Available online at www.sciencedirect.com
SCIENCE DIRECT®
Physica C 408–410 (2004) 756–758
PHYSICA C
www.elsevier.com/locate/physc

Pressure and magnetic field effects on the transport critical current in $Hg_{0.82}Re_{0.18}Ba_2Ca_2Cu_3O_{8+\delta}$ ceramic superconductor

J.L. Gonzalez [a,b,*], E.V.L. de Mello [b], E.S. Yugue [a], E. Baggio-Saitovitch [a], M.T.D. Orlando [c]

[a] *Centro Brasileiro de Pesquisas Físicas, Materia Condensada, Rua Xavier Sigaud 150, URCA, Rio de Kaneiro 22 290180, Brazil*
[b] *Departamento de Fisica, Universidade Federal Fluminense, Niteroi, Rio de Janeiro, Brazil*
[c] *Departamento de Física, Universidade Federal de Espirito Santo, Vitoria, Espirito Santo, Brazil*

Abstract

The pressure and magnetic field effects on the transport critical current density (J_{ct}) in a ceramic sample of $Hg_{0.82}Re_{0.18}Ba_2Ca_2Cu_3O_{8+\delta}$ with optimum oxygen content are studied. The rate of increase for J_{ct} with the pressure is $\partial_P J_{ct}/J_{ct} = 7.1 \times 10^{-2}$ kbar^{-1}. The dJ_{ct}/dP rate decreases with the applied magnetic field and it equals to zero for fields above 50 G. Our experimental results indicate the possible existence of two subsystems involved in the critical current transport along the sample. One subsystem is related to the weak-links (WL) or high-angle boundaries and the other is associated to the strong-links (SL). For low applied fields the transport properties of the sample are mainly influenced by the WLs and, upon increase the applied field, the J_{ct} is mainly determined by the SLs.

Keywords: Critical current density; High pressure effect; Granular superconductivity

1. Introduction

Potential technological applications of high-T_c materials demand large-dimension samples (polycrystalline materials) having high values of J_{ct} ($\sim 10^5$ A/cm^2). The principal limit for J_{ct} in these samples is the grain-boundaries (GB) between grains. These GB's have many dislocations inside which have a normal core that disrupts the superconductivity around them. This structure limits the effective area for transport of superelectrons through the GB. If the dislocations are very close to one another the disorder inside the GB is very high, and in this case the GB is identified as a weak-link [1]. On the other hand, experimental studies have demonstrated that if the angle of the boundary is low, the dislocations can act as pinning centers and the structure can support a high supercurrent. This type of GB is identified as strong-link (SL) [2].

Some studies have focussed the effects of an external pressure on the physical properties of high-T_c materials and in particular on J_{ct} (see [3,4]). Nevertheless there are not any report on the synchronized effects of the pressure and the magnetic field in J_{ct}. In this work we study this item in a ceramic Hg-1223 compound. Our study shows that the pressure increases the transport critical current without applied magnetic field at a fixed temperature. Upon increasing the magnetic field this effect decreases and it disappears for fields above 50 Oe.

2. Experimental

The high-quality Hg-1223 polycrystalline sample was obtained from a solid-state reaction method. Details on the sample preparation, its physical properties and the

* Corresponding author. Tel.: +55-212586-7503; fax: +55-212586-7540.
E-mail address: jl@cbpf.br (J.L. Gonzalez).

0921-4534/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.physc.2004.03.079

experimental set-up used in the experiment can be found in references [4,5] and references therein.

3. Results and discussion

Fig. 1 shows the *I–V* measurements for different hydrostatic pressures taken at a fixed temperature $T = 101$ K, and without applied field. The inset of Fig. 1 shows the zero-field resistivity transition for the sample. The critical temperature (T_c) was defined at the maximum of the first derivative of the $R(T)$ curve and it gave a T_c value of about 131.9 K. From the *I–V* curve the critical current was taken at the different pressures using a criterion $V_c = 2$ μV ($E_c = 8$ μV/cm). As it can be clearly noted the pressure increases the critical current. The $J_{ct}(P)$ dependence is linear and the rate $\partial_P J_{ct} = 0.07 \pm 0.02$ A/(cm^2 kbar).

At zero field the external pressure contributes to J_{ct} with two effects. First, it improves the bulk properties (superconducting gap and T_c) inside the grains, and second, the granular structure of the sample is also modified. These two effects will modify the conduction through the intergranular regions (WLs) leading to an increase of J_{ct} along the sample [4]. A previous analysis indicated that due to the lower value of the relative compressibility coefficient in high-T_c ceramics, the main factor associated to the increase of J_{ct} is the intrinsic term inside the grains. Also a theory was developed, which interconnected the relative increases of J_{ct} and T_c with the pressure [4].

The main result of our work is shown in Fig. 2. It can be noted that the increase of J_{ct} with the pressure depends on the applied field. This effect decreases when the applied field is increased and for fields about 50 G it disappears. Note that the *x*-axis is in logarithmic scale.

To understand this we have to realize that the supercurrent flows in the sample along two subsystems.

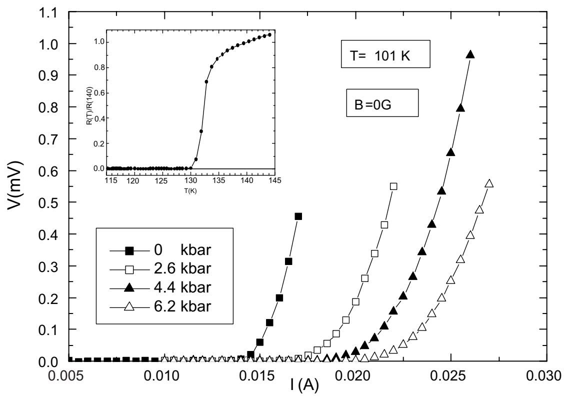

Fig. 1. *I–V* curves for different pressures.

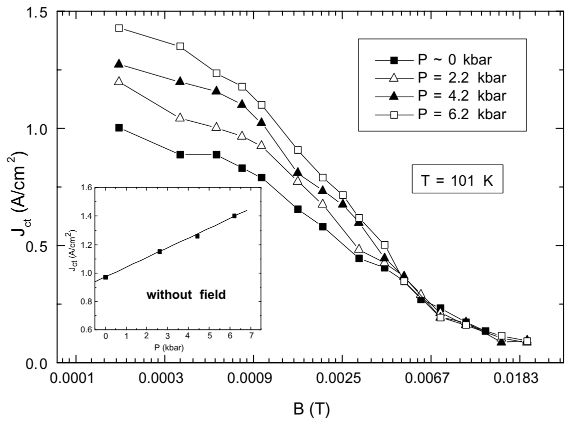

Fig. 2. $J_{ct}(B)$ for different applied pressures.

The first subsystem is the current transport through the WL (J_{CWL}) while the other occurs at the SLs (J_{CSL}). It means: $J_{ct} = J_{CWL} + J_{CSL}$. Initial results [4], and also our experimental data for $B = 0$ G, indicate that J_{CWL} is increased by the pressure. Upon increasing the magnetic field, the number of WLs that participate in the supercurrent transport, and also their own contribution (J_{CWL}), strongly decrease. Thus, at relatively higher fields the contribution to J_{ct} would be the one that originates from the SLs, namely J_{CSL}.

In the SLs, the vortex-lattice (VL) is pinned at the normal core of the dislocations. For low fields, the distance between vortices is greater than the one between dislocations, thus every vortex is pinned by at least one dislocation. An enhanced vortex pinning regime is obtained when these two distances match each to other, which produces a matching field $B_P = \phi_0/D^2 \approx 70$ T by taking a spacing between dislocations $D \approx 5.6$ nm [2]. For $B \ll B_P$ an almost constant critical current is expected [2]. In our experimental conditions the linear compressibility coefficient of high-T_c ceramics is very low [1,4]. Thus D should remain the same or a slight decrease is expected. In this sense, the net pressure effect on B_P is neglected and the J_{CLS} through the SLs, and consequently $J_{ct} \approx J_{CSL}$ is not modified by the pressure as it was experimentally detected.

4. Conclusion

The increase of J_{ct} with pressure in a Hg-1223 optimally doped compound was studied. It was verify that in our experimental conditions (low pressure and low fields) dJ_{ct}/dP is zero for fields above a certain field. We interpreted this result as an evidence of the existence of two subsystems involved in the flow of J_{ct}.

References

[1] S.E. Babcock, J.L. Vargas, Review Materials Science 25 (1995) 193.

[2] A. Diaz, L. Mechin, P. Berghuis, J. Evetts, Physical Review Letters 80 (1998) 3855.

[3] S.L. Bud'ko, M.F. Davis, J.C. Wolfe, C.W. Chu, P.H. Hor, Phys. Rev. B 47 (1993) 2835.

[4] J.L. González, M.T.D. Orlando, E.V.L. de Mello, E.S. Yugue, E. Baggio-Saitovitch, Solid State Communications 123 (2002) 405.

[5] M.T.D. Orlando, A. Sin, F. Alsina, A.G. Cunha, N. Mestres, A. Calleja, S. Piñol, F.G. Emmerich, L.G. Martinez, M. Segarra, X. Obradors, E. Baggio-Saitovitch, Physica C 328 (1999) 257.