TRIBOLOGICAL PROPERTIES AND ABRASION RESISTANCE THIN FILMS OF TUNGSTEN CARBIDE

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Abstract

Tungsten carbide (WC) is in the groups hard materials, which is used for cutting tool. The substrate sample was coated with device PVD. Coatings nc-WC/a-C:H were deposited in a vacuum chamber by magnetron sputtering. This device has four independent planar magnetrons with circular targets. Three targets were made from pure graphite and one form pure tungsten. Tungsten carbide is approximately two times stiffer than steel, with a Young's modulus of approximately 650-700 GPa. At the end of the coating process Ar / methane (Ar 25 sccm / CH_4 12.5 sccm) was admitted to chamber, which gets into the surface layer. The parameters of the process influence properties of the thin films were amourphous microstructure, hardness and adhesion to the substrate. The tribological measurements were performed the “ball-on-disc” testing method. Tribological testing (EN1071-13:2010) was performed using a ball made from Si_3N_4 with a diameter of 5 mm, with a constant load of 10 N at room temperature and humidity of 40 ±2 %. The results were analysed by profilometer and optical microscope.

Keywords: Tungsten carbide, PVD, layers, ball-on-disc

1. INTRODUCTION

Coating nc-WC/a-C:H was carried out in a vacuum chamber with magnetrons. In the chamber were made layers from three targets pure graphite (4N) and one form pure tungsten (4N).The coating was applied to the sample surface after diffusion hardening surface hardness, surface polished sample was rinsed in acetone and ultrasonic bath. The hardness of the substrate samples was 63 - 64 HRC. Polished samples (Ø 20mm, 5 mm thick) of HSS steel 19 830 were used as substrate material. It is a high-speed steel with high toughness. The chemical composition of the HSS steel DIN - HS 6-5-2, (CSN 19 830) value (wt. %) are shown in **Table 1**.

Samples were compared with two different parameters when coating. Sample WC 1 was coated the performance of the magnetron 0.7 kW (0.7 A). Sample WC 2 was coated the performance of the magnetron of 0.5 kW [1,2,3].

Table 1 Chemical composition substrate samples of HSS steel DIN - HS 6-5-2

Elements	C	Mn	Si	P	S	Cr	Mo	W	V
(wt. %)	0.8-09	0.25	0.33	0.029	0.0003	3.97	4.76	5.95	1.72

Table 2 Parameters PVD process

Layer Tungsten carbide	Pressure in chamber	Argon flow	U bias
	$4.39.10^{-4}$ Pa	25 sccm	- 50V (0.011A)

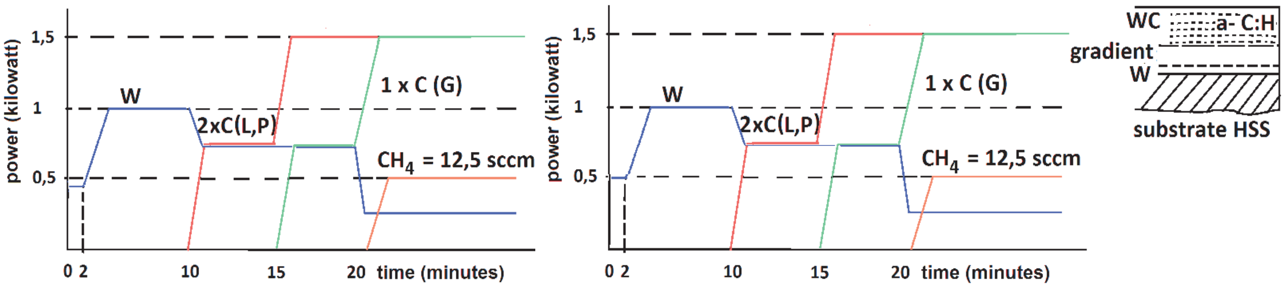


Figure 1 Deposition process for sample type a) WC1, b) WC 2

The diagrams describe of power magnetrons and procedure of coating process. On the right side of the diagram, the sample is placed with the structure layers. Magnetron parameter: W (WC1) (0.45 kW; 2.1 A), (WC2) (0.5 kW; 3.5 A).

2. EXPERIMENTAL DETAILS

2.1. Raman spectroscopy

Coated samples were analyzed by Raman spectroscopy. We can see very similar curves on the graphs (**Figure 2**).

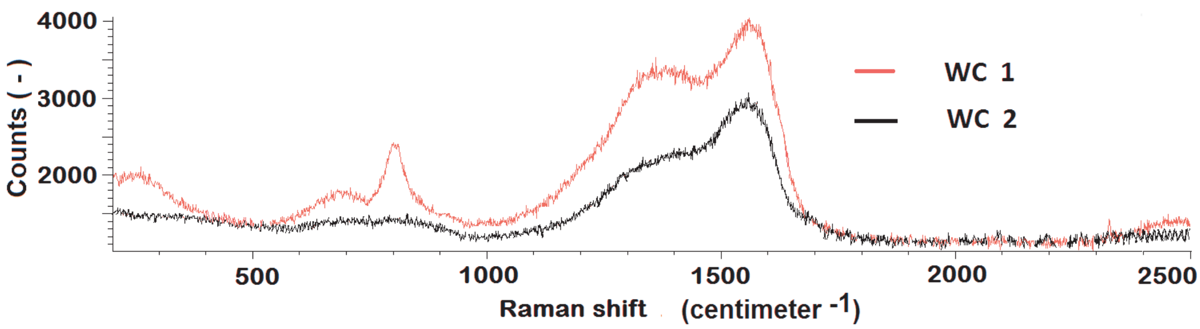


Figure 2 Raman spectroscopy samples WC 1, WC 2

Raman scattering by an anisotropic crystal gives information on the crystal orientation. The polarization of the Raman scattered light with respect to the crystal and the polarization of the laser light can be used to find the orientation of the crystal, if the crystal structure (to be specific, its point group) is known [4]. In this case, the amorphous material crystallizing germs nc-WC/a-C:H. These differences in the graphs are given different chemical composition procentual representation graphite and tungsten.

2.2. The XPS spectra analyse

The XPS spectra show except C, O, W (**Table 3)** and small contamination by N probably from the deposition process. The carbon high resolution peaks C 1s do not show significant evidence of C-W bond expected at binding energy about 283 eV [5,6]. The small component at this BE is probably also influenced by instrument broadening moreover amount of W in sample is rather low about 3 at. %, respectively 1.5 at. % therefore the significant contribution of WC to C1s peak cannot be expected. The higher BE range of 286-290 eV corresponds to carbon covalently bonded to oxygen. The main peaks should be sp2 bonded carbon at binding energy about 284.7 eV and the necessary component at 285.6 eV should represent sp3 [7].

The high resolution O1s spectra are mainly single peak character about 532.5 eV identified as general carbon to oxygen bonds and small component observed about 530.5 eV. It can be oxygen bonded in WO_3 [6]. This supports our observation of WO_3 phase in W 4f spectra.

Table 3 Chemical composition from XPS spectra

Variable	C 1s	N 1s	O 1s	W 4d5/2
1.-WC-1	90.4 %	0.5 %	7.5 %	1.5 %
2.-WC-2	89.2 %	0.6 %	7.2 %	3.0 %

From the XPS spectral analysis, we find that in the second WC sample there is more tungsten 3.0% that came to the film at the beginning of the coating process.

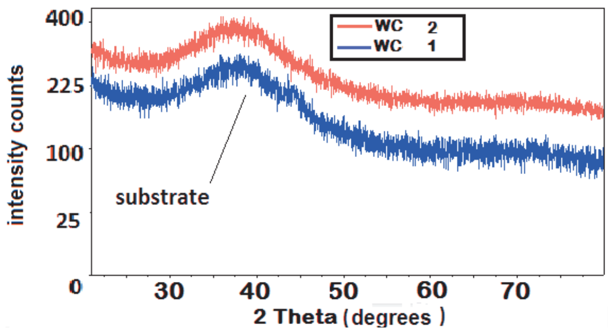


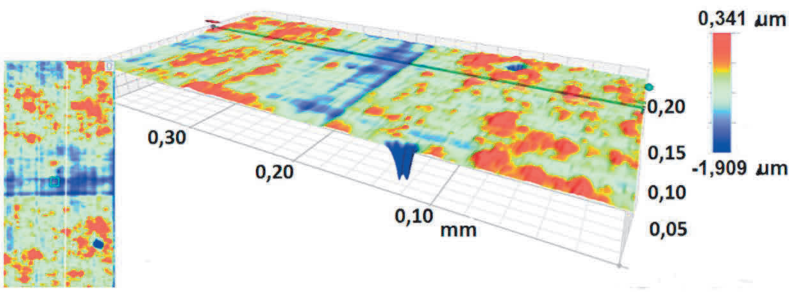
Figure 3 Difractogram of samples WC 1, WC 2

Next graph **Figure 3** shows a comparison of measured diffraction patterns of thin films WC [8,9]. The nature of diffraction patterns can be seen that both samples are amorphous. Faint diffraction peak at a sample of WC 1 at about 44° 2 theta include substrates. The nature of diffraction patterns it is not possible to determine the phase composition. It can be assumed that the layers are amorphous and can contain small germ crystallites in the nanometers. The diffraction peak corresponds to the substrate.

The following picture a comparison of difractogram thin WC layers. It is obvious that both samples are amorphous.

2.3. The of the tribological measurements is the "ball-on-disc" testing method

Polished discs (Ø 20 mm, 5 mm thick) of tool steel were used as substrate material. The CETR UMI Multi-Specimen Test System in "ball-on-disc" mode was used to estimate the tribology properties of the thin films. The CoF between the unit and the disc is determined during the test measurement [10]. Tribological testing (EN1071-13:2010) was conducted using a ball made from Si_3N_4 with a diameter of 6.35 mm, with a constant load of 10 N.



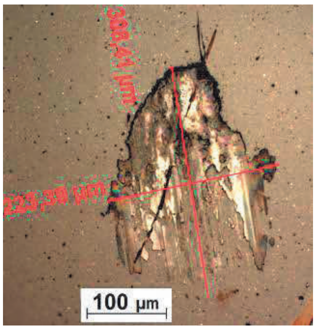
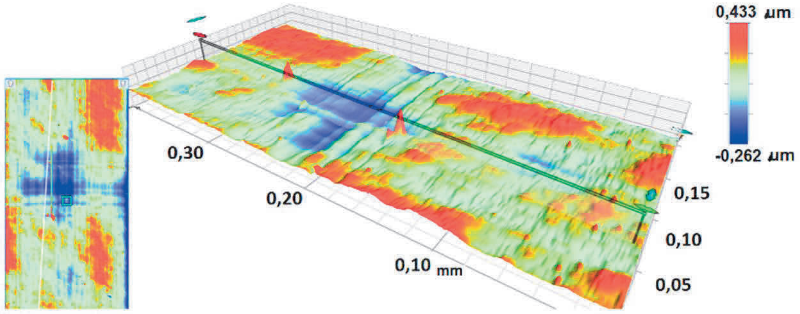


Figure 4 a) Surface of thin layer WC 1 b) Surface ball WC 1



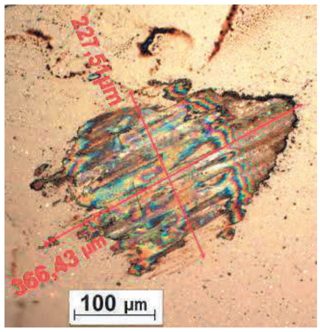


Figure 5 a) Surface of thin layer WC 2 b) Surface ball WC 2

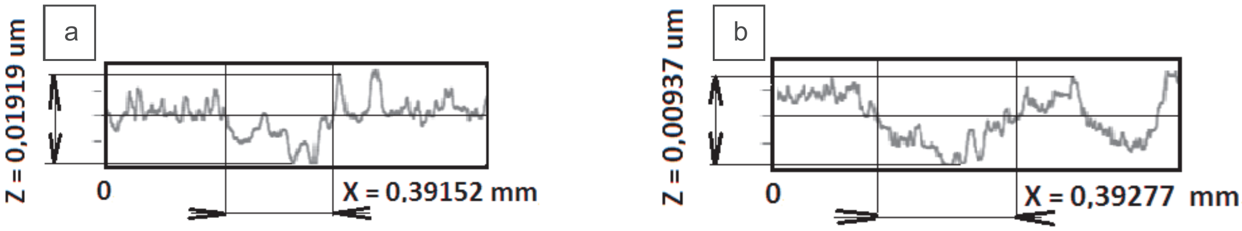


Figure 6 a) Surface profil WC 1 layer, b) Surface profil WC 2 layer

On **Figure 4a** and **Figure 4b** we can see similar surface after tribological tests. On diagrams **Figure 6a** and **Figure 4b** we can follow the surface profile of the layers.

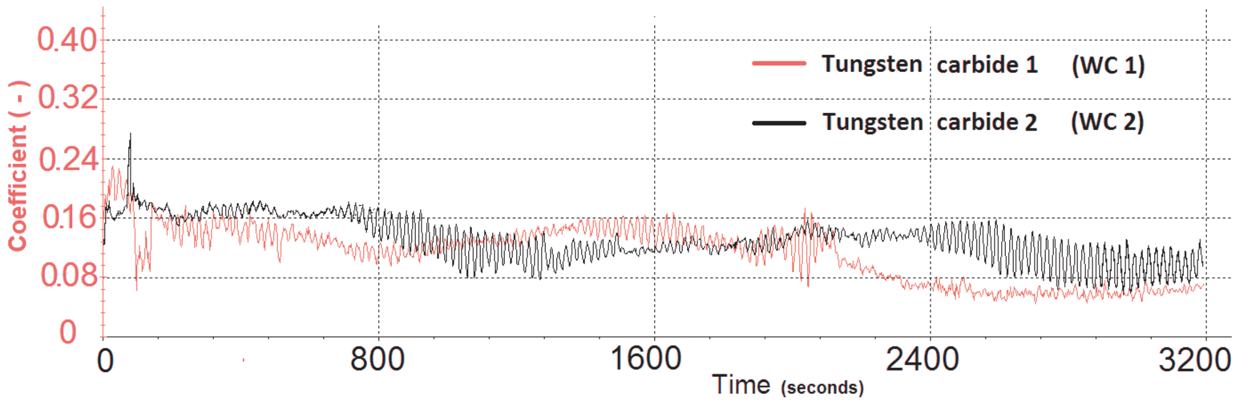


Figure 7 Coefficient of friction, surface of thin layer WC 1, WC 2

3. CONCLUSION

Two samples layers of tungsten carbide were compared diffractograms of thin layers of WC 1, WC 2. It is clear from the character of diffractive records that both samples are amorphous. The insignificant diffractive maximum for a sample of WC 1 at about 44th 2° theta is a substrate. Unfortunately, due to the nature of the diffractograms, may contain small crystals in the order of nanometers.

We can assume that according to the graph of the sample WC 2, due to friction at the friction pair of the ball, friction results in greater structural changes in terms of hardness. There are larger germ crystals in WC 2 sample.

Tungsten carbide (WC 1, WC 2) have a similar average coefficient of friction of 0.12. Sample WC 2 shows less roughness. Original roughness of the surface before coating was Ra 0.02 - 0.03. Tungsten carbide material is mainly used for machining purposes, as measured coefficient 0.12 can be further reduced by using a suitable cooling and lubricating operating fluid during machining [11,12,13]..

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