Transport IV characterisation of MgB_2 conductor at a bend radius of 50mm

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Transport IV characterisation of MgB_2 conductor at a bend radius of 50mm

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Abstract. Performance of state of the art MgB_2 multifilamentary conductor at a required bend radius is essential for many applications including but not limited to magnets and motors. The characterisation is generally done with benchmark transport Ic but further detail can be seen in IV characteristics which are undertaken in this paper. Two conductors with the same architecture but different diameters, 0.89 and 0.45 mm were measured from 32 K to 20 K in self-field in conditions of as received and deformed to a 50 mm bend diameter, corresponding to strains of 1.4 % and 0.7 % respectively. The qualifying 0.45mm conductor was further measured in background fields up to 3 T. The smaller diameter wire was found to have no signs of degradation of critical behaviour in I_c or IV characteristics.

1. Introduction

The performance of MgB_2 conductors in short lengths has improved dramatically since its discovery [1]. Research worldwide is being conducted into it suitability for winding in coils for applications such as magnets or motors.

The purpose of these measurements is to qualify a pre-selected conductor architecture for use in a magnet with a winding diameter of 100 mm. Distinguishing this work from others is qualifying measurements are not restricted to $I_c(B)$ but to a more complete IV characteristic, at different fields and temperatures and the combination of a state of the art architecture combined with an unusually small wire diameter.

Successful measurement of critical current and transport IV was previously demonstrated on various conductor architectures for currents up to 700 A and temperatures from 40 K down to 20 K [2,3].

2. Experimental

The conductors were supplied by Hyper Tech, USA, one with a diameter of 0.89 mm, the other 0.45 mm and both with the same architecture, a 6 filament, malic acid doped MgB_2 monel sheathed with copper stabilising core.

The samples were measured as received and after being deformed around a 50 mm bending radius and re-straightened using the same bend radius. Voltage current characteristics were measured in a conduction cooled cryostat with HTs current leads, and using a semi-dc method as described in previous publications [2,3]. In-field measurements applied a DC magnetic field in the radial direction.

The sample lengths were 15 cm zero field and 7 cm in field, with 1.5cm for current injection at each end and voltage taps separated by up to 7 cm and 3 cm respectively. I_c was determined using the 1 μV/cm criterion.

3. Results and Discussion

The IV data at 29.6K for the deformed 0.89mm conductor, and as received are shown in Figure 1. The straight sample has a clear power law behaviour with an I_c just over 90A. The bent sample has a lower I_c, about 87A, and a step like behaviour in IV at about 5microvolts, 90A. The step clearly shows mechanical damage in the superconductor filaments. There are two factors to consider when analysing the IV curves. Firstly the long length homogeneity of I_c has not been measured for MgB_2 conductors, presumably due to the cryogenic challenges of measurement in this temperature range and the associated cost. Secondly at these temperatures and high current densities care is taken to achieve an isothermal condition, (which is challenging with heat capacity rapidly dropping and power density increasing), yet inevitably at a certain power density heating will occur when currents are as high as 1000 A/mm^2 at 15 K. In Figure 1 the difference in I_c between the 2 conductors cannot simply be attributed to damage to the core as this may be due to long length inhomogeneity. Heating begins already at 10 μV/cm, so its behaviour above is dominated by the thermal condition of the sample, i.e. its dissipation and thermal contact with the surroundings.

The IV data in Figure 2 shows the smaller 0.45 diameter wire with the same deformation does not exhibit the step-like behaviour. The slightly higher I_c value again cannot be attributed to anything without either measuring the same sample, both deformed and as received or with a more significant change in I_c.

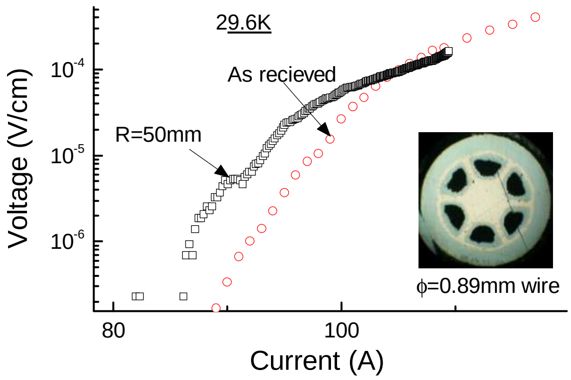

Figure 1. Current voltage characteristics of 0.89mm MgB_2 composite wire deformed and straight.

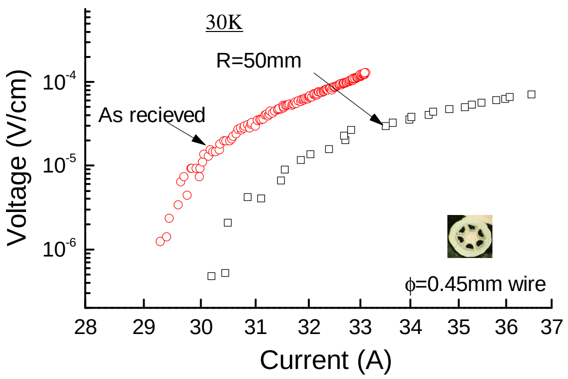

Figure 2. Current voltage characteristics of 0.45mm MgB_2 composite wire deformed and straight

The 0.45 mm diameter conductor was then measured in a range of fields and temperatures to explore if the power law behaviour was consistently present without any step-like characteristics. The data in Figure 3 at fields of 0.5, 1, 2 and 3 T show no signs of any step like behaviour in the IV curves. There is again some heating at higher voltages but this is to be expected above a certain dissipation level in a conduction cooled measurement.

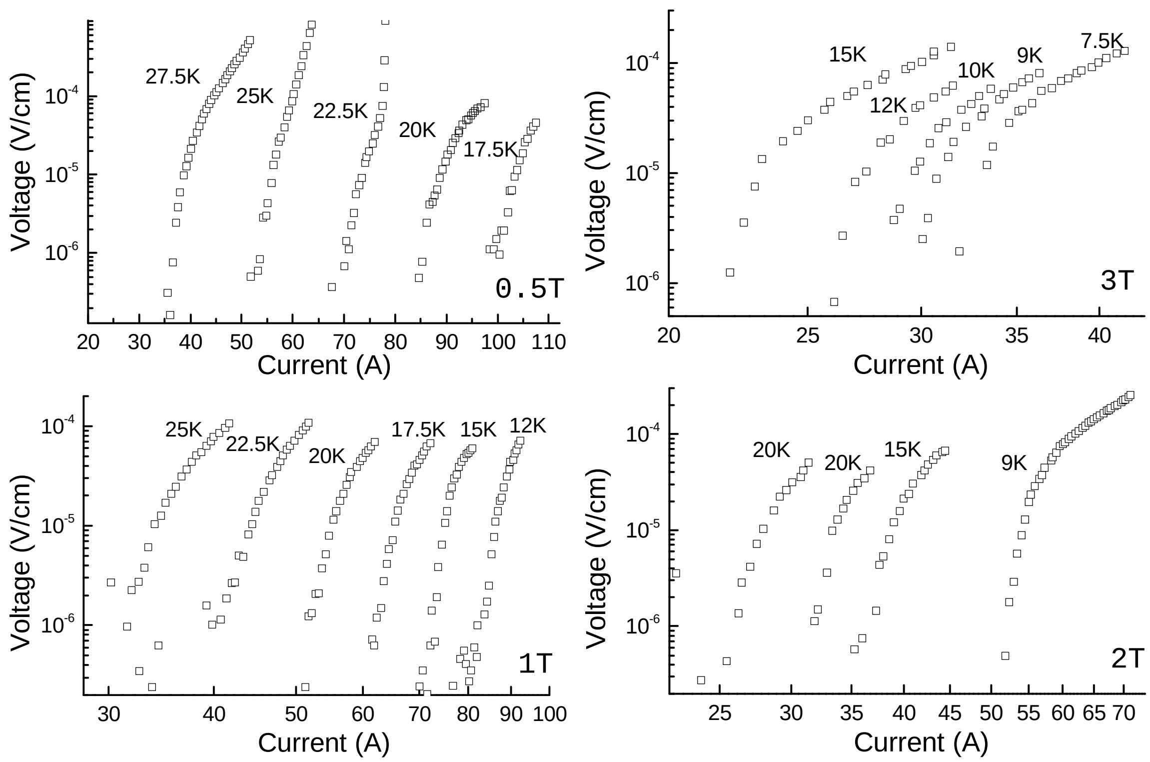

Figure 3. The voltage current characteristics of the deformed 0.45 mm conductor at a range of indicated temperatures and background magnetic fields 0.5 T, 1 T, 2 T and 3 T.

Is the strain consistent with other measurements? Measurements of strain are performed ether with a longitudinal tension or compression [4] or directly with bend radius tests [5, 6]. The tensile strain at degradation depends on the mechanical properties of the wire, the processing, and for the most recent publications varies from about 0.4 % [6] up to 0.9 % [5]. For the 0.89 mm wire the stain on the filaments using d/R where d is 0.7mm is 1.4 %, and correspondingly 0.7% for the smaller wire.

The same data for transport I_c of the 0.45mm diameter sample, bent to R=50 mm, is presented in Figure 4 at the different fields as a function of temperature and in Figure 5 as a function of field at different temperatures. The self-field values for the as received sample are plotted alongside in Figure 4 for comparison. The self-field values for Figure 5 were calculated using amperes law for an infinite wire and of the order of 0.01 T, so one order of magnitude off the plotted scale, however the interpolation can be seen.

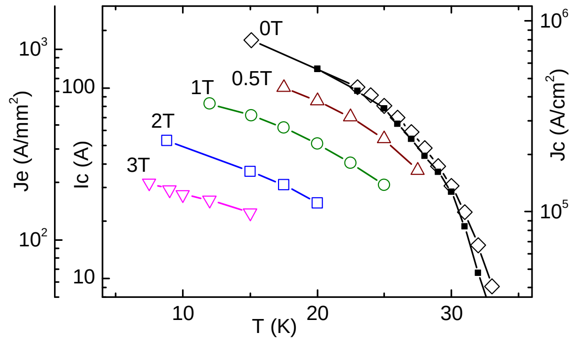

Figure 4. Log scale transport I_c , J_e, and J_c against temperature at different fields for the 0.45 mm diameter deformed sample, (open symbols). Plotted alongside is the self field for the as received sample (filled symbols).

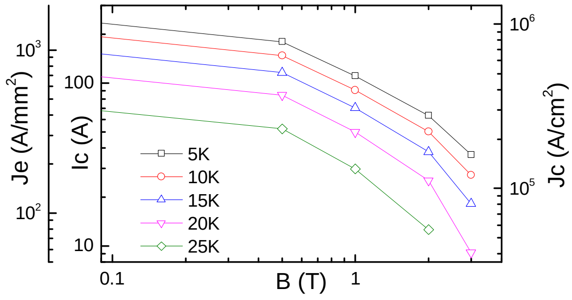

Figure 5. Log scale transport I_c, J_e, and J_c against temperature at different fields for the 0.45 mm diameter deformed sample. The lines are interpolated between data points. Self field is set artificially to 0.1 T.

4. Conclusion

Using transport IV as a characterisation tool two different diameters of state of the art conductor were tested at self field in a condition of as received and deformed to a 50 mm bend radius. The smaller diameter sample did not show any degradation, (0.7 % strain), and was further tested in fields up to 3 T and down to 7.5 K. The suitability of the 0.45 mm wire for winding at a bend radius of 50 mm is proven not just by I_c but by a more detailed picture that IV data provides.

5. References

[1] G Z Li, Y Yang, M A Susner, M D Sumption and E W Collings 2012 *Supercond Sci. Technol.* **25** 025001
[2] E. A. Young, W. O. S. Bailey, M. K. Al-Mosawi, C. Beduz, Y. Yang, S. Chappell, and A. Twin 2012 *Phys. Proc.* **36** 1343-1347
[3] E. A. Young, M. Paolella, and Y. Yang 2013 *IEEE Trans. Appl. Supercon.* **23** 8001304
[4] G Nishijima, S J Ye, A Matsumoto, K Togano, H Kumakura, H Kitaguchi and H Oguro 2012 *Supercond Sci. Technol.* **25** 054012
[5] P Kováč, I Hušek, T Melišek, L Kopera and M Reissner 2010 *Supercond Sci. Technol.* **23** 065010
[6] Kazumune Katagiri, Ryuya Takaya, KoichiKasaba, Kyoji Tachikawa, YutakaYamada, SatoshiShimura, Naoki Koshizuka and Kazuo Watanabe 2005 *Supercond Sci. Technol.* **18** S351-S355.