

# Critical current density of multilayered SmBa<sub>2</sub>Cu<sub>3</sub>O<sub>y</sub> films in the force-free state by controlling the thickness of BaHfO<sub>3</sub> layer

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The longitudinal magnetic field (LMF) effects mean various peculiar electromagnetic phenomena under the force-free state. Especially, these are some reports about the enhancement of the critical current density ( $J_c$ ) under a certain magnetic field in comparison with the  $J_c$  under self-field ( $J_c^{\text{self}}$ ). However, most of the reports are observed in the intermetallic superconductors such as the Nb-Ti wire<sup>[1, 2]</sup>, and there are few reports for REBa<sub>2</sub>Cu<sub>3</sub>O<sub>y</sub> (REBCO, RE = rare earth) high-temperature superconductor<sup>[3]</sup>.

So far, we have reported a  $J_c$  enhancement due to the force-free state on a multilayered SmBa<sub>2</sub>Cu<sub>3</sub>O<sub>y</sub> (SmBCO) film consisting of pure SmBCO layers and BaHfO<sub>3</sub> (BHO)-doped SmBCO layers<sup>[4]</sup>. In this study, we fabricated BHO-doped SmBCO multilayered films on LaAlO<sub>3</sub>(100) substrates by pulsed laser deposition (PLD) method. Controlling the length of the introduced BHO nanorods along the  $c$ -axis direction of SmBCO, we changed the number of layers and the total film thickness for a comparative review of the  $J_c$  properties under the force-free state. The number of layers and the total film thickness of the films were 250 nm with 16 layers and 500 nm with 32 or 48 layers, respectively.

As a result, the  $J_c$  peak by the LMF effect from  $J_c^{\text{self}}$  at 77 K was observed in the 32 and 48 multilayered films, respectively. These films showed the maximum  $J_c$  value at nearly 0.15 T, and these  $J_c$  value were enhanced 2% of the  $J_c^{\text{self}}$  value. In addition, The  $J_c$  enhancement magnetic field region was expanded to higher magnetic field with increasing the number of layers. This result indicates that the optimal film thickness and length of the nanorods leads to the LMF effect and the number of layers affect the enhancement of  $J_c$  value. We will discuss the results of the films with different number of layers.

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