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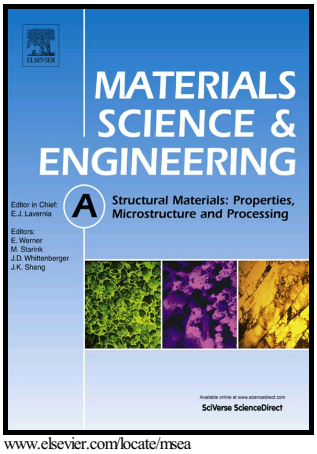

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Low-temperature anomalies of mechanical properties in Zn-Cu-Ti single crystals

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Abstract

The paper presents the results of tests carried out on single crystals of Zn-Cu-Ti. Through proper choice of the crystal growth rate, three types of structure were obtained which, besides differences in the shape and distribution of the $Zn_{16}Ti$ phase precipitates, also differed in the microsegregation of elements (Cu, Ti) in the matrix. The study showed the occurrence of anomalies in the strain hardening exponent at about 240K. The intensity of those anomalies was strongly dependent on the type of the structure examined. Moreover, it has been found that under the applied conditions of deformation (compression test, strain rate), a periodical activation of the jerky flow effect takes place. The range of conditions favourable for the jerky flow activation in a temperature-stress system is confined by a parabola. Its minimum is convergent with the temperature at which the strain hardening exponent shows the presence of the anomaly. This proves the same origin of both phenomena.

Keywords: microstructures; strengthening mechanisms; metallic material; mechanical testing

1.Introduction

The matrix of the single crystals of Zn-Ti-Cu contains up to 0.022 wt% Ti and 0.1 ... 0.15wt% Cu. Due to the addition of these two elements, the solution hardening of the matrix largely contributes to the hardening of the whole matrix–precipitates system. Studies conducted in [1-6] on single crystals of the binary Zn-Ti alloys with hypo-eutectic titanium content allowed establishing the maximum solubility of titanium in zinc at a level of 0.022wt% Ti and proved a strong increase in the degree of hardening compared with single crystals of pure zinc [1,2]. In the hypo-eutectic Zn-Ti-Cu alloys only one intermetallic phase is observed: $Zn_{16}Ti$ [4]. This phase is a partly coherent with matrix and has 290 μHV microhardness. The matrix α-Zn has 60 μHV only. The Zn16Ti particles are a relative big, micro-metric size. Thus does not introduce of significant hardening, but their distribution have a great influence on microsegregation of elements in the α-Zn matrix.

Copper addition to these Zn-Ti alloys has caused a solid solution hardening effect, but additionally generated an anomaly of mechanical properties. The phenomena is observed as rapidly increase of the hardening coefficient Θ_A in the temperature range from 220K to 260K.

The anomaly is, however, characteristic not only in Zn-Ti-Cu alloys but also in other solution-hardened binary alloys such as Zn-Ag, Zn-Ga and Zn-Cu. Moreover, in single crystals of pure metals with a hexagonal lattice (Zn, Cd), which are characterized by high values of the c/a ratios, another low-temperature anomaly is observed during deformation in (0001)<11-20> systems in temperatures below 150K (Fig.1) [7,8].

To systematize, the low-temperature anomaly observed in pure metals was marked as I-type, and the anomaly observed in solid solution hardened single crystals in the temperature range from 240K to 300K was marked as II-type.