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Structure of multicomponent and gradient PVD coatings deposited on sintered tool materials

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Materials

ABSTRACT

Purpose: Investigation of the Al_2O_3+TiC type oxide tool ceramics and cemented carbides with the multicomponent (Ti,Al)N and gradient Ti(C,N) coatings deposited with use of the cathodic arc evaporation CAE-PVD method.

Design/methodology/approach: SEM, confocal microscopy, X-ray qualitative microanalysis of elements, X-ray qualitative phase analysis.

Findings: It was stated that investigated materials have a dense, compact structure and their fracture surface topography attests their high brittleness, characteristic especially for the oxide ceramic materials. The coatings were put down uniformly onto the investigated substrate materials. They have a columnar, fine-graded structure.

Practical implications: Pro-ecological dry cutting processes without the use of the cutting fluids and in the „Near-Net-Shape" technology.

Originality/value: Application of multicomponent (Ti,Al)N and gradient Ti(C,N) types of coatings onto sintered tool materials in order to improve cutting properties of the tools.

Keywords: Tool materials; Gradient coatings; PVD; SEM; X-ray

1. Introduction

The notion of functionally graded materials is a modern idea of forming the microstructure. It has been applied to a variety of materials not only to materials under abrasive and thermomechanical load but also to biomaterials, electronic materials and energy conversion materials. Because of this there exist various processing technologies of graded materials. For hardmetals and abrasive tools, various methods e.g. mixing and stacking of different powder mixtures, and recently PVD and CVD coatings. Application of coatings on tools and machine elements is therefore a very efficient way of improving their friction and wear properties in wide range of applications [1-12]. In combination with the rapid development of new coating technologies, this has led to an accelerated increase in the use of coated components. Physical vapor deposited TiN coatings are widely used for machining of a wide variety of materials. Coatings based on (Ti,Al)N as well as Ti(C,N) were developed to provide better performance over titanium nitride since the incorporation of aluminum or carbon atoms into TiN is conducive to greater hardness and smaller coefficient of friction of the coatings [13,14]. Among a wide range of PVD methods cathodic arc vapor deposition is widely used due to its ability to provide a dense and adherent thin coating at a relatively low temperature [15].

The goal of this paper is investigation of the Al_2O_3+TiC type oxide tool ceramics and cemented carbides coated with the multicomponent (Ti,Al)N and gradient Ti(C,N) types of coatings deposited by means of the cathodic arc evaporation CAE-PVD method.

2. Experimental procedure

Experiments were carried out on cemented carbides and Al_2O_3+TiC oxide ceramics, with multicomponent (Ti,Al)N and gradient Ti(C,N) coatings using the method of physical vapour deposition of coatings from the gaseous phase in the cathodic arc evaporation (CAE) process. Specification of the investigated materials has been presented in Table 1.

The roughness measurements and observations of surface topography of the deposited coatings were made on LSM 5 PASCAL confocal microscope.

Observations of surfaces and structures of the deposited coatings were carried out on the transverse fractures in the scanning electron microscope SUPRA 25. To obtain the fracture images the Secondary Electrons (SE) detection method has been used with the accelerating voltage in the range of 15-20 kV and maximum magnification 30 000x.

The X-ray qualitative microanalysis of elements in the investigated coatings were made using the EDS X-ray energy dispersive spectrometer, featuring the standard equipment of the scanning microscope.

The evaluation of the phase composition of the investigated coatings was made using the DRON 2.0 X-ray diffractometer, using the filtered cobalt lamp X-rays with the voltage of 40 kV and heater current of 20 mA. Measurements were made within the 2θ angle range from 35-105°.

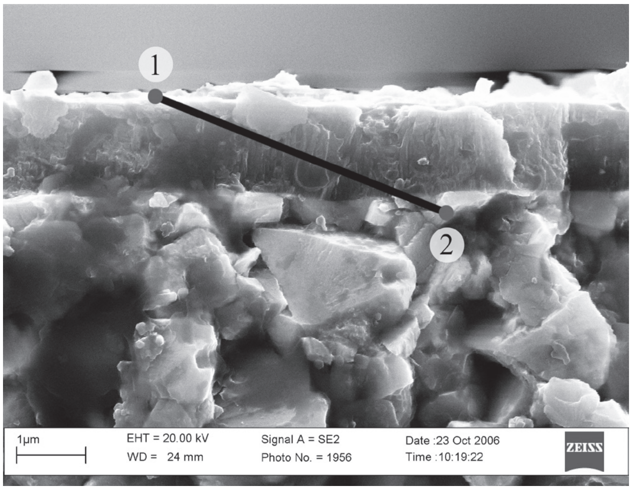

Fig. 1. Fracture surface of the gradient Ti(C,N) coating deposited onto the cemented carbide substrate

3. Results

The investigated materials are characteristic of the dense, compact structure and their fracture surface topography attests to their high brittleness characteristic especially for the oxide ceramic materials. The coatings were put down uniformly onto the investigated substrate materials. They present a characteristic columnar, fine-graded structure, depending on the coating type employed. Investigated coatings adhere tightly to the substrate (Fig. 1). Gradient of chemical composition of Ti(C,N) coating in function of distance was investigated by EDS method (Fig. 2). Detailed analysis of gradient structure has being carried out and will be introduced in future publications.

Basing on the surface morphology observations with use of the scanning electron microscope of the cemented carbides and Al_2O_3+TiC oxide ceramics with (Ti,Al)N and gradient Ti(C,N) coatings put down with the CAE-PVD method, the inhomogeneity was revealed connected with the occurrence of many drop shaped and elongated micro-particles on surface (Figs. 3, 4).

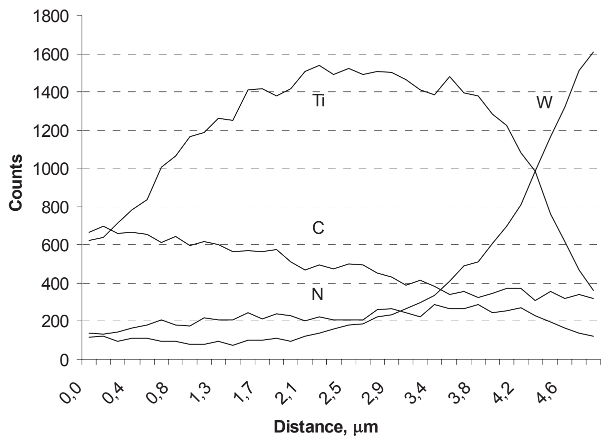

Fig. 2. Chemical composition in function of distance, obtained in EDS method

Table 1.
Specification of the investigated materials

Substrate	Coating	Coating thickness, µm	Roughness, µm
Cemented carbide*	uncoated	-	0.13
Al_2O_3+TiC		-	0.10
Cemented carbide*	(Ti,Al)N	2.2	0.14
Al_2O_3+TiC		1.6	0.27
Cemented carbide*	gradient Ti(C,N)	1.5	0.11
Al_2O_3+TiC		1.3	0.21

* phase composition: WC, TiC, TaC, Co.

The sizes of the drop-shaped micro-particles are different and vary from several tenths of a micrometer to above 2 µm; whereas in case of the elongated particles their size exceeds even 5 µm. Examinations of chemical composition of the micro-particles using the X-ray energy dispersive spectrometer EDS indicate that titanium prevails inside of the micro-particles, which suggests that these are the molten metal drops solidifying on the substrate surface (Fig. 5).

Roughness of the substrates defined by R_a parameter is within 0.10 ÷0.13 µm range. Depositing the (Ti,Al)N and gradient Ti(C,N) coatings onto the examined substrates increase of the roughness parameter from R_a = 0.14 µm for the (Ti,Al)N coating deposited on cemented carbide substrate to R_a = 0.27 µm for the (Ti,Al)N coating deposited on Al_2O_3+TiC substrate. In case of gradient Ti(C,N) coating deposited on cemented carbide substrate the roughness parameter decreased in comparision with the uncoated substrate (Table 1, Fig.6).

It was demonstrated using the X-ray qualitative phase analysis method that according to the initial assumptions coatings containing the (Ti,Al)N and gradient Ti(C,N) phases were deposited on surfaces of the investigated cemented carbides and oxide ceramics (Figs. 7, 8).

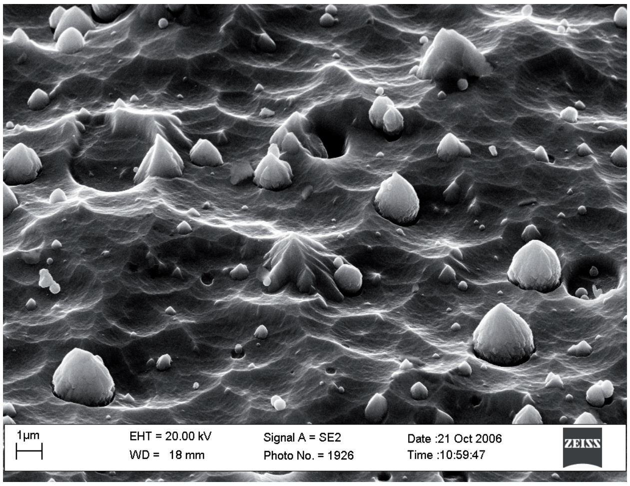

Fig. 3. Topography of the gradient Ti(C,N) coatings surface, deposited on the cemented carbide substrate

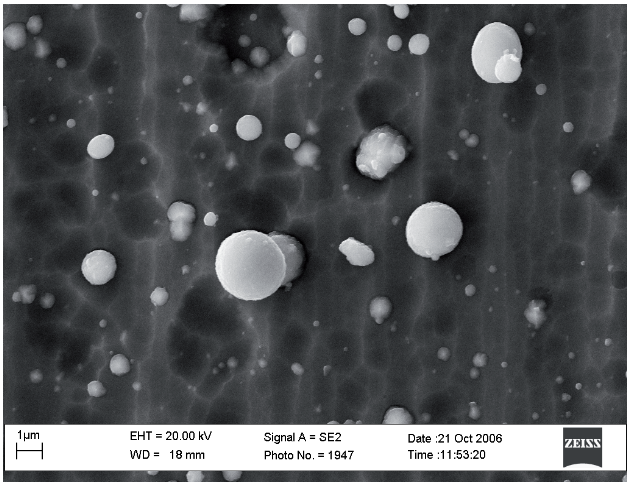

Fig. 4. Topography of the gradient Ti(C,N) coatings surface, deposited on the Al_2O_3+TiC substrate

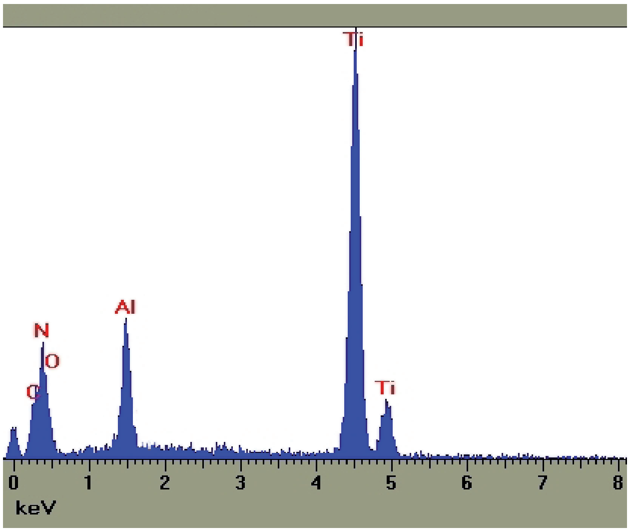

Fig. 5. X-ray energy dispersive spectrum from the surface of the gradient Ti(C,N) coating deposited on Al_2O_3+TiC substrate. Area of droplet as on Fig. 4

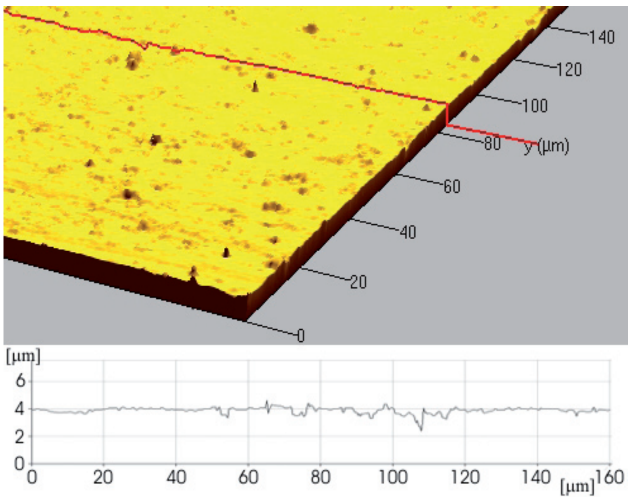

Fig. 6. Topography and roughness profile of the gradient Ti(C,N) coatings surface, deposited on the Al_2O_3+TiC substrate investigated with confocal microscope

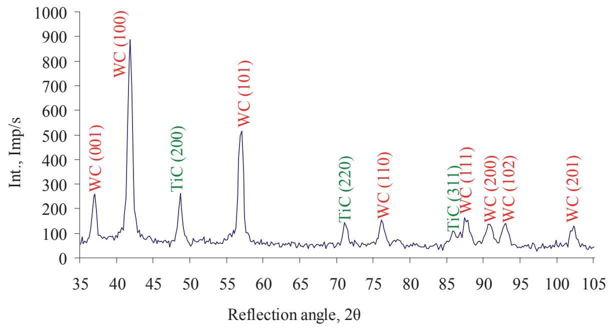

Fig. 7. X-ray phase analysis of the cemented carbide substrate

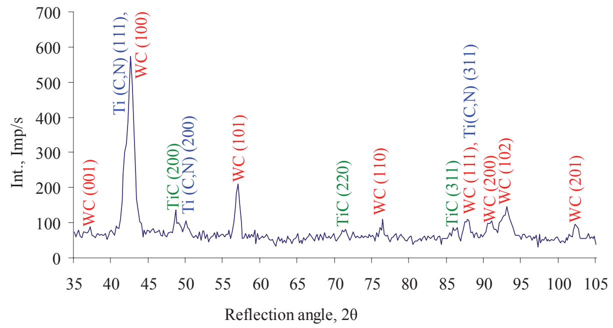

Fig. 8. X-ray phase analysis of the gradient Ti(C,N) coating deposited on the cemented carbide substrate

4. Conclusions

The results of the investigations of the Al_2O_3+TiC type oxide tool ceramics and cemented carbide are coated with the multicomponent (Ti,Al)N and gradient Ti(C,N) types of coatings with use of the cathodic arc evaporation CAE-PVD method are given in the paper. It was stated that investigated materials have a dense, compact structure and their fracture surface topography attests their high brittleness, characteristic especially for the oxide ceramic materials. The coatings were put down uniformly onto the investigated substrate materials and have a characteristic columnar, fine-graded structure. X-ray qualitative phase analysis methods and the X-ray qualitative microanalysis of elements in the investigated coatings were used to describe the structure of coatings. Detailed analysis of the mechanical and tribological properties of the materials under investigation has being carried out and the results will be introduced in future publications.

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References

[1] L.A. Dobrzański, K. Gołombek, E. Hajduczek, Structure of the nanocrystalline coatings obtained on the CAE process on the sintered tool materials, Journal of Materials Processing Technology 175 (2006) 157–162.

[2] L.A Dobrzański, J. Mikuła, The structure and functional properties of PVD and CVD coated Al_2O_3+ZrO_2 oxide tool ceramics, Journal of Materials Processing Technology 167 (2005) 438-446.

[3] L.A. Dobrzański, K. Gołombek, Structure and properties of the cutting tools made from cemented carbides and cermets with the TiN+mono-, gradient- or multi(Ti, Al, Si)N+TiN nanocrystalline coatings Journal of Materials Processing Technology 164-165 (2005) 805-815.

[4] L.A. Dobrzański, J. Mikuła, Structure and properties of PVD and CVD coated Al_2O_3 + TiC mixed oxide tool ceramics for dry on high speed cutting processes, Journal of Materials Processing Technology 164–165 (2005) 822–831.

[5] M. Soković, J. Mikuła, L.A. Dobrzański, J. Kopač, L. Kosec, P. Panjan, A. Piech, Cutting properties of the Al_2O_3+SiC(w) based tool ceramic reinforced with the PVD and CVD wear resistant coatings, Journal of Materials Processing Technology 164-165 (2005) 924-929.

[6] L.A. Dobrzański, D. Pakuła, Comparison of the structure and properties of the PVD and CVD coatings deposited on nitride tool ceramics, Journal of Materials Processing Technology 164-165 (2005) 832-842.

[7] J. Kopač, Cutting tool wear during high-speed cutting. Stroj. vestn. Vol. 50 No. 4 (2004)195-205.

[8] P. Panjan, I. Boncina, J. Bevk, M. Cekada, PVD hard coatings applied for wear protection of drawing dies, Surface and Coating Technology Vol. 200 (2005) 133-136.

[9] M. Soković, L.A. Dobrzański, J. Kopač, L. Kosec, Cutting Properties of PVD and CVD Coated Al_2O_3 + TiC tool ceramic, Proceedings of International Conference Thermec (2006) Vancouver, Canada.

[10] Y.Y. Tse, D. Babonneau, A. Michel, G. Abadias, Nanometer-scale multilayer coatings combining a soft metallic phase and a hard nitride phase: study of the interface structure and morphology, Surface and Coating Technology 180-181 (2004) 470-477.

[11] M. Cłapa, D. Batory, Improving adhesion and wear resistance of carbon coatings using Ti:C gradient layers, 12^{th} International Scientific Conference CAM^{3}S 2006, (in print).

[12] W. Lengauer, K. Dreyer, Functionally graded hardmetals, Journal of Alloys and Compounds 338 (2002) 194–212.

[13] S. PalDey, S.C. Deevi, Cathodic arc deposited FeAl coatings: properties and oxidation characteristics, Materials Science and Engineering A355 (2003) 208-215.

[14] S. PalDey, S.C. Deevi, Properties of single layer and gradient (Ti,Al)N coatings, Materials Science and Engineering A361 (2003) 1–8.

[15] S. Hogmark, S. Jacobson, M. Larsson, Design and evaluation of tribological coatings, Wear 246 (2000) 20–33.