WBP5-1

Effects of growth temperature and laser repetition rate on the shape of nanorods in $BaSnO_3$-doped $SmBa_2Cu_3O_y$ films prepared by pulsed laser deposition method

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$BaSnO_3$ (BSO) is one of the APC materials, which are known to grow up as nanorods in REBCO. Although a large number of studies have been performed on BSO-doped REBCO films, it has not been fully clarified about relationships between shape of nanorods and growth conditions such as substrate temperature (T_s) and laser repetition rate (f_L) in pulsed laser deposition (PLD) method. According to our previous simulation results, T_s and f_L have some effects on shape of nanorods. The purpose of this paper is to clarify effects of T_s and f_L on the shape of BSO nanorods and the superconducting properties, experimentally.

Using 2 vol% BSO-mixed SmBCO target, BSO-doped SmBCO films were prepared on CeO_2 buffered IBAD-MgO by PLD method, T_s is 800, 820, 840°C and f_L is 2, 5, 10, 20 Hz, respectivity. J_c versus magnetic field applied angle (J_c-θ) was measured at 77 K for the field of 1 T and 65 K for the field of 3 T. We defined the term J_c^{min} as the lowest value of the J_c-θ curves. In order to consider the shape of nanorods, we evaluated the J_c^{min} and $J_c(B//c) / J_c(B//ab)$ *depending on* T_s *and* f_L.

Fig. 1 shows the contour plot on (a) J_c^{min}, and (b) $J_c(B//c) / J_c(B//ab)$ depending on T_s and f_L at 65 K in 3 T. In Fig. 1(a), J_c^{min} has a maximum value when T_s was 800°C and f_L was 20 Hz, and as T_s became larger and f_L became lower, the value tended to decrease. This result indicates that isotropic flux pinning is achieved in the film deposited at low T_s and high f_L. On the other hand, in Fig. 1(b), $J_c(B//c) / J_c(B//ab)$ showed a maximum value when T_s was 840°C and f_L was 2 Hz, and as T_s became lower, the value tended to decrease. This result indicates that *c*-axis correlated pinning centers are included in the film deposited at high T_s and low f_L. From these facts, we argued that straight BSO nanorods along the *c*-axis of SmBCO grow in the films deposited at high T_s and low f_L, in contrast, short and inclined BSO nanorods grow in the films deposited at low T_s and high f_L. This tendency is almost the same with the previous simulation result. These results clearly show that the shape of nanorods can be controlled by T_s and f_L. We will compare this result with the films doped with other BMO materials.

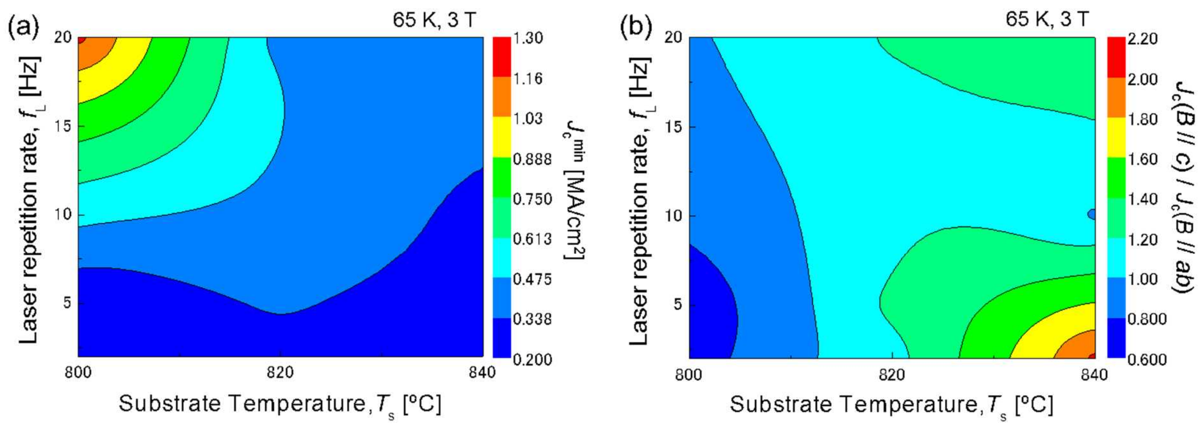

Fig.1 Contour plot of (a) J_c^{min}, and (b) $J_c(B//c)$ / $J_c(B//ab)$ depending on substrate temperature T_s and laser repetition rate f_L at 65 K in 3 T.

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(2) The metal substrates were provided by Dr. Y. Iijima of Fujikura Ltd.

Keywords: nanorods, REBCO, Artificial pinning center, Pulsed laser deposition

WBP5-2

Thickening of $YBa_2Cu_3O_y$ coated conductors fabricated by self-heating technique in Pulsed Laser Deposition method and evaluation of the superconducting properties

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$REBa_2Cu_3O_y$ (REBCO) coated conductors (CCs) are expected for high critical currents (I_c). In order to improve the I_c, it is essential to increase the film thickness while maintaining the high critical current density (J_c). However, it has been reported that *a*-axis oriented grains as the film thickness increases are generated and J_c decreases[1]. The occurrence of *a*-axis grains is due to the decrease in surface substrate temperature during the deposition. Thus, many research groups have developed the method of a heating substrate. For example, one of the methods is self-heating (S-H) technique. This technique is a method to heat the substrate by the Joule effect. The system provides rapid thermal response compared with the conventional heating system that heats the substrate with a heater[2].

In this study, we fabricated $YBa_2Cu_3O_y$ (YBCO) CCs on IBAD-MgO substrates which were heated by S-H technique in pulsed laser deposition (PLD) method. A thermocouple temperature ($T_{T.C.}$) was measured by attached thermocouple to substrate. $T_{T.C.}$ was maintained by proportional-integral-derivative (PID) control during the deposition. For comparison, YBCO CCs without PID control are also fabricated. We fabricated a thick film of which thickness was about 0.9 - 8.6 µm was prepared under the conditions of $T_{T.C.}$ = 758 and 783 °C, oxygen partial pressure P_{O2} = 200 mTorr, and laser energy density D = 1.5 J/cm^2.

Fig. 1 shows thickness dependence of I_c deposited at different $T_{T.C.}$. It was confirmed that I_c was increased by PID control. I_c reached about 750 A/cm-width (77 K, self-field) and was saturated in the film at $T_{T.C.}$ = 758°C at the thickness of thicker than 4.9 µm. This result might show that dead layer including *a*-axis oriented grains and other phases is formed on the surface of the CCs in thickening. We will report the microstructure of pure YBCO thick CC and superconducting properties of $BaHfO_3$-doped YBCO thick film in magnetic fields.

This work was partly supported by JSPS (19K22154), JST-ALCA, and JST-A-STEP. The metal substrates were provided by Dr. Y. Iijima of Fujikura Ltd.

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Keywords: Self-heating technique, PLD method, REBCO, YBCO

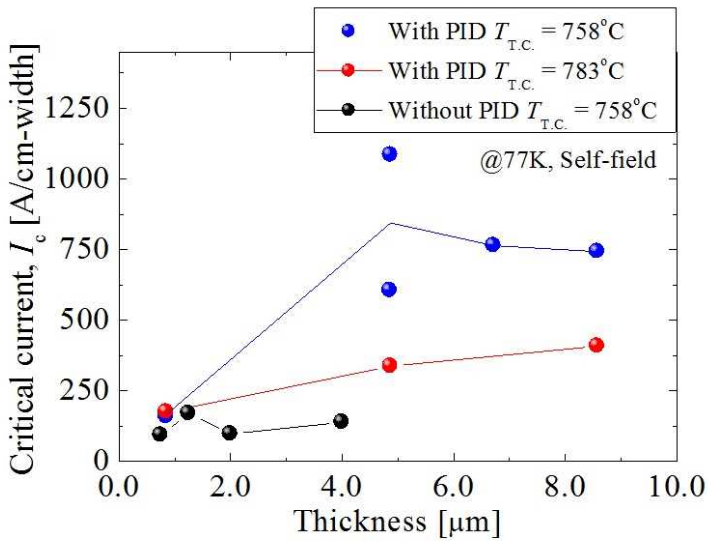

Fig. 1 Thickness dependence of I_c in YBCO CCs deposited at various $T_{T.C.}$s with and without PID control of substrate temperature

WBP5-3

Deposition of thick superconducting YBCO films using the surface laser heating

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Cost reduction for $REBa_2Cu_3O_y$ (REBCO) coated conductors (CCs) are of interest in the recent applications such as magnets and motors. Establishment a technology to fabricate the thick REBCO layer with the larger I_c is one solution to reduce the amount of the REBCO CCs. However, the thickness of the REBCO layer is usually limited less than 3 μm in the CCs because the superconducting property of the REBCO layer significantly degrades at the large thickness due to the *a*-axis-oriented grains [1]. The deposition of the REBCO layer at a sufficiently high temperature suppresses the *a*-axis oriented grains [2]. Therefore, various heating methods have been studied such as the hot wall heating [3], the direct resistance heating [4], and the laser heating [5]. In this work, we combined the conventional resistance heating with the laser heating to the surface of the CCs by using an infrared CW laser.

YBCO films were deposited on IBAD-MgO tapes using the pulsed laser deposition with a KrF excimer laser. During the deposition, the tapes were heated with a SiC heater and a diode laser (wavelength: 915 nm). To stabilize the absorption of the heating laser, the diode laser turned on when the REBCO seed layer with 500 nm thickness was deposited.

Fig. 1 shows the film thickness dependence of the ratio of the *a*-axis oriented grains for the YBCO CCs fabricated using only the SiC heater and both the heaters. As results, the *a*-axis oriented grains are suppressed with the laser heating. Furthermore, this method is effective to fabricate the 5 μm thick REBCO films. In the future, we plan to evaluate the properties of the fabricated CCs and to fabricate further thick films.

This work was partly supported by JSPS (19K22154), JST-ALCA, JST-A-STEP, the Amada foundation, and the NU-AIST alliance project. The IBAD-MgO metal substrates were provided from Dr. Y Iijima of Fujikura Ltd.

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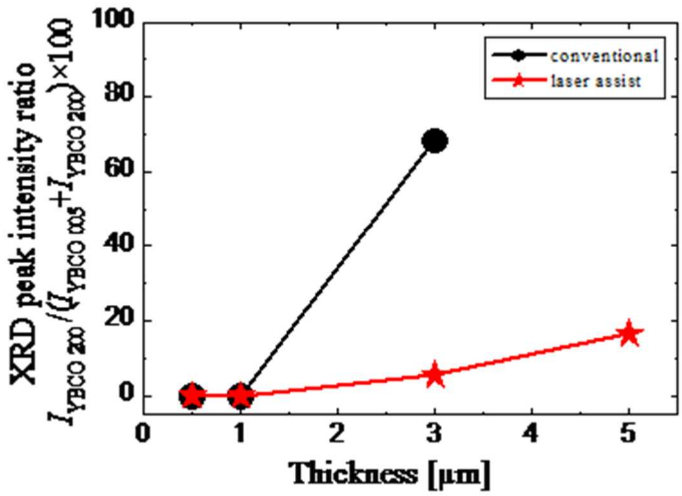

Fig. 1 The film thickness dependence of the ratio of *a*-axis oriented grains in the YBCO CCs fabricated with the conventional resistance heating and with the surface laser heating.

Keywords: YBCO, PLD, laser heating, thick film

WBP5-4

Fabrication of $BaTiO_3/YBa_2Cu_3O_y$ Multi-layered Films for Superconducting Capacitors

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High Q value is necessary for the wireless power transfer. The resistance in the circuit degrades the Q factor, thus it is important to use elements with a low internal resistance such as superconductor [1]. However, the reports on LC resonance using capacitors with superconductor are still few compared with the one with metal electrodes. Therefore, in this study, we fabricated multi-layered films with $BaTiO_3$ (BTO) films epitaxially grown on REBCO films for electrode as superconducting capacitors, and measured their dielectric properties. BTO is known as a material with an extremely high relative permittivity ε_r of more than 10,000, and epitaxially grows on REBCO because of its perovskite structure as same as REBCO [2].

Figure (a) shows the structures of the fabricated multi-layered films. 100 nm BTO films were deposited on a half area of 300 nm thick YBCO films grown on IBAD-MgO substrates by the PLD method. The YBCO and the BTO films are separately coated by two Ag electrodes with 8 mm^2 area using the sputtering. The equivalent circuit of the films are as follows; the capacitors with the YBCO superconducting electrode, the BTO dielectric, and the Ag metal electrode. The crystalline orientation of the film was evaluated by the XRD. The capacitance density C was measured at the room temperature (RT) and at 77 K by the four probe measurements using an LCR meter.

The XRD patterns of the films consisted of BTO (h00) peaks and YBCO (00l) peaks. Figure (b) shows the frequency f dependence of the impedance Z in the films at both the temperatures. Z at each temperature was sufficiently insulative of ~10 MΩ at ~ kHz, and was inverse proportional to f like a capacitance at f = 1~10 kHz. C of the films were 0.45 μF/m^2 at RT and 0.21 μF/m^2 at 77 K, and ε_r was 5.0×10^{-3} and 2.3×10^{-3}, respectively. The series resistance was too small to be measured, therefor we will investigate superconducting properties of the YBCO electrodes by using the magnetization measurement. We will also report on the capacitors using YBCO for both the electrodes.

This work was partly supported by JSPS (19K22154) and JST-ALCA, and JST-A-STEP. The metal substrates were provided by Dr. Y. Iijima of Fujikura Ltd.

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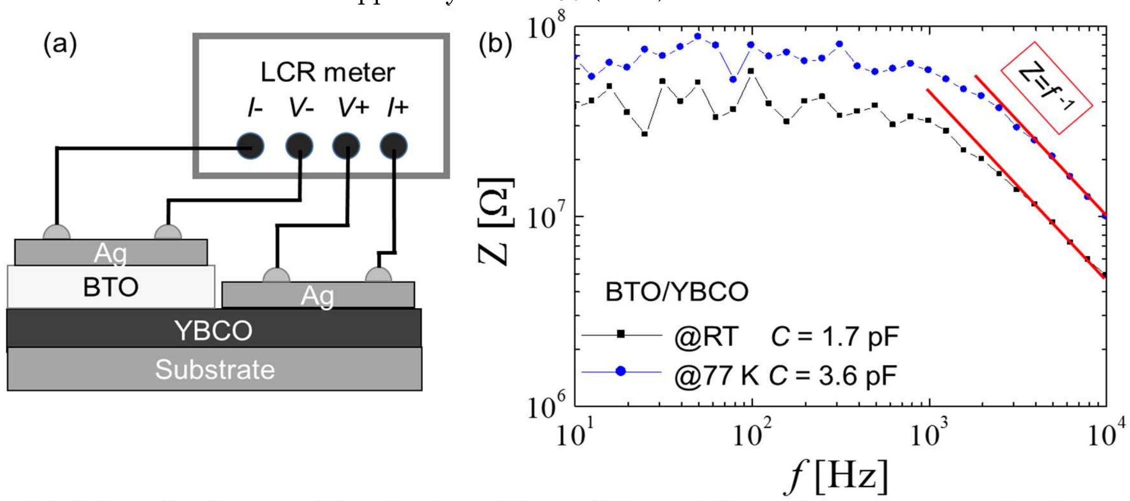

Fig. (a) Schematic diagram of the structure of the multi-layered film and the measurement set up.
(b) Frequency dependences of impedance in the BTO/YBCO multi-layered films at RT and 77 K.

Keywords: REBCO, capacitor, BaTiO3, PLD

WBP5-5

The in-field J_c in RTR-PLD $EuBa_2Cu_3O_y$+$BaHfO_3$ coated conductors

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$REBa_2Cu_3O_y$(RE=Rare Earth: REBCO) coated conductors (CCs) derived from Reel-to-Reel Pulsed Laser Deposition (RTR-PLD) are promising to be valuable for magnet applications because of the high superconducting performance and reproducibility [1]. For practical applications, enhancement of the in-field J_c for RTR-PLD $EuBa_2Cu_3O_y$(EuBCO) CCs has been reported by the introduction of $BaHfO_3$ nanorods (BHO NRs) as flux pinning centers [2,3]. For further enhancement of the in-field J_c, understanding the effect of size, density, distribution and shape of the BHO NRs is very important.
In this work, in order to investigate the effect of BHO NRs on the in-field J_c, we prepared RTR-PLD $EuBa_2Cu_3O_y$(EuBCO) CC with various vol.% of BHO NR-doped EuBCO (EuBCO+BHO) CCs. Up to 3 vol.%, no degradation of T_c and self-field J_c are observed. The EuBCO+3 vol.%BHO CCs shows the highest in-field J_c and nearly isotropic angular dependence of J_c in this work. The mechanism of improvement of the in-field J_c by the addition of BHO NRs will be discussed based on crystallinity, transport properties and microstructure.

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Keywords: Critical Current, RTR-PLD, BHO NRs, Coated Conductor

WBP5-6

Effect of laser energy and laser repetition frequency on BHO shape in PLD method

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For applications of $REBa_2Cu_3O_y$ (REBCO: RE = Rare Earth) high temperature superconductor, REBCO coated conductors (CCs) are required. Problems facing REBCO CCs are reducing production costs and improving critical current density (J_c) in magnetic fields isotropically. We have developed a technique called REBCO Growth using REBCO buffer layer (REGREB) technique which has made it possible to fabricate REBCO CCs with good performance at high production rate. There have been many reports that the J_c in magnetic fields have been improved by the introduction of artificial pinning centers (APCs). However, it is known that $BaHfO_3$(BHO), which is a typical APC, become *c*-axis correlated pinning centers. Therefore, we aimed to establish a technology to control microstructure by Pulsed Laser Deposition (PLD) method in order to improve J_c isotropically.
In this study, we focused on the relationship between laser repetition frequency (f_L) and laser energy (E_L) per pulse in the PLD method and the effect of these on the BHO shape was examined by changing f_L and E_L while keeping a high deposition rate.
Using a KrF excimer laser and a Reel to Reel system, BHO-doped $SmBa_2Cu_3O_y$ (SmBCO) CCs was fabricated on IBAD-MgO tape by the REGREB technique. Three samples were prepared, E_L was changed to 80, 90, and 100 mJ. In order to keep the deposition rate, f_L was set to 100, 70, and 64 Hz, respectively. The deposition rate was 13-18nm/sec.
Fig. 1 shows the angular dependence of J_c (J_c-q) at 77 K and 1 T. All three samples showed curves of almost the same shape. When E_L changes, the amount of evaporation per pulse and the kinetic energy of the evaporated particles would change. However, since the degree of supersaturation is high at the high deposition rate, it is considered that these changes due to E_L did not have a significant effect on the microstructure. Also, J_c peak at the B // c (q = 0°), which is often observed in the BHO-doped samples, was not confirmed. We speculated that the APC did not play *c*-axis pinning center.
We will compare the J_c-q curve at high and low deposition rate in order to clarify the effect of E_L.

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Keywords: REBCO, BHO, Reel to Reel, PLD

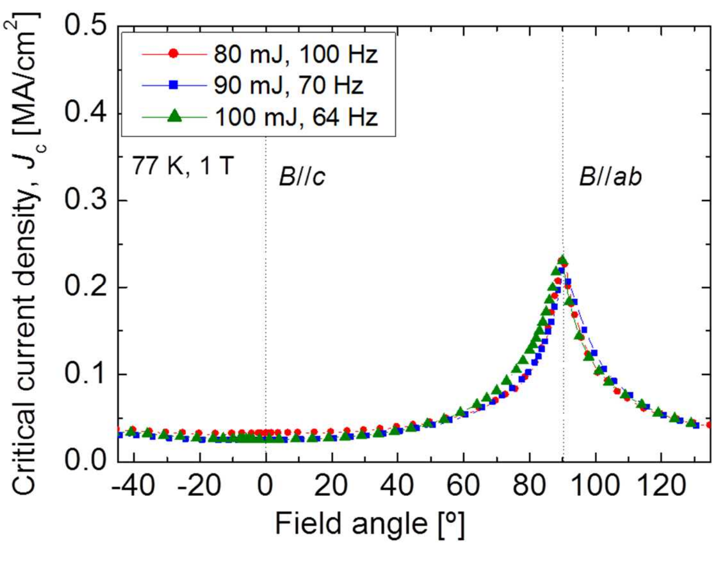

Fig. 1 The angular dependence of J_c (J_c - θ) at 77 K and 1 T.