Microstructure and Current Transport of Tl-1223 Thin Film Superconductors

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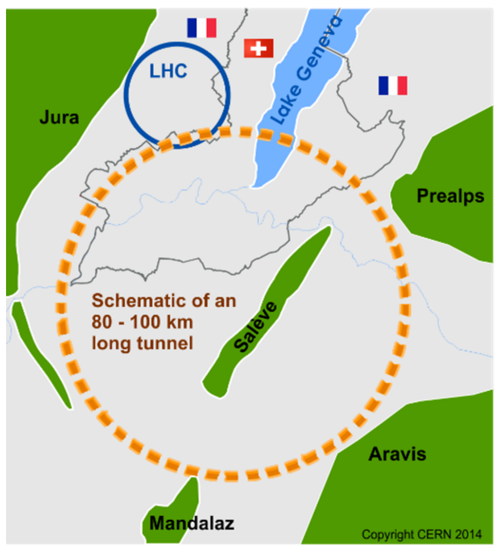
Introduction

The FCC-hh design study explores possibilities for a next-generation high energy hadron-hadron collider with a center-of-mass collision energy of 100 TeV. In such a collider the counter-rotating proton beams emit high amounts of synchrotron radiation. For this reason a beam screen held at 50 K is envisioned in order to guarantee cryogenic efficiency. As part of the beam screen design a superconducting coating is planned which could be suitable for carrying the beam image currents and lowering the beam impedance in order to guarantee a high beam stability margin [1, 2]. Such a superconducting coating may be realized through revisiting the well-known but still technologically unexploited thallium-based cuprates. For the development of the coating thin films of Tl-1223 were grown on untextured silver substrates. Here we present the very first results obtained from Scanning Electron Microscopy and magnetization measurements.

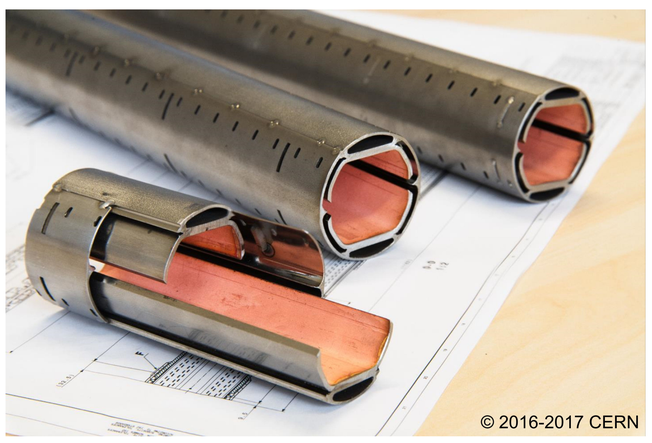
The Future Circular Collider Study: FCC-hh

Design study for a next-generation high-energy hadron-hadron collider

- ~ 100 km tunnel infrastructure at CERN site
- Center-of-mass collision energy of **100 TeV**
- Superconducting Nb_3Sn magnets capable of generating a dipole field of **16 T** at 1.9 K will steer proton beams
- The two counter rotating proton beams emit **synchrotron radiation**
- Total synchrotron power of accelerator ~ 4.8 MW
- Synchrotron radiation cannot reasonably absorbed by magnets at 1.9 K



HTS Coating for the Beam Screen



Meeting vacuum requirements, the synchrotron radiation will be absorbed by a **beam screen** kept at **50 K**

There are consequences on the beam stability:

- Joule heating in the screen
- Excitation of wakefields

described by **beam impedance** = directly proportional to **surface impedance** of material facing beam

- Current design in LHC: **copper**
- Surface impedance of copper at 50 K **may not be low enough** to guarantee a safe operational margin for the FCC-hh beam
- **Only HTS-materials have lower surface impedance at 50 K**

Operation of HTS is challenging:

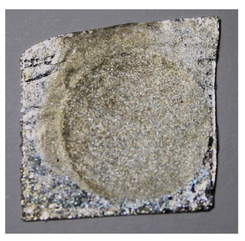
- Proton bunches induce peak currents of ~ 25 A
- HTS coating needs to remain superconducting up to a field of 16 T

HTS required properties:

- Upper critical field ~ 70 T at 50 K
- Critical current density larger than 2.5×10^8 A m^{-2} at 50 K and 16 T

- **HTS satisfying these requirements presently not available**
- **Our proposition:** Revisit Tl-based compounds: $Tl_xBa_2Ca_yCu_{y+1}O_z$: **Tl-1223**
  - Crystallographically similar to Bi-based HTS
  - Low anisotropy: Flux pinning properties similar to those of Y-123
  - High T_c values (~ 125 K): Advantageous for operating conditions in the FCC
  - Can be overdoped easily: good strategy for increasing inter-granular J_c

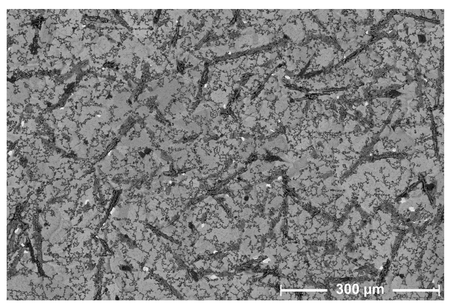
Samples



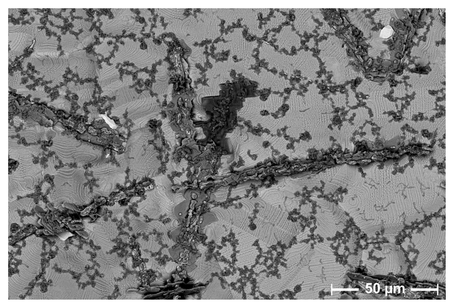
- Samples reacted in electrochemical cells
- Films deposited on untextured silver substrate, diameter ~ 10 mm
- Deposition time: 300 s, 600 s
- Samples cut to ~ 4 × 4 mm^2 squares for magnetization measurements

Results

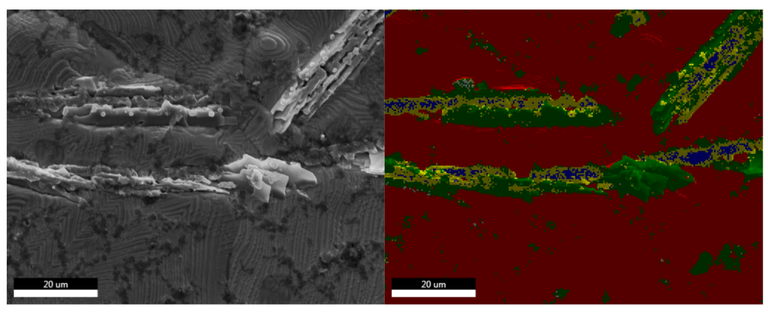
Scanning Electron Microscopy



Overview of the sample surface:
Dark areas indicate the deposited film

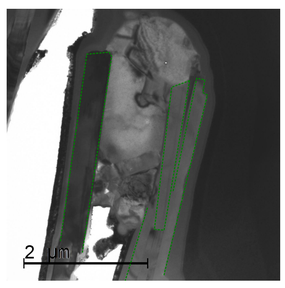


Zoom into the surface:
Plate-like structures become visible

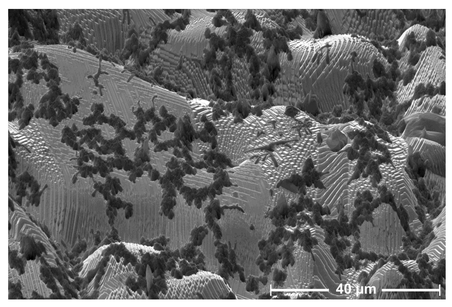


EDX Spectroscopy:

- Areas with Tl-1223 signatures
- Other Tl-based phases
- Ag substrate



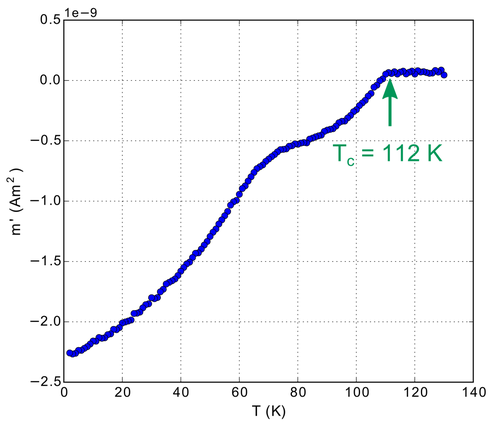
TEM image: green dashed lines indicate Tl-1223 regions



70° tilt image of the sample surface

Magnetization Measurements

- T_c measured around 112 K:
- Stems from Tl-1223 grains
- Small signal:
- Mostly intra-grain shielding in the Tl-1223 superconducting grains
- Second transition around 70 K hints at inter-grain coupling



Summary and Outlook

- HTS beam screen for the FCC: investigation of thallium-based superconductors
- SEM images show Tl-1223 on silver substrate
- First sample exhibits T_c at 112 K
- Next step: investigate current transport by means of Scanning Hall Probe Microscopy

References

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