

Current Flow Analysis of TI-1223 Superconductors by Scanning Hall Probe Microscopy and TEM Investigations

S. Holleis,¹ A. Moros,² J. Bernardi,² A. Leveratto,³ A. Saba,³ E. Bellingeri,³ S. Calatroni⁴ and M. Eisterer¹ ¹ Atominstitut, TU Wien, Stadionallee 2, 1020 Vienna, Austria ² USTEM, TU Wien, Wiedner Hauptstraße 8-10, 1040 Vienna, Austria ³ CNR SPIN, 16152 Genoa, Italy ⁴ CERN, 1211 Geneva 23, Switzerland





Introduction

The FCC-hh design study included investigations on various high temperature superconducting materials to act as part of the beam screen. A superconducting coating on the beam screen should improve cryogenic efficiency and beam impedance mitigation for a high beam stability margin [1,2]. The extreme conditions in such a collider make high critical currents at high temperatures necessary. Our study focuses on the still technologically unexploited thalliumbased cuprates. For the development of the coating, Tl-1223 pellets are prepared and Tl-1223 thin films are grown on various substrates. We present the microstructural analysis of these Tl-based superconductors performed with Scanning Electron Microscopy and Transmission Electron Microscopy where the chemical composition of the superconducting grains and especially the phase formation is demonstrated. Furthermore, we mapped the magnetic field above the sample surface by means of Scanning Hall Probe Microscopy. By comparing the local magnetization of the superconducting grains with microstructural features we determined the reasons for varying current flow in different parts of the superconductor.

Inversion of the Remnant Magnetic Field

► The critical current density is calculated for a grain cluster by inversion of the remnant field and amounts to 6×10¹⁰ Am⁻².



HTS Coating for the Beam Screen

- The high amounts of synchrotron radiation will be absorbed by a beam screen kept at 50 K.
- An HTS coating should enable a high beam stability margin since these materials have a lower surface impedance than copper at 50 K.
- ► Our proposition: Tl-1223



TEM Investigations on Current Flow

- ► Two TEM samples were prepared by using a **Focused Ion Beam**:
- (1) from an area with magnetic signal(2) from an area without magnetic signal
- ▶ Both samples show the desired Tl-1223 phase but only (1) exhibits c-axis alignment.



Thin Film on STO Substrate

- The samples are prepared by electrochemical deposition.
- The remnant magnetic field of the superconducting thin film is mapped by Scanning Hall Probe Microscopy.
 The magnetic signal is directly compared to the microstructure of the sample.







100

80

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-20





Thin Film on Ag Substrate

- ► The sample exhibits large superconducting grains of the Tl-1223 phase.
- Scanning Hall Probe Microscopy shows the remnant field of each individual grain.
- Comparison with an optical image shows a perfect match of the magnetic signal with the superconducting grains.
- ▶ Inversion of the remnant field gives the current flow in each grain.





Summary

- ▶ Tl-1223 thin films on STO and Ag substrate were analyzed.
- ► The remnant field was mapped by means of Scanning Hall Probe Microscopy.
- The results were compared with the microstructure in order to investigate varying current flow in the grains and across grain boundaries.

References

[1] S. Calatroni et al. Superconductor Science and Technology, 30(7), 2017.

[2] S. Calatroni and R. Vaglio. *IEEE Trans*actions on Applied Superconductivity, 27(5), 2017.





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