Intrinsic pinning in Fe- and Cu-based superconductors

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Besides strong thermal fluctuations due to the small coherence length and relatively high critical temperature, vortex matter in Fe and Cu-based superconductors share other characteristics such as their layered structure. These in turn have important consequences in determining how vortices are trapped by different pinning potentials. Angular dependent critical current measurements are extremely useful to determine in which way vortices are trapped and how effective different pinning centers are. It is also important to extract all the information available about vortex dynamic from non-linear transport experiment; namely analyze the power-law dependence often found between electric field and applied current. The exponent N, gives important microscopic information about the depinning processes that vortices undergo.

A common feature among iron and cuprate high temperature superconductors is the layered structure; consisting of intercalated conducting and insulating planes. This intrinsic layering gives rise to the electronic mass anisotropy as well as a periodic planar pinning potential. Depending on the insulating layer size the anisotropy of the compound can vary from close to 1 up to hundreds for Bismuth- or Mercury-based superconductors. The effect on vortices, also known as intrinsic-pinning, of these periodic planar potentials should not depend on the specifics of different materials but rather be universal. In this talk I will show transport measurements, consistent of critical current and N values, of the different angular regimes of the vortex dynamics that confirm the generality of the intrinsic pinning found in YBCO films as well as in iron based superconductors.

We will explore theoretical description of these angular regimes, both in the 3D vortex regime where vortices are considered as continuous lines, as well as in the 2D regime where vortices along the ab-planes are considered to be pancake like.

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In-field Critical Current Density of BaHfO$_3$ doped PLD-REBCO Coated Conductors

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BaHfO$_3$ (BHO) doping into pulsed laser deposition (PLD) processed REBa$_2$Cu$_3$O$_{7-\delta}$ (RE=rare earth, REBCO) coated conductor (CC) is one of the most promising methods for introduction of artificial pinning centers (APCs) because enhanced critical current density ($J_c$) can be maintained for thick superconducting layer over 2μm [1]. We also reported BHO doped GdBCO CC shows superior in-field $J_c$ [2]. However, the effectiveness to different rare-earth composites such as SmBCO and EuBCO which is expected to be possible CCs for superconducting power devices is not yet clarified. In this study, we have investigated current transport property of PLD-REBCO CCs (RE=Sm, Eu, Gd) doped with 3.5mol% BHO. As a comparison with GdBCO CC without APCs [3], enhancement of in-filed $J_c$ has been confirmed as shown in Figure 1. This result indicates that BHO doping into SmBCO and EuBCO CCs is very effective for in-field $J_c$ enhancement around liquid nitrogen temperature. To draw a $J_c$ map on a $B$-$T$ plane which is useful for considering the design of superconducting devices taking into account the operation conditions, we also discuss the analytical expression of current transport property based on the percolation transition model and scaling law of the flux pinning.

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Figure 1. In-field $J_c$ characteristics for various PLD processed REBCO CCs (RE=Sm, Eu, Gd) at 77K and 65K.
Atomic scale characterization of REBa$_2$Cu$_3$O$_{7-\delta}$ films with BaHfO$_3$ artificial pinning centers by high resolution scanning transmission electron microscopy

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Critical current ($I_c$) of superconductor (SC) films under magnetic field is strongly influenced by not only dispersions but also morphologies of artificial pinning centers (APCs) in general. Moreover, nanostrains caused by lattice mismatch at the interface between APCs and SCs are similarly the source for the enhanced vortex pinning of the SCs [1]. BaHfO$_3$ (BHO) is acknowledged as the best candidates of APCs for REBa$_2$Cu$_3$O$_{7-\delta}$ (REBCO), which shows utmost thickness dependence and isotropic angular dependence of $I_c$ values for REBCO [2]. Therefore, it is necessary to investigate the nanostrains present at the interface between APCs and the SCs, at the atomic scale precision.

BHO introduced REBCO (RE = Gd, Eu) films were fabricated by pulsed laser deposition method. Samples for high resolution scanning transmission electron microscopy (HR-STEM) observation were prepared by ion beam method. Atomic scale imaging was performed by spherical aberration corrected STEM (JEM-ARM200F), then microstructures of BHO/REBCO interface was then examined by Fourier transformation (FFT), inverse Fourier transformation (IFFT) and Geometrical Phase Analysis (GPA) methods.

BHO nanorods and nanoparticles were dispersed within the REBCO, where {100} and {110} facets with misfit dislocations were present at their interfaces, as shown in Fig. 1. It was also that high strain regions were present around misfit dislocations.

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![Figure 1. Atomic scale characterization of misfit dislocations at BHO/GdBCO interfaces.](image-url)
Minimization of nanoparticle size of flux pinning centers in YBa$_2$Cu$_3$O$_y$ films by TFA-MOD process

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REBa$_2$Cu$_3$O$_y$ (REBCO, RE is rare earth element such as Y and Gd) coated conductors have been considered as the strategic materials for electric power industries, such as energy transports, energy storages and coil applications [1]. Although YBCO is the promising material among those REBCOs due to its high critical current density ($J_c$) over 1 MA/cm$^2$ at 77 K in self-field, its $J_c$ decreases with the increase of magnetic fields which makes YBCO incapable for industrial applications. Recently, improvement of $J_c$ in magnetic field has been performed by introducing flux pinning centers into the YBCO film artificially [2]. There are close correlation between $J_c$ and the pinning centers [3], so that the microstructures of pinning centers have to be controlled carefully to optimize $J_c$ characteristics effectively.

In this work, YBCO films with BaMO$_3$ (BMO, M = Zr, Hf) nanoparticles were fabricated by a metal organic deposition (MOD) method using trifluoroacetates (TFA). An additional heating process was introduced between calcination and crystallization intentionally to minimize the size of BMO nanoparticles in the film [4]. As a result, the average particle sizes of BZO and BHO were reduced from 34 to 19 nm and from 23 to 17 nm, respectively. Consequently, $J_c$ values of the YBCO films with BZO and BHO at 77K in 5T (B//c-axis) were enhanced from $2.4 \times 10^4$ to $1.2 \times 10^5$ A/cm$^2$ and from $1.8 \times 10^4$ to $2.4 \times 10^4$ A/cm$^2$, respectively as shown in figure 1.

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![Figure 1. Dependence of $J_c$ on magnetic field.](image-url)