Contribution ID: **120** Contribution code: **P-MON-2** Type: **Poster**

μSR Study of Superconductivity Above H_{c2}: A Filamentary State in Type-II Superconductors

Monday, 29 August 2022 18:40 (20 minutes)

The standard interpretation of the phase diagram of type-II superconductors was developed in the 1960s and has since been considered a well-established part of classical superconductivity. In particular, according to the standard picture, in a sample of type-II materials of a planar geometry in a parallel (in-plane) field, superconductivity nucleates at Hc3 approximately twice as big as the upper critical field Hc2. Between these critical fields the superconducting phase exists in a form of a thin surface sheath. Contrarily, in the same sample but in the perpendicular (out-of-plane) field superconductivity nucleates in the bulk at Hc2 and there is no superconductivity above this field. However, upon closer examination a number of fundamental issues arises that leads one to question this standard picture. To address these issues, we studied equilibrium properties of niobium samples near and above the critical field Hc2 in parallel and perpendicular magnetic fields. The samples investigated were very high-quality films and single-crystal disks with the Ginzburg-Landau parameters in the range from 0.8 to 1.3. A set of complementary measurements has been performed, which include bulk muSR, dc magnetometry, electrical transport and scanning Hall-probe microscopy. Contrary to the standard scenario, we observed that a superconducting phase is present in the sample bulk above Hc2 and the field Hc3 is the same in both parallel and perpendicular fields. It will be shown that above Hc2 the superconducting phase forms filaments parallel to the field regardless of the field orientation. Near Hc2 the filaments preserve the hexagonal structure of the preceding vortex lattice of the mixed state, and the filament density continuously falls to zero at Hc3.

References:
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Session Classification: Posters

Track Classification: Superconductivity