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ION SPUTTERING OF TARGETS CONTACTING WITH IONIZED METAL VAPOR FLOW FOR COMPOSITE COATING DEPOSITION

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Ion sputtering is one of commonly used methods for deposition of composite coatings but it has drawbacks, mainly, low deposition rate and employing of gas ions; the latter brings the gas into the coatings. These drawbacks may be overcome in some cases if we use combination of non-gas ion sputtering with high rate electron beam (EB) evaporation and metal vapor ionization for ion generation [1]. For example, EB will intensively evaporate components with greatest contents in the composite coatings, but metal vapor ions will sputter components with small contents in the coatings. Herein the sputtered components may be refractory metals. Consider, for instance, such alloys for coatings as Ti-8Al-1V-1Mo, Ti-6Al-2Sn-4Zr-2Mo, and Ti-6Al-2Sn-4Zr-6Mo used for manufacturing gas turbine blades. Molybdenum in these alloys is refractory element and is not congruently evaporated as compared with the other metal elements in the alloys. Combination of matched ion sputtering of Molybdenum with EB evaporation may allow solving the problem of obtaining desired composition of coatings.

To approbate such approach, we have simulated Mo target sputtering with Ti^+ ions with help of the code TRIM-95 [2]. The results are presented in Table 1, where E_i is energy of bombarding Ti^+ ion, S is Mo sputtering coefficient, E_{Mo} is average energy of sputtered Mo atoms, R is coefficient of Ti^+ ion reflection from Mo target. The data point out the possibility of effective Mo sputtering with Ti^+ ions when the ion energy E_i (determined by the target potential relatively the vapor plasma ion source) is in the range of 2-3 keV.

Table 1. Mo sputtering with Ti^+ ions

E_i, keV	S	E_{Mo}, eV	R
1.0	1,2	77	0,12
2.0	1,8	150	0,1
3.0	2.0	200	0,09

To experimentally approve such approach to Mo sputtering, keeping in mind the aim of obtaining the composite coating, an evaporation/ sputtering set-up have been built. The latter consists (see Fig. 1) of EB gun, generating beam directed to the ingot of evaporated Ti alloys, an electrode system to support an arc discharge over the melted ingot surface in the metal vapor media for metal ion generation, a sputtered target system (we use two Mo targets T1 and T2) under negative bias voltage ($-U1$ and $-U2$) and a substrate under negative bias voltage ($-U$) [1]. The EB power was 40 kW. The arc discharge current was 50-200 A. The target bias voltages was pulse modulated (rate was 1 kHz, duty cycle D = 0.9, $U1$ = $U2$ = 2.5 kV). The substrate bias voltage also was pulse modulated (rate was 1 kHz, duty cycle D = 0.1-0.9, U = 0-2 kV).

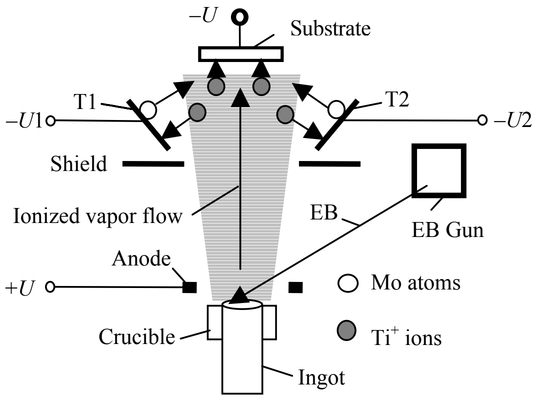

Fig. 1: Schematic diagram of the experimental set-up. EB is electron beam, T1 and T2 are Mo targets, –*U* is negative substrate bias voltage, –*U*1 and –*U*2 are negative target bias voltages, +*U* is anode voltage for supporting ionizing arc discharge.

The lower target surfaces are shielded from the metal vapor flow, therefore metal ions, mainly Ti^{+} ions, can bombard and sputter the upper target surface; then sputtered Mo target atoms go to the substrate. The value of Mo atom flow to the substrate depends on the arc discharge current, the target bias voltage and geometry of the system. Fig. 2 depicts distributions of metal elements in the coating; one can see presence of Mo in the deposited alloy with Mo content of about 2 w. % that is higher than in the ingot. Note, when the targets were under zero bias voltage Mo content was less than 0.3 w. %.

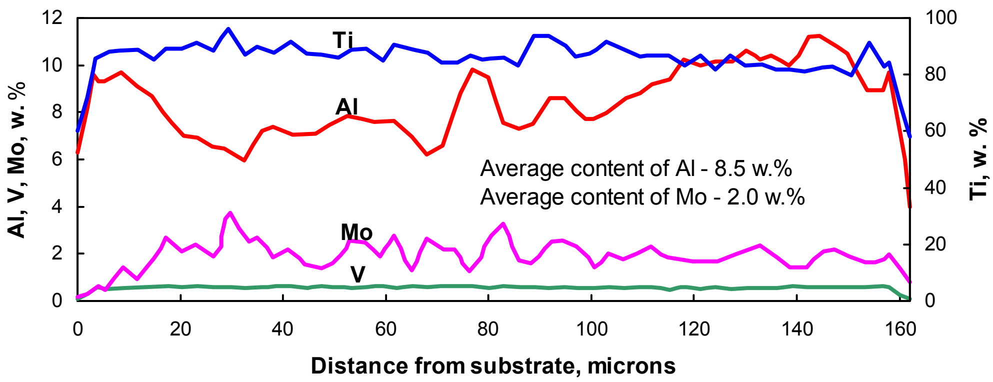

Fig. 2: Chemical element distribution in the composite coating obtained by EB evaporation of Ti-8Al-1V-1Mo ingot and sputtering of Mo target. Target voltages $U1 = U2 = -2.5$ kV, substrate bias voltage was zero, ionizing arc discharge current was 140 A, average target ion current density was about 3 mA/cm^2.

Thus, one can see contacting negatively biased metal targets with ionized metal vapor flow allows doping deposited composite coatings with target materials in the controllable mode.

Reference

[1] I.V. Belousov, V.I. Biber, A.I. Kuzmichev, R.L. Memmen, 2005 *Eur. Pat. Bull.* **38** EP1577417
[2] J.F. Ziegler 1994 *TRIM – The Transport of Ions in Matter* (Yorktown, NY: IBM-Research).