FORMATION OF HARD SURFACE LAYERS ON THE BASE OF (NB,TI,W)C CARBIDES IN HARD ALLOY BY COMPRESSIVE PLASMA FLOWS

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Due to high hardness, high wear, corrosion and heat resistance sintered hard alloys are widely used in modern industry as cutting, drilling and punching tools especially in conditions of high temperature and corrosive environments. Further increase of hard alloys' operating characteristics is by far one of the most actual task of material science. Concentrated energy flows allow to alloy material surface layer with components of previously deposited coating. Alloying occurs due to melting of coating and its mixing with melted hard alloy surface layers. Treatment by compressive plasma flows (CPF) provides uniform distribution of alloying element throughout melted layer as well as diffusive saturation with plasma forming gas as it was shown in the earlier works /1, 2/. Introduction of additional elements gives an opportunity to change initial structure and phase composition of the surface layers and as a consequence to influence on their mechanical properties. It is known that dissolution of niobium in titanium and tungsten carbide with formation of solid solution provides increase of fracture toughness and compressive stress. Besides that niobium has high chemical affinity to nitrogen and carbon. That is why the formation of niobium nitride, carbide and carbonitride phases is possible during treatment. This effect can also results in increase of hard alloy mechanical properties.

Investigation of the structure and mechanical properties of layers formed after deposition of Nb coatings on T15K6 (WC-15TiC-6Co, wt. %) hard alloy and following treatment by compression plasma flows (CPF) in nitrogen atmosphere was the aim of this work.

Experimental

A niobium coating was formed on WC-TiC-Co hard alloy (WC-15TiC-6Co, wt.%) using the cathodic arc vapour deposition. The coating thickness was ~ 2 μm. The samples were tetrahedral plates with sizes of 10x10x4mm. The CPF treatment was carried out with 5 pulses at gas-discharge magnetoplasma compressor of compact geometry. The pressure of the plasma-forming nitrogen was 3 Tor. The discharge duration was ~ 100 μs. The length of formed CPF was 8 cm. The operating voltage at the capacitor bank was varied in the range of 2,5 - 4 kV. According to the calorimetric measurement the value of the energy density absorbed by the sample surface was approximately 14 and 34 J/cm^2 for the voltage of 2,5 and 4 kV correspondingly. Area of uniform plasma treatment exceeds the samples' sizes. Phase composition of modified layers was studied by X-ray diffraction (XRD) in Bragg-Brentano geometry with CuK$_\alpha$ radiation (Ultima X-ray Difractometer). Hardness of the samples was tested by means of a Wilson Instruments 402MVD hardmeter with a Vickers indentor under the load ranging from 0,5 to 1N.

Results and discussion

Phase composition of the Nb/hard alloy system before treatment corresponds to WC and (Ti,W)C carbides and Nb film. CPF treatment by 5 pulses with voltage of 2,5 kV at the nitrogen pressure of 3 Torr leads to Nb film partial melting and formation of (Nb,Ti)C phase (fig. 1a). Increase of voltage (3, 4 kV) results in full melting of Nb film and surface layer of hard layer with the following mixing of components in the melt. One can see that Nb diffraction line is absent at this treatment regime while diffraction lines of (Nb,Ti)C, (Ti,W)C solid solutions and NbC, Nb_2N, W_2C are appeared at diffraction pattern (fig. 1 b,c).

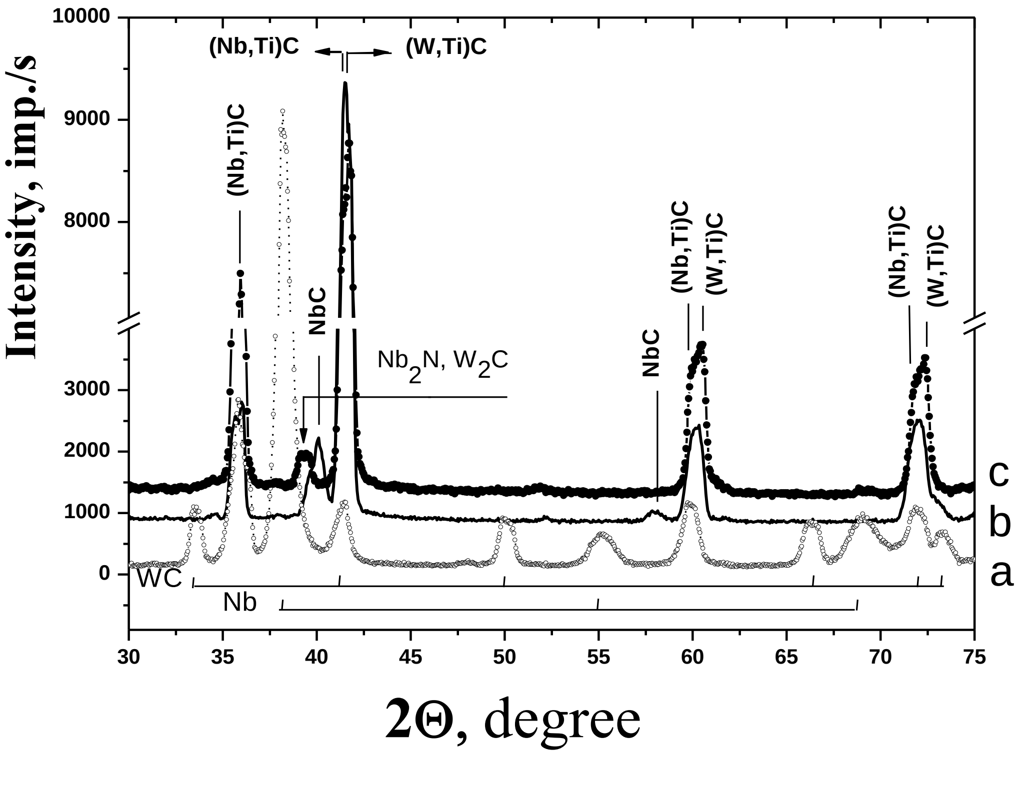

Fig. 1. Diffraction patterns of the Nb/hard alloy system after CPF treatment with 5 pulses at nitrogen pressure of 3 Torr with voltages of:
(a) – 2,5 kV; (b) – 3 kV; (c) – 4 kV

The dependence of hardnes of the Nb/hard alloy system after CPF treatment on the voltage of the capacitor bank is shown in the table. The findings show that the rise of capacitor bank voltage up to 3-4 kV lead to the growth of the surface layer hardness up to the value of 24-34 GPa due to the increase in the surface layer of carbides containing niobium volume fraction.

Table. Hardness of the Nb/hard alloy system after CPF treatment by 5 pulses at nitrogen pressure of 3 Torr for a different voltage of the capacitor bank

Voltage, kV	Hardness, GPa
source object	6,2±0,1
2,5	13,9±1,7
3	25,7±3,6
3,5	35,8±6,6
4	34,9±3,8

Earlier conducted investigations /3/ showed that CPF treatment of zirconium-hard alloy system under similar values of voltage resulted in formation of both carbide and nitride phases containing zirconium - (Ti,Zr,W)C and ZrN. Difference with the results of this experiment (mainly carbide phases with niobium are formed) can be explained by the fact that niobium carbide possess lower formation enthalpy than that of niobium nitride.

Conclusions

Treament of Nb/hard alloy system by 5 pulses of compressive plasma flows (pulse duration of 100 μs, capacitor bank voltage 3 - 4 kV, energy density absorbed by the surface of 34 and 41 J/cm^2, nitrogen atmosphere in the vacuum chamber with residual pressure of 3 Tor) leads to formation of new niobium containing phases in the surface layer: NbC, (Ti,Nb)C, Nb_2N. The growth of capacitor bank voltage at CPF impact results in the increase of the formed layers hardness from 6 to 34 GPa.

References

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