Journal of Optoelectronics and Advanced Materials Vol. 7, No. 1, February 2005, p. 427 - 430

EFFECT OF SILVER ADDITION ON THE SUPERCONDUCTING PROPERTIES OF $LaBa_2Cu_3O_{7-\delta}$ CERAMICS

E. Nazarova*, K. Nenkov[a,b], A. Angelow, A. Zahariev

Institute of Solid State Physics, Bulgarian Academy of Sciences, 72 Tzarigradsko Chaussee Blvd., 1784 Sofia, Bulgaria.
[a]IFW, Institute of Solid State and Materials Research, P.O. BOX 270016, D-01171 Dresden, Germany
[b]International Laboratory of High Magnetic Fields and Low Temperatures, Gajowicka 95, 53-529 Wroclaw, Poland

The behavior of the AC magnetic susceptibility, as a function of temperature and the external magnetic field, has been investigated for sintered $LaBa_2Cu_3O_{7-\delta}$ (La123) and La123 + 20wt% Ag specimens. It has been observed that the screening capabilities are smaller for the Ag-doped sample, and that the irreversibility line is degraded as well. The constant temperature magnetic susceptibility decreases with visible oscillations in both types of sample, due to Josephson junction effects. These observations have been explained by different order parameter suppression at the superconductor-insulator (S-I) and superconductor-normal metal (S-N) interfaces.

(Received December 9, 2004; accepted January 26, 2005)

Keywords: Sintered La123, Ag additions, Magnetic properties, Quantum oscillations

1. Introduction

Recently, Ag has been used for welding different YBCO domains [1] and for increasing the material tensile strength in order to trap high magnetic fields (12 T at 20 K) [2]. The influence of Ag addition on the magnetic properties of 123 superconductors is very important for such practical applications. Usually a YBCO+Ag system has been investigated, but even in this case the results for $J_c(B)$ are controversial and depend on the processing conditions [3-5].

The latest developments for light rare earth (Re) superconductors of 123 type shows that substitution of Re atoms on the Ba sites raises the flux pinning in these compounds and makes them better than good quality Y123 [6]. The evolution of the flux pinning attributed to variable compositional fluctuations has been investigated in melt-processed ternary $(Sm,Eu,Gd)Ba_2Cu_3O_{7-\delta}$ superconductors [7]. Thorough research is needed for practical exploitation of these compounds. The effect of Ag addition to the ReBCO superconductors is also not sufficiently investigated, either for melt texture growth materials or for samples obtained by the solid-state reaction method.

It has previously been established that the current path in the Ag doped $LaBa_2Cu_3O_{7-\delta}$ bulk samples is based on the proximity-coupled grains, and that the $J_c(T)_{H=0}$ dependence below T_c is quadratic [8]. By increasing the Ag content up to 20 wt %, J_c(77K) has been increased by almost one order of magnitude compared to the non-doped compound [9]. In this paper, we investigate the influence of the magnetic field on the S-I-S and S-N-S (S = superconductor, I = insulator, n = normal metal) coupled grains in pure and 20 wt % Ag doped $LaBa_2Cu_3O_{7-\delta}$ samples.

* Corresponding author: nazarova@issp.bas.bg

2. Experimental details

The samples investigated, $LaBa_2Cu_3O_{7-\delta}$ (La123) and $LaBa_2Cu_3O_{7-\delta}$ + 20 wt% Ag (La123+Ag), were prepared by the solid-state reaction method described in detail previously [9]. $AgNO_2$ was finally added to the calcined powder for preparation of the La123+Ag specimen. Samples were characterized by SEM and XRD analysis. The AC magnetic susceptibility was measured with a Lake Shore 7000 Series Susceptometer. For measurements of the constant temperature susceptibility as a function of the magnetic field, a Quantum Design PPMS was used.

3. Results and discussion

Fig. 1 shows the temperature dependences of the AC magnetic susceptibility for both types of sample. For the La123 specimen, broad intra-grain and inter-grain transitions are observed starting at T_{cintra} = 80 K and T_{cinter} = 48 K respectively. Similar behavior is seen for the Ag doped sample, but T_{cintra} and T_{cinter} are about 7 to 8 K lower than in La123. Only one χ'' peak reflecting the AC losses in the inter-granular region is observed, because the value of the AC magnetic field used is too small to penetrate the individual grains.

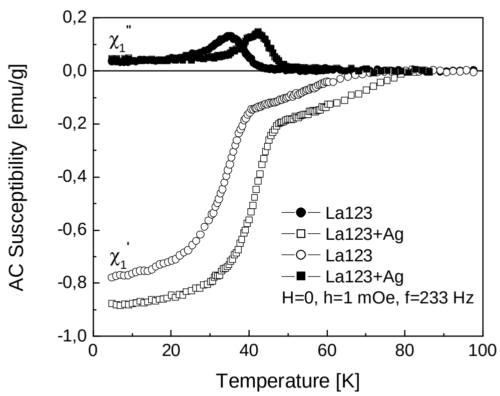

Fig. 1. AC magnetic susceptibility as a function of temperature.

Unlike the YBCO system, which forms only a stoichiometric compound, La123 forms a solid solution $La_{1+x}Ba_{2-x}Cu_3O_y$, due to the La^{3+} - Ba^{2+} substitution. Superconductivity in both systems is dependent on the hole concentration in the CuO_2 planes. Substitution of La (3+ valence) for Ba (2+ valence) increases the number of electrons. For charge compensation, a reduction of the formal copper valence or an increase in the oxygen content may occur. In both cases, this causes the critical temperature to go down. T_{cintra} values for our samples are of the order of 80 K and we attribute this to the presence of anti-site defects in them. Both samples are orthorhombic, with similar lattice parameters (a = 3.8764 Å, b = 3.9292 Å and c = 11,7878 Å for La123, and a = 3.8909 Å, b=3.9454 Å and c=11.8161 Å for La123+Ag sample). This means that Ag does not enter the crystallographic structure of the 123 compound. It has been observed to give individual peaks in the X-ray diffractograms. SEM investigations also support this by showing the absence of Ag atoms in the grain structure. Ag is randomly distributed through the specimen between the grains. Therefore, different grain boundary conditions exist in doped and non-doped samples. The variations of the grain boundary content significantly influence the inter-granular current in the absence of a magnetic field [8], and suppress the screening capabilities of La123+Ag when an AC magnetic field is applied.

We also investigated the behavior of the AC magnetic susceptibility for both samples, in the presence of small DC fields. In Fig.2 (a,b), the temperature dependences of the AC magnetic susceptibility for different DC magnetic fields are presented for both samples. We established that the DC fields used do not influence the intra-granular transition in La123+Ag and La123 samples. However the inter-granular transition is strongly affected by the presence of a DC field, and the effect is higher for La123+Ag. On increasing the value of the DC magnetic field, the temperature at which the AC loss peak appears in the compound decreases. Using these experimental results, we constructed the irreversibility lines for both samples, as presented in the Fig.3. Comparison of the irreversibility lines for La123 and La123+Ag indicates that the nonlinear AC response in the

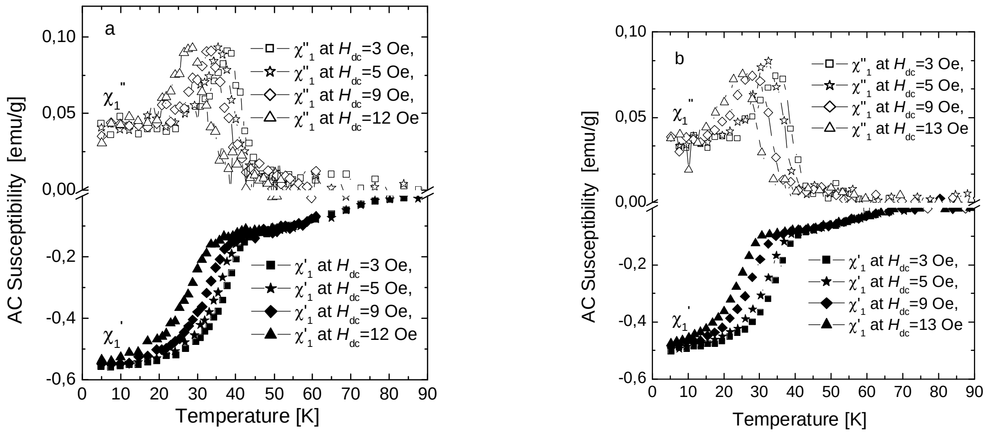

Fig. 2. AC magnetic susceptibility as a function of temperature for undoped (a) and Ag-doped (b) samples at different magnetic fields H_{dc}; h_{ac} = 1 mOe, f = 233 Hz.

Ag-doped sample starts at lower values of (H, T) than in the undoped one. Similar results have been obtained when a modulus of third harmonics has been used to construct the irreversibility line. Ag inclusions do not act as pinning centers [10]. Therefore, the reduction of the screening in the Ag-doped sample could result from order parameter depression near the S-N-S grain interface.

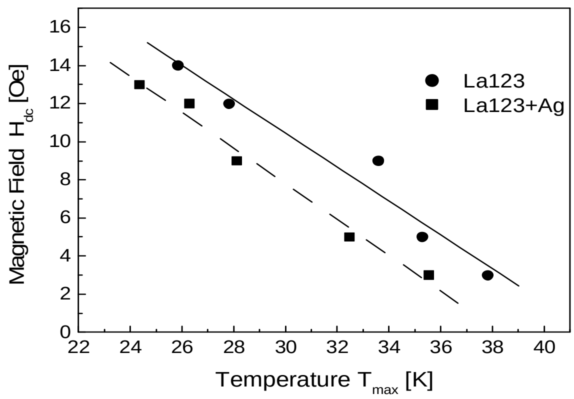

Fig. 3. Irreversibility lines determined from the χ''_1. The lines present the best linear fit.

The main contributing factors to the value of the tunnel current are: (1) the value of the order parameter in the bulk superconducting material and its reduction at the interface, (2) the reduction of the order parameter after crossing the boundary. The exact boundary conditions are defined in terms of an extrapolation length "b" defined as the distance in the non-superconducting material at which the order parameter falls to zero [11]. Let us compare the boundary conditions for S-N and S-I boundary at low temperatures. In the presence of magnetic field we have an inter-granular current path in both samples only at low temperatures (far from T_c). The normal metal coherence length, ξ_N, becomes large at these temperatures. For example, ξ_N = 66 nm at 4 K for Ag, instead of 15 nm at 77 K [12]. The order parameter on the S side is reduced, together with the extrapolation length in the normal metal (b_N). In contrast, at the S-I interface some recovery of order parameter on the S side exists, and the extrapolation length in the I side (b_I) is larger than b_N. As a result, the current screening in the La123 sample is higher than that in the La123+Ag one.

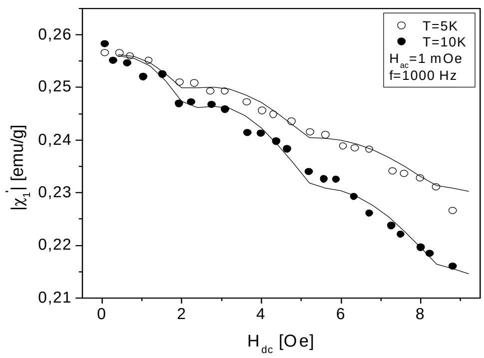

Fig. 4. Behaviour of χ_1' as a function of the applied magnetic field at different temperatures, for the La123 sample. The lines represent theoretical approximations of experimental data with sin(x)/x, appropriately normalized and expanded.

In order to check the applicability of this scheme to our samples, we investigated the dependence of the constant temperature χ_1' as a function of magnetic field. The temperature and the applied magnetic field have to be low enough to save the inter-grain connections. In both samples, we observed that the value of the susceptibility decreases, with visible oscillations due to Josephson junction effects. The oscillations were suppressed on increasing the values of the temperature and magnetic field (Fig. 4). This is a result of the progressive disconnection of junctions. It is more sensitive in the S-N-S network, due to further order parameter depression by the magnetic field. Finally, χ_1' becomes controlled by the diamagnetic properties of the grains.

4. Conclusions

We have demonstrated that S-I-S and S-N-S Josephson junctions govern the behavior of our bulk La123 and La123+Ag samples in low magnetic fields. The small screening capabilities of the Ag-doped sample are explained by the higher suppression of the order parameter and extrapolation length at S-N interface in comparison to the S-I one, at low temperatures and magnetic fields.

References

[1] S. Iliescu, X. Granados, E. Bartome, S. Sena, A. E. Carrillo, T. Puig, X. Obrados, J. E. Evetts, Supercond. Sci. Technol. **17,** 182 (2004).
[2] S. Gruss, G. Fuchs, G. Krabbes, P. Verges, G. Stover, K. H. Muller, J. Fink, L. Schultz, Appl. Phys. Lett. **79**, 3131 (2001).
[3] E. S. Vlakhov, V. T. Kovachev, M. Polak, M. Majoros, Y. B. Dimitriev, S. Jambazov, E. Kashchieva, A. Staneva, Physica C **175**, 335 (1991).
[4] D. Pavuna, H. Berger, M. Affronte, J. Van der Mass, J. J. Capponi, M. Guillot, P. Lejay, L. J. Tholence, Solid State Commun., **68**, 353 (1988).
[5] D. F. Lee, X. Chaud, K. Salama, Physica C **181**, 81 (1991).
[6] M. Murakami, N. Sakai, T. Higuchi, S. I. Yoo, Supercond. Sci. Technol. **9**, 1015 (1996).
[7] A. Hu, N. Sakai, G. Zhou, K. Inoue, N. Chikumoto, M. Murakami, Physica C **402**, 127 (2004).
[8] E. Nazarova, A. Zahariev, A. Angelow, K. Nenkov, J. Supercond. **13**, 329 (2000).
[9] E. Nazarova, M. Kostova, A. Zahariev, I. Iordanov, Cond. Matt. Mater. Comm. **2**,31 (1995).
[10] E. Nazarova, K. Nenkov, Proc. 11th Intern. School on Cond. Matter Phys., Varna, Ed. J. M. Marshall, A. G. Petrov, A. Vavrek, D. Nesheva, D. Dimova and J. M. Maud, UK, 2000, p.388
[11] G. Deutscher, Physica C **153-155**, 15 (1988).
[12] K. A. Delin, A. W. Kleinsasser, Supercond. Sci. Technol. **9**, 227 (1996).