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Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

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ON THE JOINT ACTION OF β-RADIATION AND A SURFACE-ACTIVE MEDIUM ON THE MECHANICAL PROPERTIES OF ZINC SINGLE CRYSTALS

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In work carried out in our laboratory, the action of surface-active metallic melts, covering the surface of the metal being tested with a thin layer, on the mechanical properties of more refractory metals has been studied in detail. It was found, in particular, that single crystals of zinc, cadmium, and tin, covered with a thin film of mercury or gallium, under uniaxial tension at a constant deformation rate, exhibit a sharp decrease in strength and ductility. These effects are associated with the penetration of atoms of the active melt into the deforming metal along structural defects that develop during the deformation process ($^{1-5}$). Adsorption of atoms of the surface-active melt on the newly formed internal interfaces —nuclei of fracture—substantially facilitates the formation and growth of cracks, which lead to rapid failure of the metal at low stresses. An increase in the number of structural defects arising in the process of deformation and corresponding to a given stage of it, which may be caused, for example, by irradiation, should apparently lead to a considerable increase in the magnitude of the effect of the surface-active melt, since this thereby facilitates the possibility of penetration of melt atoms into the deforming metal.

Fig. 1. Influence of β-irradiation on the plastic deformation of zinc single crystals of orientation $\chi = 27°$. Curves marked with crosses refer to specimens stretched in the field of the radiator. Deformation rate:
1—2.5% min^{-1}; 2—10% min^{-1}; 3—40% min^{-1}

In the present work, results are presented on the action of β-radiation on the mechanical properties of zinc single crystals, approximately 1 mm in diameter, covered with a thin film of mercury (thickness $\sim 5\ \mu$).

As the radiation source, a preparation containing the β-active isotope P^{32}, with a half-life of 14.3 days and maximum radiation energy $E_m = 1.7$ MeV, was used.

Fig. 2. Plasticizing action of β irradiation during rest of a crystal without removing the load. Irradiated (1) and nonirradiated (2) specimens had orientation $\chi \simeq 29°$

Figure 2: Fig. 2. Plasticizing action of β irradiation during rest of a crystal without removing the load. Irradiated (1) and nonirradiated (2) specimens had orientation $\chi \simeq 29°$

The radioactive preparation, in the form of disodium phosphate in an amount of 10 ml with a total activity of 100 mCu, was evaporated on 7 boats made of stainless steel, which were then mounted vertically on the inner surface of a cylinder with a slit along a generatrix. The single crystal under test was introduced through this slit and placed in

at the center of the cylinder. Radiation from the boats, directed toward the center of the cylinder, created the most favorable conditions for use of the preparation. After each half-life period the boats were removed from the irradiator and replenished with a fresh portion of disodium phosphate with an activity of 50 mCi. Thus, throughout the entire investigation the activity of the irradiator was maintained at a level close to 100 mCi.

Tensile testing of the specimens in the presence of the irradiator was carried out on a Polanyi apparatus equipped, for these purposes, with electric sensors and a special platform on the lower clamp. The readings of the spring dynamometer were observed on the scale of a cathode-ray oscilloscope calibrated in loads, or by means of a microammeter. The specimens were mounted in the clamps of the apparatus while the irradiator was in a lead container; then, with the aid of a manipulator, the irradiator was removed from the container and mounted on the lower clamp of the apparatus.

Fig. 2. Plasticizing action of β-irradiation during rest of a crystal without removing the load. Irradiated (1) and nonirradiated (2) specimens had orientation $\chi \simeq 29°$.

A preliminary study was made of the process of plastic deformation of single crystals of pure zinc (99.99%) at various constant rates of extension and with the inclusion of pauses, during which the load remained applied to the specimen.

Figure 1 presents deformation curves of zinc single crystals of orientation $\chi_0 \simeq 27°$, obtained at different rates of extension in the presence of the irradiator (curves marked with crosses) and without it (curves with dots). Under continuous extension, after preliminary exposure for 2 hours, strengthening appears at the initial stage of extension—a slight increase in the yield point due to the braking of dislocations by interstitial atoms and vacancies arising in the crystal lattice under corpuscular bombardment (^{6}), as well as some increase in the relative elongation to fracture, most noticeable at low deformation rates (2.5% min^{-1}).

Figure 3

Figure 3: Figure 3

The presence of irradiation during deformation is manifested more clearly during extension in the pause regime. After the first minute of extension, and then after every three minutes of extension, 3-minute pauses were introduced, during which plastic flow of the specimens was observed owing to straightening of the spring dynamometer. In the later pauses, corresponding to higher stresses, the drop in the dynamometer readings as a result of plastic flow of the crystal is 270–280 g, whereas in crystals deformed in the absence of the irradiator, during the same pauses the load drop is only 130–150 g. The plasticizing, i.e., weakening, action of β-active irradiation is shown in Fig. 2 using crystal No. 1 (irradiated) and No. 2 (nonirradiated) as examples.

At lower stresses, i.e., in the initial stage of deformation, the plasticizing action of irradiation is manifested to a lesser extent. This to some degree confirms the results of work (^{7}).

An exceptionally interesting result was obtained under the combined action on zinc single crystals of β-radiation and an active melt—mercury. Amalgamated zinc single crystals of orientation $\chi \simeq 50^\circ$, po

those that had received a 7-day exposure and were stretched in the β-emitter practically lose their strength and break at stresses of $\sim 20\ \mathrm{g} \cdot \mathrm{mm}^{-2}$ along the basal plane at the very earliest stages of deformation, at $\varepsilon = 1$-1.5% (Fig. 3). Control specimens of the same orientation, after 7 days' holding in the amalgamated state without irradiation, show a significantly higher strength (about $200\ \mathrm{g} \cdot \mathrm{mm}^{-2}$) and likewise break along the basal plane at small elongation. Evidently, irradiation activates the process of migration of the active medium along defects of the crystal-lattice structure to the new internal separation surfaces appearing and developing during deformation; this leads to brittle fracture at very low stresses.

Fig. 3. Effect of β-irradiation on the deformation process of zinc single crystals ($\chi \simeq 50^\circ$) containing a thin film of mercury on the surface. Zinc single crystals after amalgamation received a 7-day (1) or a 15-min (2) exposure in the field of the emitter and were then stretched under irradiation. Control (non-irradiated) specimens are indicated by dots. Deformation rate $\sim 10\%\ \mathrm{min}^{-1}$.

Figure 4 presents deformation curves for single crystals with $\chi \simeq 35^\circ$, which, after amalgamation, received exposure in the field of a β-emitter for 50 h (marked by crosses) and were not subjected to irradiation (marked by dots). Stretching at a rate of $10\%\ \mathrm{min}^{-1}$ at temperatures of 20° and −196° was carried out outside the emitter field. It is seen from this graph that pre-irradiated specimens exhibit greater strength when stretched in liquid nitrogen. At the same time, the irradiated specimens also show greater plasticity, i.e., a larger elongation before rupture, both at room temperature and at the temperature of liquid

Figure 4

Figure 4: Figure 4

nitrogen. The increase in plasticity of irradiated amalgamated zinc single crystals indicates the prevailing role of selective alloying of the single crystals with mercury along structural defects during a comparatively short holding time (50 h), whereas a longer holding in the amalgamated state (up to 170 h) leads to an equalization of the plastic properties of irradiated and non-irradiated specimens as a result of ordinary (regular) alloying of the single-crystal lattice with mercury. The fact that the strength of irradiated specimens at room temperature proves to be lower than that of non-irradiated specimens also points to this. The considerable increase in the strength and plasticity of pre-irradiated amalgamated zinc crystals when stretched in liquid nitrogen is of fundamental importance, since it indicates

Fig. 4. Effect of β-irradiation on zinc single crystals $\chi \simeq 35^\circ$ during exposure after amalgamation for 50 h. Irradiated specimens are indicated by crosses. Stretching was carried out at a rate of 10% min^{-1} at +20°C (1) and at -196° (2) outside the emitter field.

a new physicochemical route for increasing the strength of a metal. This route consists in the use of strongly surface-active substances—metallic melts—for penetration into defective regions of the metal structure at comparatively high temperatures and in the locking of these defects by a solidified active melt when the temperature is lowered. An increased density of structural defects can be created in the metal both as a result of irradiation and by other methods.

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