PROCEEDINGS OF THE INTERNATIONAL CONFERENCE
NANOMATERIALS: APPLICATIONS AND PROPERTIES
Vol. **3** No 1, 01FNC04(3pp) (2014)

Effect of Composition on Structure and Mechanical Properties of Ion-plasma Coatings of Quasi-binary System TiB_2-WB_2

O.V. Sobol'[1,*], O.A. Shovkoplyas[2,†], V.M. Beresnev[3,‡], M.G. Kovaleva[4,§]

[1] *National Technical University "Kharkiv Polytechnical Institute", 21, Frunze Str., 61002 Kharkiv, Ukraine*
[2] *Sumy State University, 2, Rymsky Korsakov Str., 40007 Sumy, Ukraine*
[3] *V.N. Karazin Kharkiv National University, 4, Svobody Sq., 61022 Kharkiv, Ukraine*
[4] *Belgorod State National Research University, 85, Pobedy Str., 308015 Belgorod, Russia*

(Received 15 July 2014; published online 29 August 2014)

For ion-plasma coatings of quasi-binary system TiB_2-WB_2 the influence of composition on structure and adhesion strength has been analyzed. It has been determined, that the content of boron atoms in the coating increases with the increase of concentration of Ti, and the phase of (Ti, W)B_2 is formed. Meanwhile, the strong bond Ti-B, which is formed, leads to an increase of brittleness of the coatings. The greatest resistance to brittle cracks formation was inherent to the coatings with high W content in which the main phase is β-(W, Ti)B.

Keywords: Ion-plasma coatings, Nanostructure, Ti-W-B System, X-ray diffraction, Elemental composition, Phase composition, Mechanical characteristics.

PACS numbers: 81.07.Bc, 81.15.Cd, 62.25.-g, 61.05.cp, 61.50.Ks

1. INTRODUCTION

One of the promising ways of increasing strength and cracking resistance is creation of new materials based on quasi-binary systems of transition metal diborides [1–2]. The boundary between the phases and the grains, which are formed in these phases, plays a decisive role in increasing strength and fracture toughness at the same time [3].

In this context, the system TiB_2-W_2B_5 with the limited solubility of its components in the solid state is of great scientific interest. This fact opens up the prospects for strengthening such materials by decomposition of supersaturated solid solution, stabilized as a result of high thermalization speed of deposited particles from the ion-plasma flows [4].

2. EXPERIMENTAL DETAILS

The coatings have been received by the ion sputtering (magnetron scheme) of hot pressed targets with different volume contents of their constituent WB_2- and TiB_2-components (from 0.7 to 100.0 mol.% TiB_2). The planar magnetron scheme has been used for sputtering. Sputtering has been carried out in the medium of the inert gas Ar under the pressure (2–3) mTorr. The deposition speed is approximately 0.2 nm/s. Monocrystalline silicon (370 μm thick) and Ta (1000 μm thick) served as a substrate.

Phase composition, structure and substructure of condensates have been researched by X-ray diffraction methods on DRON-3M apparatus in Cu – K_α radiation. The analysis of phase composition of the coatings has been carried out resorting to the card file ASTM.

The composition has been defined on fluorescent data by the method of energy-dispersive X-ray spectroscopy, EDX.

Investigation of coatings in order to determine their adhesive and cohesive strength, scratch resistance and defining the destruction mechanism was carried out using a scratch tester Revetest (CSM Instruments).

3. RESULTS AND DISCUSSION

The analysis of the elemental composition showed that with increasing the content of titanium atoms, the coatings contain more bound boron (Table 1).

Table 1 – Elemental composition of the coatings of different series, defined by fluorescent spectroscopy method

Series No.	Composition, at.%		
	Ti	W	B
2	0.29	43.20	56.51
3	0.57	35.94	63.41
4	1.19	34.61	64.20
5	1.89	33.10	65.01
6	4.62	30.33	65.05
7	9.97	24.89	65.14
8	21.12	12.36	67.43
9	31.82	–	68.12

When this occurs, the formation of nanostructured state takes place in the coatings (the size of crystallites is from 3 to 100 nm). When the content of titanium atoms in the coating is low (up to Ti / W = 1.89 / 33.10 ≈ ≈ 0.06), preferential formation of lower borides β-(W, Ti)B with a rhombic lattice with a structure type CrB (space group Cmcm) takes place.

---

[*] sool@kpi.kharkov.ua
[†] sana@mss.sumdu.edu.ua
[‡] beresnev-scpt@yandex.ua
[§] kovaleva@bsu.edu.ru

When the content of titanium atoms is high, the phase (Ti, W)B_2 with hexagonal lattice (structural type AlB_2) is formed. This transition occurs through the formation of two-phase state from β-(W, Ti)B- and (Ti, W)B_2-phases when the content of titanium is from 0.2 to 10 at.%.

By means of scratch-testing method, the analysis of adhesion strength of the obtained coatings with the tantalum substrate has been carried out. Scratching of the surface of the coating under continuous loading of indenter is set as a base for the investigation. During the tests, the material was subjected to deformation in the elastic and elastic-plastic areas to limit state with subsequent destruction under the horizontal movement of indenter, pre-embedded to a certain depth. As a criterion for the adhesive strength, the critical load L_C, which leads to failure of the coating, is used [5]. The research results for the samples of series 4 (with a low content of Ti) and series 8 (with a high content of Ti) are shown in Fig. 1.

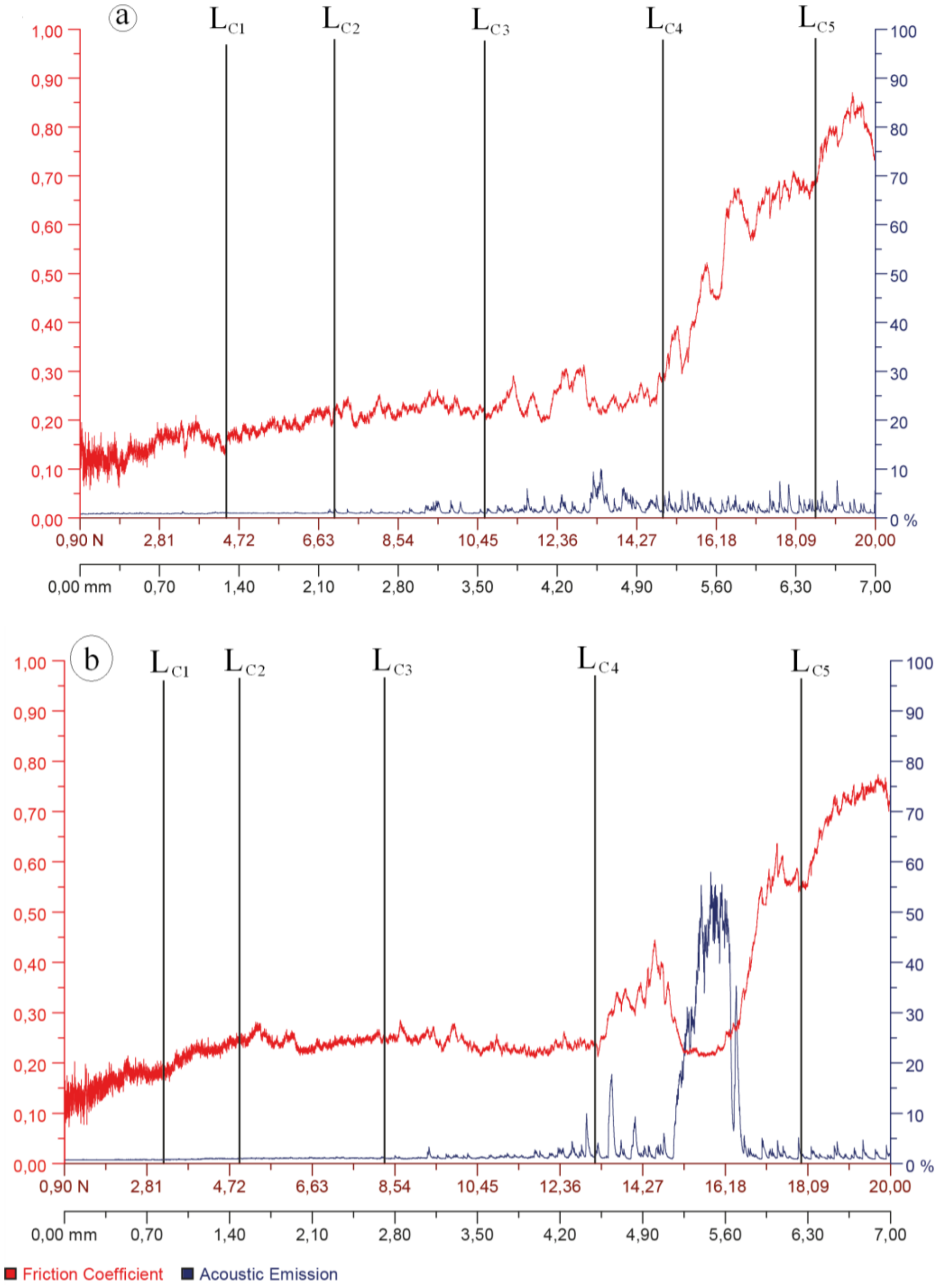

Fig. 1 – Changes in the averaged values for the amplitudes of acoustic emission and the coefficient of friction for the coatings of series 4 (a) and 8 (b) (T_S = 970 K)

In this case L_{C1} characterizes the moment of the first chevron cracks appearance; L_{C3} – destruction that gets cohesively-adhesive nature; L_{C5} – plastic abrasion of the coating to the substrate.

Analysis of the obtained data shows that increasing the content of Ti in the coating increases the coefficient of friction from 0.12–0.17 (for different states of the coating of series 4) to 0.13–0.19 (for analogous states for the coating of series 8).

Appearance of the peak of acoustic emission in the area between points L_{C4} and L_{C5} is connected with the appearance of cracks and chips due to brittle fracture of the coating (Fig. 1b, 2). Thus, a further increase in load leads to chipping at the edges of the wear track (Fig. 2b).

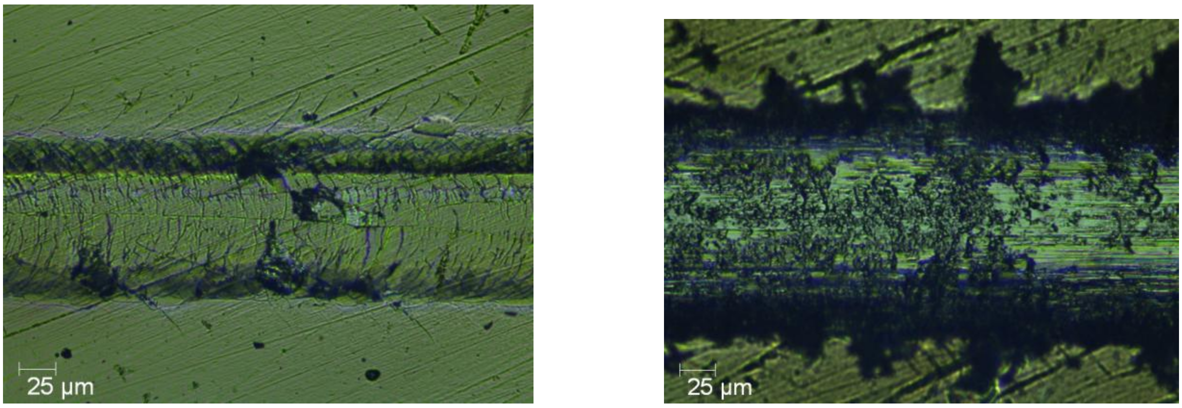

Fig. 2 – Wear tracks in the area of critical points L_{C4} (a) and L_{C5} (b)

As seen from the obtained results: increasing of W content and formation of two-phase state β-(W, Ti)B and (Ti, W)B_2 leads to a greater plasticity of the coating. This becomes apparent in formation of cracks at much higher loads (Table 2).

Table 2 – Critical load L_C for the coatings of series 4 and 8

Series No.	L_{C}, N				
	1	2	3	4	5
4	4.411	7.010	10.619	14.899	18.562
8	3.194	4.946	8.301	13.171	17.934

At high loads (greater than 10 N) in the case of small content of Ti (Series 4), the cracks of small length with a relatively big formation density are formed. A high content of titanium atoms in the coating as a result of formation of strong Ti-B bond leads to increase in hardness and to simultaneous increase in brittleness of material. This is observed in formation of large chips (Fig. 2b) at lower loads (13–17 N) (Table 2).

ACKNOWLEDGMENTS

The work was performed by the authors in the framework of state budgetary scientific research works 0112U000402 and 0112U001382, as well as integrated project 0113U001079, funded by the Ministry of Education and Science of Ukraine.

REFERENCES

1. H. Willmann, P.H. Mayrhofer, P.O.A. Persson, A.E. Reiter, L. Hultman, C. Mitterer, *Scripta Mater.* **54**, 1847 (2006).
2. O.V. Sobol', O.A. Shovkoplyas, *Tech. Phys. Lett.* **39** No 6, 536 (2013).
3. A.D. Pogrebnyak, V.N. Borisyuk, M.V. Kaverin, R. Krause-Rehberg, A.G. Ponomarev, M.A. Bilokur, K. Oyoshi, Y. Takeda, V.M. Beresnev, O.V. Sobol', *Phys. Met. Metallogr.* **114** No8, 672 (2013).
4. N.A. Azarenkov, O.V. Sobol, V.M. Beresnev, A.D. Pogrebnyak, S.V. Lytovchenko, O.N. Ivanov, *Materialovedenie neravnovesnogo sostojanija modificirovannoj poverhnosti* (Sumy: Sumskij gosudarstvennyj universitet: 2012) [in Russian].
5. J. Valli, *J. Vac. Sci. Technol.* **A4**, 3007 (1986).