2005

Effect of doping on flux pinning of GdBa2Cu3O7-y

L Zhang
Nanjing University, lz811@uow.edu.au

X B Xu
Nanjing University

S Y Ding
Nanjing University

M H Zheng
General Research Institute for Non-ferrous Metals

L Xiao
General Research Institute for Non-ferrous Metals

See next page for additional authors

Publication Details
Effect of doping on flux pinning of GdBa2Cu3O7-\(y\)

Abstract

Cylindrical single grains of GdBa 2Cu3O\(_y\) sGd-123d with a diameter of 25 mm were successfully fabricated by melt-texture growth sMTGd process in air to study the influence of different starting powders on flux pinning. Measurements of the magnetic critical current density \(J_{cd}\) showed that it was possible to fabricate large Gd-123 single grain with a high \(J_c\) at high temperatures and fields by means of properly controlling the starting powders of Gd 2O3, BaCO3, and CuO before the process.

Keywords

Effect, doping, flux, pinning, GdBa2Cu3O7

Disciplines

Engineering | Physical Sciences and Mathematics

Publication Details


Authors

L Zhang, X B Xu, S Y Ding, M H Zheng, L Xiao, H T Ren, Y L Jiao, Xiaolin Wang, Zhi W. Lin, and Jian G. Zhu

This journal article is available at Research Online: http://ro.uow.edu.au/aimpapers/201
Effect of doping on flux pinning of Gd Ba$_2$Cu$_3$O$_7$ y


Citation: Journal of Applied Physics 97, 10B101 (2005); doi: 10.1063/1.1846571

View online: http://dx.doi.org/10.1063/1.1846571

View Table of Contents: http://scitation.aip.org/content/aip/journal/jap/97/10?ver=pdfcov

Published by the AIP Publishing
Effect of doping on flux pinning of GdBa$_2$Cu$_3$O$_{7-y}$

L. Zhang, X. B. Xu, and S. Y. Ding

National Laboratory of Solid State Microstructures, Department of Physics, Nanjing University, Nanjing 210093, People’s Republic of China

M. H. Zheng, L. Xiao, H. T. Ren, and Y. L. Jiao

General Research Institute for Non-ferrous Metals, Beijing 100088, People’s Republic of China

X. L. Wang

Institute for Superconducting and Electronic Materials, University of Wollongong, New South Wales 2522, Australia

Z. W. Lin and J. G. Zhu

University of Technology Sydney, New South Wales 2007, Australia

(Presented on 11 November 2004; published online 2 May 2005)

Cylindrical single grains of GdBa$_2$Cu$_3$O$_y$ (Gd-123) with a diameter of 25 mm were successfully fabricated by melt-texture growth (MTG) process in air to study the influence of different starting powders on flux pinning. Measurements of the magnetic critical current density ($J_c$) showed that it was possible to fabricate large Gd-123 single grain with a high $J_c$ at high temperatures and fields by means of properly controlling the starting powders of Gd$_2$O$_3$, BaCO$_3$, and CuO before the MTG process. © 2005 American Institute of Physics. [DOI: 10.1063/1.1846571]

I. INTRODUCTION

Since the discovery of high-temperature superconductors (HTSCs), their engineering applications at liquid-nitrogen temperatures and at fields have drawn much more attention. The large scale applications of HTSC materials are crucially dependent on their critical current density ($J_c$) and irreversibility field ($H_{irr}$). Unfortunately, a sintering sample of HTSC is of weak links and thus of very low $J_c$ and $H_{irr}$. To eliminate the weak links, the so-called melt-texture growth (MTG) process has been developed, enhancing $J_c$ significantly. To further improve $J_c$, the MTG process has been improved and tremendous progress has been made. It was pointed out that the high $J_c$ of the textured YBa$_2$Cu$_3$O$_{7-y}$ (Y-123) system originated from homogeneously dispersed fine Y$_2$BaCuO$_5$ (Y-211) particles. We note that the oxygen deficient clusters are effective to pin flux lines, especially at relatively low fields, and are responsible for the second peak effect in $J_c$.

An important progress on the MTG process for Y-123 materials is the substitution of Y by light rare earth (LRE: Nd, Sm, Eu, and Gd) elements. Contrasting with Y-123 compounds, the LRE–Ba–Cu–O (LRE-123) HTSCs have higher $J_c$ and $H_{irr}$, respectively. The LRE-123 systems easily form into weak links and thus of very low $J_c$ and $H_{irr}$. To eliminate the weak links, the so-called melt-texture growth (MTG) process has been developed, enhancing $J_c$ significantly. It was pointed out that the high $J_c$ of the textured YBa$_2$Cu$_3$O$_{7-y}$ (Y-123) system originated from homogeneously dispersed fine Y$_2$BaCuO$_5$ (Y-211) particles. We note that the oxygen deficient clusters are effective to pin flux lines, especially at relatively low fields, and are responsible for the second peak effect in $J_c$.

In addition, some amount of the LRE-BaCuO$_5$ (LRE-211) phase are added into the LRE-123 systems to improve the flux pinning. Because GdBa$_2$Cu$_3$O$_{7-y}$ (Gd-123) in the LRE-123 systems shows the slightest Gd–Ba substitution even when fabricated in air, and the “in air” processing will lower fabricating cost, the process of fabricating Gd-123 in air has received much more interests. In order to improve the electric-magnetic properties of Gd-123 in a wider field range, including low and high fields, we fabricated two types of large Gd-123 bulk materials using different starting powders by the in air processing.

II. EXPERIMENT

Two specimens were fabricated with the same nominal composition but different starting powders of Gd$_1.3$Ba$_{2.3}$Cu$_{3.3}$O$_{7-}$ and GdBa$_2$Cu$_3$O$_{5.4}$ and GdBa$_2$Cu$_3$O$_{5.4}$, which are denoted as S1 and S2, respectively. The Gd-123, Gd-211, and BaCuO$_2$ powders were synthesized from high-purity Gd$_2$O$_3$, BaCO$_3$, and CuO by solid-state reaction method, respectively. The precursor powder of sample S1 was prepared by mixing Gd$_2$O$_3$, BaCO$_3$, and CuO by solid-state reaction method, respectively. The precursor powder of sample S2 was prepared by mixing Gd$_2$O$_3$, BaCO$_3$, and CuO by solid-state reaction method, respectively. The precursor powder of sample S1 was prepared by mixing Gd$_2$O$_3$, BaCO$_3$, and CuO by solid-state reaction method, respectively. The precursor powder of sample S2 was prepared by mixing Gd$_2$O$_3$, BaCO$_3$, and CuO by solid-state reaction method, respectively.

To avoid excessive LRE-Ba substitution, variations of the MTG processes, such as postannealing in Ar atmosphere, using of Ba-rich precursors, and employing large crystallization rate, have been developed. In addition, some amount of the LRE-BaCuO$_5$ (LRE-211) phase are added into the LRE-123 systems to improve the flux pinning. Because GdBa$_2$Cu$_3$O$_{7-y}$ (Gd-123) in the LRE-123 systems shows the slightest Gd–Ba substitution even when fabricated in air, and the “in air” processing will lower fabricating cost, the process of fabricating Gd-123 in air has received much more interests.
top surfaces of the S1 and S2 pellets before the melt process- 
ing started. Al₂O₃ plates were chosen as substrates during the 
domain growth. In order to avoid the loss of the liquid phase 
in the period of the solidification, MgO single-crystal plates 
were used to separate the samples from the Al₂O₃ substrates.

The melting process was performed in an isothermal box 
furnace in air. The samples were heated at a rate of 
300 °C/h to 1070 °C so as to melt partially, which is above 
the peritectic temperature of the Gd-123 phase but below the 
one of Nd-123. After a 0.5–1 h holding, the temperature 
decreased rapidly to about 1060 °C, which is just above the 
peritectic transition temperature of Gd-123. Subsequently, 
the samples were cooled slowly to 1020 °C at a rate of 
0.3–0.5 °C/h and then cooled down to room temperature at a 
rate of 100 °C/h. The as-grown samples are nonsupercon-
ducting owing to low oxygen content. Therefore, a postan-
nealing in oxygen atmosphere is necessary. In this experi-
ment, the samples were annealed at 400 °C for 50 h in 
flowing oxygen. In this way, samples with a single domain 
and with a diameter of 25 mm were fabricated successfully.

Two samples of 4×2×0.2 mm³ were cut from S1 and 
S2, respectively, to conduct a magnetic measurement. The 
magnetization-temperature (M-T) measurement at 10-Gs 
field cooling showed that Tc of samples S1 and S2 are 90 and 
87 K, respectively. Magnetic hysteresis loops at various tem-
peratures and fields parallel to the c axis up to 7 T were 
carried out by means of a commercial vibrating sample mag-
netometer. The field sweep rate was dH/dt=0.12 T/min in 
the measurements.

III. RESULTS AND DISCUSSION

The field dependence of magnetization (M-H) for S1 
and S2 at different temperatures are shown in Fig. 1. Because 
of Jcს M, shown in Fig. 1 are in fact the field dependence of 
Jc. It is seen that at 20 K, the lowest temperature in our 
measurements, Jc of S2 is higher than that of S1 for all the 
applied fields (−7T≤H≤7T). This higher Jc of S2 at low 
temperatures and fields maybe related to the fact that S2 has 
fine Gd-211 particles in its starting powder, which were the 
effective pinning centers. Whereas in S1 less Gd-211 
might be on the precipice. Less Gd-211 phase means saving 
some Gd ions in S1. The saved Gd ions react with BaCuO₂, 
forming Gd₁ₓBa₂−ₓCu₃O₇ solid solution particles which are 
more effective pinning centers at higher temperatures and 
fields. This understanding is supported by the following fact. 
With elevated temperature, for example, at 60 and 74 K [see 
Figs. 1(b) and 1(c)], the Jc of S2 is still larger than that of S1 
only at low fields, whereas at the fields higher than a cross-
over field where Jc of S2 is equal to that of S1, the Jc of S1 
is higher than that of S2. This crossover of the Jc(H) rela-
tionship implies that the irreversibility field of S1 is higher 
than that of S2, as shown in Fig. 2. Because the temperature 
has been normalized with Tc, the higher Hirr of S1 does not 
result from its higher Tc. When the temperature ascends fur-
ther, say T=78 K [see Fig. 1(d)], the Jc of S1 is higher than 
that of S2 for the whole field (also −7 T≤H≤7 T), support-
ing the explanation further.

FIG. 1. Magnetic hysteresis loops of the samples (a) at T=20 K, (b): at T =60 K, (c): at T=74 K, and (d) at T=78 K.

FIG. 2. The irreversibility fields of samples S1 and S2.
Now we compare the magnetic critical current densities of our samples, which are estimated by the well-known extended Bean critical state model. As an example, the \( J_c \) vs magnetic field curves at 78 K for S1 and S2 are shown in Fig. 3. The \( J_c \) at zero magnetic field is of the same order of magnitude as reported. According to the above discussion, it is possible to further improve \( J_c \) of MTG Gd-123 bulk at different fields by properly controlling their starting powders, although more work is needed.

IV. CONCLUSIONS

In summary, cylindrical single grains of GdBa\(_2\)Cu\(_3\)O\(_y\) with a diameter of 25 mm were successfully fabricated in air in terms of different starting powders. The measurements showed that the starting powders influence the \( J_c \) vs magnetic field curve apparently. The sample with the Gd-211 addition in the starting powder has higher \( J_c \) at low temperatures and fields. On the other hand, the sample fabricated using Gd\(_{1.8}\)Ba\(_{2.4}\)Cu\(_{3.4}\)O\(_y\)+0.2BaCuO\(_2\) as starting powders has higher \( J_c \) at high temperatures and fields. The results suggested that it was possible to obtain a large Gd-123 single grain with high \( J_c \) by properly controlling the starting powder gradients by a simpler and cheaper process.

ACKNOWLEDGMENTS

This work was supported by the Ministry of Science and Technology of China (Grant No. G1999064602), National Nature Science foundation of China (NNSFC, Grant No. 19994016), and Open Foundation of Testing of Nanjing University (Grant No. 0204001308).

---


---

**FIG. 3.** The critical current densities vs applied magnetic field for S1 and S2 at 78 K.