Superconducting characterization of prototype LTS samples

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ESR13 project

- APC
- No APC

ESR13 $Nb_3Sn$

ESR13 $MgB_2$

Next steps
ESR13 focuses on the superconducting and magnetic characterization of superconducting samples suitable for FCC-hh or FCC-driven applications.

- **$Nb_3Sn$**
  - Artificial pinning centres (APC) doped wires, Columbus (USA)

- **$MgB_2$**
  - New “clusters” design wires, Moscow (RU)
  - 10T magnets (tapes) and FCC high current links (wires), Genova (IT)

**Project scope:**

ESR13 project.
Project structure:

- Characterize the sample received from companies:
  - $T_c$ measurements via AC susceptibility (SQUID)
  - $B_{c2}$ and $J_c$ via resistive and magnetic measurements
  - Local properties via Scanning Hall Probe Microscopy (SHPM)

- Collaborate with ESR12 (A.Moros, TU Wien), trying to relate these quantities with microstructural properties

- Find relations with the manufacturing process and discuss with the sample suppliers about the possible improvements to be done
ESR13 project state of the art

- ESR13 \( Nb_3Sn \)
  - APC
  - No APC

- ESR13 \( MgB_2 \)

Next steps
Prerequisites:

- Nb₃Sn wires are the best candidates envisaged for building the FCC-hh 16T dipole-magnets (cheaper than HTS)
- FCC-target performances ($J_c = 1.5 \text{ kA/mm}^2$ at $B_{\text{appl}} = 16\text{T}$ and $T=4.2\text{ K}$) not yet reached with state-of-art commercial wires

Technology ("Internal oxidation method"): 

- Oxygen selectively oxidizes Zr instead of Nb
- ZrO$_2$ nanoparticles to be used as additional pinning centres (intra and inter-granular)
- Nanoparticles should catalyse as well the A-15 grain size refinement, so that increasing $J_c$ ($J_c = f(1/d_{\text{grain}})$)
Milestones

- Characterization of prototype binary (ZrO$_2$ nanoparticles in A-15 phase) APC wires

- Higher Jc values than commercial wires

- Shifted $F_p / F_{p \text{ max}}$ peaks

- Low Bc$_2$

Grain size refinement

Local inhomogeneities

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ESR13 Nb$_3$Sn APC
Characterization of prototype ternary (ZrO$_2$ nanoparticles + Ta in A-15 phase) APC wires

- Samples-slices prepared down to polishing limits (40 to 10 μm)

Magnetization measurements: Tc and hysteresis loops

- Offset (100%)
- 90%
- 50%
- 10%
- 0%

SHPM

Possible to perform Tc-radial analysis (radial inhomogeneities investigation)
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- ESR13 $Nb_3Sn$
- ESR13 $MgB_2$

Next steps
8 samples received

Milestones:

1. **AC magnetometry** - in the range of temperature from 5 to 19 K; Magnetic moment of wire sample as a function of temperature - M(T) curve for assessing $T_c$ distribution.

2. **Scanning Hall Probe Microscopy (SHPM)** - in the range of temperature from 5 to 19 K; Magnetization maps of individual sub-elements and clusters, $T_c$ distribution within sub-elements and clusters and its variation between central and peripheral sub-elements.
ESR13 $Nb_3Sn$ no- APC: „clusters“ sample

- AC Magnetometry

- SHPM : Meissner-state measurements

- SHPM : Remnant field-state measurements

Remnant field scans used for local current evaluation

In line with the state-of-art RRP wires (@ 10K, 0 T)

No evidence of A-15 cross-sections variations ($f(T)$)

No radial $T_c$ distribution achievable

No field penetration into the resistive separators
Sample without *clusters* (**T4**-distributed Nb)

Line scans reveal an inter-subelements coupling

- **SHPM**: Meissner and remnant-field scans on other samples
ESR13 project state of the art

- ESR13 $Nb_3Sn$
  - APC
  - No APC

- ESR13 $MgB_2$

Next steps
• 4 samples received

1 wire

+ MgB₂ powder

1. **Magnetometry (SQUID)**-
   • In the range of temperature from 5 to 39 K; Magnetic moment of wire sample as a function of temperature - M(T) curve for assessing Tc distribution.
   • Hysteresis loops (Jc) and Bc₂ (SQUID)

• Milestones:

2. **Scanning Hall Probe Microscopy (SHPM)** –
   • In the range of temperature from 5 to 39 K; Magnetization maps of individual sub-elements,
   • Tc distribution within sub-elements (if possible)
   • Jc from Biot-Savart law inversion

Together with ESR7 (M. Donato, ASG Superconductors)
ESR13  \( MgB_2 \)

- **Sample preparation**

- **AC Magnetometry**

- **Jc from Hysteresis Loops**

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SHPM: Remnant field-state measurements

Remnant field profile of single sub-element
10K, 2T applied

Only one tape analysed so far

High magnetic background (Nichel)

On thin slices (<80 μm) reliable Jc extrapolation from Biot-Savart inversion (results comparable with those from resistive measurements)
ESR13 project state of the art

- **ESR13**  $Nb_3Sn$
  - APC
  - No APC

- **ESR13**  $MgB_2$

**Next steps**
Next steps

**Nb$_3$Sn APC**

- Sample preparation getting more important: new thin slices required for SHPM
- Analyse local properties data (radial inhomogeneities, local currents) and relate them with microstructural ones
- Analyse magnetometry data for Jc and Bc2 evaluation

**Nb$_3$Sn no APC**

- Focus on samples with innovative layouts (T7 & T8) for local properties investigation
- Isolate sub-elements (Cu-etching) for individual magnetic measurements
- Relate results with microstructural ones (barriers width, elemental composition)

**MgB$_2$**

- New samples (new powder composition, new doping) coming: compare and understand performance differences from Jc and granulometry data
- Etching of Nichel/Monel from bulk samples in order to measure with less magnetic background
- Secondment in ASG Superconductors in October
Thanks for your attention!