www.sphinxsai.com

ChemTech

International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN : 0974-4290
Vol.6, No.3, pp 1699-1701, May-June 2014

ICMCT-2014 [10th – 12th March 2014]
International Conference on Materials and Characterization Techniques

Origin of Stable Critical Current Densities to High Applied Magnetic Fields in Ceria Doped YBCO Superconductors

P. Missak Swarup Raju[1], S. Pavan Kumar Naik[1], N. Devendra Kumar[3], T. Rajasekharan[2], V. Seshubai[1]

[1]School of Physics, University of Hyderabad, Hyderabad, India.
[2]Gandhi University of Knowledge Technologies, Vindhya C4, IIIT Campus, Hyderabad, India.
[3]S.U.P.R.A.T.E.C.S., University of Liège, Liège, Belgium.

Corres.author: swarupraj@gmail.com

Abstract : Present work is focused on understanding various defects and their effectiveness in pinning the flux lines at different applied magnetic fields. Nano-particle of Ceria were added to $YBa_2Cu_3O_{7-x}$/ Y_2BaCuO_5 (Y211) composite synthesized through preform optimized infiltration growth process in 2, 5 and 10 weight % and Critical current densities (J_c) in these composites were measured at 65 and 77 K. The micrographs obtained on these composites at different magnifications indicate refinement in Y-211 particle size and presence of defects in various length scales, starting from few nanometres to few microns. It has been proposed that the current density obtained in superconducting samples can be correlated to the size of the flux pinning defects occurring in them which is indicated by peak field where maximum pinning occurs. The samples in the present study exhibited a stable J_c values to high fields due to the presence of multiple peak fields. The present work brings fourth the origin of such stable J_c to high magnetic fields and their correlation with the observed flux pinning centers.
Keywords: YBCO superconductors; flux pinning; CeO_2 nanoparticles; critical current density.

Introduction and Experimental Details

The critical current density J_c is an important parameter which determines the potential of superconducting oxides with high critical temperatures (T_c) for practical applications. Elimination of weak links in sintered sample consequent improvement of J_c were achieved by Jin et al. [1] with the process called melt textured growth (MTG). Melt processed $REBa_2Cu_3O_{7-d}$(RE-123 for the present study RE=Y) containing Pt, CeO_2, ZrO_2 and $BaCeO_3$ have been widely studied because of the ability of these additives to considerably refine Y_2BaCuO_5(Y-211) grain size in the final product thus enhanced current densities in the materials. Infiltration and Growth (IG) process developed afterwards has addressed issues regarding shrinkage, pores, voids and larger Y-211 sizes in the final product fabricated through MTG process [2]. In order to sustain J_c to high fields, finer structural defects with continuous superconducting matrix is much desired. Hence it is interesting to study the effect and influence of grain refining nanoparticles in continuous matrix in sustaining J_c to high fields.

2, 5 and 10 wt. % of CeO_2 nanoparticles were added to the Y-211 powder through the solution route and then pressed into pallets to form preforms for IG process following a preform optimized Infiltration growth process(POIGP) as described by Devendra et al [3]. In the following discussions, for the sake of convenience, the preform samples containing 2, 5, and 10 wt. % ceria will be referred to as Ce-2, Ce-5 and Ce-10 respectively. Four probe DC electrical resistivity and AC susceptibility measurements were carried out in order to obtain T_c of these composites. The current densities (J_c) supported by the samples Ce-2, Ce-5 and Ce-10 as a function of applied magnetic field, were estimated from magnetic hysteresis loops recorded at different temperatures using a PPMS facility. Microstructural studies were carried out under Carl Zeiss made Field Emission Scanning Electron Microscope (FESEM).

Results and Discussion

The present work is aimed at understanding the J_c values at high fields. It is known from the literature that fine defects of the order of coherence length [4] responsible for pinning flux. The electrical resistivity and ac susceptibility of the samples Ce-2, Ce-5 and Ce-10 were measured as a function of temperature. The results are shown in Figs. 1 (a) and (b) respectively.

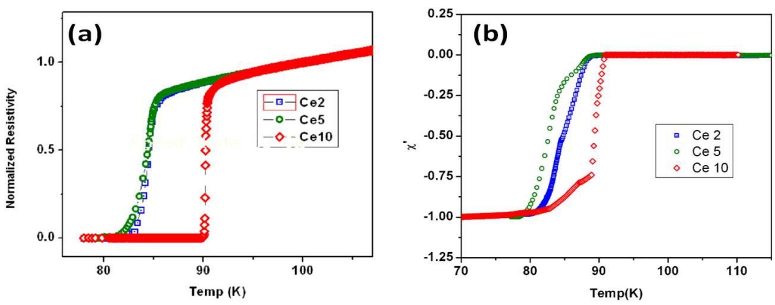

Fig. 1. (a) The electrical resistivity, and **(b)** the real part of ac susceptibility of the samples Ce-10 (diamond), Ce-2 (square) and Ce-5 (circle) are plotted with respect to temperature.

A shift in the diamagnetic transition to below 92 K and considerable width of the transition in χ' vs. T can be observed predominantly in Ce-2 and Ce-5. In the Ce-10 sample, there is a considerable amount of Y-123 phase with T_c close to 92 K, whereas in Ce-2 and Ce-5 samples, substantial part of the material consists of lower T_c phases. This can possibly be attributed to the dissolution of Ce in the Y-123 phase forming solid solutions having lower T_c. Cerium substitution in Y-123 lowers the T_c [5].

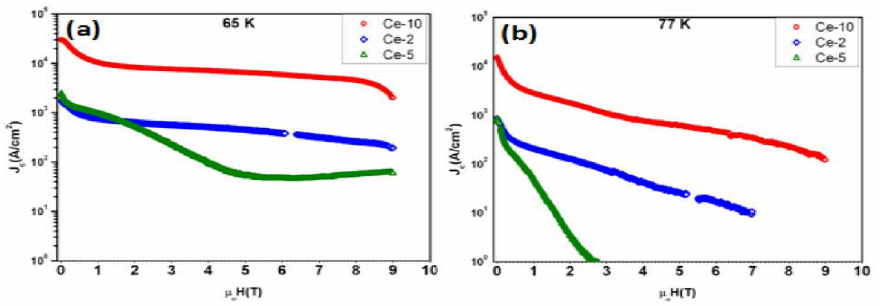

Fig. 2. J_c is plotted against applied magnetic field for the samples Ce-10 (red), Ce-2 (blue) and Ce-5 (green) at **(a)** 65 K, and **(b)** at 77 K.

The J_c(H) obtained in samples Ce-2, Ce-5 and Ce-10 at 65 K and 77 K are shown in Figs. 2 (a) and (b) respectively. Since, the observed variation in J_c(H) is not systematic with ceria content; we have repeated the complete experiment and confirmed that such an anomalous J_c(H) behaviour of the Ce-5 sample is reproducible. Fig. 3 shows the FE-SEM image of the Ce-5 sample in comparison with those of the Ce-2 and Ce-10 samples at the same magnification. It is observed from the low magnification picture of the Ce-5 sample that there is considerable amount of macro-porosity occurring as a result of improper infiltration. On the other hand the Ce-2 sample shows very little porosity, and the Ce-10 sample, almost none at all.

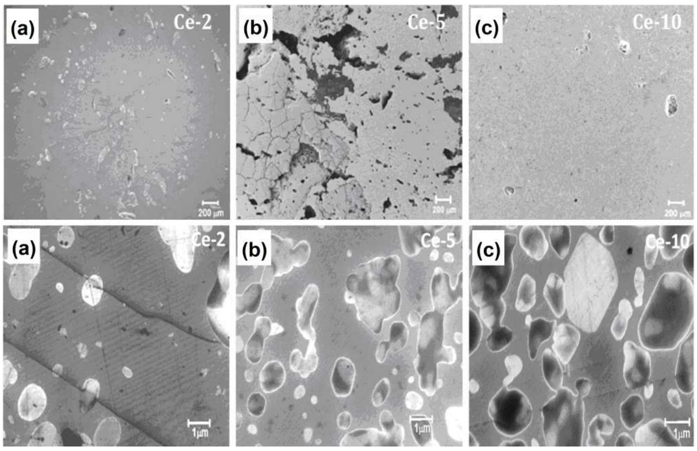

Fig. 3. It can be observed that there are very few macroscopic defects in the **(a)** Ce-2 sample and **(c)** the Ce-10 sample. **(b)** Large areas with macroscopic defects can be observed in the Ce-5 sample may be due to improper liquid phase infiltration.

It has been reported [6] that the current density obtained in superconducting samples can be correlated to the size of the flux pinning defects occurring in them, the equation $H_p = \frac{2\emptyset_0}{\sqrt{3}(a_f)^2}$, where H_p is the peak field at which the maximum pinning occurs, $\emptyset_0$ is the flux quantum and a_f is the vortex lattice spacing. High current density in the POIGP samples to high fields is a result of flux pinning defects occurring in the sample spanning wide size ranges [3]. The high values of J_c was correlated to the occurrence of wide spread twinning in the Y-123 matrix. Electron Back Scatter Diffraction (EBSD) suggested that the occurrence of fine defects around the Y-211 particles was associated with dense distribution of fine Y-211. The Ce-10 and Ce-2 samples show J_c values almost independent of H up to 9 T at 65 K. This might be correlated with the fine grain (≥ 1 µm) size of the Y-211. Fig. 3 shows twinning in all the CeO_2 doped samples, which indicated the presence of fine structural defects of the order of few lattice units. Absence of macro defects and observed twinning in Ce-2 and Ce-10 samples due to homogeneously distributed Y-211 and nanoparticles account for the observed flat J_c, which is almost independent of applied field up to 9 T at 65 K. A detailed study of flux pinning is under way to ascertain the above claims.

References

1. Jin S. Tiefel T.H. Sherwood R.C. Davis M.E. van Dover R.B. Kammlott G.W. Fastnacht R.A. and Keith H.D., High critical current density in Y-Ba-CuO superconductors, Applied Physics Letters. 1988, 52, 2074-2076.
2. Sudhakar Reddy E. and Rajasekharan T., Fabrication of textured $REBa_2Cu_3O_7/RE_2BaCuO_5$ (RE = Y, Gd) composites by infiltration and growth of RE_2BaCuO_5 preforms by liquid phases, *Superconductor Science Technology*, 1998, 11, 523–534.
3. Devendra Kumar N. Rajasekharan T. Ravi C. Gundakaram and Vummethala Seshubai, Extensive Nanotwinning: Origin of High Current Density to High Fields in Preform-Optimized Infiltration-Growth-Processed YBa2Cu3O7−δ Superconductor, *IEEE transactions on applied superconductivity*, 2011, 21, 3612-3619.
4. Batlogg B., Physical Properties of High- T_c Superconductors, *Physics Today*, 1991, 44, 44.
5. Monot I. Verbist K. Hervieu M. Laffez P. Delamare M.P. Wang J. Desgardin G. and Van Tendeloo G., Microstructure and flux pinning properties of melt textured grown doped $YBa_2Cu_3O_{7-\delta}$, *Physica C*, 1997, 274, 253-266.
6. Suematsu H. Okamura H. Nagaya S. and Yamauchi H., Role of the twin boundary for the occurrence of peak effect in Y-Ba-Cu-O superconducting bulks melt grown under varied oxygen pressure, Supercond. Sci. Technol., 1999, 12, 274.

*****