Surface Morphology of Zink after Irradiation by High Power Ion Beam

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Abstract – Surface morphology of zinc irradiated by high power ion beam with average ion current density of 10–150 A/cm^2 and pulses number of 1–3 has been investigated. Optical microscopy and microinterferometer was used to analyse surface morphology irradiated sample. The morphology features on the irradiated zinc were craters and waviness. Clear wavy relief and surface cracks was observed for high power ion beam irradiated with small average ion current density. Results are discussed on basis of physical properties of the zinc and stress wave and the quasi-static thermal stresses induced by high power ion beam irradiation.

1. Introduction

In the past two decades the high power ion beam treatment of metals and alloys is a high efficient and promising method for their surface modification [1].

In the case of using a high power ion beam the main factors responsible for the improvement in performance of materials are high-rate (~10^9–10^{10} K/s) heating/cooling and temperature gradients (~ 10^9 K/m) in the subsurface layers of the target material [2]. Such rates are high enough to promote formation of non-equilibrium microstructure such as amorphous and metastable phase. In the case of high power ion beam irradiation the surface morphology of metals and alloys undergoes a great change, mostly roughening with features of craters and waviness formation [3, 4]. The effect of high power ion beam irradiation on the surface morphology of different metals and alloys is not fully understood. In the present work surface morphology of zinc irradiated by a high power ion beam was investigated to elaborate the interaction mechanism of the high power ion beam with metallic materials.

2. Experimental

The target materials was zinc (99.95%) with coarse gains. Speciment were cut into 15×15×2 mm plates mechanically polished on the one hand. Samples irradiation was performed in technological accelerator "Temp" with one or three pulses of duration τ_b = 50 ns and average ion current density 10, 50, 100, 150 A/cm^2. The reproducibility of ion current density from pulse to pulse is better than 20%. The beams consisted of carbon ions (70%) and proton (30%) and had elliptic cross section. Investigation of the surface relief, surface fracture zinc irradiated high power ion beam were carried out by optical microscope "Neophot-2". The phase state of the unirradiated and irradiated samples were inspected by X-ray diffraction "Dron-3M" with Cu-K_α radiation.

3. Results and Discusion

Figure 1 shows the surface morphology of the unirradiated sample zinc. As shown in Fig. 1 on the surface of sample the defects brought after polishing are present. Fig. 1,b–c shows the surface morphology of samples irradiated high power ion beam with different average ion current density. Fig. 1 indicates that the observed surface morphology depends on the average ion current density and the number of pulses. The surface morphology of irradiated samples was characterized by presence of the craters and waviness with different shapes and sizes. Single craters and clear wave relief was observed at irradiation high power ion beasm with average ion current density of 10 A/cm^2. This wave relief is similar wave relief which was observed on Ni_3Al irradiated by high power ion beam [5]. The wave reliefs have various orientation at different grains of zinc.

a b c

Fig. 1. Surface morphology of: (a) the unirradiated samples and the irradiated by one pulse with average ion current density 150 (b), 10 (c) A/cm^2 (× 200)

The wavelength of wave relief is practically the same as diameter of crater (see Fig. 1,c). Formation of the wave relief on the zinc surface for such small average ion current density can be explained by physical properties of zinc. Zinc have high velocity evaporation at liquid and solid state. Therefore, high pressure pulse appears at irradiation of zinc by a high power ion beam with small average ion current density. Such pulse may be the main factor responsible for the formation of wave relief [5]. Surface cracks at some grain zinc irradiated with average ion current density of 10 A/cm^2 was observed. This cracks appears after a solidification of the melted surface layer of the target.

It is known that zinc become a brittle at 200 °C. In the case of high power ion beam irradiation the stress wave with amplitude $\sigma \leq 50$–60 MPa and the quasi-static thermal stresses which reach $\sigma_{qs} \leq 3$–5 GPa appears in target [5]. Thus a target irradiated high power ion beam will destroy by the quasi-static thermal stresses when surface temperature reach 200 °C.

4. Conclusion

Thus the high power ion beam irradiation caused the craters and wave relief formation on surface of zinc target. When the quasi-static thermal stresses exceed tensile strength of a zinc at 200 °C take place fracture of target.

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