

STRUCTURE AND MECHANICAL PROPERTIES MODIFICATION OF HARD ALLOY BY MULTIELEMENT ION IMPLANTATION

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Introduction

The joint high doses ion implantation of metal and nitrogen, boron in tool materials is able to amplify their hardness and wear properties. Meanwhile tool materials geometry will be changeless. The modified layer of tool materials does not spall in service. The strengthened coatings on tool materials have no these features. The property modification of tool materials due to formation of high defect density and dispersed hard segregations. In elemental content of segregations contain implantation atoms and self atoms [1,2]. As is known zirconium borides layers possess high hardness and thermal stability. The simultaneous high doses of nitrogen, boron and zirconium ions implantation in tool materials is able to form highly consistent and wear resistance layers. Thus goal of this paper is investigation of structure state and mechanical properties of WC-Co hard alloy after high doses implantation of nitrogen or krypton, boron and zirconium ions.

Experimental procedures

The phase composition of hard alloy was tungsten carbide and cobalt. The concentration of cobalt in alloy was 16 atomic fraction. Finally, the hard-alloyed samples were mechanically polished to a mirror. Dual elemental composition of ions was carried out by implantation - (Zr, B, N) and (Zr, B, Kr). The parameters of irradiations were: energy – 40 keV, dose - $5 \cdot 10^{17}$ ions/cm², current density – mA/cm².

The phase composition of the samples was investigated using X-ray diffraction analysis (XRD) in the Bragg- Brentano geometry, with a Cu K α radiation. Microhardness of the samples was tested by means of a 401MVD “Wolpert” microhardmeter with a Vickers indenter under the load ranging from 0,1 to 0,5 N. The tribological properties of implanted hard-alloyed samples were investigated by pin-on-plane tests with a reciprocating mode. The pin was made of WC hard alloy with a radius of curvature of about 0,2 mm. The dry sliding speed and the load were equal to 4 mm/s and 0.1 N, respectively.

Results and discussion

The results of XRD-investigation of hard-alloy implanted by both ionic groups are presented in Fig. 1. After implantation the angular position on diffraction pattern of tungsten carbide diffraction maxima do not change. But at

the same time intensities of WC diffraction lines at the angular range 31-49 degrees increases in 1.3 – 1.5 times. Maximal rise of WC reflexes intensities occurs in case of zirconium boron krypton implantation. Intensities of diffraction lines at angle range more than 63 degrees corresponding to WC do not change after implantation by ions of both types (see Fig. 1).

It is suggested that intensities increase of WC diffraction lines corresponding to 001, 100 and 101 crystal planes is due to formation of WC grains texture in the result of multielement implantation. At the XRD-pattern of implanted samples Co diffraction lines are not observed but at the XRD-pattern of as-sintered hard alloy these reflexes are detected (see Fig. 1). For both implantation types precipitation of Co_5Zr , zirconium carbide (ZrC), carbide of cobalt and tungsten ($\text{Co}_3\text{W}_3\text{C}$) occurs. If nitrogen is used instead of krypton only Co_5Zr will formed.

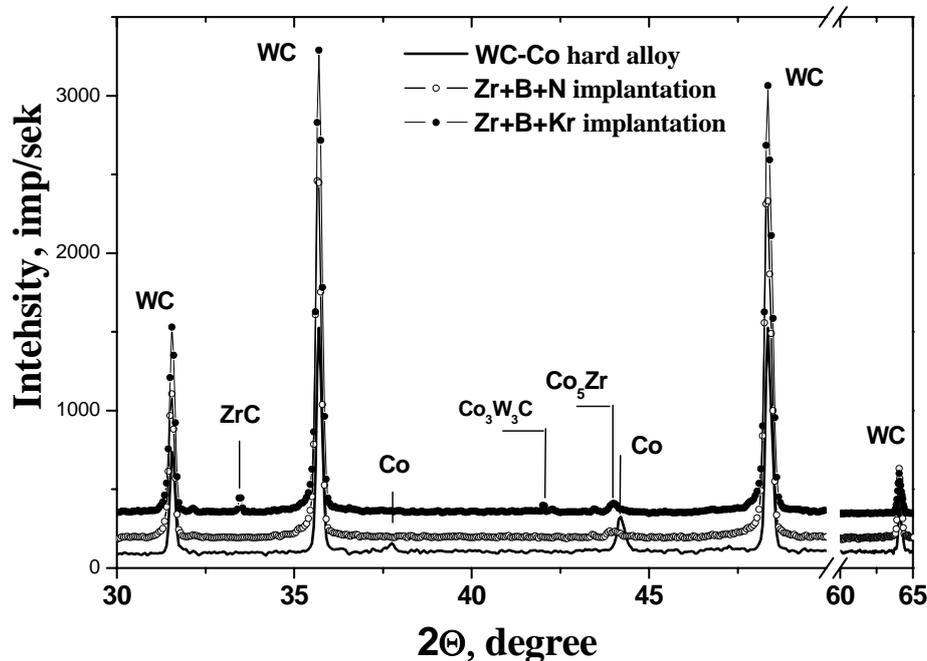


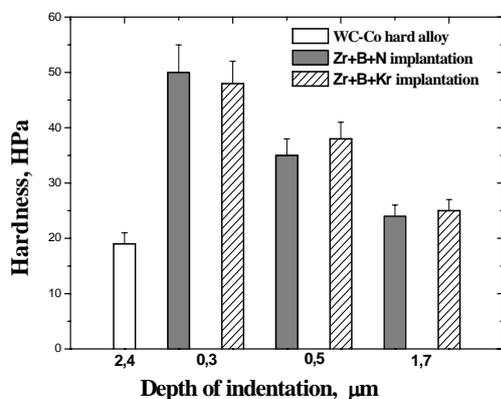
Fig.1. XRD-pattern of as-sintered WC-Co hard alloy sample and WC-Co hard alloy samples implanted by (Zr, B, N) and (Zr, B, Kr) ions.

Hardness measuring data obtained for the samples before and after implantation are presented in Fig. 2 (a) as function of indentation depth. As a result of implantation microhardness of WC-Co hard alloy at depth of 0.2 μm increases in 2.5 times and reaches the value more than 50 GPa. Data of WC-Co hard alloy implantation by ions of different types show microhardness increase mainly by 30 – 50 %. Significant hardness increase (up to 40 GPa) appears in the case of boron implantation when compressive stresses in WC-Co implanted lattice are formed. Hardness rise also occurs after implantation by Mo and W at TiC-WC-Co hard alloy and formation of Mo, W, Ti double and triple carbides at

the hard alloy's carbides boundaries [3, 4].

As compared with literature data concerning WC-Co alloy implantation

a)



b)

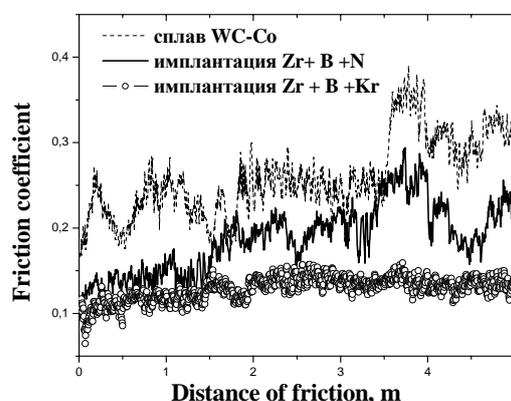


Fig.2. (a) WC-Co hard alloy microhardness as a function of indentation depth both before and after implantation by (Zr, B, N) and (Zr, B, Kr) ions. (b) WC-Co hard alloy friction coefficient as a function of friction path both before and after implantation by (Zr, B, N) and (Zr, B, Kr) ions.

by zirconium, boron and nitrogen ions microhardness greater magnitude in our experiment is a result both of precipitation of intermetallic and carbide compounds contained more ductile Co phase and WC grains texture formation. It is supposed that radiation-enhanced diffusion of implanted and free atoms to carbides grains stimulates WC texture formation and precipitation.

In Fig.2 (b) one can see friction coefficient both before and after implantation as a function of friction path. In the case of untreated samples friction coefficient rises with increase of friction path (Fig. 2 b). There are significant variation of friction coefficient over short time intervals. Increase of friction coefficient value when spherical indenter is embedded in the material is qualitatively explained by Bowden – Tabor model excluding effects of processes of adheres to the indenter, cracking and wear particles transport in wear track. As the material wears and indenter embeds real contact area of the indenter and the material increases. This causes the increases of friction coefficient.

As it is known from literature [5,6] several mechanisms control features of hard alloy wear and friction coefficient changes. Firstly it is brittle fracture without plastic deformation of tungsten carbide. Secondly it is selective remove of cobalt binder with subsequent tearing of hard alloy's grains. Adhesive interaction between the indenter and the hard alloy mainly causes friction coefficient “instantaneous” increase over short time interval which one can see on figures as stochastic fluctuations of friction coefficient.

As it is shown at Fig. 2 b the implantation of zirconium, boron, nitrogen and krypton ions influences friction coefficient decrease. Decrease of friction coefficient up to value 0,1 occurs in the case of zirconium, boron and krypton implantation. “Instantaneous” relative changes of friction coefficient also decreases more than twice. Differences in tribological properties of the hard alloy layer implanted by different ions types indicate the influence of implanted ions types on adhesive interaction decrease at contact area. Microhardness values after implantation of different ions types are close and detect identical wear resistance to abrasive wear. Therefore, mechanism of adhesive interaction controlled by cobalt in case of implantation is replaced by brittle wear of carbide phases as cobalt combines with zirconium, tungsten and carbon forming more hard compounds. So mostly growth of volume fracture of carbide phases formed in the result of implantation of zirconium, boron and krypton increases hard alloy wear resistance.

Conclusions

Changes of structure phase composition and mechanical properties of WC-Co hard alloy in result of simultaneous implantation of Zr, B, N and Zr, B, Kr ions with energy 40 keV and ion current density was 0.1 mA/cm². In the result of multielement implantation in hard alloy layer ~ 0.2 μm formation of tungsten carbide grains texture occurred, cobalt transformed into intermetallic and carbide compounds (Co₅Zr, Co₃W₃C). In case of krypton ions use in implantation process ZrC additionally formed. Hardness of modified layers increased in 2.5 times. Friction coefficient decreased in both cases. Its maximal decrease up to 0.1 occurred in case of Zr, B and Kr implantation.

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