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Microarticle

The electrical properties of coating obtained by vacuum arc deposition

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ABSTRACT

This paper investigates the electrical properties of the coating based on Ti–C–B system. The coating was obtained by vacuum-arc method by spraying of multi compound cathode prepared by reactive hot pressing of Ti, carbon black and amorphous B powder mixture.

The electrical conductivity of the coating was measured in temperature range of 10–320 K which was about $\sigma = 4.8 \cdot 10^3\ \Omega^{-1}\ \text{cm}^{-1}$ in the entire temperature range. The carrier concentration measured was about $n = 1 \cdot 10^{22}\ \text{cm}^{-3}$. The charge carriers' mobility varies between 10 and −7 and changes sign at temperature about $T = 225$ K.

1. Introduction

Composite coatings based on Ti–C–B system are applied as protective coatings for cutting tools. It is due to their high melting point, chemical inertness, good wear and corrosion resistance and good electrical properties [1–4]. Electrical properties of the coatings are not well investigated [4]. Nevertheless this material may be promising for electronic applications as a material for high temperature electrical contacts.

2. Experimental procedure

Ti–C–B coating were deposited on the surface of SiO_2 plate by vacuum arc method. The principal scheme of experimental setup is shown in Fig. 1. The conditions of the process of pulsed vacuum-arc deposition were the following. Capacitive storage with a total capacity of 4000 μF charged to a voltage of 300 V was used. The pulse repetition rate of discharge was 5 Hz and the pulse duration was of about 2 ms. Maximum discharge current was of 800 A. Pre-vacuum chamber was evacuated to a pressure of not more than $1 \cdot 10^{-3}$ Pa. Before coating deposition, the substrate was treated by argon ions with energy of 1.5 keV. Distance from the cathode to the substrate was about 200 mm.

A consumable cathode with diameter of 40 mm was manufactured by reactive sintering of the mixture of Ti, amorphous B and carbon black powders using hot pressing with pulse heating. The temperature of sintering was 1200 °C and the pressure was 50 MPa.

The study of the temperature dependence of conductivity and charge carriers' mobility of thin composite film Ti–C–B was carried out by traditional 6-probe method in a transverse magnetic field configuration (I⊥B). Solder contacts for Uσ and Uh measuring have been checked for ohmic previously. Temperature dependence measurements in temperature range of 10–320 K were carried out using installation with cryogenic complex of JENIS company.

3. Results and discussion

Given the geometry of the sample and the measurement results the temperature dependence of conductivity $\sigma(T)$ in the temperature range 10–320 K was plotted (see Fig. 2).

Specific conductivity increases monotonically in the range of 10–250 K with increasing temperature, showing the first maximum at 175 K and the second one at 250 K. This process is obviously related to the activation of impurities and starts at 250 K and the specific conductivity decreases sharply, due to the depletion of impurity conductivity. The value of charge carrier's mobility change sign at temperature about $T = 225$ K (see Fig. 2).

Coatings based on Ti–C–B are multiphase system comprising a plurality of non-stoichiometric phases of titanium carbides and borides. Most likely, the contribution to the total conductivity is made by charge carriers of opposite signs. Clarification of the mechanisms of conductivity in such a complex system is a separate complicated problem. The change of sign in the conductivity is

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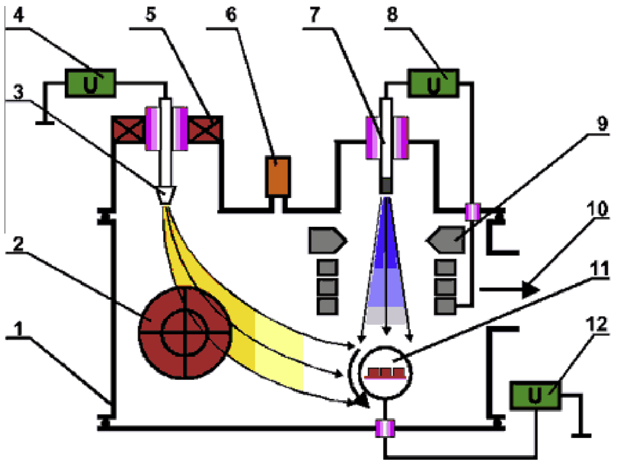

Fig. 1. Principal scheme of experimental setup. 1 – vacuum chamber; 2 – deflecting magnetic system; 3 – stationary source of metal plasma; 4 – power supply for stationary source metal plasma; 5 – focusing magnetic system; 6 – gauge; 7 – pulse source of metal plasma; 8 – power supply for pulse source of metal plasma; 9 – anode of plasma pulse source; 10 – to vacuum pump; 11 – carousel with substrates; 12 – a source of stage bias

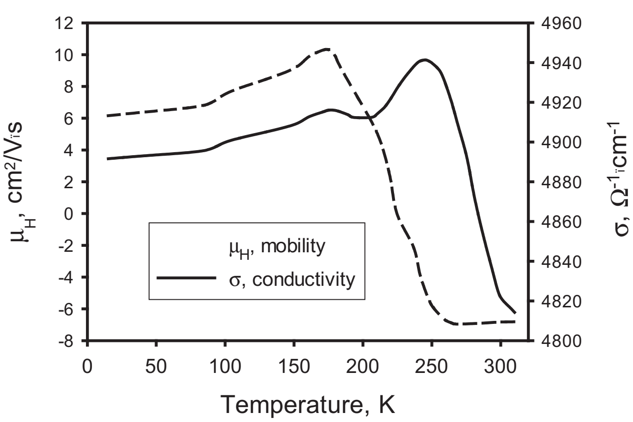

Fig. 2. Temperature dependence of electrical conductivity and charge carriers' mobility of Ti–C–B coatings.

likely a consequence of changes in the contribution of different carriers in the total conductivity.

The concentration of free charge carriers n varies slightly with increasing temperature and is all over the temperature range $n = 1 \cdot 10^{22}$ cm^{-3} before and after the change of the sign of the majority charge carriers. The first maximum in the dependence of $\sigma(T)$ (Fig. 2) at $T = 175$ K coincides on temperature with the maximum in the dependence of the mobility $\mu(T)$ (Fig. 2), which is due to both the change of the type of charge carrier, and hence the value of mobility as and presumably scattering mechanisms. The sharp decrease in specific conductivity in temperature range of 250–325 K corresponds to a change of temperature dependence of charge mobility and output them on the shelf (see Fig. 2). The high conductivity $\sigma = 4.8 \cdot 10^3$ Ω^{-1} cm^{-1} at a low mobility of the composite (the value of μ is about 6 cm^2/Vc) is obviously due to the high carrier concentration $n = 1 \cdot 10^{22}$ cm^{-3} and high defect concentration typical for the coatings.

4. Conclusion

Good thermal and wear resistance inherent to titanium carbides and borides and high conductivity allows to use this material for the manufacture of high-temperature contacts.

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