Temperature and strain-rate dependence of the flow stress of tantalum single crystals in cyclic deformation

M. Werner

To cite this version:

M. Werner. Temperature and strain-rate dependence of the flow stress of tantalum single crystals in cyclic deformation. Revue de Physique Appliquee, 1988, 23 (4), pp.672-672. <10.1051/rphysap:01988002304067200>. <jpa-00245821>

HAL Id: jpa-00245821
https://hal.archives-ouvertes.fr/jpa-00245821
Submitted on 1 Jan 1988

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
TEMPERATURE AND STRAIN-RATE DEPENDENCE OF THE FLOW STRESS OF TANTALUM SINGLE CRYSTALS IN CYCLIC DEFORMATION

M. WERNER
Max-Planck-Institut für Metallforschung, Institut für Physik, 7000 Stuttgart 80, FRG

In recent years progress has been made in our understanding of the strong dependence of the flow stress of b.c.c. metals on temperature and strain rate below a critical temperature $T_k$ (knee temperature). It is now generally accepted that the mobility of screw dislocations represents the strain-rate-controlling factor [1,2]. Because of their three-fold symmetry straight $<111>$ screw dislocations in a b.c.c. crystal are sessile. The high Peierls barrier may be overcome with the aid of an applied stress or thermal activation making the screw dislocations mobile.

The most appropriate theoretical model appears to be the formation and migration of kink pairs on the screw dislocations [3]. A recent theory of Seeger describes the "thermal" component of the flow stress $\tau_*$ near and below the knee temperature by means of two different mechanical models and two different thermodynamical approximations. The analytical expressions are valid in well-defined ranges of stress and temperature.

As discussed elsewhere [4] the kink-pair formation may be calculated by the diffusion theory based on the work of Kramers. At sufficiently low temperatures the kinks can move unhindered. This gives the same results as the transition-state theory. By contrast, at higher temperatures the low mobilities correspond to viscous motion of the kinks. The kinks are subject to Brownian forces due to their interaction with lattice vibrations. These effects may be described in terms of either a kink mobility $\mu_k$ or a kink diffusivity $D_k$ given by the Einstein-Nernst relationship.

For the calculation of the enthalpy of a pair of kinks, $H_{kp}(\tau_*)$, two different mechanical models may be used [3]: for small stresses we can use the elastic interaction approximation with a Coulomb potential. Then $H_{kp}$ is given by

$$H_{kp} = 2H_k - 2\alpha (\tau_*)^{1/2},$$

where $2H_k$ denotes the enthalpy of a pair of two isolated kinks, and $\alpha$ can be expressed as

$$\alpha = \left[ \frac{3\beta y_k}{2 T_{p}} \right]^{1/2}.$$

In equation (2) $\gamma_k$ denotes the pre-logarithmic factor of the dislocation line-tension, $b$ the Burgers vector and $a$ the height of the kinks.

At large stresses the kink-pair formation enthalpy may be calculated from the line-tension model [3,4]. In the special case of a so-called Eshelby potential we have

$$H_{kp} = 2H_k \left[ 1 - \frac{\tau_*}{2T_p} \left( 1 - \ln \frac{\tau_*}{4T_p} \right) \right],$$

where $T_p$ is an effective Peierls stress.

The experimentally determined knee properties can be compared to the theoretical predictions and provide a critical test of the theoretical assumptions.

The cyclic deformation experiments were carried out in a servo-hydraulic closed-loop control MTS-machine using plastic strain control. The advantage of the present experimental procedure is that all measurements can be performed on only one single specimen which has been predeformed into cyclic saturation, i.e. at nearly constant microstructure.

Measurements were carried out over a range of temperatures from 80 K to 450 K using an isopentane bath cooled by liquid nitrogen or a heated silicone oil bath. Figure 1 shows the temperature dependence of $\tau_*$ for five different plastic shear-strain rates varying from $2 \times 10^{-5}$ s$^{-1}$ to $6 \times 10^{-3}$ s$^{-1}$.