Effect of Artificial Pinning Centers' Dimensionality on In-field Performance of $YBa_2Cu_3O_x$ Thin Films

P. Mele[1,9], M. I. Adam[2], S. Saini[1], A. K. Jha[3], T. Horide[3], K. Matsumoto[3], S. Awaji[4], Y. Yoshida[5], A. Ichinose[6], R. Kita[7], J. Gazquez[8], R. Guzman[8],
T. Puig[8], X. Obradors[8]

[1] Hiroshima University, Japan, [2] Universiti Tenaga Nasional, Malaysia,
[3] Kyushu Institute of Technology, Japan, [4] Tohoku University, Japan,
[5] Nagoya University, Japan, [6] CRIEPI, Japan, [7] Shizuoka University, Japan,
[8] ICMAB-CSIC, Barcelona, Spain
[9]Institute for Sustainable Sciences and Development, Hiroshima University, Kagamiyama 1-3-1, 739-8530 Higashi-Hiroshima, Japan

E-mail: pmele@hiroshima-u.ac.jp

Abstract - 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). 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, though 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. The ultimate approach was a combination of advantages of 1D- and 3D-APCs pinning, utilizing the 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 between surface-modified YBCO+ ~2A% Y_2O_3 targets and mixed YBCO+ 4wt% BSO targets. 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)]×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.

Keywords (Index Terms) - Coated conductors, $YBa_2Cu_3O_x$, artificial pinning centers, nanoparticles, nanorods, critical currents, pinning force.