coefficient of proportionality is defined as the normal density, ρ_n. This gives

$$\rho_n = \lim_{\vec{v}\to 0} (\vec{J}_n/\vec{v}) = -\frac{4\pi}{3h^3}\int_0^\infty p^4 \frac{d}{dE}\left(\frac{1}{1+e^{E(p)/kT}}\right) dp, \quad (6)$$

which is identical with Landau's expression, except for use of the Fermi in place of the Einstein-Bose distribution function. It also agrees with that derived from (2) with the BCS value for Λ/Λ_T.

If the whole system is displaced in momentum space and moves with a velocity $\vec{v}_s$, the pairs have a common velocity $\vec{v}_s$. Defining $\vec{v}_n = \vec{v} + \vec{v}_s$ and $\rho_s = \rho - \rho_n$, it follows quite generally that for small v,

$$\vec{J} = \rho\vec{v}_s + \rho_n\vec{v} = \rho_s\vec{v}_s + \rho_n\vec{v}_n, \quad (7)$$

and the associated increase in free energy is

$$\Delta F = \tfrac{1}{2}\rho_n \vec{v}_n^{\,2} + \tfrac{1}{2}\rho_s\vec{v}_s^{\,2}. \quad (8)$$

The other equations of the two-fluid model of liquid He also follow. In particular, it is possible to construct states, in the way Feynman[5] has done for He, for which $\vec{v}_s$ is a slowly varying function of position. As for He, it is required that curl $\vec{v}_s = 0$.

The two-fluid model provides a basis for a discussion of persistent currents, particularly if we neglect magnetic effects. If there is a current-carrying state with $\vec{v}_s = 0$, scattering of individual particles can reduce $\vec{v}_n$ to zero, but such scattering will not change $\vec{v}_s$. Only a force which acts on all or a large fraction of the electrons can do so. A more complete discussion of persistent currents would require taking the Meissner effect into account and use of nonlocal relations.

Because of the very high attenuation of the normal component from interaction with the crystal lattice, phenomena such as second sound would be difficult to observe in superconductors.[2] It is possible that the peculiar results reported recently by Spiewak[6] on magnetic field dependence of high-frequency penetration may be associated with a counter flow of normal and superfluid components perpendicular to the surface in the penetration region. The wavelength of second sound in tin at the frequency she used (10^9 cps) is expected to be of the order of the penetration depth. However, use of local relations outlined above is questionable for this problem because, except very near T_c, the coherence distance is larger than the penetration depth.

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GENERATION OF PRISMATIC DISLOCATION LOOPS IN SILICON CRYSTALS

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The occurrence of helical dislocations in silicon was recently reported by the author.[1] They are formed when gold and copper are diffused simultaneously into the crystals at 1200°C, followed by quenching as in the method used for copper decoration.[2] Diffusion of gold alone forms helices which can be detected by etching. The detailed mechanism whereby these dislocations are formed has not yet been fully established. Similar helical dislocations have been observed in as-grown germanium crystals by Tweet.[3] In this case there is little doubt that climb induced by the condensation of vacancies is responsible for the phenomenon. For the purposes of this discussion it will be assumed that this process is also involved in the formation of helical dislocations in silicon crystals.

Helical dislocations have previously been observed in calcium fluoride crystals by Bontinck and Dekeyser.[4] It has been proposed that these dislocations result from climb processes in which vacancies are generated.[4-7]

Amelinckx et al.[6] have suggested that prismatic dislocation loops found in association with helices are formed by the cancellation of the screw component in the region of the loops by an interacting dislocation. Generation of similar loops by a mechanism involving only a single helical dislocation has been observed in silicon. Figure 1 shows a typical system which allows certain qualitative deductions about the generation of the dislocations to be made. The following mechanism is suggested:

At elevated temperature, there exists initially

FIG. 1. Generation of prismatic loops from a helical dislocation. The dislocations have been decorated with copper and photographed with infrared sensitive plates. Separation of turns of the helix is about 10 microns.

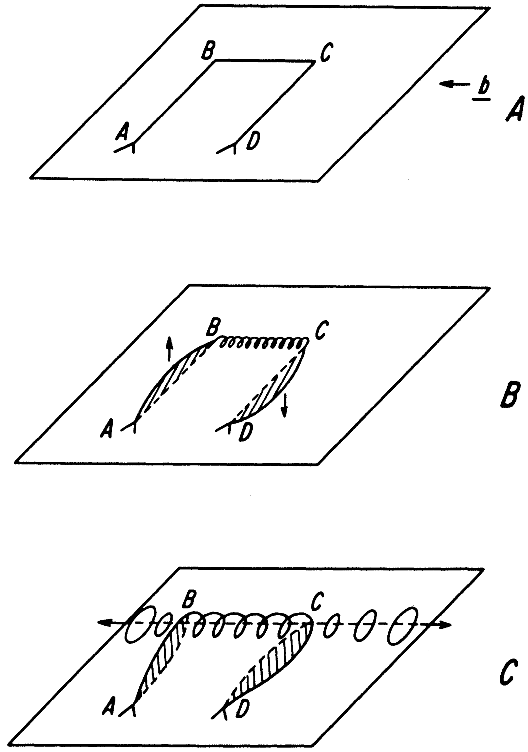

FIG. 2. Suggested mechanism for generation of prismatic loops. (a) Initial glissile dislocation loop *ABCD* with pinning points *A* and *D*. (b) Climb in the early stages of cooling. The dotted lines are the projections of *AB* and *CD* on the glide plane. *AB* and *CD* have moved perpendicular to the glide plane by acquiring a total number of vacancies equivalent to single planes of atoms indicated by the shaded areas. The screw portion *BC* has formed a helix with relatively small diameter. (c) After additional condensation of vacancies, the ratio between spacing of turns to diameter increases and causes mutual repulsion. This forces *AB* and *CD* apart. Some of the turns of the helix intersect *AB* and *CD* to form prismatic loops. The loops are repelled away from the helix and from each other into regions of higher vacancy concentration where they increase in diameter.

a glissile dislocation with pure edges *AB* and *CD*, each pinned at one end and joined together at the other end through screw *BC* [Fig. 2 (a)]. When the crystal is cooled, a supersaturation of vacancies appears. The dislocation loop climbs and thus acts as a sink for the excess vacancies. Initially, a uniform flux of vacancies converges upon all parts of the dislocation, driving *AB* and *CD* in opposite directions perpendicular to the glide plane and converting *BC* into a helix of many turns, as shown in Fig. 2 (b). Other authors[6,8] have considered the formation of a helical dislocation by climb. This Letter is not concerned with the mechanism of formation of a helix but rather with the modification of one which is already formed as vacancy condensation continues.

The entire configuration in Fig. 2 (b) can glide parallel to the Burgers vector b even though it is no longer confined to a single plane. The chemical stress produces a mechanical stress in the form of repulsion between adjacent turns of the helix. The repulsion can be relieved by glide of the turns over the surface of a cylinder coaxial with the helix. The helix expands and forces *AB* and *CD* apart. The angle between *AB* and *CD* and the axis of the helix decreases steadily and eventually successive turns of the helix intersect *AB* and *CD* and form closed loops. The closed loops are repelled from the helix and from each other and can glide on a cylinder concentric with the helix. Their diameter will increase by further climb as they glide into regions of relatively higher excess vacancy concentration.

With a sufficient initial supersaturation in vacancies, a large number of coaxial prismatic loops can be derived from this source.

It is interesting to observe in Fig. 1 that the closed loops are more widely spaced than the turns of the helix. This would be anticipated because forces between turns of the helix are balanced by the oppositely directed forces acting on *AB* and *CD*.

It follows from Fig. 1 and from the above analysis that there is mechanical equilibrium between the various parts of the dislocation loop. However, there is no evidence of a balance between chemical and mechanical stresses. If such a balance did exist, the relatively low line tension of edge dislocations with large radii of curvature would enable them to acquire vacancies at the expense of helices and small prismatic loops. This is not observed. The total climb of the edges is not significantly different from that represented by the sums of the areas of the prismatic loops and of the projected areas of the turns of the helix. This indicates that steady-state conditions do not prevail and therefore Weertman's[8] prediction of the final form of the helices does not apply. Instead, a dynamical theory is required to explain the observations.

The mechanism described appears to account for many of the observed sequences of coaxial prismatic loops; a series of over a hundred loops is not unusual. In other cases large numbers of coaxial prismatic loops are found to be completely isolated from other dislocations. The generating mechanism in such cases is not known.

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SHOCK-WAVE COMPRESSION OF ALUMINUM

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Use of a new reflected-light technique with oblique shock waves allows dynamic pressure-compression measurements to be made in the region between existing dynamic measurements (50 to 500 kb) and the elastic regime. Previous methods[1,2] using argon gaps were restricted to pressures above about 50 kb in order to produce flashing of the argon. Although pin techniques have been successfully used at low pressures with plane geometries,[3-5] their use with the oblique shock method would seriously restrict the number of data points obtained. (When used with optical techniques, the oblique shock method provides continuous pressure-compression data over large ranges of pressure.) The new technique is free of the above restrictions and thus provides a method for examining the transition between elastic and "hydrodynamic" behavior. Further, considerably greater overlap with Bridgman's[6,7] static data than now exists can be obtained. This possibility is of fundamental significance since several experimentally unevaluated assumptions are necessary to the interpretation of shock-wave results. The feasibility of the method has been demonstrated for aluminum.

Shock and free-surface velocity measurements were made along the center line of the face of a wedge-shaped specimen backed by a line-initiated slab of high explosive as shown in Fig. 1. Rotating-mirror streak-camera[8] observations of a light beam reflected from the aluminum-coated Mylar foil and from the clear Mylar film give the arrival times T_1, of the shock, and T_2, of the free-surface, respectively, at points down the wedge face. Air shock complications were removed by evacuating the foil-film system. (It is estimated that maximum displacement of the outer foil due to reflection of the remaining air shock amounts to less than 5 microns.)

The detonation velocity U_d was determined by measuring the time of closure by the detonation ionization front of silver foil switches placed along the explosive slab. The shock velocity at a distance z down the wedge face is given by $U_s = U_d \sin \alpha$, where $\alpha = \operatorname{arccot}(\cot A + C\ U_d$

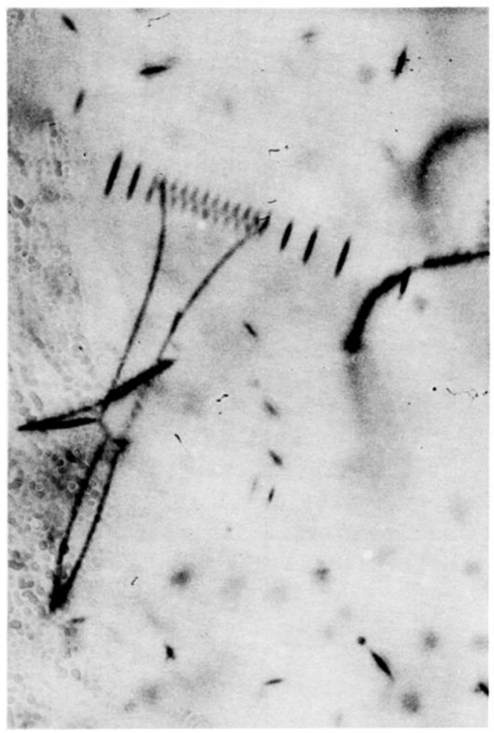

FIG. 1. Generation of prismatic loops from a helical dislocation. The dislocations have been decorated with copper and photographed with infrared sensitive plates. Separation of turns of the helix is about 10 microns.