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Experimental analysis of physical phenomena occurring in PVD coatings on Oxide Tool Ceramics

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Introduction

The thesis is to establish the crucial physical phenomena during the process of coatings applying of multi-component coatings obtained in the Physical Vapour Deposition process on Al2O3 based oxide tool ceramic substrate with the use of numerical analysis in the virtual environment. In the paper it was used physical and mathematical calculations to establish the geometry of a sample with the help of computer numeric analysis. It was established the best process parameters of coatings applying in order to obtain the value of stresses which don't exceed their plasticity limits. Numeric analysis is made with the help of Finite Elements Method using program Ansys. Physical phenomena registered in the material is caused by cooling process which leads to creation of stresses, which values have important influence on adhersion of coatings to the material substract. The calculation was performed with the help of a static analysis in a range of occuring stresses in substrate and also in coatings PVD with the use of linear-isotropic elastic material model.

Materials

The investigations were carried out on samples in the form of indexable inserts made of oxide tool ceramics based on Al_2O_3 + ZrO_2 coated with multicomponent coatings such as TiN, TiN+(Ti,Al,Si)N, TiN+(Ti,Al,Si)N+TiN, TiN+(Ti,Al,Si)N+(Al,Si,Ti)N, (Ti,Al)N in the PVD cathodic arc evaporation process.

Results

Qualitative analysis of the X-ray phase carried out with Bragg-Brentano geometry confirmed that the analyzed coatings were obtained on a ceramic substrate based on Al_2O_3 + ZrO_2 (Fig. 1). A texture analysis allows to conclude, based on a qualitative analysis of the registered single polar figures (Fig. 2), that the differentiated growth plane for TiN and Ti(Al,N) coatings is a plane from the {111} family. Stress measurementsanal coatings were performed using the sin2ψ method (Fig. 3). The angular position of the recorded reflexes was determined with the Gaussian curve adjustment method. Figures 4 show an image of surface topography of the (TiAl)N coatings obtained with an AFM microscope. The results of thickness, microhardness, adhesion, roughness and stresses of the analysed coatings are presented in the first table.

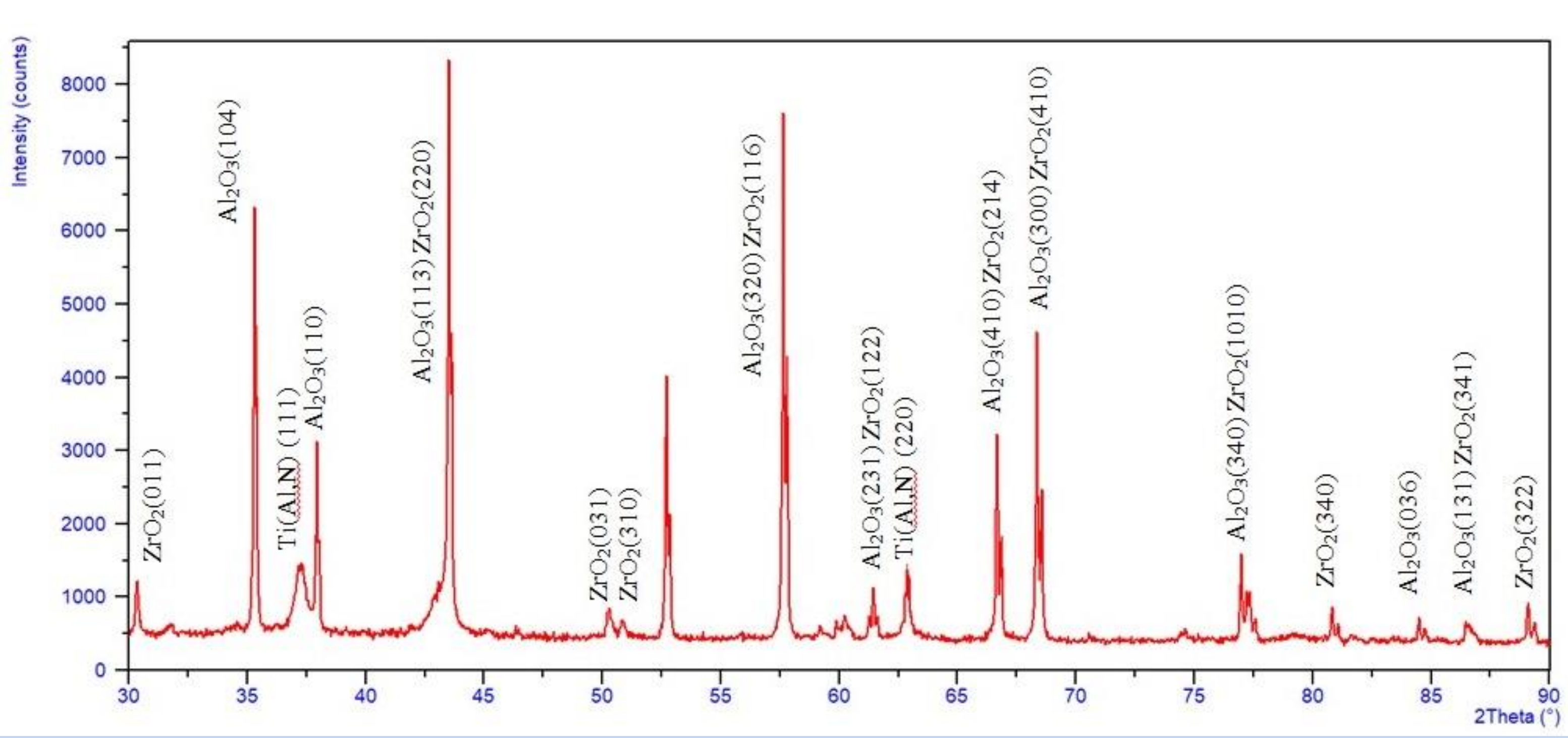

Fig.1. Diffraction patterns of the (Ti,Al)N coating deposited on oxide ceramic tool materials substrate Al_2O_3+ZrO_2.

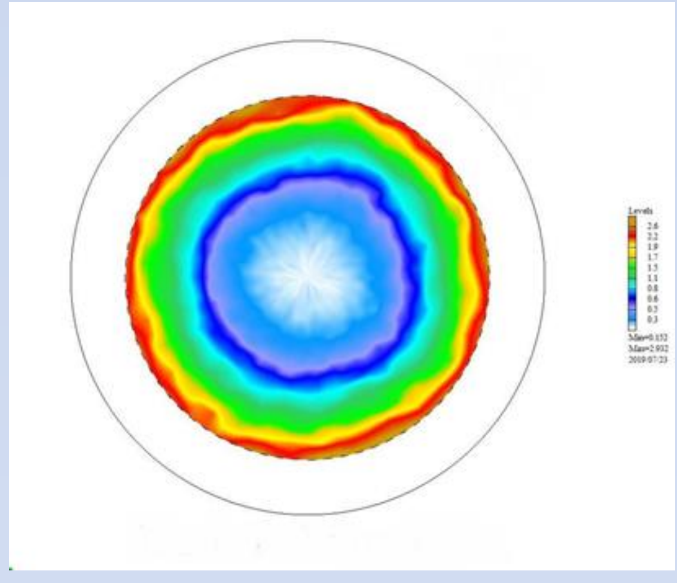

Fig. 2. Experimantal pole figures (220) of (Ti,Al)N coating deposited on oxide ceramic tool materials substrate Al_2O_3+ZrO_2.

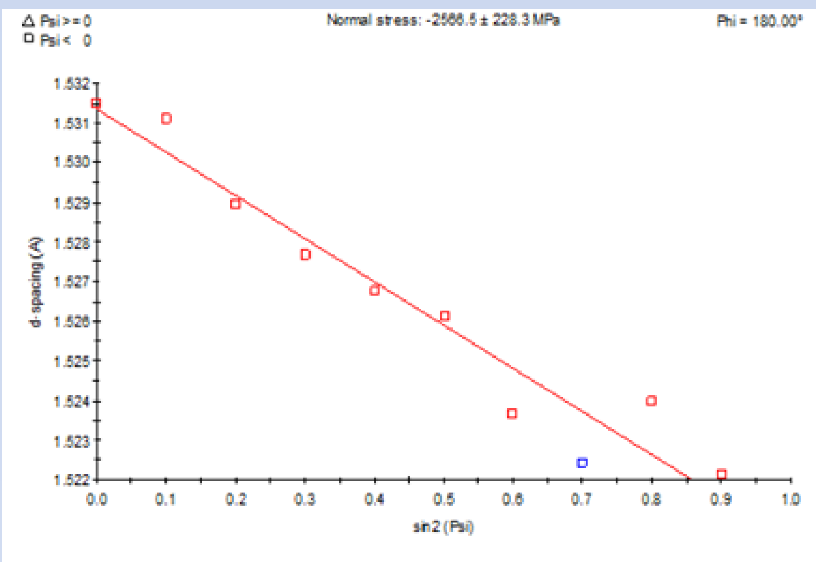

Fig. 3. Variations in the interplanar distance value d of reflex (220) of the (Ti,Al)N coating in the function of $\sin^2$

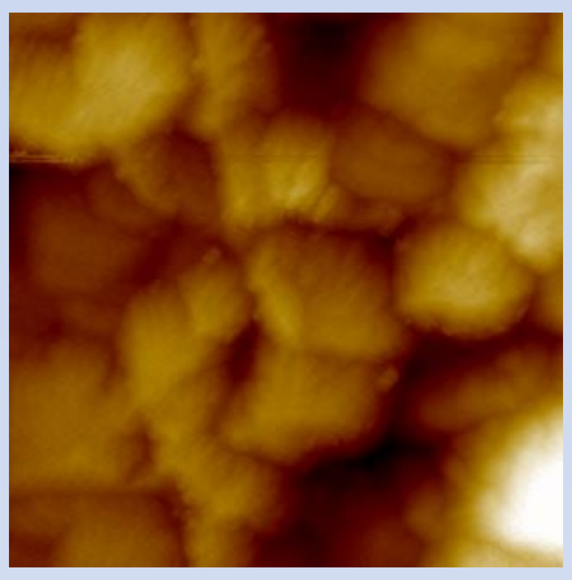

Fig. 4. Surface image of (TiAl)N coating made with the AFM microscope. Scanning range of 10 µm.

Table 1. Results of the measurement of mechanical properties of the analysed coatings.

Coatings	Thickness [µm]	Microhardness HV 0.07 [GPa]	Adhesion Lc [N]	Roughness Ra [µm]	Stresses [MPa]
TiN	0.8	22.7	45	0.37	-689 ±115,8
TiN+(Ti,Al,Si)N	1.9	19.22	40	0.43	548±121,8
TiN+(Ti,Al,Si)N+TiN	2.3	40.9	76	0.37	-
TiN+TiN(Ti,Al,Si)N+(Al,Si,Ti)N	2.2	21	78	0.40	-
(Ti,Al) N	2.2	32.9	82	0.23	-2566,5 ±228,3

Conclusions

1. It was found based on the investigations conducted that the highest microhardness of 40.9 GPa is exhibited by TiN+(Ti,Al,Si)N+TiN coatings, whereas the lowest by 19.22 GPa TiN+(Ti,Al,Si)N coatings.
2. The dependency between the value of stresses and the substrate adhesion of the investigated coatings is indicated by the results of the examinations of internal macrostresses for the analysed coatings. The coatings showing high adhesion to the substrate are characterised by high compressive stress values.
3. The observations of the analysed coatings' surface topography using the atomic force microscopy (AFM) methods reveal that the characteristic finish of the columns forming the respective coatings, observed on the surface, are in the shape of inverted pyramids, cones or craters characteristic for the PVD process.
4. No significant influence of the coating type on the roughness of the coating surface was found. The results obtained, depending on the material investigated, were in the Ra range from 0.23 µm to 0.43 µm.