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陽極酸化アルミナテンプレートを通してイオンミリングによる YBCO 薄膜におけるナノ欠陥の導入

Introduction of Nanodefects in YBCO Films by Ion-milling Through Anodic Aluminum Oxide Templates

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Second generation high-T_c superconducting (HTS) wires have received enormous interest in recent years due to their potential use in large scale applications operating at high magnetic fields and temperatures of 30–77 K, including generators, motors and magnets. Recent advances have led to successful methods for enhancing both self-field and in-field critical current density (J_c) of $YBa_2Cu_3O_{7-\delta}$ (YBCO) films, specifically methods involving nanoengineering of artificial pinning centers (APCs), e.g. $BaZrO_3$ nanoinclusions [1]. Metalorganic deposition (MOD) using trifluoroacetate (TFA) precursors is a well-established method for coated conductor development [2], but fluorine-free MOD (FF-MOD) is more attractive because the hydrofluoric acid released as a byproduct in the TFA approach is a major environmental concern. However, these films are characterized by a lack of effective flux pinning centers particularly as the film thickness is increased. This study represents the first attempt for introducing APCs into these FF-MOD YBCO superconducting films utilizing a top-to-bottom approach. Here we employ free-standing nanoporous anodic aluminum oxide (AAO) membranes [3], which are widely used as templates and masks for fabricating a wide range of nanostructured materials. Using the AAO membranes as templates, crystalline defects were introduced into YBCO films using conventional argon ion milling. AAO membranes with nanopores ~100 nm in diameter, hexagonally arranged with interpore distances of ~100 nm were employed as masks onto various YBCO films prepared by FF-MOD technique on STO substrates buffered with ~30 nm CeO_2 layers. A schematic of the setup is shown in Fig. 1. The AAO-masked films, including pristine YBCO films as well as those with minute additions of rare-earth (Dy and Gd), were subjected to Ar ion milling at various conditions. Due to possible oxygen loss that occurs in the YBCO films during the milling process, the films were annealed afterwards at 450°C for 1 h in flowing oxygen. Microstructural evaluation before and after milling via SEM and AFM measurements in conjunction with chemical etching revealed the successful introduction of nanoscale defects into the films. Electrical characterization confirmed a moderate enhancement of the self-field J_c (77.3 K) of ~20% for the pristine and Gd-added YBCO samples, and ~40% for the Dy-added sample. Moreover, at 1 T and 77.3 K, more than two to three times increase in J_c was confirmed, part of this enhancement coming from random pinning effective over all field directions. This result is explained by local heating and disordering effects from the ion milling process combining with the high density of *ab* stacking faults typical for MOD films to allow for oxygen rearrangement in the regions of the stacking faults. Details will be discussed during the presentation.

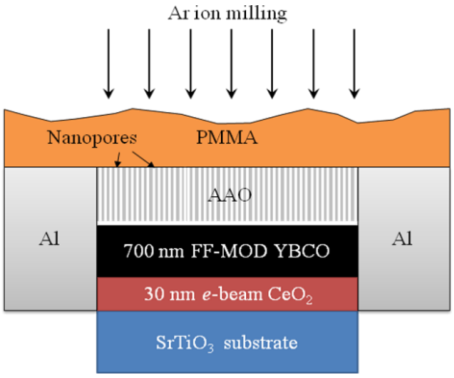

Fig.1. Schematic illustration of the setup for introducing nanoscale defects into YBCO films using free-standing AAO templates.

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References

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