Effect of artificial pinning centers` dimensionality on in-field performance of $YBa_2Cu_3O_x$ thin films

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Introduction of nanosized Artificial Pinning Centers (APCs) was widely used to strongly enhance critical current (J_c) and global pinning force (F_p) of $YBa_2Cu_3O_x$ (YBCO, T_c = 92 K) in magnetic field. Furthermore, nanoengineering approach to control microstructure, distribution, concentration and dimensionality of APCs represent a powerful tool to understand the pinning mechanisms.

At first, we considered addition of $BaSnO_3$ (BSO) to YBCO films grown on $SrTiO_3$ substrates by Pulsed Laser Deposition (PLD) [1]. By ablation of mixed BSO-YBCO targets with increasing BSO content (2~9 wt%), we obtained high quality YBCO thin films incorporating BSO in form of nanorods, which are classified as one-dimensional APCs (1D-APCs). YBCO films added with 4 wt% BSO have J_c = 0.3 MA/cm^2 and F_p^{MAX} = 28.3 GN/m^3 (77K, 3T, B//c). However, J_c is intrinsically anisotropic with the direction of applied magnetic field (with a maximum for B//c axis) and this is a critical issue for practical applications, since the value of J_c might be constant in all directions of applied magnetic field.

To solve this issue, we tried the incorporation of Y_2O_3 nanoparticles (three-dimensional APCs, 3D-APCs) inside the YBCO film, using surface-modified YBCO targets. Areas of Y_2O_3 sectors on YBCO target were increased (2.51%, 5.44% and 9.22% of the YBCO pellet area). Randomly distributed Y_2O_3 particles, which density was proportional to the area of sector, were incorporated in YBCO films. Consistently with the microstructure, J_c was isotropic. The 5.44 A% Y_2O_3 added sample presented F_p^{MAX} =14.3 GN/m^3 (77K, 3T, B//c)) which is significantly large, tough inferior to the value reported in YBCO-BSO films in same conditions. We further used the single vortex dynamics model to account for vortex pinning in the samples. The 5.44A% Y_2O_3 -YBCO film result shows a good agreement with the model fit up to 4 T of the applied magnetic field [2].

Ultimate approach was combination of advantages of 1D- and 3D-APCs pinning, with coexistence of BSO nanorods and Y_2O_3 nanoparticles. Multilayered films, alternating YBCO+Y_2O_3 and YBCO+BSO layers were prepared in PLD chamber by switching surface-modified YBCO+ ~2A% Y_2O_3 target and mixed YBCO+ 4wt% BSO target. Different combinations, varying the thickness of layers, were tried. Best result was obtained with the combination [(90 nm YBCO+BSO)/(30 nm YBCO+Y_2O_3)]$\times$3 presenting F_p^{MAX} =17.6 GN/m^3 (77K, 2.2T, B//c). Co-existence of random and correlated pinning in the periodically structured 1D+3D APCs-added YBCO films can be discussed on the bases of the global pinning models [3].

[1] P. Mele K. Matsumoto, T. Horide, A. Ichinose, Y. Yoshida, M. Mukaida, S. Horii, R. Kita, SuST. 21 (2008) 032002; [2] P. Mele R. Guzman, J. Gazquez, T. Puig, X. Obradors, S. Saini, Y. Yoshida, M. Mukaida, A. Ichinose, K. Matsumoto, M. I Adam. SuST (2014), submitted; [3] P. Mele, M. I. Adam, et al., in preparation