Action of High Power Ion Beam on Dielectric Film on Metal Substrate

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Abstract – The formation surface morphology in a system "thin dielectric film – metal substrate" under the action of a high-power ion beam of nanosecond duration was studied. Data on the morphology formed at high power ion beam irradiation of 90–200-nm-thick GeO films on aluminum alloys substrates are presented. Possible mechanisms of morphology formation in irradiated thin dielectric film on metal substrates are considered.

1. Introduction

The high power ion beam (HPIB) has been proved to be an efficient method for surface modification of various materials [1-4]. Direct irradiation of an ion beam onto a solid surface results in rapid melting and solidification with heating and cooling rates up to 10^{10} K/s. These rates can promote mixing, rapid diffusion and the formation of amorphous and microcrystalline surface layers, which consequently improve mechanical performance of material surfaces. Many researchers have used HPIB to irradiate a wide variety of metals and alloys such as carbon steel, stainless steel, aluminum and titanium alloys. The results have demonstrated some improvements in the fields of materials as surface hardness, wear resistance, oxidation and corrosion resistance. The most typical features (frequently negative) of the surface relief at HPIB irradiation are craters of varied size and shape. The crater size and spatial distribution depend on the beam energy density and the phase state of the target material. The crater formation on surface various metal and system "thin metal film – metal substrate" was investigated previously [5–6]. However, HPIB surface modification of systems "thin dielectric film-metal substrate" has the large perspective for improvement of corrosion resistance. In this work, we study the action of HPIB on thin dielectric film deposited on metal substrate.

2. Technique of experiment

Aluminium alloys was selected as model substrate material. The samples with diameter 12 mm and thickness 2 mm were used as target materials. Samples were mechanically polished and were cleaned in acetone followed by air-drying. GeO was selected as model dielectric material. GeO thin film was deposited by thermal evaporation in vacuum onto aluminium substrates. The films were deposited at substrate temperatures not exceeding 120 °C. The dielectric thicknesses were varied within an interval of 90–200 nm. The dielectric film was deposition on one half of aluminium substrate only. After HPIB irradiation a surface morphology both half was compared. A Temp accelerator was used for irradiating the samples with a 300-keV proton–carbon beam (30% H^+ and 70% C^+) at an average current density of up to 150 A/cm^2 and irradiation duration of 60 ns. The average current density ion beam was varied in our experiments. The dielectric film thickness was much smaller than the range of carbon ions and protons of the beam in the film material. At the same time, the substrate thickness was much greater than the ion range. The surface morphology of ion-irradiated samples was examined using Neophot-2 and Biolam optical microscopes and studied in a Solver Pro atomic force microscope (AFM).

3. Results and their discussion

Surface morphology system "thin film GeO – aluminium substrate" after HPIB irradiation dependent on current density of ion beam and initial condition of surface substrate. Figure 1 shows initial surface morphology aluminium alloy AD33T1. The right half of all samples is covered with thin film GeO.

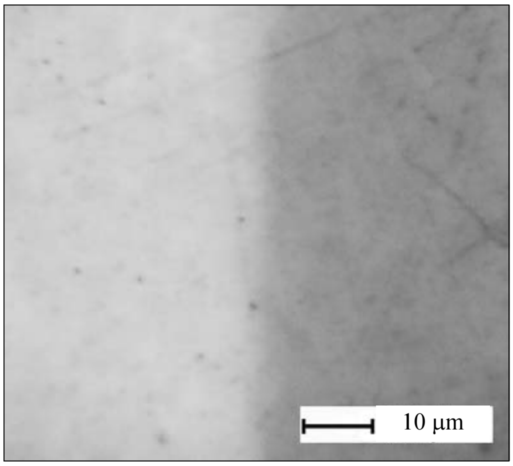

Fig. 1. Initial surface morphology of AD33T1 with thin film GeO (right half)

HPIB irradiation of thin dielectric film on metal substrate can result in a cracking of film and it delamination from substrate because large difference of coefficient of thermal expansion of film and a substrate. The considerable cracking is observed at the large thickness of a dielectric film comparable with a ion path. At dielectric thickness used in the present work cracking and delamination is observed only in small local areas of the substrate. HPIB irradiation with small current density (up to 20 A/cm^2) does not vary the surface morphology of aluminium alloy but the small reduction of thickness of GeO film is observed because sputtering of film by ion beam and sublimation GeO at heating of film. It is appreciable on change interference coloring of dielectric film.

Crater formation on the surface of aluminium alloy is observed at increasing current density up to 50 A/cm^2 (Fig. 2).

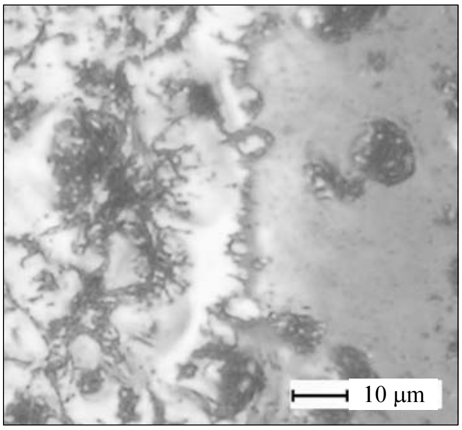

Fig. 2. Surface morphology of AD33T1 (right half – GeO film) after HPIB irradiation with j = 50 A/cm^2

At that, the surface of dielectric film starts to be deformed because of melting of a metal substrate under GeO film. At increasing current density the crater size on metal surface of substrate increases (Figs. 3 and 4).

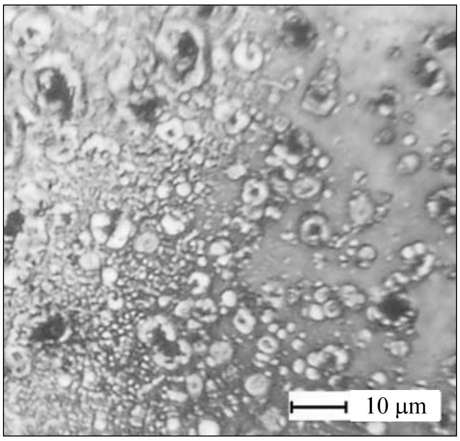

Fig. 3. Surface morphology of D16T (right half – GeO film) after HPIB irradiation with j = 100 A/cm^2

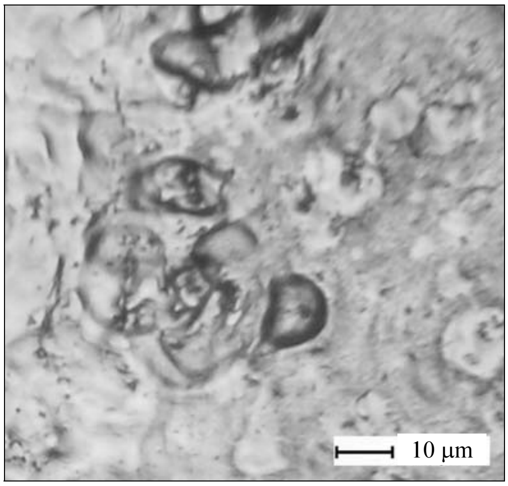

Fig. 4. Surface morphology of D16T (right half – GeO film) after HPIB irradiation with j = 150 A/cm^2

On right half substrate (covered by dielectric film) formed craters with smaller size and depth. Hard dielectric film with higher melting temperature is limited hydrodynamical movement molten layer of substrate.

At the large current density ion beam were observed partial decomposition of GeO also.

4. Conclusions

Thus, HPIB irradiation of thin dielectric film on surface of aluminium alloys lead to increasing a surface roughness if current density exceed 20 A/cm^2.

References

[1] H.A. Davis, G.E. Remnev, R.W. Stinnett, and K. Yatsui, Mater. Res. Bull. **21**, 58 (1996).

[2] A.D. Korotaev, S.V. Ovchinnikov, Y.I. Pochivalov, A.N. Tyumentsev, K.A. Shchipakin, M.V. Tretjak, I.F. Isakov, and G.E. Remnev, Surf. Coat. Technol. 1**05**, 84 (1998).

[3] Y.F. Ivanov, G.E. Remnev, and B.A. Makeev, Fizika i Khimij Obrabotki Mater. **3**, 62 (2001).

[4] A.D. Korotaev, A.N. Tyumentsev, Yu.P. Pinzhin, and G.E. Remnev, Surf. Coat. Technol. **185**, 38–49 (2004).

[5] X. Wang, M.K. Lei, and J.S. Zhang, Surf. Coat. Technol. **201**, 5884–5890 (2007).

[6] V.S. Kovivchak, T.V. Panova, R.B. Burlakov, and V.I. Blinov, Poverchnost' **4**, 69–71 (2006).