Over-critical current resistivity characterization of ReBCO commercial coated conductors: modified E-J curves

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Introduction

A good knowledge of the **resistivity** of commercial high temperature superconducting (HTS) tapes is required in modelling. Models such as the power-law have been shown to be not reliable to model and optimize cost and performances of superconducting devices operating in the **overcritical current regime (I>Ic)**.

Ultra-Fast current pulses

The electrical resistivity for **very high current** is difficult to retrieve because the **overheating** can **destroy** the **tapes**. The **Pulsed Current Measurement (PCM)** technique [1], allows to inject **current pulses** up to **1600 A** as short as **15 µs**. This avoids their destruction and allows to perform **resistivity** measurements in **high (overcritical) current regimes**.

Data analysis through FEA

Due to current sharing and heating effects it is difficult to know the **amount of current** carried by the superconducting layer and its temperature, and therefore its resistivity **ρ(I,T)**. Using Finite Element Analysis (**FEA**), a post-processing method based on the so-called **Uniform Current (UC) model** [2,3] allowed to calculate the evolution of the **temperature profile** across the thickness, as well as the **amount of current** flowing in each layer, therefore to **estimate** the resistivity of the ReBCO layer in the **overcritical current (OC) regime (Fig. 1)**.

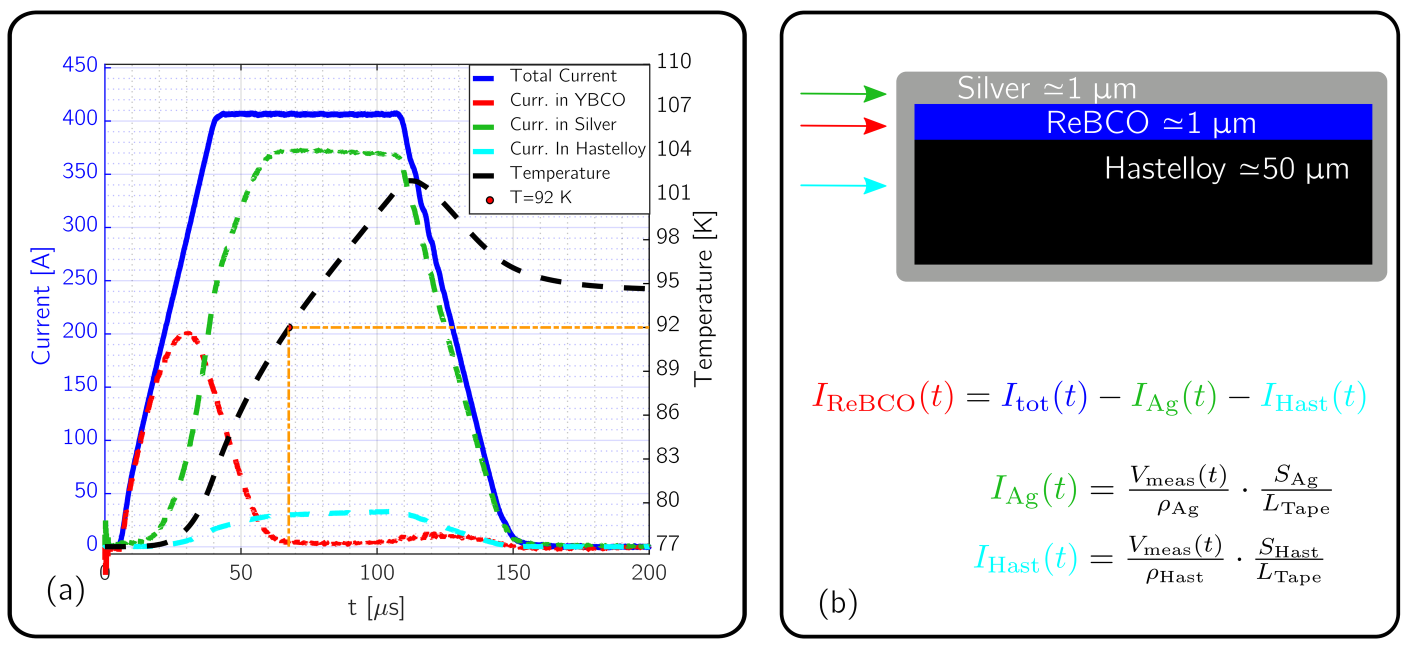

Figure 1: (a) Example of squared pulse injected in the HTS tape (blue), temperature profile (black) and current distribution among the layers (dashed lines).
(b) Current sharing among the layers calculated with the UC model.

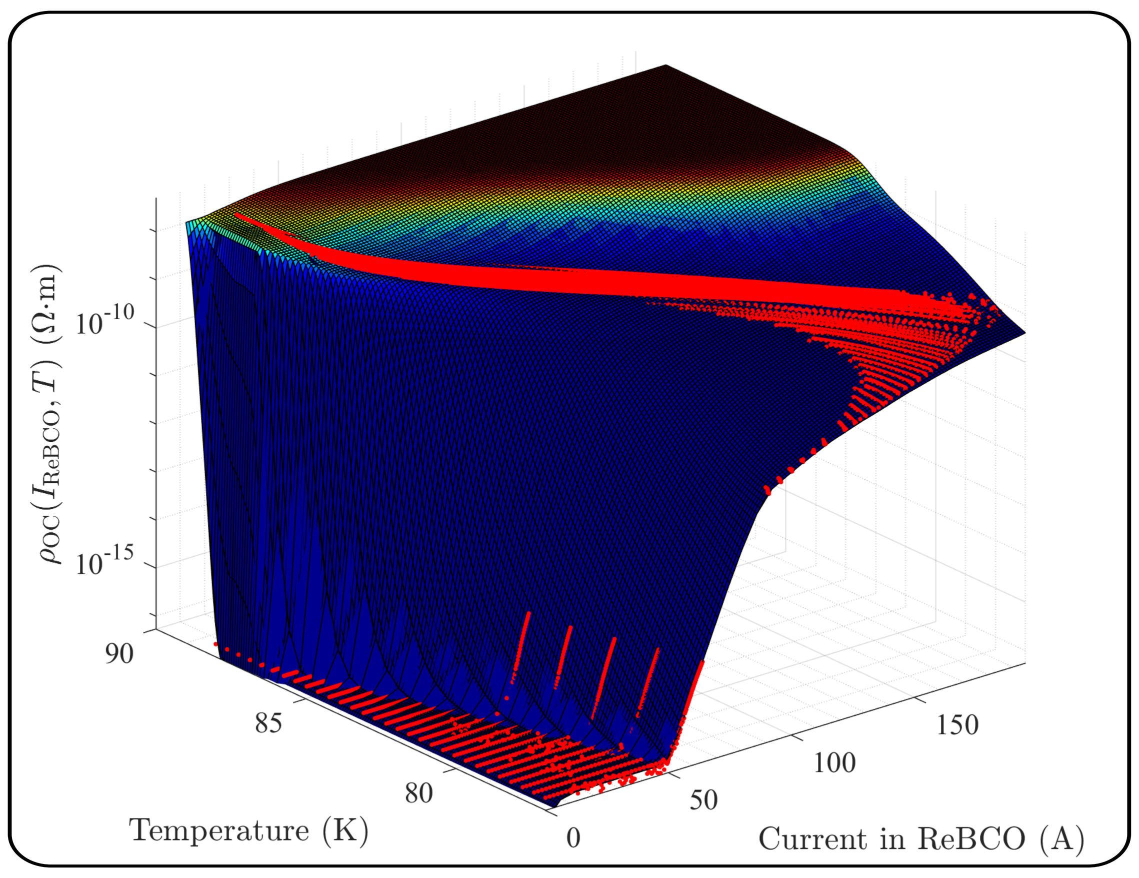

Figure 2: Experimental data processed with FEA (red dots) and Regularized Surface.

A modified E-J characteristic

All the **characterized tapes (Fig. 2)** from various manufacturers **present** a **significant decrease** of the slope of the **E-J characteristic** in the OC regime.
It is possible to FIT the curves with a **modified version** of the **collective pinning E-J law (Fig. 3)**:

$$\rho(I,T) = \rho_c e^{\frac{U}{k_b T}\cdot\left[1-\left(\frac{I_c}{I}\right)^{\mu}\right]} \cdot \left(\frac{I}{I_c}\right)^{\eta-1}$$

A deviation from the power-law

The **modified E-J curve** is described by the quantities:

$$\frac{U}{k_b T} \in [10 \div 25] \quad \mu \in [0.5 \div 4] \quad \eta \in [1 \div 5]$$

The relation with the physical meaning has to be investigated in other works.

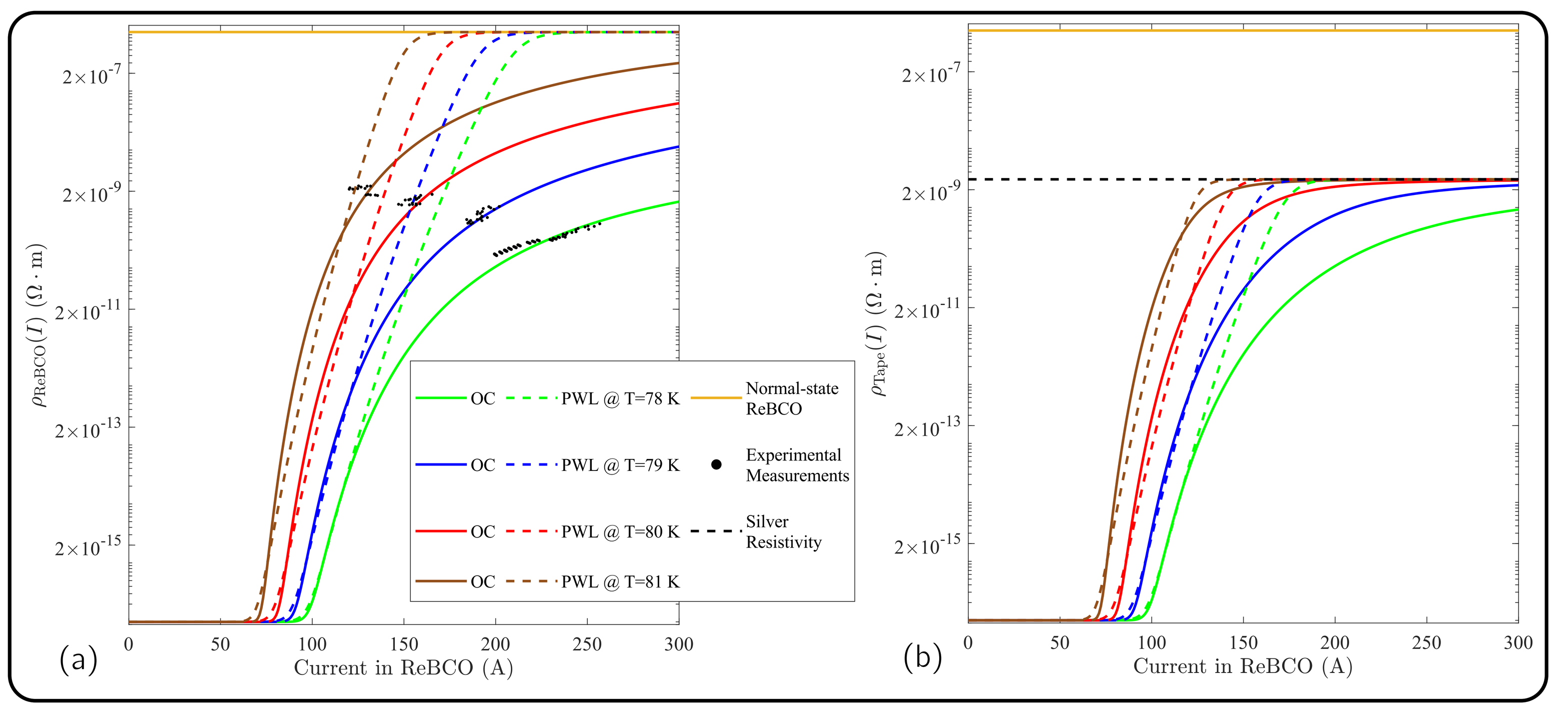

Figure 3: (a) Power-law and improved E-J characteristic of the ReBCO layer, in parallel with its normal state resistivity.
(b) Comparison of the overall resistivity of the tape, in parallel with the silver resistivity at 92 K.

Impact on simulations

In **Figure 4a** we present **DC Fault Current** measurements performed on an HTS tape in comparison with **simulations,** where their power-law and the OC surface in **Fig. 2** are used.
The limited current is better approximated with the OC data.

In **Figure 4b** a simulation shows the impact of using the OC surface respect to the power-law as characteristic.
The tape quench faster using the power-law model.

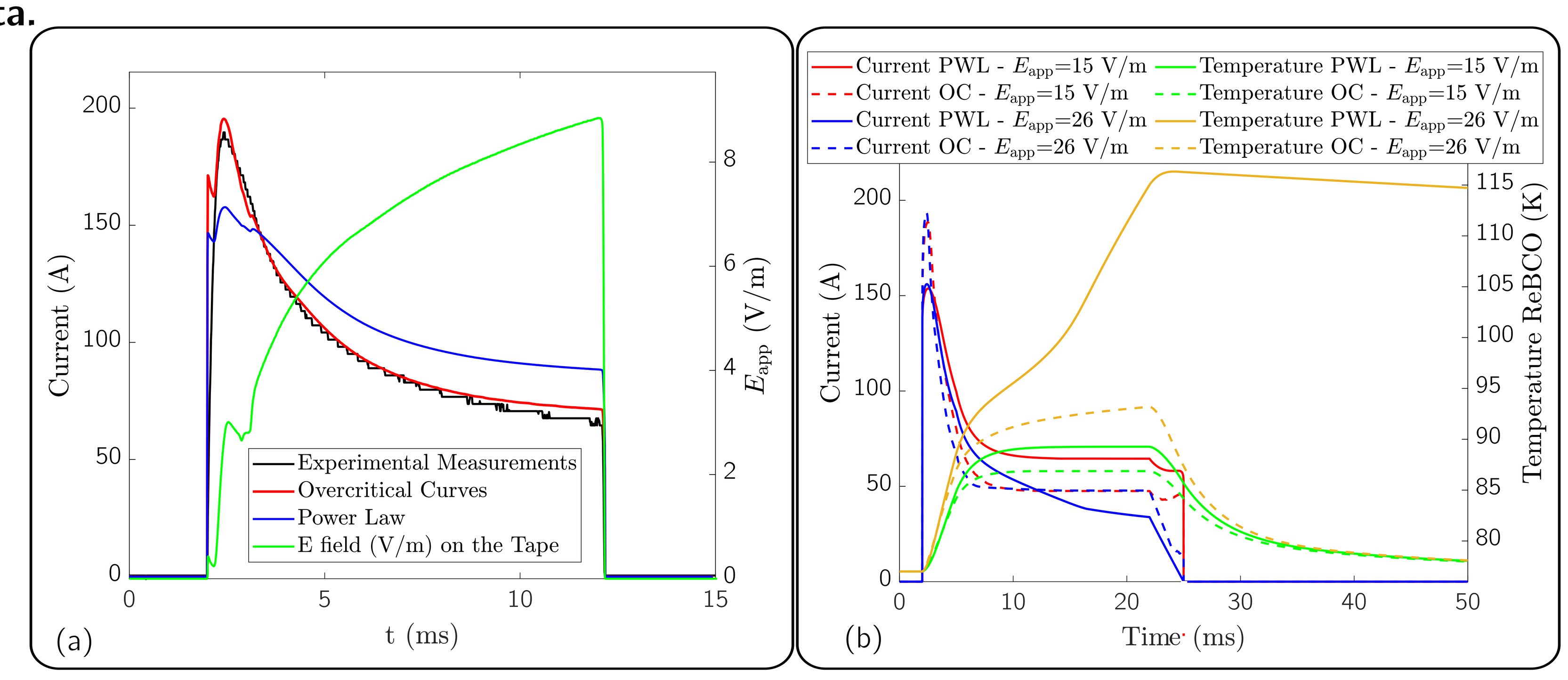

Figure 4: (a) Comparison between experimental DC fault measurements and different E-J curves models.
(b) Impact of OC and PWL for different applied electric field.

Conclusions

Achievements

1 - The overcritical current regime was successfully characterized
2 - By simulations we showed how critical is an accurate E-J law
3 - A modified version of an E-J characteristic is proposed

Next Steps

1 - Extensive analysis on the data collected
2 - Assessing by simulation the reliability of the new curve

Reference:
[1] F. Sirois et al.,10.1109/TASC.2009.2018304
[2] N. Riva et al, 10.1109/TASC.2019.2902038
[3] S. Richard et al., 10.1063/1.5095637

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