PACS: 81.40.-z, 81.40.Gh, 81.40.Pq, 81.65.Lp, 81.65.Ps, 81.90.+c

STRUCTURE AND PROPERTIES OF DIFFUSION COATINGS ON BASED OF BORON FORMED ON HARD ALLOYS IN AN EXTERNAL MAGNETIC FIELD

Doctor in Technical Sciences, professor Svetlana Chernega,
postgraduate Ihor Poliakov, PhD in Technical Sciences,
assistant professor Catherine Grinenko, student Roman Romovich, student Nikolai Mayorov
National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute»,
Department of metallurgy and heat treatment
e-mail: smchernega@ukr.net, polykov_igor@ukr.net

Abstract: *It was investigated the structure, phase and chemical composition, thickness diffusion boride layers obtained after boriding and complex saturation boron and copper with simultaneous action an external magnetic field (EMF) on hard alloy T5K10. It was established that the application of an external magnetic field allows to intensify the process of diffusion saturation hard alloys boron and by 2 hours chemical – thermal treatment with simultaneous action EMF get such thickness diffusion boride layer which is formed by 4 hours chemical – thermal treatment without EMF. It was found increase microhardness diffusion layers formed on the hard alloys on 2 – 2.5 GPa (30 - 30.5 GPa) that is associated with a decrease areas of coherent scattering and as a result increase operating parts that work in conditions of intensive wear.*
Keywords: *boron, boriding, boron layer, copper, structure, diffusion, microstructure, microhardness, external magnetic field.*

1. Introduction

Hard alloys provide high capacity under different operating conditions. Hard alloys WC-TiC-Co – titanium tungsten is used for the treatment of viscous materials: steel, brass [1 – 2], but their application field is narrowed due to low strength. One of the ways to improve the operational characteristics alloys are applying coatings, such as the use of chemical – heat treatment (CHT) [3 – 5]. However, doesn't definitive data on the positive effects of this method CHT to improve wear resistance hard alloys products [6 – 7]. To create technology of boriding hard alloys that gives stable results, it is necessary to investigate the mechanism of boride layer, processes of diffusion and redistribution of elements in boride layer and the transition zone hard alloy.

The aim of this work was to investigate the structure and characteristics of complex diffuse boride coatings on hard alloys obtained in boriding powder mixtures with the addition copper containing elements: Cu_2O with simultaneous action an external magnetic field.

2. Materials and Experiment

Processes borating and complex saturation with boron and copper performed powder method in a special at a temperature of 975 °C during 2, 4 and 6 hours using fusible valves. Saturation steels boron or boron and copper performed in powder mixtures on the basis of technical boron carbide B_4C with the addition of powders Cu_2O, as a source of copper and fluoroplast as activating additions.

To create a magnetic field coil (solenoid) used, which consisted of 635 windings tires aluminum alloy, the size of 10x20 mm; the current strength – 60 A; the magnetic induction – 35 mT. For magnetic thermo chemical treatment in coil placed high temperature furnace with crucible and packed in them saturated mixture for boriding with samples of hard alloys.

Investigation of the structure of boride coatings on hard alloys performed on microsections subjected a high temperature etching at 400°C at excerpt 30 minutes in the furnace with followed by cooling to room temperature in air.

Microstructural studies coatings and measuring the thickness of diffusion layers was carried out on metallographic microscope Axio Observer A1m, Zeiss, in the range the increase 100...1000.

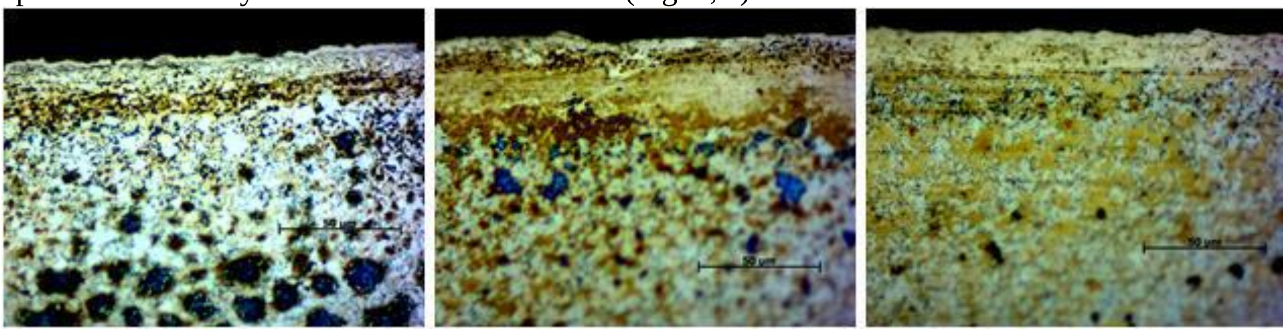
Microhardness measurements were carried out on the equipment PMT – 3 no less than 15–20 fields of view at a load of 0.49 – 0.98 N. Measuring accuracy microhardness was – ±300 MPa.

Research of the chemical composition of coatings performed microrengenospectral analysis on electronic scanning microscope – SEM 106 with increasing in 2000 time, accuracy – 0.01% by weight.

Phase composition, quantitative analysis phase, the periods of the crystal lattice, volume of elementary lattice phase, regions of coherent scattering in boride coatings were analyzed for X-ray diffractometer Ultima-IV of Rigaku (Japan), in the copper Kα monochromatic radiation.

3. Results and discussion

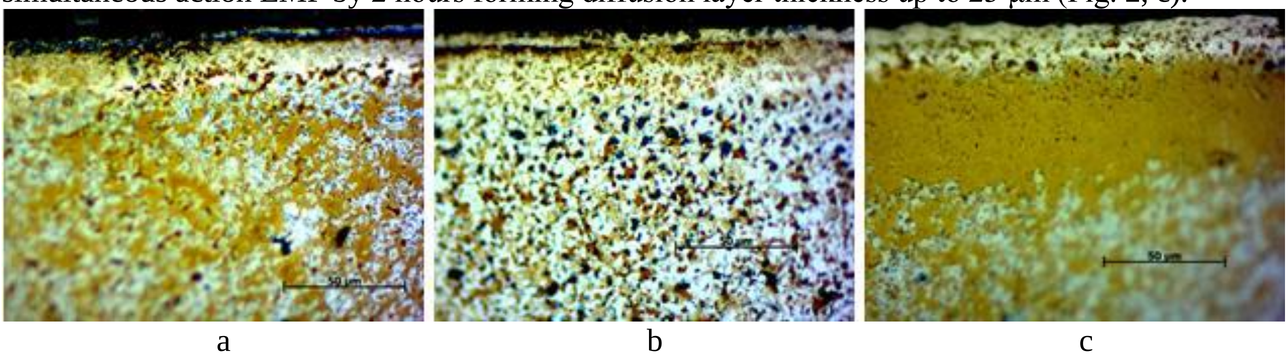
Investigation of the structure of hard alloy T5K10 with diffusion boride coatings obtained after boriding and complex saturation boron and copper in different physical – chemical conditions showed that after diffusion boriding during 4 hours on the surface hard alloy T5K10 formed diffusion layer thickness up to 25 μm (Fig. 1, a), and during 6 hours – up to 40 μm (Fig. 1, b). At applying the EMF on the surface of hard alloy T5K10 formed diffusion layer thickness up to 20 microns by 2 hours diffusion saturation (Fig. 1, c).



a b c

Fig.1: Microstructures boride coatings on solid alloy T5K10 obtained after boriding without action EMP (a, b) by the duration of saturation 4 (a) and 6 (b) hours and in conditions action EMP (c) by the duration of saturation 2 hours, x500 (thermal etching)

At the the complex saturation with boron and copper by 4 hours diffusion saturation on the surface of hard alloy T5K10 observed formation boride layer thickness up to 25 μm (Fig. 2, a), and by 6 hours - up to 35 μm (Fig. 2, b) whereas at complex saturation boron and copper with simultaneous action EMP by 2 hours forming diffusion layer thickness up to 23 μm (Fig. 2, c).



a b c

Fig.2: Microstructures boride coatings on solid alloy T5K10 obtained after: a – complex saturation boron and copper without action EMP, duration saturation 4 hours; b – complex saturation boron and copper without action EMP, duration saturation 6 hours; c – complex saturation boron and copper in conditions action EMP, duration saturation 2 hours, x500 (thermal etching)

Established that boriding with using EMF allows to increase microhardness of surface layers hard alloy T15K6 up to 30 – 30.5 GPa and complex saturation boron and copper – up to 28 GPa, in comparison with the diffusion boration without application EMF for which the microhardness amounts to 27,5 GPa, complex saturation boron and copper without action EMP – 25 GPa (Fig. 3).

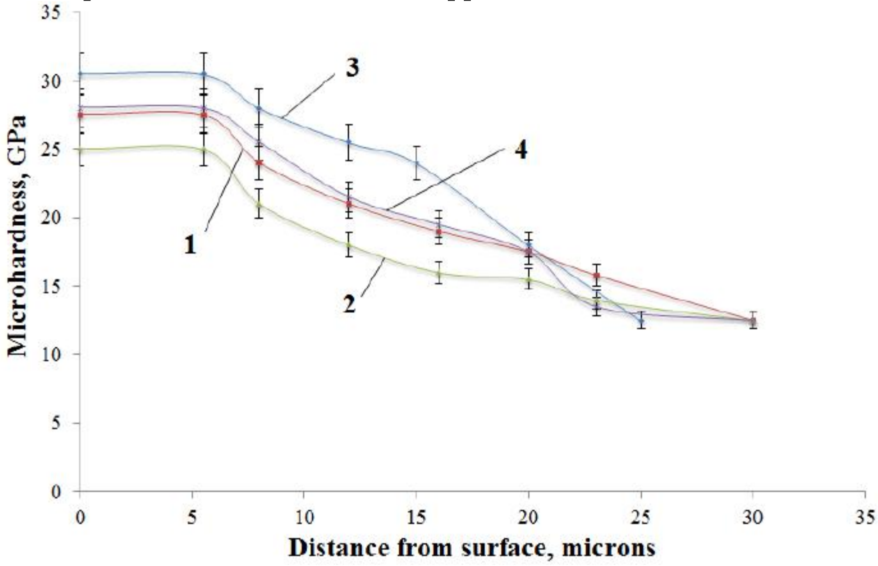
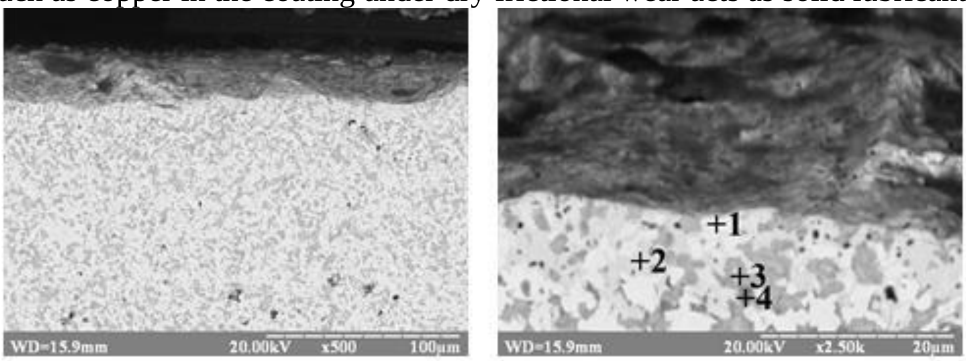


Fig.3: Change microhardness by thickness diffusion boride coatings on hard alloy obtained in different physical – chemical conditions: 1 – boriding without EMF; 2 – complex saturation with boron and copper without EMF; 3 – boriding at the simultaneous action EMF; 4 – complex saturation with boron and copper with simultaneous action EMF

To determine the chemical composition of the coating was applied microanalysis by using scanning electron microscope – SEM-106I with increasing in 2000 time, accuracy 0.01 wt. %.

Microrengenospectral analysis has established presence copper on the surface of boride coating (Fig. 4 – 5, Table 1 – 2). Formation separate inclusions copper leads to increased wear resistance, such as copper in the coating under dry frictional wear acts as solid lubricant.



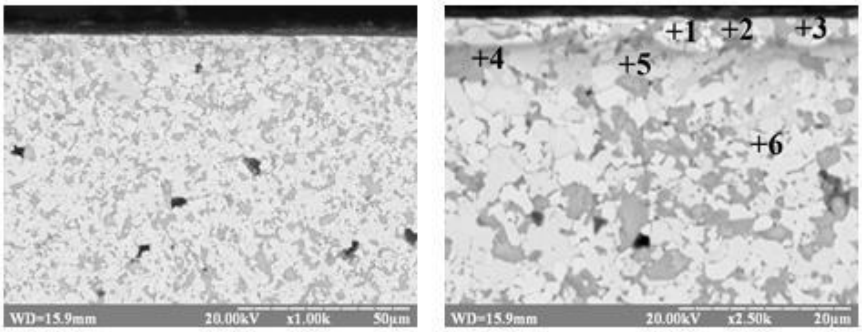
a b

Fig.4: The structure of cross sections grindin with boride coatings on hard alloy T5K10 obtained after complex saturation boron and copper without action EMP by saturation duration 6 hours (a – x500; b – x2500) (chemical analysis determined the points +1, +2, +3, +4)

Table 1

The chemical composition of the diffusion boride layer on hard alloy T5K10, obtained after complex saturation boron and copper without action EMP

Elem.	**Position**				
	General	**+ 1**	**+ 2**	**+ 3**	**+ 4**
	wt. %				
Ti (K)	7,17 ± 0,32	0,22 ± 0,18	0,19 ± 0,10	42,02 ± 0,70	11,31±0,49
Co (K)	12,90 ± 0,61	0,34 ± 0,26	35,88 ± 0,65	2,89 ± 0,38	44,37 ± 1,12
W (M)	79,06 ± 0,67	99,13 ± 1,73	63,93 ± 1,16	55,09 ± 1,05	40,68 ± 1,17
Cu (K)	0,87 ± 0,46	0,31 ± 0,19	0,00	0,00	3,64 ± 0,63



a b

Fig.5: The structure of cross sections grindin with boride coatings on hard alloy T5K10, obtained after complex saturation boron and copper in conditions action EMP by saturation duration 2 hours (a – x1000;b – x2500) (chemical analysis determined the points +1, +2, +3, +4, +5, +6)

Table 2

The chemical composition of the diffusion boride layer on hard alloy T5K10, obtained after complex saturation boron and copper in conditions action EMP

Elem.	**Position**						
	General	**+ 1**	**+ 2**	**+ 3**	**+ 4**	**+ 5**	**+ 6**
	wt. %						
Ti (K)	45,75±0,74	0,42±0,18	31,81±0,64	0,00	19,16±0,51	0,49±0,21	44,68±0,73
Co (K)	8,30±0,59	0,75±0,28	1,32±0,33	2,27±0,33	14,92±0,65	32,35±0,84	1,74±0,36
W (M)	45,12±0,77	98,83±1,52	66,87±1,24	97,20±1,85	65,92±1,21	67,16±1,18	53,58±1,17
Cu (K)	0,83±0,45	0,00	0,00	0,53 ± 0,41	0,00	0,00	0,00

To establish the phase composition boride coatings formed after boriding and complex saturation boron and copper in different physical – chemical conditions performed X-ray analysis.

At the study surfaces hard alloy T5K10 with diffusion boride coatings formed at boriding without action EMP X-ray analysis was established that in the surface layer up to 10 – 15 microns formed phases: B_2CoW_2, CoB, TiB, WB, TiC and WC (Fig. 6).

At applying the EMP observed change the phase composition and on diffractograms taken from the surface of hard alloy T5K10 with diffusion boride coating obtained after boriding in conditions action EMP fixed presence phases CoB, Co_2B, TiB, WB, W2B, TiC та WC (Fig. 7).

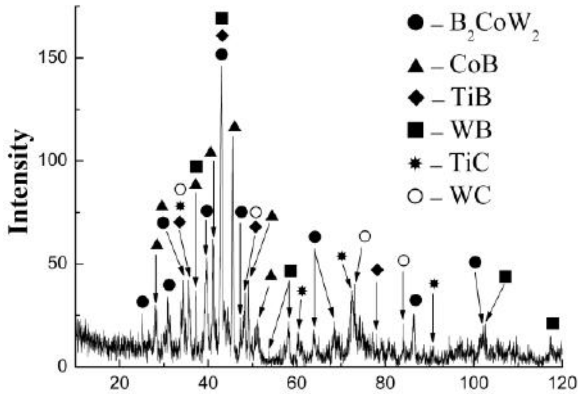


Fig.6: Diffractograms taken from the surface of hard alloys T5K10 with boride coatings obtained after boriding without action EMP in Cu Kα monochromatic radiation

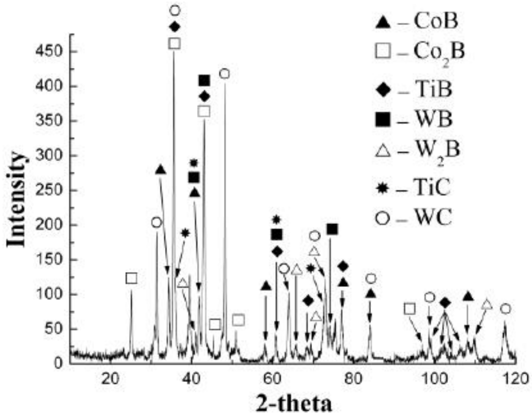


Fig.7: Diffractograms taken from the surface of hard alloys T5K10 with boride coatings obtained after boriding in conditions action EMP in Cu Kα monochromatic radiation

At the study diffusion boride coatings obtained after complex saturation boron and copper without action EMP was established following phase composition: B_2CoW_2, CoB, WB, TiC, WC and Cu (Fig. 8).

After complex saturation boron and copper in conditions action EMP formed diffusion boride coatings next phase composition: B_2CoW_2, TiB, WB, WC and Cu (Fig. 9).

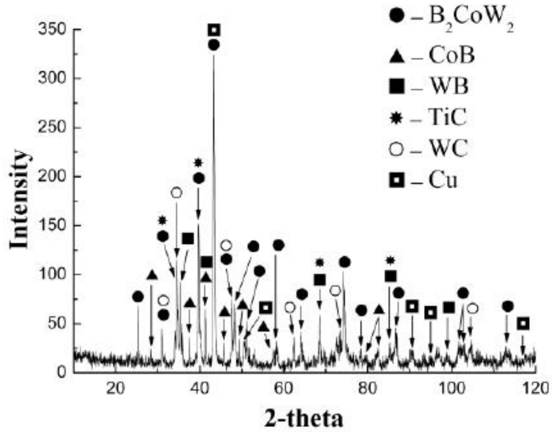


Fig.8: Diffractograms taken from the surface of hard alloys T5K10 with boride coatings obtained after complex saturation boron and copper without action EMP in Cu Kα monochromatic radiation. Diffraction peaks Cu responsible crystallographic planes: (111) (200) (311) (222) (400)

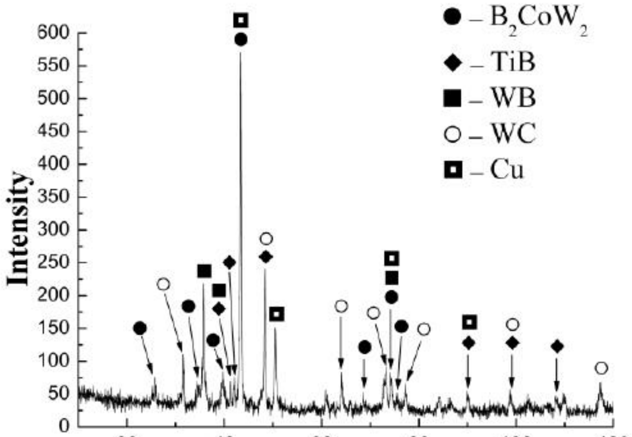


Fig.9: Diffractograms taken from the surface of hard alloys T5K10 with boride coatings obtained after complex saturation boron and copper in conditions action EMP in Cu Kα monochromatic radiation. Diffraction peaks Cu responsible crystallographic planes: (111) (200) (311) (222) (400)

Testing wear resistance were carried out on rollers produced of hard alloys, which are used to rolling aluminum profiles. Investigations have shown that the boride coating allow in 2 times increase the term of operation rollers. When the rollers working without coating can be made of 10 tons aluminum profiles, whereas at the application of the boride coatings is reached value of 21 tone.

CONCLUSIONS

At the application EMP allows in 2 times to reduce the duration of saturation products from hard alloys. Boride phases that are formed in the magnetic field have less periods, and accordingly the volume of elementary crystal lattices and less value areas of coherent scattering.

Established that the application of an external magnetic field allows to intensify the process of diffusion saturation hard and increase microhardness diffusion boride layers formed on the hard alloys on 2 – 2.5 GPa (30 - 30.5 GPa) and as a result increase operating parts that work in conditions of intensive wear.

REFERENCES

[1] Bogoduhov S.I. Improving the performance of hard alloys by heat treatment / S.I. Bogoduhov, A.S. Kills, E.A. Shein, A.S. Yasakov, R.R. Khaibullin // Bulletin of the Orenburg State University. – №5 (124). – 2011. – P. 164 – 170.

[2] The use of plasma ceramic coatings in friction pairs of end seals / O.A. Zelenkevich, N.G. Taran, G.E. Lazarev, B.M. Kudryavtseva // Chemical and petroleum engineering. – 1990. – № 4. – P. 28 – 30.

[3] Klinskaya-Rudenskaya N.A. Comparative analysis of the composite coatings based alloys Ni-Cr-B-Si with refractory borides, obtained by different methods / N.A. Klin-Rudenskaya, V.A.Kopysov // Physics and Chemistry of Materials Processing. – 1995. – № 3. – P. 63 – 68.

[4] Moiseenko O.I. Tool materials / O.I. Moiseenko, H.O. Chkalov.–K.: Higher school, 1982. – 196 p.

[5] Berzina I.G. Distribution of boron, tungsten, titanium and cobalt alloys in solid borated / I.G. Berzina, E.B. Gusev, B.V. Zakharov, G.N. Fedin, V.M. Fedin // Physics of Metals and Metallography.–1984 – T.57, № 4. – P. 713 – 718.

[6] *Zakhariev Z.* Preparation and some properties of boride diffusion layers hard WC – TiC – Co alloys / Z. *Zakhariev, K. Petrov, M. Christov* // J. Less-Common Metals. – 1981. – 82. – P. 57 – 62.

[7] Berzina I.G. On the distribution of boron diffusion zone borated hard alloys used for the manufacture and machining of rolling stock / I.G. Berzina, E.B. Gusev, B.V. Zakharov and others // Proceedings of the Institute of Railway Engineers, Engineering. – 1982. – Vol. 701 – P. 24 – 27.