. Defects and failures occurring on mono-layer coatings during their deposition process feature the main cause of their inferior corrosion resistance. This is caused by a shorter path of the corrosive agent needed to penetrate inside the material.

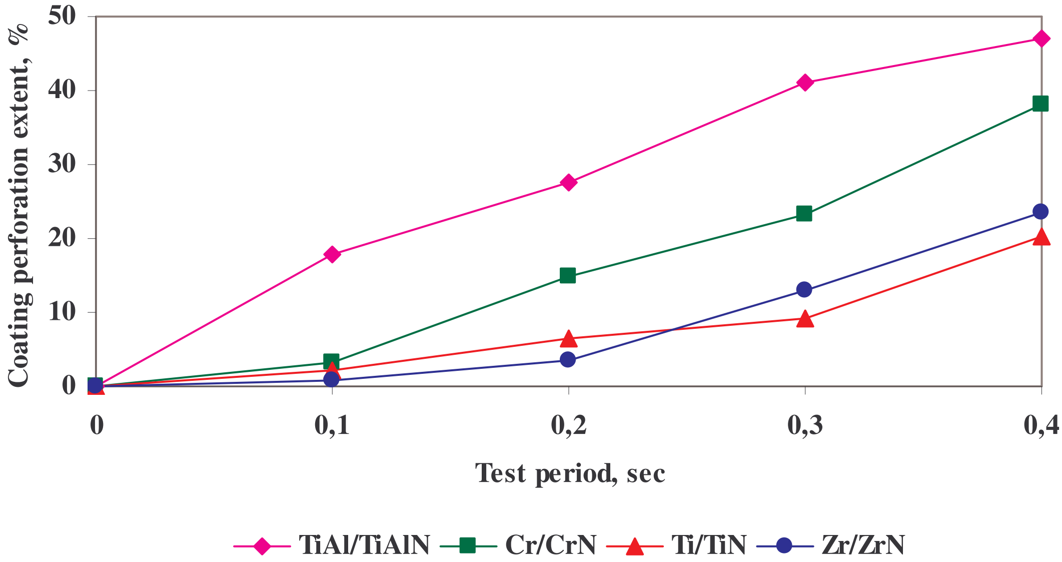

Fig. 2. Extent of perforation of the multiple-layer coatings put down onto the CuZn40Pb2 substrate depending on the erosion test time period

4. SUMMARY

Basing on the investigation results it was found out that the mono-layer coatings demonstrate lower resistance to the corrosion agents attack, compared to the multi-layer ones. This may be explained by the fact that the multi-layer coating deposition system offers better possibilities to prevent corrosion causes like scratches or crevices. In case of the tribological tests, however, the mono-layer coatings demonstrate higher resistance to erodent and abrasion wear, and a better adhesion to substrate, compared to the multi-layer coatings presented in [6]. The multi-layer system does not provide the sufficient anti-wear protection, unlike the mono-layer coatings, in which a single, thick nitride layer features a good protection of various materials during the mutual interaction of the rubbing elements in their relative motion.

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