Crystal Growth, Metallurgy, and Sample Quality of the Ferromagnetic Superconductor UCoGe

K. E. Avers[1,2,3,4], M. D. Nguyen[1], J. W. Scott[1], A. M. Zimmerman[1], S. M. Thomas[3], P. F. S. Rosa[3], E. D. Bauer[3], J. D. Thompson[3], W. P. Halperin[1]

[1] Department of Physics and Astronomy, Northwestern University, Evanston, Illinois 60208, USA
[2] Center for Applied Physics & Superconducting Technologies, Evanston, Illinois 60208, USA
[3] Los Alamos National Laboratory, Los Alamos, NM 87545, USA
[4] Department of Physics, Quantum Materials Center, University of Maryland, College Park, Maryland 20742, USA

The impact of sample quality and metallurgy on unconventional superconductors is a long explored discipline, and has made it prudent to investigate a given material grown using a variety of techniques in order to optimize its superconducting properties. In particular, the uranium containing ferromagnetic superconductors UGe_2, UCoGe, URhGe and UTe_2 can exhibit widely varying properties depending on details of how they are made. Unlike congruently melting superconducting systems like UPt_3, the UCoGe crystal structure remains stable off the ideal 1:1:1 stoichiometry and has a small peritectic decomposition temperature range, which has complicated single crystal growth quality and control. This motivated our attempt to grow single crystals of UCoGe using an ultra-high vacuum electron-beam floating-zone refining system, as shown in Fig. 1 [1]. After our UCoGe single crystals were annealed at 900 C for two weeks they exhibit well defined signatures of superconductivity and ferromagnetism in resistivity, heat capacity and magnetization, which is consistent with high-quality samples grown by other methods [2]. Using scanning electron microscopy, we observed that annealing caused an off-stoichiometric uranium rich phase of UCoGe to liquefy and flow through cracks and voids in the crystal, which induced damage and disorder at the surface that manifests in resistivity, but not heat capacity and magnetization. Fortuitously, polishing away the damaged surface eliminates the discrepancies in resistivity, which suggests that all future electrical transport on UCoGe should be done on polished surfaces to ensure better comparison across multiple publications. Our results also support the notion that the exact stoichiometry of the UCoGe crystal is vital for optimizing the superconducting and ferromagnetic transition temperatures [3].

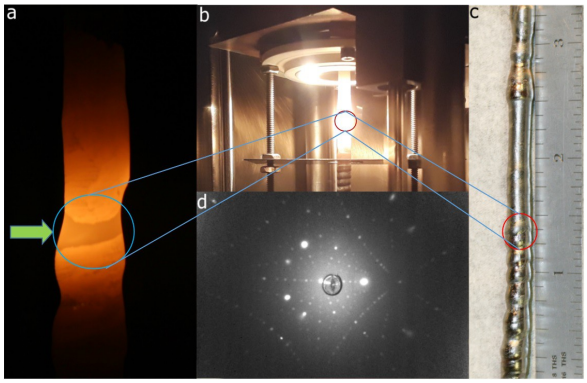

Fig. 1: The UCoGe ingot during zone refining (a and b), after zone refining (c), and Laue X-ray pattern taken near [010] orientation (d). Adapted from Ref. [1].

References

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