

PDF hosted at the Radboud Repository of the Radboud University Nijmegen

The following full text is a publisher's version.

For additional information about this publication click this link.

<http://hdl.handle.net/2066/29437>

Please be advised that this information was generated on 2018-12-14 and may be subject to change.



Dependence of critical current densities in Chevrel phase superconducting wires on magnetic fields up to 25 T

A. Gupta^{a,*}, N. Cheggour^a, M. Decroux^a, J.A.A.J. Perenboom^b, V. Bouquet^c,
P. Langlois^d, H. Massat^d, R. Flükiger^a, Ø. Fischer^a

^aDPMC-GAP, University of Geneva, 24 quai Ernest-Ansermet, 1211 Geneva-4, Switzerland

^bHigh Field Magnet Laboratory, University of Nijmegen, Nijmegen, The Netherlands

^cLaboratoire de Chimie Minerale B, University of Rennes, France

^dLab. de Physicochimie des Matériaux, CNRS, 92195 Meudon Cedex, France

Abstract

$V-I$ characteristics have been measured, in several monofilamentary Chevrel phase superconductors (CPS) wires made using prereacted powders of both pure SnMo_6S_8 (SMS) and $\text{Pb}_{0.6}\text{Sn}_{0.4}\text{Mo}_6\text{S}_8$ (PSMS) compounds, in applied magnetic fields up to 25 T. The values of J_c in different wires lie in the range $\sim 5 \times 10^7$ – 10^9 A/m² at 4.2 K and 9 T. In the SMS wires the critical current density $J_c(B)$ tends to vanish at the expected ideal B_{c2} . In contrast, for PSMS wires the $J_c(B)$ tends to vanish at fields much smaller than the expected B_{c2} for pure PbMo_6S_8 (PMS) and nearer to that of the SMS. The $V-I$ characteristics at the dissipative onset are highly non-linear and show a power law behaviour $V = kI^n$ with a typical n -value (1.8 K, 25 T) > 17 .

1. Introduction

It has been long realised that some of the CPS with high $B_{c2}(0)$ (35 T – SMS and 60 T – PMS) fulfil the requirements for high field applications at 1.8–4.2 K. In the optimised CPS wires we have now achieved record values of $J_c(4.2 \text{ K}, 9 \text{ T}) \geq 10^9$ A/m² [1]. However, the challenge for CPS lies in its use at field > 20 T, where the J_c of Nb_3Sn is intrinsically limited. In this work we address the three following questions: (1) In all reports on the best CPS wires until date [2, 3] the field (B_{c2}^*), at which $J_c \Rightarrow 0$, was found to be much smaller than the ideal B_{c2} ; (2) the scatter in the values of J_c , especially when its B dependence does not alter much, in differently processed wires; and (3) how sharp are the $V-I$ transitions at high fields in the CPS wires. Following the

line of reasoning developed in Refs. [4, 5] and the measured $V-I$ characteristics in the present work on pure SMS and several PSMS (Sn substituted (PMS) wires, we show that grain boundary superconducting properties and granularity (both macro and micro) lie at the origin of these questions.

2. Experimental

The powder and wire preparation was explained in detail in Ref. [6]. See Table 1 for the compositional and processing details of the wire reported in this work. Short wire samples (3–13 cm) were heat treated under hot isostatic pressing conditions at 900°C and 2 kbar for 30–120 min. $V-I$ characteristics were measured at 1.8 and 4.2 K with magnetic field ($B = 1$ –25 T) applied perpendicular to the current direction. The J_c is defined at a 10 $\mu\text{V}/\text{cm}$ criterion.

* Corresponding author.

Table 1
Powder and composition of the wires

No.	CPS powder	Barriers
1	SMS	(Sw)/Nb/Cu/Steel
2	PSMS + 0.2Sn	(Ex)/Nb/Cu/Steel
3	PSMS + 10%P	(Sw)/Nb*/CuNi30
4	PSMS + 0.2Sn + 10%P	(Sw)/Nb*/CuNi30
5	PSMS + 0.2Sn + 10%P	(Sw)/Nb*/CuNi30/Steel
6	PSMS + 0.2Sn	(Sw)/Nb*/CuNiBe

P – 1.1 Pb + MoS₂/Mo precursors; Nb – Powder processed; Nb* – melt processed; Ex – Extruded; Sw – Swaged.

3. Results and discussion

In Fig. 1(a) we show J_c as a function of B at 4.2 and 1.8 K for both SMS and PSMS wires. For both the compounds, we observe nearly the same $J_c(B)$ dependence. Only at high fields >20 T the $J_c(B)$ for SMS drops slightly faster as compared to the PSMS. Changing the voltage criterion for J_c definition do not change the results appreciably. In Refs. [5, 7] we had shown that the limiting mechanism for pinning, in polycrystalline CPS samples heat treated at temperatures $\leq 1000^\circ\text{C}$ for reasonable times, could be a flux line shear along the grain boundaries. Thus we might use Kramer plots for determining B_{c2}^* , which are shown in Fig. 1(b). For SMS wire $B_{c2}^* = 27.5\text{ T}$ (4.2 K) and $= 33\text{ T}$ (1.8 K) approach the ideal $B_{c2}(0) = 35\text{ T}$ in excellent agreement. However, for the PSMS wire $B_{c2}^* = 31.5\text{ T}$ (4.2 K) and $= 38\text{ T}$ (1.8 K) are much smaller than the expected ideal $B_{c2}(0) = 60\text{ T}$ for pure PMS and nearer to that of the SMS. This may indicate that the flux line shear channels in PSMS wire have a composition near to SMS, which can be caused by an excess of Sn at the grain boundaries. Note that our results of B_{c2}^* in SMS wire suggest that at temperatures of 1.8–4.2 K, the irreversibility line [8, 7] for this compound lies very near to the expected ideal $B_{c2}(T)$ line.

In Fig. 2 we show J_c as a function of B for different PSMS wires (see Table 1), all hot isostatically pressed at 900°C and 2 kbar for 2 h. In spite of the fact that the absolute values of J_c lie in a scatter window of more than one order of magnitude, the $J_c(B)$ dependence is the same for all the wires. This clearly indicates that the main difference in these wires is that of the effective supercurrent – carrying cross-section. Several reasons depending on the magnitude of the J_c scatter, like macrogranularity – cracks, porosity, and microgranularity – Josephson coupled grain boundaries due to incomplete sintering or severe degradation, might be responsible.

In Fig. 3 are shown on a double logarithmic scale the $V-I$ characteristics for PSMS wire no. 2, which has

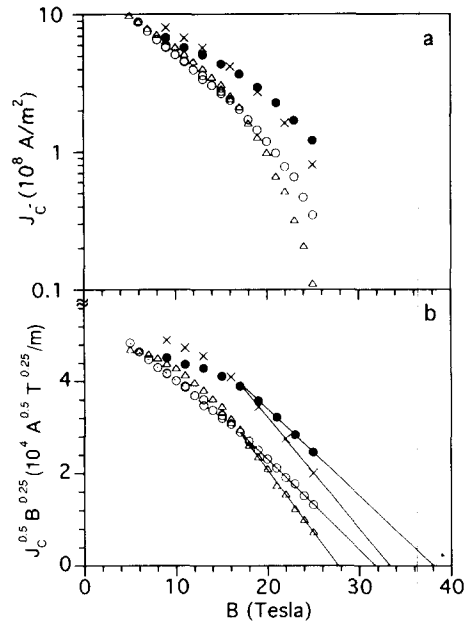


Fig. 1. (a) J_c versus B for wire no. 1 (Δ) and 5 (\circ) at 4.2 K; 1 (\times) and 5 (\bullet) at 1.8 K. (b) Kramer plots for the same data.

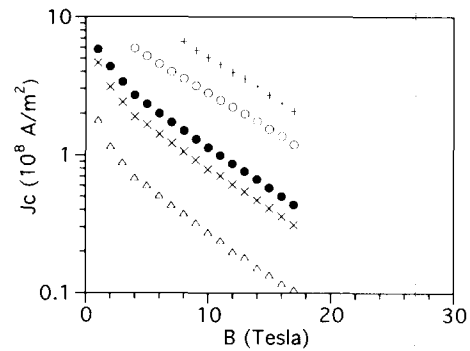


Fig. 2. J_c versus B for wire no. 2 (\circ), 3 (Δ), 4 (\times), 5 ($+$) and 6 (\bullet).

a $J_c = 3.5 \times 10^8\text{ A/m}^2$ at 4.2 K and 9 T. The jumps in the $V-I$ observed at currents $> J_c$ (see $V-I$ at 13 T and 14 T in Fig. 3) may be accounted by a “current induced flux flow avalanche” in the wires (see also Ref. [9]). The dissipative onset is rather abrupt and in the 10^{-5} – 10^{-7} V window, the $V-I$ follow a power law ($V = kI^n$). As shown in Fig. 4 the n -values decrease monotonically with B . Note also that the n -values at 1.8 K are a factor ~ 3 higher than at 4.2 K. Similar $V-I$ behaviour also observed in single crystal high- T_c cuprates has been discussed within vortex glass and collective pinning theories, where the activation barrier for flux motion is shown to have a non-linear

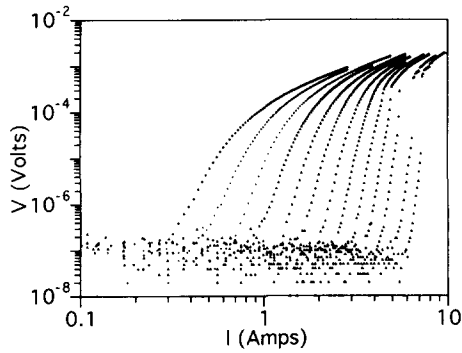


Fig. 3. V - I characteristics for the wire no. 2 for $B = 13$ T (right) to 25 T (left) in steps of 1 T.

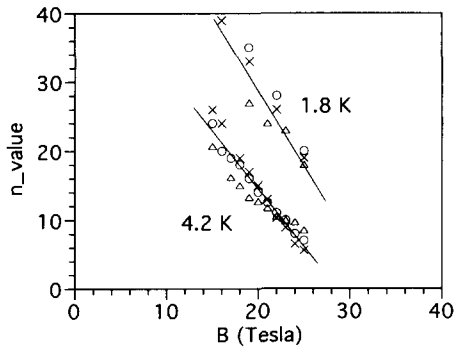


Fig. 4. n -values versus B for wire no. 1 (\times), 2 (\circ) and 5 (Δ). The solid lines are only a guide.

dependence on J/J_c . However, in our polycrystalline CPS samples, where the flux lines might flow along the grain boundaries, the distribution of T_c and B_c in the grain boundaries may be the origin of the observed behaviour [10]. These aspects need to be further explored.

4. Conclusions

The conclusions of this work are as follows:

1. In a typical J_c - B plot (see Fig. 1(a) of CPS wires), the $J_c(B)$ curve will stretch vertically by a reduction in granularity and horizontally by improving the superconducting properties of the grain boundaries.
2. The relatively high n -values (≥ 6 at 4.2 K and ≥ 17 at 1.8 K) in both SMS and PSMS wires at 25 T indicate the potential for their high field applications.

References

- [1] N. Cheggour et al., to be published.
- [2] G. Rimikis et al., IEEE Trans. Appl. Supercond. 27 (1991) 1116.
- [3] H. Yamasaki et al., J. Appl. Phys. 70 (1991) 1606.
- [4] M. Decroux et al., IEEE Trans. Appl. Supercond. 3 (1993) 1502.
- [5] A. Gupta et al., Proc. ICMAS'93 (Paris) Pub. IITT Int. (1993) 402.
- [6] N. Cheggour et al., Proc. ICMAS'93 (Paris) Pub. IITT Int. (1993) 402.
- [7] A. Gupta et al., Presented at M²HTSC (Grenoble '94), Physica C, in press.
- [8] C. Rossel et al., Physica C 165 (1990) 233.
- [9] P.F. Hermann et al., Physica C 202 (1992) 61.
- [10] R. Wördenweber, Cryogenics 32 (1992) 1098.