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Microscopic Parameters of a Superconductor Retrieved from the SANS and LE-muSR Spectra

By definition, properties of the S (superconducting) state are determined by Cooper pairs (CP). The pairs' mobility allows them to organize into a perfectly ordered lattice of microwhirls (MW) formed by the field induced currents in CPs, thereby reducing entropy of the pairs'ensemble down to zero. The latter entails zero temperature of the ordered CPs, one of the consequences of which is zero resistivity of the S state [1]. An estimated parameter of the MW lattice is ~ 100 nm; hence, in principle, it can be measured by SANS; the chief difficulty there is a low contrast of the ordered currents on a background of disoriented microscopic currents at zero field, since the latter are much larger than the former. Here we will report on the SANS probing of the Meissner and mixed states performed on a ZFC single crystal Nb disc using non-polarized polychromatic neutrons. No ordered structure was detected in the Meissner state. The data obtained in the mixed state allowed us to investigate the dynamics of the lattice formed by thermodynamically equilibrium flux lines and to determine microscopic parameters of the S state: the radius of MWs r_i and number density of CPs n_{cp}. The value of r_i is consistent with that obtained from the LE-muSR spectra. The found n_{cp} is close to half the density of conduction electrons, which confirms, for the first time, the assumption of Gorter and Casimir of 1934.

[1] V. Kozhevnikov, Electrodynamics of Superconductors (CRC Press, 2025).

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