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Observation of temperature dependent magnetic flux trapping in superconductor of type I

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The understanding of underlying physics of Meissner effect and flux trapping in type I superconductors is of great importance, both from fundamental and industrial research point of view [1]. In ideal type I superconductors, such as Lead (Pb) as investigated in the present study, is expected to exhibit complete expulsion of externally applied magnetic field. This behavior is independent of whether the sample is in single crystal or poly-crystalline form. In the present work, we investigate both single crystal with $\langle 100 \rangle$ orientation and poly-crystalline Pb samples of high purity (99.999%) using polarized neutron tomography measurements, with varying temperature. Contrastively, we observe that magnetic field expulsion as well as the flux trapping depends not only on the sample, but also on the crystallographic orientation of sample with respect to an external magnetic field and temperature variation. Both $\langle 100 \rangle$ Pb single crystal orientation and poly-crystalline samples exhibit partially expelled and trapped magnetic field in the field cooled (FC) data. Similar images patterns are observed for both the samples. Above TC ($\approx 7.19\text{K}$), no fringe pattern is evidenced, while below TC evolution of fringe pattern is seen around the sample. This indicates the expulsion of magnetic field in superconducting state. Also, further investigations show that after the sample is field cooled below TC and field is switched off, signatures of flux trapping (figure shown below) are observed. Although, poly-crystalline Pb sample showed larger flux trapping than $\langle 100 \rangle$ Pb single crystal. This indicates that both Pb single crystal and poly-crystalline sample did not show the ideal superconducting behavior. It is interesting to note that this behavior, particularly in comparison to $\langle 100 \rangle$ Pb single crystal, is in contrast to the previously reported results $\langle 110 \rangle$ Pb single crystal [2]. Wherein, $\langle 110 \rangle$ Pb sample apparently showed an ideal Meissner effect, i.e. no flux trapping has been evidenced. In conclusion, the present results indicate that the fundamental complex physics has not been fully understood, and therefore call for further theoretical studies.

References

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