Equilibrium diagram of the Cu-Se system.

Figure 2

Equilibrium diagram of the Cu-Se system.

References

Received 7 February and accepted 21 March 1972

Z. OGORELEC
B. MESTNIK
D. DEVČIĆ
Institute of Physics
University of Zagreb
Yugoslavia

On the amplitude-independent internal friction in crystalline solids

Recent work on the background internal friction in alkali halides [1], high-purity copper [2] and alpha-brasses [3], has established the inapplicability of the Granato-Lücke model to the results, over a wide frequency spectrum. To explain the observed features, the depth and coherency of the internal microstress-fields have to be taken into account [4]. In this note we present new measurements of the background internal friction in high-purity brass polycrystals containing from 0.1 to 5 at% of zinc. These results
bridge the gap between corresponding ones on copper and on concentrated alpha-brasses [3]; they are briefly discussed in the light of the model outlined in [4].

The experimental procedure was similar to that reported by Spears [3]. Polycrystals of 45μm grain size containing 0.1, 1.0 and 5 at.% of zinc were studied, and measurements were correlated with results previously obtained with similar alloys containing up to 30% of zinc [3]. Details relating to the impurity content, and to experimental procedure, were essentially as outlined before [3]. Rod-shaped specimens oscillated longitudinally in vacuo at 12 kHz, at a strain amplitude of about 10^-7; the internal friction was amplitude independent. No characteristic peaks, e.g. of the Bordoni or Hasiguti types were observed in the temperature range used, 100 to 280 K. The rods were pre-strained various amounts at room temperature immediately before the measurements were made. Results, together with some relating to specimens of concentrated alloys, are shown in Figs. 1 and 2.

A strong dependence of Q^-1 on prestrain and concentration is evident; it should be noted that the Q^-1 ordinate in Fig. 1 is scaled up by a factor of 10 for the dilute alloy (a) compared with the concentrated one (b).

The maxima of the curves correspond in all cases approximately to the end of the linear, "stage II" work-hardening region, which, as in polycrystalline copper for example [5], is well defined in annealed brasses. The correlation of Q_max, corresponding to peaks in isotherms of the type shown in Fig. 1, with zinc content (Fig. 2a) and temperature (Fig. 2b) are linear; the deviation indicated by the point corresponding to 25 at.% of zinc, in Fig. 2a, is probably a consequence of enhanced short-range order, possibly near dislocations. Similar anomalies at concentrations corresponding to Cu_5Zn have also been observed in the low-temperature stress relaxation of α-brasses [6].

In the "vibrating kinks" model [4] the length L_r and the activation energy for the displacement of a kinked segment, H_r, are related, such that

\[ \frac{H_1}{L_1} = \frac{H_2}{L_2} = \ldots = \frac{H_{\text{max}}}{L_{\text{max}}}, \]

where the upper limit, H_{max}, depends upon the strain, and H_r relates to a single kink. Also, it is assumed that the product of the number of L-segments per unit volume, N(L), and the length, i.e. N(L)\cdot L, is constant, independent of L within the range of available L-values. With this distribution one then obtains [4]

\[ Q^{-1} = \frac{\Omega N_{\text{max}} L_{\text{max}} G h^2}{2\lambda \sigma_{\infty}} \left( kT / H_{\text{max}} \right) \ln(\omega / \omega_{\text{D}}), \]  

where Ω is an orientation factor, λ the mean spacing between adjacent geometric kinks on dislocations in the absence of an applied stress, G the shear modulus, σ_∞ a constant equal to about 10^-6G, ω_D a "Debye" frequency, and ω the vibrational frequency of the specimen.

Except for the non-zero intercepts on the abscissa, i.e. about 20 to 50 K in Fig. 2b, the linearity in T, required by Equation 1 is observed. The discrepancy is readily explained if it is considered that Equation 1 is valid only for \( L \gg L_1 \), a "refinement" which was not included in the derivation of the equation.

---

Figure 1 The effect of tensile prestrain on Q^-1 of polycrystals containing (a) 0.5 at. % Zn and (b) 10 at. % Zn, at 280 K(1), 230 K(2), 180 K(3) and 130 K (4). Results for the concentrated alloy are from reference [3].

Figure 2 Dependence of Q_max on zinc content (a) and on temperature (b). Data referring to concentrations of zinc in excess of 5 at.% are taken from reference [3].