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Superclimb of Dislocations in Solid $^{4}$He

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Edge dislocation with superfluid core can perform $superclimb$ – non-conservative motion (climb) assisted by superflow along its core. Such dislocation, with Burgers vector along the C-axis, has been found in ab initio simulations of hcp solid $^{4}$He [1]. Uniform network of superclimbing dislocations can induce isochoric compressibility \( \chi = dN/d\mu \) which is finite (in contrast to ideal solid where it vanishes) and, practically, independent of the network density. Here \( N \) is total number of atoms and \( \mu \) is chemical potential [1]. Such giant response has been observed by Ray and Hallock during superfluid flow events through solid He4 [2]. Study [3] of superclimbing dislocation within the model of Granato-Lücke string, subjected to Peierls potential and to vanishing bias by \( \mu \), has found that \( \chi \) exhibits wide peak in the intermediate range of temperatures (T) - above some \( T_p \) determined by Peierls energy and below \( T_s \sim 0.5 \) K above which superfluidity of the core essentially vanishes. Non-Luttinger type behavior characterized by \( \chi \sim L^{b} \) scaling as some power \( 1 < b \leq 2 \) of dislocation length \( L \) is observed in the wide peak region. Biasing superclimbing dislocation by finite \( \mu \) (due to a contact with liquid $^{4}$He through vycor electrodes [2],[4]) can induce core roughening caused by thermally assisted tunneling of jog-antijog pairs through the barrier produced by combination of Peierls potential and the bias [5]. The threshold for this effect scales as \( \mu_c \sim 1/L^{a} \) with some power \( a \approx 1.7 \). The roughening is found to be hysteretic below some temperature \( T_{\text{hyst}} \). At \( T_{\text{hyst}} < T < T_{R} \), with \( T_{R} \) determining temperature of thermal roughening, \( \chi \) exhibits strong and narrow resonant peak leading to a dip in the core superfluid sound velocity. This mechanism is proposed as an explanation for a strong and narrow dip observed in critical superflow rate [4]. It is found that the dip characteristics are sensitive to the bias by \( \mu \) and, therefore, this can be used as a test for the proposed mechanism. It is also predicted that the dip depth at given \( T \) should be periodic in the period $\sim \mu_c$.


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