Electrical and mechanical behavior of electrical, Pb- and Cd-free, joints with normal- and superconducting materials at low temperatures

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Introduction

As the European Union is working at present on different guidelines like RoHS (Restriction of Hazardous Substances) to ban cadmium and lead for industrial application, this study has focused on investigating alternative, Pb- and Cd-free, joining techniques.

For the electrical and mechanical investigations, the following HTSL conductor types have been used:

- HTSL Var1: AMSC
- HTSL Var2: Super Power SCS12100-CF
- HTSL Var3: Super Power SF12100

Joining Techniques

- **Clamping**

Two conductors are pressed by M8 screws using a torque of M = 12.5 Nm. An electrically isolating foil between the copper blocks ensures the current flow exclusively in the conductors.

- **Adhesive bonding**

A 2 component non-conductive room temperature curing adhesive was used. A mating force of F = 3.5 kN was found as the best compromise between joint resistance R_V, tensile force F_Z and conductor stress σ.

- **RMS soldering**

After the firing impulse, only a very localized, short-term heat input is generated, which melts the solders on both sides of the reactive multilayer system (RMS) of the stacked Al-Ni foils.

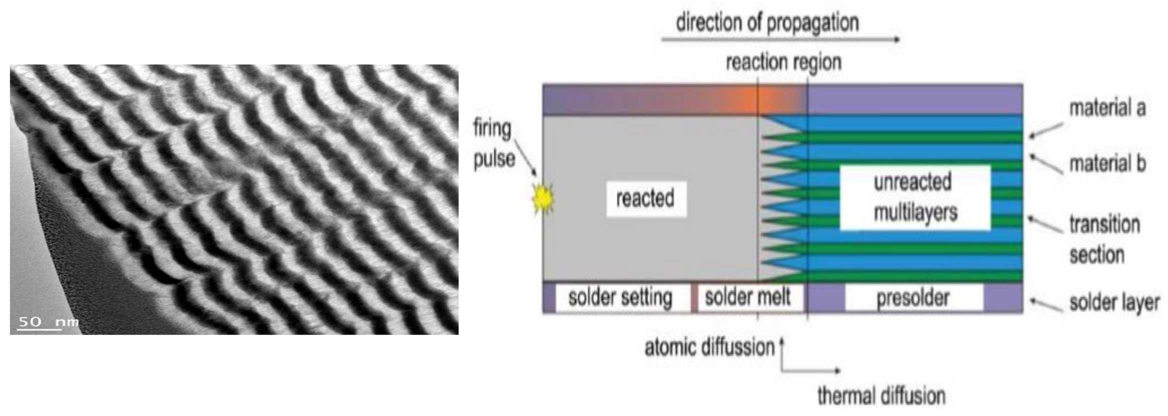

Fig.1: TEM view of un-reacted RMS foil and reaction process of RMS soldering [photos provided by IWS-Fraunhofer Institut Dresden]

Electrical Characterization: Measurement principle and test results

First, the material resistance of the HTSL conductors is measured at a distance of 45 mm. A 4-point measurement method is used with potential tappings.

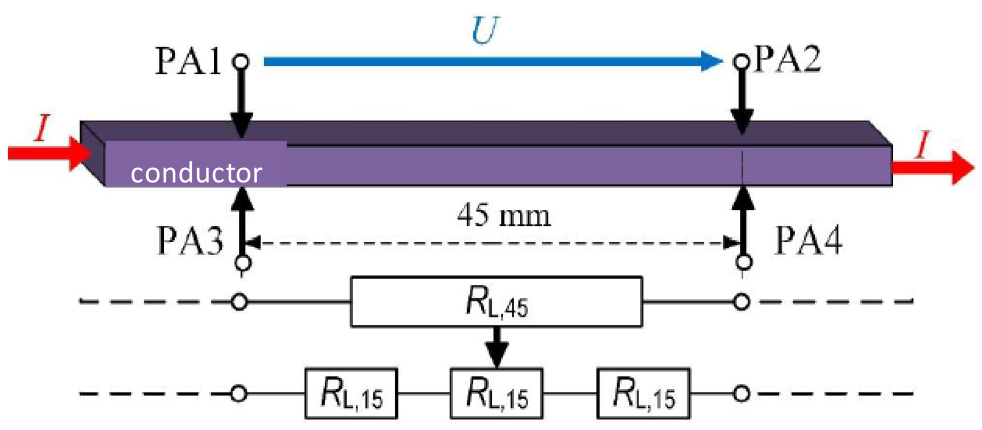

Fig.2: schematic measurement principle

The material resistance $R_{L,15}$ is calulated at a distance of 15 mm:

$$R_{L,15} = 1/3\ R_{L,45}$$

Then, the HTSL conductors are joined with an overlapping length of 15 mm with the face-to-face method.

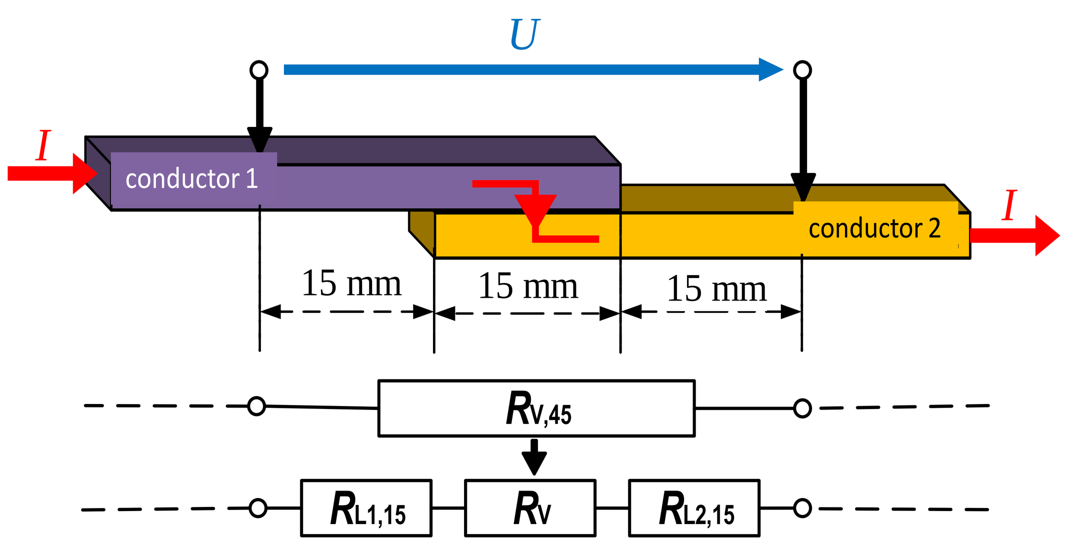

Fig.3: measurement at joined conductors

The joint resistance R_V is calculated from the measured values:

$$R_V = R_{V,45} - (R_{L1,15} + R_{L2,15})$$

All measurements have been performed at AC current load:

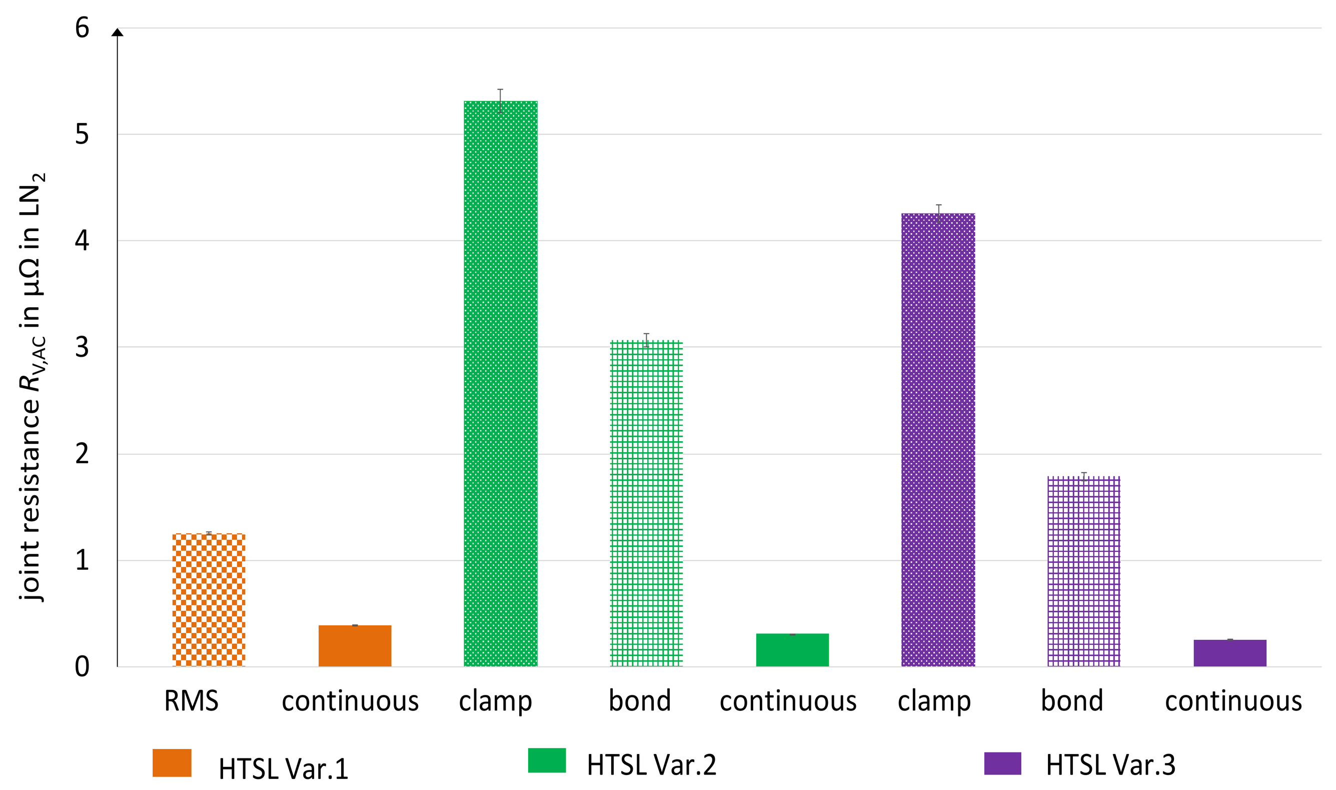

Fig.4: Comparison of AC joint resistances $R_{V,AC}$ and material resistance of continuous conductors

Mechanical Characterization: Test set-up and test results

Tensile tests have been performed with a tensile testing machine and a LN_2 tight insulation tube:

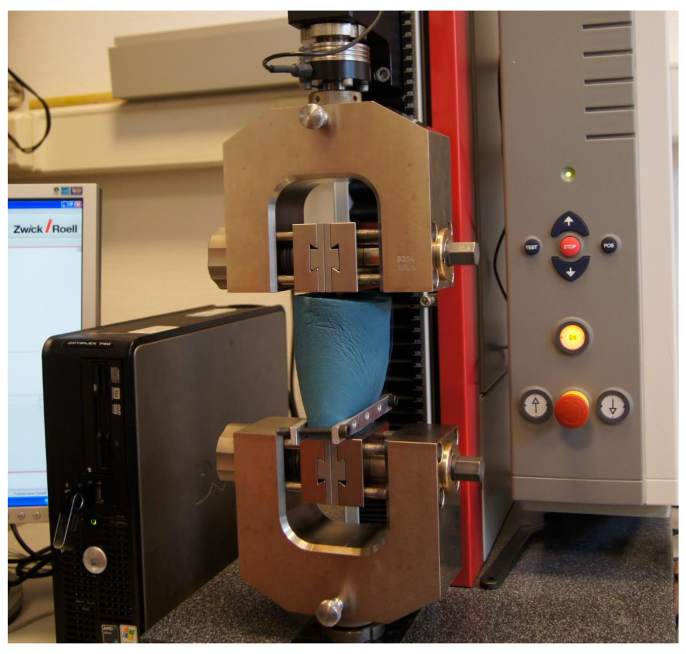

Fig.5: mechanical test set-up

The mechanical strength of the HTSL conductor joints is compared at room temperature and in LN_2 :

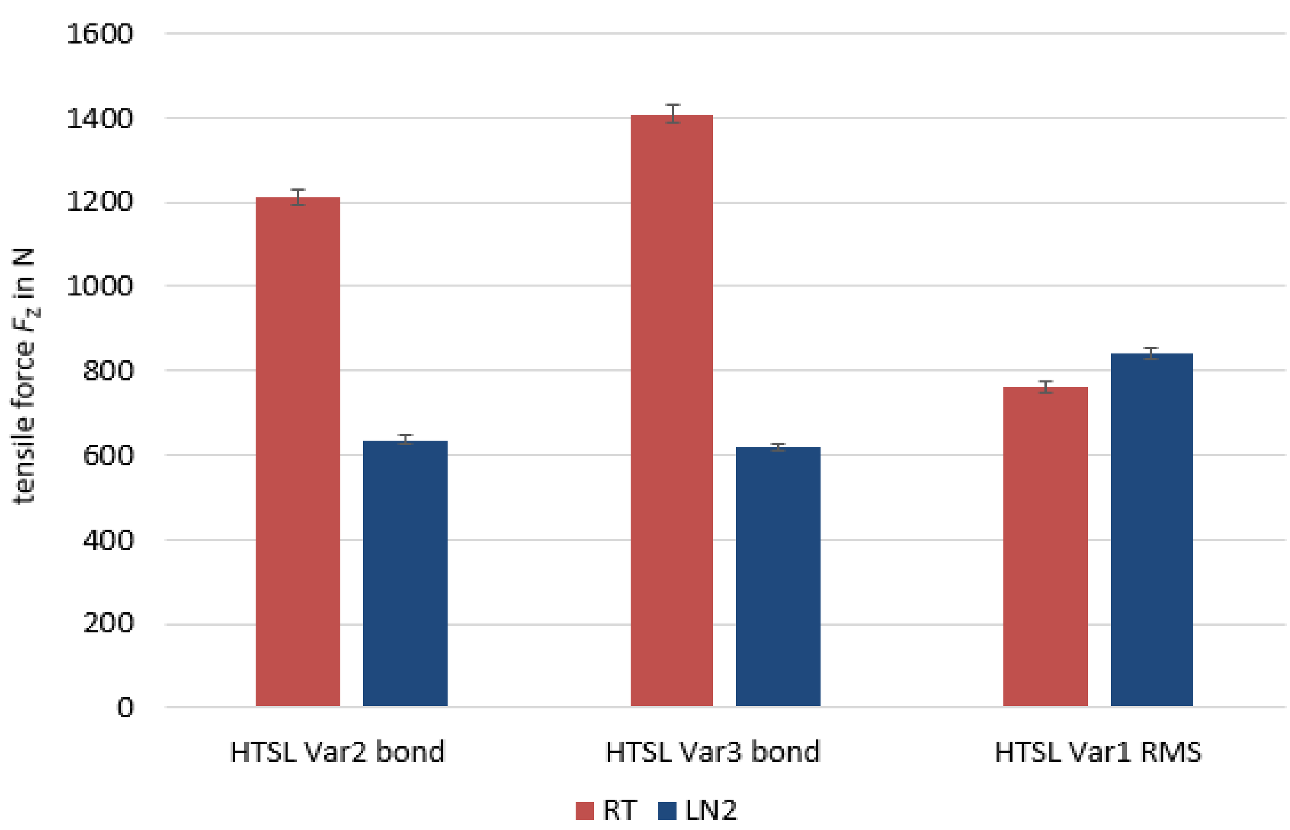

Fig.6: mean values of tested tensile strength F_Z at room temperature and in LN_2

Crucial for the application in a real device is the force at the 0,2% elastic limit, where no permanent damage occurs:

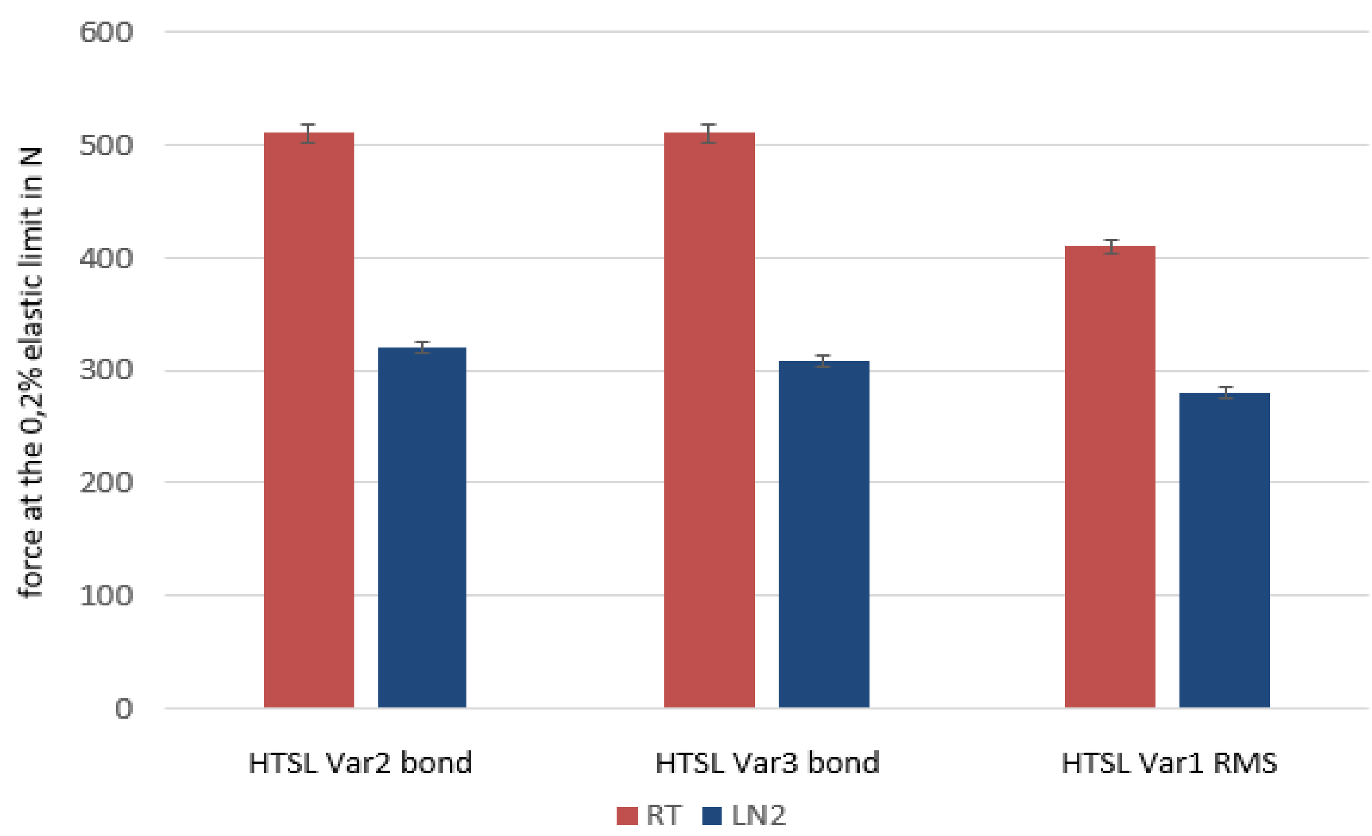

Fig.7: determined force at the 0,2% elastic limit at room temperature and in LN_2

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