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Magnetic Properties of a Melt-Textured Pellet of $(Nd_{0.33}Eu_{0.38}Gd_{0.28})Ba_2Cu_3O_y$ + 0.035 mol% Zn

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Recently, a striking positive effect of tiny Zn doping on crystal growth quality has been found in melt-textured (Nd,Eu,Gd)$Ba_2Cu_3O_y$ pellets. The material could be easily grown from MgO seed, possessing a rather high lattice mismatch to the superconducting compound. In the present work we study spatial distribution of local magnetic properties and chemical composition of a $(Nd_{0.33}Eu_{0.38}Gd_{0.28})Ba_2Cu_3O_y$+0.035 mol% Zn pellet. The plane cutting the pellet into two halves along the symmetry axes of the opposite *a*-axis growth sectors is investigated. While the chemical composition only slightly fluctuates, magnetic properties show quite an interesting spatial variation.

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1. Introduction

Melt-textured RE-$Ba_2Cu_3O_y$ pellets (RE=rare earth) of a few cm in diameter are capable of trapping magnetic fields of tens Tesla (the present record, achieved between two $YBa_2Cu_3O_y$ pellets of 26.5 mm diameter, cooled to 29 K, reaches 17.24 Tesla [1]). But LRE-$Ba_2Cu_3O_y$ compounds with LRE=Sm, Nd, Eu, Gd exhibit significantly better electromagnetic properties than $YBa_2Cu_3O_y$. Evidently, these materials are big candidates for being magnetic hearts of small mobile diagnostic and other devices, with the main advantage of the compactness and magnetic field strength. The dominance of LRE-$Ba_2Cu_3O_y$ superconductors stacks in the ability of LRE elements to exchange positions with Ba atoms. This effect, called solid solution, introduces an exceptionally effective point-like pinning disorder to the superconducting lattice, capable of an effective pinning

of magnetic fluxons. Excellence in this direction belongs to the ternary compounds (Nd,Eu,Gd)$Ba_2Cu_3O_y$, especially those with the Nd:Eu:Gd ratio around 33:38:28, where a structure of nanoscopic lamellas appears, filling the channels between regular twin boundaries and thus significantly increasing the irreversibility field [2]. Such bulk materials, however, have suffered from spatial inhomogeneity and any improvement in this direction would imply also improvement in macroscopic electromagnetic characteristics. Recently, it has been found that an addition of a small amount of Zn strikingly improves the crystal growth quality in $(Nd_{0.33}Eu_{0.33}Gd_{0.33})Ba_2Cu_3O_y$ [3]. Moreover, this material could be easily grown from MgO seed, having a significant lattice mismatch with respect to the superconducting matter. In the present work we study magnetic properties and chemical composition profile over a $(Nd_{0.33}Eu_{0.38}Gd_{0.28})Ba_2Cu_3O_y$+0.035 mol% Zn pellet prepared by this novel technique.

2. Experimental

The $(Nd_{0.33}Eu_{0.38}Gd_{0.28})Ba_2Cu_3O_y$ "NEG-123" pellet was produced from high-purity commercial powders of Nd_2O_3, Eu_2O_3, Gd_2O_3, $BaCO_3$, and CuO mixed in nominal composition. The starting powders were thoroughly grounded and calcined at 880°C for 24 h with intermediate grinding. Sintering was carried out at 900°C for 15 h at Ar/0.1% O_2. 5 mol% of the NEG-211 powder was added, together with 0.5 mol% Pt, to refine the NEG-211 particles, and 0.035 mol% ZnO, to improve growth control of the compound. The well-mixed powders were pressed into pellets 20 mm in diameter and 10 mm thick, consolidated by cold isostatic pressing to 200 MPa, and melt-grown in Ar/0.1% O_2 atmosphere and gas flow of 300 ml/min [3]. By means of the high-resolution X-ray powder difractometer RINT2200 we found that the sample was single-phase with less than 3 mol% of the secondary phase. The chemical profile analysis, based on the X-ray emission spectrometry and the X-ray mapping image analysis, was studied by means of the electron microprobe JXA-733 JEOL on the cut plane running through the middle of the pellet (see Fig. 1 left). For magnetic measurements

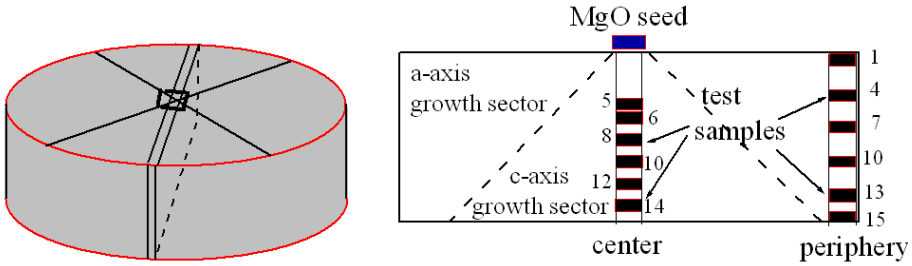

Fig. 1. Sketch of the investigated pellet with the marked position of the studied platelet (left); scheme of this platelet with marked positions of the magnetic test samples 1.5 × 1.5 × 0.4 mm^3 in size, shown as small black boxes (right).

three series of samples of $a \times b \times c = 1.5 \times 1.5 \times 0.4$ mm^3 in size were cut as indicated in Fig. 1 right. Magnetic hysteresis loops (MHLs) were measured by vibrating sample magnetometer in fields from –2 to +9 T at 77 K, with magnetic field applied parallel to the c-axis. The magnetic J_c values were estimated using the extended Bean critical state model, $J_c = 2\Delta m/[a^2c(b - a/3)]$, where c is the sample thickness, a and b are the transverse dimensions ($b \geq a$), and Δm is the MHL in magnetic moment units.

3. Experimental results

The magnetic study showed interesting results. While magnetic properties at the pellet periphery exhibited a very small variation (Fig. 2a), at the pellet center they significantly varied, especially as regards the secondary peak appearance (Fig. 2b). The samples 1, 4, 7, and 10 from the pellet periphery exhibited practi-

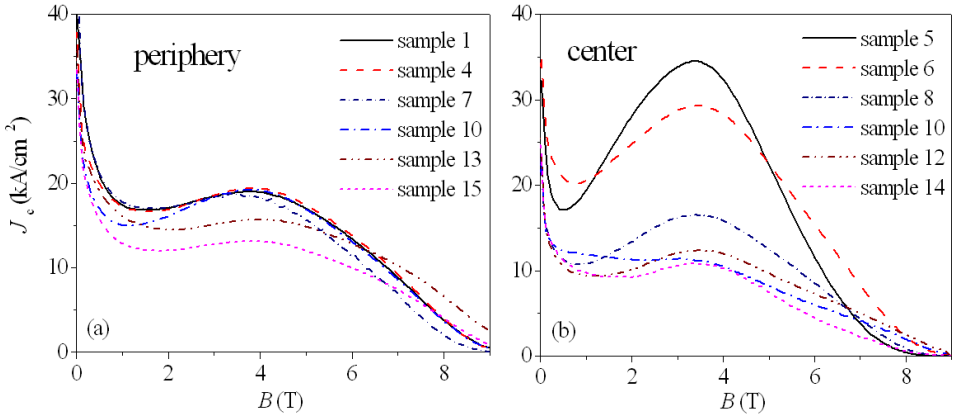

Fig. 2. Comparison of magnetic hysteresis loops measured at 77 K on a series of samples at the pellet periphery (a) and at the pellet center (b). Samples are marked starting from the pellet top towards the pellet bottom.

cally identical MHLs, only two samples closer to the pellet bottom had a slightly lower secondary peak but a significantly higher irreversibility field, especially sample 13. Surprising is also the rather high central peak of nearly constant height (the graphs are not normalized). Let us note that all these samples originated from the a-axis growth sector (central part of the pellet). On the other hand, the samples from the c-axis growth sector showed a strong magnetic property fluctuation. Samples 5 and 6 from this series exhibited an exceptionally high secondary peak and a relatively low irreversibility field. For the rest of the samples, the secondary peak decreased with increasing distance from the seed and finished with a rather low height, quite stable in the bottom samples (Nos. 10–14). Simultaneously, the irreversibility field slightly increased. In all cases, with only one exception, a high-field shoulder appeared on the $J_c(D)$ dependence, indicating the presence of the

nanoscale lamellar substructure filling regular twin plane channels, characteristic of the Eu excess around Eu:Gd=38:28 [2]. This structure with lamellae width and period of 3–5 nm is commensurate with vortex core dimension and prevents thus vortex matter channeling along the twin plane channels. This phenomenon is exceptionally effective at high magnetic fields and enhances irreversibility field by factor nearly 2 [2]. The shoulder was particularly evident in the peripheral sample 13, giving rise to the irreversibility field significantly above 9 T. The very high secondary peak in samples 5 and 6 from the center series might be attributed to both the LRE/Ba solid solution and oxygen deficiency. Both these sources contribute to the point-like pinning disorder, responsible for the secondary peak formation. At the moment, we can only speculate on the exact proportion between these two sources. Let us note that these samples did not exhibit the high-field shoulder and, consistently, had the lowest irreversibility field of all the investigated samples. This fact might imply a possibility of an insufficient pellet oxygenation in its center (in spite of the one week long oxygenation process). A common annealing of different small test samples in flowing oxygen is under way. This should answer this question. With respect to the high-field shoulder appearance and variation, the chemical microanalysis was mainly focused on the Nd:Eu:Gd ratio fluctuation. The study showed a systematic shift from the nominal ratio Nd:Eu:Gd=33:38:28 to 29:46:25 but a rather low fluctuation over the pellet volume, inconsistent with the rather strong fluctuation of magnetic properties in the central zone. Further annealing in oxygen and its effect on the local magnetic properties should elucidate the persisting questions. Our study indicates a still wide space for technology optimization. We believe that statistical studies like the present one will significantly help in this point.

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