Elasticity, Plasticity and Defects in Helium Crystals

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The elastic properties of solid ^{4}He change dramatically at temperatures between 50 and 200 mK, the same range where torsional oscillator (TO) measurements showed unusual behavior. The two types of experiment have the same dependence on temperature, amplitude and ^{3}He concentration. It now seems clear that the TO anomalies reflect changes in the helium's shear modulus, rather than mass decoupling of a supersolid. The shear modulus changes are due to dislocations, which are mobile at high temperatures and can reduce the shear modulus by as much as 80%, a phenomenon we describe as "giant plasticity". Below 200 mK, they can be pinned by ^{3}He impurities, restoring the helium's intrinsic stiffness. By growing single crystals in an optical cell, we could study the behavior of dislocations in helium in great detail. We identified the dislocations' glide direction, confirmed that the dislocation damping at high temperature was due to phonon scattering ("fluttering"), used this dissipation to measure dislocation densities and lengths, and studied the interaction between dislocations and mobile ^{3}He impurities. Temperature, impurity concentration and crystal quality can be varied over wide ranges in solid helium. This makes it a unique model system for materials science, in which the defects responsible for elastic and plastic behavior can be studied in great detail.

Section: QS - Quantum solids

Keywords: solid helium, elasticity, shear modulus, dislocations, giant plasticity

INVITED PAPER