According to the theory of Dienes and Damask(6) the temperature independent diffusion effected by radiation corresponds to a linear annealing mechanism for the additional defects. These authors find under steady-state conditions for the diffusion coefficient due to radiation the proportionality

\[ D' \approx \frac{k}{\alpha} \]

where thermal diffusion already has been neglected. The quantity \( k \) is the constant defect production rate caused by radiation, and \( \alpha \) the proportionality constant for the annealing process. With the estimated value for \( k \) and the measured quantity \( D' \alpha \) would be about \( 10^{10} \text{ cm}^2\text{cm}^{-2} \). In the model of Dienes and Damask \( \alpha \) corresponds approximately to the dislocation density. Then the high value of \( 10^{10} \text{ cm}^2\text{cm}^{-2} \) for this quantity is improbable for the well annealed copper specimen. The assumed theory for the description of the annealing mechanism therefore seems to be insufficient for the interpretation of these experiments.

A similar behavior was also observed for the self-diffusion in lead subjected to \( \alpha \)-radiation.(16)

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**Slip in twinned copper crystals**

Since the time Blewitt et al.,(1) first reported deformation twinning in copper single crystals, other workers have also reported deformation twinning in other f.c.c. metals.(2,3) However slip in twinned crystals, which is of interest in the study of ductile fracture in twinned crystals or in grains of polycrystalline metal with annealing twins, has not been considered. The purpose of this letter is to present a simple geometrical analysis of deformation in a twinned structure.

During the testing of crystals with the tensile axis parallel to \([111]\) bounded by faces parallel to \((110)\) and \((112)\), deformation twinning was observed at 78°, 20° and 4.2°K.(4) Twinning does not convert the whole crystal to the twin orientation, rather a laminated structure of alternating twinned and untwinned matrix results.

Deformation after Lüders-band type propagation through the gauge section was observed to proceed by slip on systems which did not violate strain compatibility across the twin boundary. Figure 1 shows two tetrahedra bounded by \([111]\) planes and \((110)\) directions, one on the left corresponds to the original matrix with the tensile axis parallel to \([111]\) and one on the right, the twinned orientation. Twinning in the \([111]\) \([111]\) as indicated results in an orientation which has the tensile axis parallel to a \([110]\) 19° 28' toward \((001)\) from \((112)\). The \([111]\) planes in the twinned orientation are labelled \(T_1, T_2, T_3\) and \(T_4\); the twinning plane is that plane common to both orientations and

![Fig. 1. Two tetrahedra with a common \(\{111\}\) (twinning) plane; \((\{111\}\)\(\{111\)), the twinning system. That on the left represents the original, untwinned orientation, that on the right the twinned orientation. \(T_1, T_2, T_3\) and \(T_4\), the octahedral slip planes in the twinned orientation. Tensile axis parallel to \([111]\).](image)
Fig. 2. (a) Slip through twinned [111] crystal. Twin lamellae are the white traces; tensile axis horizontal, (110) surface, × 500.

(b) Laminated structure of twinned and untwinned matrix. Traces of twin plane run diagonally down from left to right; tensile axis horizontal, (110) surface, × 250.
parallel to (111) and T₁. From Fig. 1 it is evident that slip can take place on T₄[011], T₃[110] and on T₂ in [011] and [110] without violating strain compatibility. Furthermore T₄[011] can criss-slip onto (111) and T₃[110] onto (111). It was possible to determine from the angular deflection as the slip trace crossed the twin boundary which {111} planes were continuous†. In every case it was found to be either T₄(111) or T₃(111).

Figure 2(a) clearly shows the continuity of the slip traces as slip proceeds across a twinned region. In highly twinned regions, short transverse traces become more predominant (Fig. 2(b)) and near the fracture these traces join up. Slipping off occurs by localized shear in a zone parallel to these traces.

Upon twinning the Schmid factor for the systems T₄[011] and T₃[110] becomes 0.455 compared to 0.272 for all active slip systems in the original orientation. Hence should a shear stress concentration build up at the twin plane, Livingston and Chalmers’ analysis(6) of computing resolved shear stresses on slip systems across a grain boundary shows that the most highly stressed systems in the original matrix are the (111) [011] and (111)[110]. These systems are precisely those which are favored from strain compatibility conditions.

From the symmetry of (111)[011] — T₄[011] and (111)[110] — T₃[011] combinations with respect to the tensile axis, for a crystal which upon twinning still remains geometrically uniform, double shear is expected. A crystal displaying just this has been observed.(6) For twinned crystals originally oriented for single slip, one of the above combinations has a larger resolved shear stress and hence planar shear would be expected. The shear fracture in twinned crystals observed by Blewitt et al.(7) could be explained in this way.

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† This determination was facilitated by the fact that the lattice rotation in (111) crystals was small making the surface analysis simple. Furthermore, the measurements were made on the thick end of slightly tapered crystals where the Lüders front had terminated.
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