$H$, the overall $\eta(H)$ decreases at high light intensities. At low temperatures these effects are inhibited because the rate of formation of triplet excitons via the $(T_1T_1)$ state is low. These and other results will be described in detail in a forthcoming publication.

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# QUANTUM MECHANICAL TUNNELING OF DISLOCATIONS*

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Measurements of the temperature dependence of the yield stress in tungsten crystals show a temperature-independent region, which is consistent with Gilman's theory of quantum mechanical tunneling of dislocations.

Dislocation motion[1] is normally considered to occur by thermally activated processes, with the barrier height depending upon the imposed shear stress $\sigma$, i.e., the strain rate $\dot{\epsilon}$ at which a crystal deforms varies as $\dot{\epsilon} \sim e^{-W(\sigma, \cdots)/kT}$, where $W$ is the potential barrier, $T$ the temperature at which the process occurs, and $k$ is Boltzmann's constant. For most metals in the range of temperatures studied, plastic deformation is interpreted as a classical process. On the other hand, many bcc crystals exhibit a sharp temperature dependence of the critical resolved shear stress, and the work done by the external stress raises the dislocation up the potential barrier which opposes the motion of the dislocation. If the stress raises the dislocation high enough, then thermal activation over the barrier is not required; instead the dislocation can tunnel through the barrier. We wish to report on some observations of plastic deformation of tungsten crystals, which are consistent with the general requirements for dislocations tunneling through potential barriers.[2]

The observations were made on relatively pure crystals of tungsten (99.99+% pure), grown by standard electron-beam zone-refining techniques. Tensile specimens were obtained by chemical polishing of the as-grown crystals, so that no extraneous plastic deformation was introduced by such operation as grinding or spark erosion. This was essential, since such processes are known to introduce extraneous dislocations and thereby mask the true temperature dependence of the critical resolved shear stress.[3] Tensile deformation was carried out in a tensile machine,

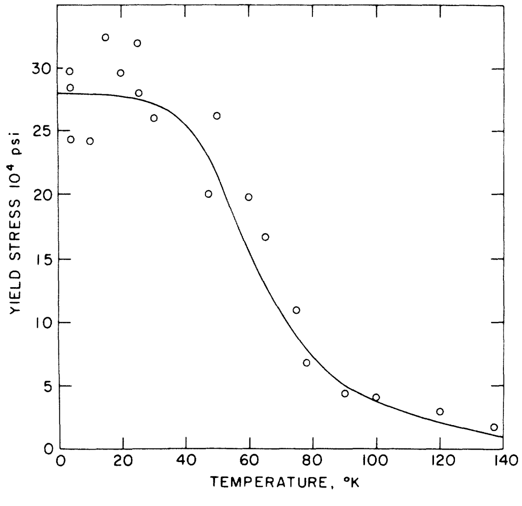

FIG. 1. Temperature dependence of the yield stress in single-pass zone-refined tungsten. Specimens prepared by electrolytic dissolution, without plastic deformation. All specimens were of the same orientation.

in which tests could be performed at various temperatures between 4 and 120°K. This temperature range is a relatively unexplored temperature regime for plastic deformation experiments. Some measurements of the yield stress for tungsten crystals are shown in Fig. 1, where the conditions of the test are given.

In discussing these results, it is important to emphasize that the observed behavior for the yield stress at low temperatures is not associated with twinning. An extensive microscopic examination of specimens deformed in this temperature range reveals no twinning. Secondly, the stress-strain curves show no characteristic yield drops, such as that associated with twinning. We take the absence of any observed twinning as an indication that some basic atomic resistance is rate determining for the motion of the dislocations. It is important for our context, not whether this involves dislocation splitting or kink generation, but simply that a large barrier to dislocation motion exists.

In general the sharp temperature dependence from 80 to 20°K insures the presence of the steeply varying potential required if tunneling is to occur at substantial rates. Secondly, the temperature independent region (between 4 and 20°K) is another characteristic of tunneling processes.[2] In summary, then, we report some observations of the mechanical properties of tungsten crystals, which are consistent with quantum mechanical tunneling of dislocations.

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# OBSERVATION OF ELECTRON POLARIZATION IN PHOTOEMISSION

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We have found that photoelectrons from ferromagnetic gadolinium show spin polarization, the preferential direction of the magnetic moment being parallel to the magnetization of the sample. Our experiment yields a degree of polarization $P = (5.27 \pm 0.70)\,\%$. $P$ did not vary significantly over the energy range from 2.8 to 5.0 eV of the incident light.

Photoemission from solids is a three-step process: (i) By absorbing a photon, the electron goes into an excited state; (ii) it diffuses through the solid and may reach the surface; (iii) it crosses the surface barrier if its energy is high enough and no scattering occurs. The purpose of this Letter is to give experimental evidence that during this process the spin direction of the electron is at least partly conserved. This means that a new method has been found for the investigation of spin polarization in electronic energy bands and also a new way of producing polarized electron beams.

The electron spin polarization of photoelectrons was measured by means of Mott scattering. Ferromagnetic Gd was chosen because it is known to be a very efficient photoemitter with a low work function.[1] In addition, one knows from positron-annihilation experiments[2] that a nonvanishing electron spin polarization exists in the