WBP6-1

Improvement of critical current densities for Hf, Ce and La doped Gd123 thin film fabricated by fluorine-free MOD method

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Copper oxide superconductors have been expected for the next generation superconducting wire materials because of their high T_c and J_c in magnetic fields. In this study we have fabricated Hf, Ce and La doped Gd123 films by the fluorine-free MOD method to improve J_c. T_c indicated around 92 K and it didn't change for Hf and La doped films. J_c increased by about 63 % at 77.3 K and 1 T for 2 mol% Hf doped film than that for non-doped film. Furthermore we found the improvement of the crystal structure by La doping. Additionally, J_c indicated 3.10 MA cm^{-2} at 77.3 K and 0 T, and 0.32 MA cm^{-2} at 77.3 K and 1 T for 2 mol% Hf and 1 mol% La doped film. J_c increased by about 50 % at 77.3 K and 0 T for 2 mol% Hf and 1 mol% La doped film than that for 2 mol% Hf doped film. Jc increased by about 68 % at 77.3 K and 1 T for 2 mol% Hf and 1 mol% La doped film than that for non-doped film. We analyzed the density of effective pinning center (n_{eff}) according to the single vortex theory. n_{eff} indicated 7.74 m^{-2} and increased by about 95 % at 4.2 K for 2 mol% Hf doped film than that for non-doped film. In conclusion, the effective APCs in magnetic fields were introduced by Hf doping and the improvement of the crystallization was observed by La doping. We also have studied the optimization of the heat treatment condition and investigated the properties of Ce doped film to improve J-$_c$ further.

Keywords: fluorine-free metal organic deposition, GdBa2Cu3Oy, Hf, Ce and La doping

WBP6-2

Film thickness dependence of in-field J_c in (Y,Gd)BaCuO+$BaMO_3$ (M=Zr, Hf) nanoparticle CCs

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$REBa_2Cu_3O_y$ (REBCO) coated conductors (CCs) derived from the Trifluoroacetate-Metal Organic Deposition (TFA-MOD) process are a promising candidate for magnet applications because of the low-cost and the high critical current density (J_c). However, practical applications, such as MRI, generators, etc., require further enhancement of the in-field critical current (I_c). For high in-field I_c, increasing film thickness and the suppression of the formation of large second phase precipitates and uniform dispersion of pinning centers are important. So far, we have succeeded in obtaining high in-field I_c by controlling the crystal growth rate and introducing $BaZrO_3$ nanoparticles (BZO NPs) into the TFA-MOD $(Y_{0.77}Gd_{0.23})Ba_2Cu_3O_y$ (YGdBCO) CCs [1]. Recently, we have reported more improvement of in-field J_c by introducing $BaHfO_3$ (BHO) NPs instead of BZO NPs because of the former's higher NP density and smaller NPs size [2]. However, the effect of film thickness dependence of in-field J_c is not yet clear.

In order to investigate the film thickness dependence of the magnetic field (B) = 0.3 T, we prepared 12 vol.% BHO doped YGdBCO (+12BHO) CCs with various thicknesses. We found several common characteristics obtained in samples prepared by both pulsed laser deposition (PLD) and MOD REBCO CCs. For thinner films (d < 400 nm), a rapid decay of J_c (J_c μ $1/d^{0.5}$) is observed for with and without BHO NPs. For thicker films, the J_c value is almost constant. These thickness dependences of J_c may be caused by the change from 2D pinning to 3D pinning. We will discuss the influence of natural defects and BHO NPs on the thickness dependence of J_c in MOD-REBCO CCs based on a theoretical pinning model.

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Keywords: Critical Current, MOD, Thickness Dependence, Nanoparticle

WBP6-3

The influence of carrier density on the in-field J_c of (Y,Gd)BCO+BZO CCs

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Trifluoroacetate-metal organic deposition (TFA-MOD) produced $REBa_2Cu_3O_y$ (REBCO) coated conductors (CCs) are an important research subject because of the potential for low-cost and excellent superconducting properties. A high critical current density (J_c) in magnetic field for REBCO CCs is critical for magnetic applications. For the enhancement of the in-field J_c, there are two ways: 1) introducing pinning centers, and 2) carrier density control. So far, we have succeeded in obtaining higher in-field J_c by adding $BaZrO_3$ nanoparticles (BZO NPs) in TFA-MOD $(Y_{0.77}Gd_{0.23})Ba_2Cu_3O_{7-\delta}$ CCs ((Y,Gd)BCO+BZO) [1, 2]. However, the influence of the carrier density on the superconducting properties of TFA-MOD (Y,Gd)BCO+BZO CCs is not clear. In this work, in order to investigate the influence of carrier density on superconducting properties, we fabricated $(Y,Gd)Ba_2Cu_3O_y$ and $(Y,Gd)Ba_2Cu_3O_y$+BZO CCs with various post annealing conditions. The (Y,Gd)BCO+BZO CC with optimum annealing conditions shows higher carrier density at 300 K and higher self-field J_c ($J_c^{s.f.}$) compared with that of other conditions. Moreover, the in-field J_c of (Y,Gd)BCO+BZO CC with optimum conditions is higher. We will discuss the mechanism of the improvement of the superconducting properties based on crystallinity, carrier density, critical temperature and self-field J_c.

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Keywords: Critical current, O2 Anneal, BZO, TFA-MOD

WBP6-4

Investigation of interim heat treatment process on TFA-MOD method for production of $BaZrO_3$ added $REBa_2Cu_3O_y$ coated conductors with high in-field performance

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The trifluoroacetate metal-organic deposition (TFA-MOD) method has been commonly recognized as a low-cost technique for production of $REBa_2Cu_3O_y$ (RE: rare-earth, REBCO) coated conductors (CCs), and also considered as having a slightly lower superconducting property comparing with the CCs by the vapour method. On the other hand, low cost CCs with high performance in the magnetic-field have been required for electric power applications. In our previous study, we have developed two new techniques which were called interim-heat-treatment (IHT) [1] and ultrathin-once-coating (UTOC) [2] in order to enhance the in-field critical current density ($J_c(B)$) of $BaMO_3$ (M: metal element) added MOD-REBCO CCs, and achieved significant improvement of the $J_c(B)$ property of CCs. The IHT technique is a process to form an appropriate precursor film before the crystallization process of the REBCO, and the fundamental theoretical analysis of the IHT technique was previously reported [1]. In this study, we have investigated and optimized the effects of IHT atmosphere on the $J_c(B)$ performance of $BaZrO_3$ added $Y_{0.77}Gd_{0.23}Ba_2Cu_3O_y$ (YGdBCO/BZO) CCs. XRD measurements of the film after IHT at 580°C for 240 min under argon atmosphere confirmed the significantly coarsening of CuO. On the other hand, significantly coarsening of CuO was not observed in the film after IHT under oxygen atmosphere. The coarsening of CuO in IHT films is not good for obtaining high superconducting performance of YGdBCO/BZO CCs since that may cause of formation of *a*-axis orientation during the crystallization step [3]. The high $J_c(B)$ value at 77 K and 3 T (*B*//*c*) of >0.5 MA/cm^2 was obtained for YGdBCO/BHO CC with IHT at 580°C for 240 min under oxygen atmosphere.
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