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Abstract

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CREEP OF ZINC SINGLE CRYSTALS IN LOW-MELTING METALLIC MELTS

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The works of P. A. Rebinder, V. I. Likhtman, and their co-workers have shown that low-melting metallic melts cause a considerable decrease in the strength and plasticity of single crystals of more refractory metals ([1–3]). In these experiments, carried out under conditions of a constant rate of extension of single-crystal zinc and cadmium wires, liquid tin, lead, tin–lead alloys, and mercury were used as surface-active melts of low-melting metals.

In earlier works ([4]) on the influence of ordinary organic surface-active substances on the creep of metallic single crystals, it was found that the creep rate increases markedly as a result of the adsorption of surface-active molecules contained in the surrounding medium. In this connection, the study of the creep of metallic single crystals in such strongly surface-active media as melts of low-melting metals is of considerable interest.

Zinc single crystals were chosen as the objects of study; on these we investigated the regularities of the action of low-melting melts under conditions of extension at a constant deformation rate. Tin and lead, as well as alloys of these metals in various ratios, were chosen as the surface-active medium.

The low-melting metal was applied to the surface of the zinc single crystals in the form of a thin coating by electrolytic deposition. The thickness of this coating was 3–5 μ. Tin–lead alloys on the zinc surface were obtained by the same method, by dosing the corresponding amounts of tin and lead into the coating.

The creep of single-crystal zinc wires, both in the absence of a surface-active metallic coating and with such a coating, was studied over a wide temperature range from room temperature to 350–400°. The constant tensile stress was selected so that it was approximately 0.7–0.8 of the yield point of the given single crystal at the test temperature. The single crystals were grown from pure zinc (99.99 Zn) by the zone-crystallization method developed in our laboratory ([4]).

At low temperatures (up to the melting of the surface coatings), the surface coatings considerably slow the rate of steady-state creep, which is associated with the inhibition of the shear-formation process along slip planes as a result of the presence on the surface of the single crystal of a thin polycrystalline film ([5]). In the presence of a tin coating, beginning at 250°, a considerable increase in the rate of steady-state creep of zinc single crystals is observed. Figure 1 shows creep curves of zinc single crystals at a temperature of 350° in an inert gaseous medium (nitrogen) and under the same conditions, but with a thin film of tin on the zinc surface. The rate of steady-state creep v_m increases

in the presence of a tin coating by a factor of 15. Table 1 gives data on the change in the rate of steady-state creep of zinc single crystals at different test temperatures.

A lead coating, applied to zinc single crystals in the form of a thin film, reduces the rate of steady-state creep at all test temperatures. The corresponding data are given in Table 1. We had previously established that molten lead is an inactive medium with respect to zinc ([2]), not causing changes in the strength and plasticity of zinc single crystals under conditions of tension at a constant deformation rate.

Table 1

Rate of steady-state creep of zinc single crystals when tested in an inert gas $(v_m)_0$ and in the presence of a thin film of tin or lead on the surface of the single crystals $(v_m)_a$

t, °C	P, $g \cdot mm^{-2}$	$(v_m)_0 \cdot 10^4$, min^{-1}	$(v_m)_a \cdot 10^4$, min^{-1}	$(v_m)_a/(v_m)_0$
Tin film	**Tin film**	**Tin film**	**Tin film**	**Tin film**
200	76	0.7	0.2	0.3
280	51	1.7	10	6.0
350	19	1.0	15	15.0
Lead film	**Lead film**	**Lead film**	**Lead film**	**Lead film**
300	45	3.0	1.9	0.6
400	19	11.0	5	0.45

The fact that a molten film of lead at 400° reduces the rate of steady-state creep of zinc single crystals is apparently connected with a slight dissolution of zinc in molten lead and with the smoothing, as a result of this, of dangerous surface defects. In the presence of a tin coating this effect also takes place, but it is not manifested because of the high surface activity of tin.

Table 2 gives data for the rate of steady-state creep of zinc single crystals coated with alloys of tin with lead in various concentrations.

Figure 2 shows a plot of the dependence of the magnitude of the effect of the change in the rate of steady-state creep $\frac{(v_m)_a}{(v_m)_0}$ on the tin content in the Pb–Sn

Fig. 1. Creep curves of zinc single crystals: I —not coated with tin; II —coated with tin. $t = 350^{\circ},\ P = 19.1$ g/mm^2

Figure 1: Fig. 1. Creep curves of zinc single crystals: I —not coated with tin; II —coated with tin. $t = 350^{\circ},\ P = 19.1$ g/mm^2

Fig. 2. Dependence of $(v_m)_a/(v_m)_0$ on the Sn content in the alloy

Figure 2: Fig. 2. Dependence of $(v_m)_a/(v_m)_0$ on the Sn content in the alloy

alloy. With increasing concentration of the surface-active component—tin—the magnitude of the effect also increases, reaching a maximum at 100% tin content.

Fig. 1. Creep curves of zinc single crystals: *I* —not coated with tin; *II* —coated with tin. $t = 350^{\circ},\ P = 19.1$ g/mm^2

Fig. 2. Dependence of $(v_m)_a/(v_m)_0$ on the Sn content in the alloy

Thus, the results of the investigation we carried out are in complete agreement with the data obtained earlier on the increase in the creep rate of metallic single crystals in a surface-active medium.

Molten tin, which is a very strong surface-active substance for zinc (and also for various carbonaceous and alloyed—

steels), sharply lowers the level of normal tensile stresses under conditions of stretching at a constant rate of deformation, which leads

Table 2

Steady-state creep rate at 350° of zinc single crystals coated with a tin–lead alloy at various concentrations

Alloy	$(v_m)_0 \cdot 10^4$ min^{-1} without coating	$(v_m)_a \cdot 10^4$ min^{-1} with coating	$(v_m)_a/(v_m)_0$
90% Pb – 10% Sn	1.3	1.7	1.3
80% Pb – 20% Sn	1.0	3.0	3.0
50% Pb – 50% Sn	1.1	4.5	4.0
20% Pb – 80% Sn	3.3	20.0	6.0

to a considerable decrease in ductility (the amount of deformation before fracture) and strength [2]. However, under creep conditions, when the constant stress acting on the metal is lower than the stress of brittle separation, in the presence of a surface-active melt there appears an adsorption effect of plasticization, expressed in a significant increase in the creep rate of the metal.

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Note: Figure translations are in progress. See original paper for figures.