Order-disorder transitions in ternary alloys

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SUMMARY

Among the various types of crystal defects, dislocations have shown to be particularly important. It is their behavior which determines the mechanical properties of crystalline solids. In addition, dislocations may play important roles in crystallization, in the precipitation of phases in the solid state and in phase transformations. For these reasons knowledge of dislocations is indispensible for metallurgists and material scientists.

Due to the great variety of possible dislocation processes which occur during plastic flow, it will never be possible on a purely theoretical basis to predict the evolution of the dislocation structure under different deformation conditions and to calculate the macroscopic properties of a material with sufficient accuracy. Rather, for an understanding of mechanical properties, the common procedure is to define phenomenological relationships experimentally, to correlate these with transmission electron microscopic observations on the crystallography of slip and on the evolution of the dislocation structure and hence to deduce the physical nature of the controlling dislocation mechanisms. In this thesis we report the results of investigations along these lines on CuNiZn alloys which show ordering as well as clustering. For the ordered alloy Cu_2NiZn two structures are possible: $L1_0$ and $L1_2$ type, that might have important consequences for the mechanical behavior. Several physical properties of the alloy Cu_2NiZn have been determined as a function of the quench temperature and/or the in situ temperature. The results are summarized in the following:

The second order elastic constants have been measured as a function of the quench temperature. They decrease with increasing quench temperature, i.e. decreasing long-range order, until the order-disorder transformation temperature T_{c1} is reached. Above this critical temperature the elastic constants are almost independent of the quench temperature, corresponding to an internal structure which remains almost the same.

The presence of two ordered structures for Cu_2NiZn, and hence

an order-order transformation at a critical temperature T_{c2}, is confirmed by the results of accurate measurements of the lattice parameter. The critical temperatures obtained by this technique are $T_{c1}=775\pm12$ K and $T_{c2}=595\pm7$ K.

The yield stress of Cu_2NiZn as a function of the quench temperature and the deformation temperature has been explained in terms of the stress necessary to operate a Frank-Read source with an initially edge-oriented superlattice dislocation having a length of 1.45 μm.

The strain hardening cannot be explained by the {100} cross-slip mechanism (as is often done for these type of ordering alloys), but can be interpreted by the formation of APB tubes.

Ductility measurements are in agreement with the well known latent hardening effect in these types of ordering alloys. Slip predominately occurs at one or two slipsystems, which number is to small to accomodate the complex boundary conditions and hence fracture occurs at small strains.

Vickers microhardness measurements revealed that the extent of APB domain strengthening in Cu_2NiZn is small. The microhardness as a function of the APB domain size can be accounted for by a modified equation for Cottrell's domain strengthening.

The activation energy deduced from the kinetic studies of APB domain growth at several temperatures is about the same as the activation energy for diffusion of Zn or Ni in the alloy Cu_2NiZn. Therefore, APB domain growth is probably a diffusion controlled process.

The order-disorder transformation in Cu_2NiZn should be a first order process according to theoretical predictions, which is confirmed by the measurement of the quasi-binary cross-section $Cu_{50}Ni_{50-x}Zn_x$.

The value of the APB energy obtained from the configuration of superlattice dislocations is in agreement with theoretical predictions for this alloy. The APB energy deduced from the configuration of superlattice dislocation dipoles is not reliable. Its value is about three times smaller than the value obtained from the superlattice dislocations.

The stacking fault energy has been calculated from the dimensions of extended dislocation nodes by applying several theoretical models. These models are subjected to a test of internal consistency.