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# COMMENTS ON THE ROLE OF DISLOCATIONS IN SUPERCONDUCTORS

By

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It is well known that plastic deformation often causes significant changes in $T_c$ and drastic changes in $H_c$. Such effects have been related by some investigators to the "filamentary" nature of superconducting materials. Mendelssohn(1) first suggested (1935) that hard superconductors are inhomogeneous and consist of interconnected superconducting filaments separated by volumes of normal material. Shaw and Mapother(2) suggested that dislocations may be the defects that act as the filaments in hard superconductors. Hauser and Buehler(3) determined the effect of plastic deformation on single and polycrystalline samples of niobium and rhenium. They showed that, in general, the critical field necessary to transform the final superconducting material into normal material was increased by plastic deformation. Also, they clearly demonstrated that the dimensionless resistance term, $R/R_o$, (where $R_o$ is the resistance at room temperature and R is the corresponding value just above $T_c$) for rhenium single crystals could be markedly increased by plastic deformation; a strain of 47 per cent produced a tenfold increase. $T_c$ was raised from 1.8° to 2.1°K by the plastic deformation.

In a subsequent paper, Hauser(4), showed that deformed rhenium single crystals behaved anisotropically. He selected cylindrical crystals in which the active slip plane made an angle of approximately 30° with the specimen axis. With these, he measured the transition field strength at a number of current levels and strains. By varying the direction of the applied magnetic field, he was able to show that the superconducting characteristics of the deformed rhenium were markedly

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anisotropic. At a given current the transition field was found to be a minimum when the field was perpendicular to the active slip plane. Hauser concluded that the anisotropic superconducting properties were due to the nonuniform dislocation distribution, and that the role played by the dislocations was that of superconducting filaments. Another interpretation of these observations is possible.

Some evidence is inconsistent with the interpretation that dislocations act as superconducting "pipes". For example, specific heat measurements of $V_3Ga^{(5)}$ have shown that even at high fields the majority of the volume is still in the superconducting state. The volume fraction of material near the core of dislocations is much too small to account for the large volume fraction of $V_3Ga$ in the superconducting state.

Based upon knowledge of the structure of dislocations, the general nature of their distribution in deformed crystals, and their propensity to react with impurity atoms, the authors of this letter suggest that the role of dislocations may be a secondary one.

Dislocations produce major distortions in crystal lattices, and in deformed material they form tangled networks with numerous junctions. Such networks tend to scatter electrons as they move through the lattice of the material in the normal state. We would also expect similar scattering to occur when the material was in the superconducting state. However, it is well established that when dislocations are present, the superconducting current at a given field is greatly increased. Conversely, at a given current, the superconducting state is stable at higher fields. If dislocations cannot logically be considered to be superconducting pipes, how and why do they affect superconductivity?

We believe that the dislocations act as scavengers for the interstitial impurity atoms that are known to have deleterious effects on superconductivity. This concept is supported by the rhenium single crystal work of Hauser$^{(4)}$ (whose interpretation, however, was based upon the thought that dislocations act as superconducting pipes). A reanalysis of his results showed that dislocations do not aid superconductivity but, instead, they tend to destroy it. Supporting this view, Figs. 2 and 3 of the Hauser paper, show clearly that with a current of 2.0 amperes and at a field strength of 40 gauss, superconductivity no longer existed in the direction parallel to the slip plane, whereas in the direction of the specimen axis (30° to the slip plane), the crystal was still strongly superconducting(6). The role of dislocations is particularly clear for hexagonal rhenium crystals, wherein dislocation networks tend to lie parallel to the single slip plane.

More than a decade ago it was predicted that dislocations in body-centered cubic metals would act as "sinks" for interstitial impurity atoms(7). The proof of this has been repeatedly demonstrated experimentally (e.g., see Reference 8). It has also been shown that impurities introduced by annealing in a poor vacuum have a deleterious affect on the superconducting properties of niobium and rhenium(3). Thus, an alternate explanation of Hauser's rhenium single crystals results is that dislocations act as scavengers rather than as superconducting pipes. This may be deduced from the results of Hauser and Buehler(3), which show that the $T_c$ for rhenium is increased by straining and room temperature aging. Their studies of the effects of contamination during annealing clearly showed that impurities markedly lower the $T_c$ for this material.

The authors of this letter suggest, therefore, that the important roles played by dislocations in superconductors are those of electron scattering (rather than acting as superconducting pipes) and scavenging. The ability of dislocations to purify the neighboring material by attracting and capturing dissolved impurity atoms may well account for the marked enhancement of superconducting properties produced by plastic straining. This concept should be generally applicable to all superconducting materials that are deleteriously affected by trace amounts of interstitial impurities.

## ACKNOWLEDGMENT

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