Available online at www.sciencedirect.com
SCIENCE DIRECT®
Physica C 426–431 (2005) 1108–1112
PHYSICA C
www.elsevier.com/locate/physc

Control of Y_2O_3 nanoislands deposition parameters in order to induce defects formation and its influence on the critical current density of YBCO films

P. Mele [a,g,h,*], K. Matsumoto [a,h], T. Horide [a,h], O. Miura [b,h], A. Ichinose [c,h], M. Mukaida [d,h], Y. Yoshida [e,h], S. Horii [f,h]

[a] *Department of Materials Science and Engineering, Yoshida-Honmachi, Sakyo-Ku, Kyoto University, Kyoto 606-8501, Japan*
[b] *Department of Electrical Engineering, Tokyo Metropolitan University, Tokyo 192-0364, Japan*
[c] *CRIEPI, 2-6-1 Nagasaka, Yokosuka 240-0196, Japan*
[d] *Yamagata University, Yamagata 992-8510, Japan*
[e] *Nagoya University, Nagoya 464-8603, Japan*
[f] *University of Tokyo, Tokyo 113-8656, Japan*
[g] *INFM and DCCI, Genova University, Via Dodecaneso 31, 15165 Genova, Italy*
[h] *CREST-JST, Saitama 332-0012, Japan*

Received 23 November 2004; accepted 22 March 2005
Available online 12 July 2005

Abstract

We successfully introduced high-density linear defects as artificial pinning centers (APCs) of the quantized vortices into YBCO films, during the film deposition procedure. APCs were introduced perpendicular to the film surface by using the distributed nanosized Y_2O_3 islands prepared on $SrTiO_3(100)$ substrates. It is possible to induce strong changes on the shape and density of the Y_2O_3 islands by varying the deposition conditions. The highest Y_2O_3 islands density, 226/μm^2, was obtained with fifteen laser pulses at 800 °C of substrate temperature. Even if only 10% of the induced defects act as effective pinning centers, J_c of YBCO film grown on the Y_2O_3 nanoislands/$SrTiO_3$ substrate increased to 1.8×10^7 A/cm^2 (20 K, $B \| c$, 0 T), which is 1.5 times higher than that of the pure YBCO film.

PACS: 74.72.Bk; 74.78.Bz

* Corresponding author. Address: Department of Materials Science and Engineering, Kyoto University, Yoshida-Honmachi, Sakyo-Ku, Kyoto-Shi 606-8501, Japan. Tel.: +81 75 7535 486; fax: +81 75 7535 486.
E-mail address: pmele@htsc.mbox.media.kyoto-u.ac.jp (P. Mele).

0921-4534/$ - see front matter
doi:10.1016/j.physc.2005.03.043

Keywords: YBCO; Artificial pinning center; J_c; Vortex pinning

1. Introduction

The critical current density (J_c) of superconductor materials is determined by the pinning of vortices due to the crystalline defects [1]. The high temperature superconductors (HTS) possess very high J_c values at low temperature even in high magnetic fields. Many kinds of crystalline defects, such as fine precipitates of non-superconducting phases, dislocations, vacancies, grain boundaries, and so on, are considered to act as pinning centers [2]. However, the J_c values rapidly decrease with increasing temperature in magnetic field. The main reasons of the J_c depression are recognized to be the intrinsic crystalline anisotropy of HTS and the thermal fluctuations [1]. Nevertheless, the lack of effective pinning centers should be noted as one of the main reasons.

We have investigated a novel technology by means of a nanostructure engineering to create artificial pinning centers (APCs) in HTC materials. We introduced high-density extended linear defects into *c*-axis oriented $YBa_2Cu_3O_{7-x}$ (YBCO) films. They were induced perpendicularly to the YBCO film surface (i.e. parallel to *c*-axis) during the film deposition, by the distributed nanosized Y_2O_3 islands on $SrTiO_3$ (100) substrates. These linear defects act as strong pinning centers so that we succeeded to effectively pin the vortices and consequently enhance the in-field J_c at 77 K [3].

Recently, some groups demonstrated that the introduction of nanoparticles into YBCO films, acting as three-dimensional pinning centers, were effective to enhance J_c [4,5]. However, the one-dimensional pinning centers induced by Y_2O_3 nanoisland formation present the considerable advantage that their formation can be controlled by varying the deposition conditions of the Y_2O_3 islands.

In this paper, we describe how both J_c and volume pinning force F_p of YBCO films are widely influenced by varying the Y_2O_3 deposition parameters. We focus our analysis on low temperature region (20–60 K) in order to avoid the flux creep contribution.

2. Experimental

A lambda physics KrF excimer laser (wavelength = 248 nm) was used for pulsed laser deposition (PLD). The Y_2O_3 target was ablated for producing Y_2O_3 nanoislands on $SrTiO_3$(100) substrates. The deposition of Y_2O_3 was carried out using a laser energy of 240 mJ/pulse at a substrate temperature of 800 °C under an oxygen partial pressure of 200 mTorr. 10, 15, 25 and 30 laser pulses for Y_2O_3 target ablation were chosen in order to control the density of Y_2O_3 nanoislands on $SrTiO_3$. Subsequently, 100 nm thick YBCO films were grown by PLD on the substrates at a temperature of 780 °C. The oxygen partial pressure of 200 mTorr and the laser energy of 340 mJ/pulse were used for the deposition of YBCO films, and after growth the films were cooled to room temperature within an hour in 500 Torr of oxygen. For comparison, YBCO films were simultaneously prepared on pure $SrTiO_3$ substrates.

Crystal phase and the orientations of YBCO films were determined by θ–2θ X-ray diffraction and X-ray rocking curve with CuK_α radiation. The surface structures of the Y_2O_3 nanoislands grown on $SrTiO_3$ substrates were observed by an atomic force microscopy (AFM).

The electrical characteristics of the samples were measured by inductive method using a SQUID. Critical current density J_c versus magnetic field B relations when the field was applied parallel to the *c*-axis of the film ($B\|c$) were evaluated using the modified critical state model in the temperature range of 20–60 K and in the field range of 0–7 T.

3. Results and discussion

Typical AFM image of sample prepared by the 15-pulse PLD process is shown in Fig. 1. The Y_2O_3 nanoislands were formed randomly on the $SrTiO_3$(100) substrates, and each nanoisland was isolated and homogeneously distributed.