Introduction of Nanorods into Superconducting Films to Improve Critical Current Density and Their Growth Mechanism

Background

High-Tc superconductors hold a superconducting state by introduction of quantum fluxoids under magnetic fields. It is necessary to stop the quantum fluxoid movement owing to the Lorenz force to flow large current with zero electrical resistance. Therefore, the normal electrical conductivity region with a size of a few nm (pinning centers) where magnetic flux exists stably should be introduced into superconducting films. Impurity materials such as $BaZrO_3$ form impurity nanorods owing to a self-alignment inside the $REBa_2Cu_3O_y$ superconducting films [*1] deposited by a pulsed-laser deposition technique [*2]. It is known that these structures work as effective pinning centers. The conceptual configuration of nanorods as pinning centers is shown in Fig. 1. Although it is necessary to obtain the optimum size and distribution of nanorods to flow larger current, the growth mechanism has not been clarified yet.

Objectives

The purpose of this study is to clarify the relation between nanorod microstructures and preparation conditions to make clear the nanorod growth mechanism.

Principal Results

1. Quantity of impurity addition and impurity material dependencies of nanorod structures

Nanorods are formed in all impurity ranges from 1 to 12 wt%. Nanorod diameter is approximately 10 nm in this region as shown in Fig. 2. It is found that nanorod number density increases with increase of impurity addition. It is confirmed that nanorods form a triangle lattice without condensation in the case of 10 wt% of high impurity addition as shown in Fig. 3. Furthermore, the nanorod diameter is varied between $BaZrO_3$ and $BaSnO_3$ which have a slightly different lattice length. It was suggested that the interface energy affects the nanorod formation because the nanorod diameter does not depend on the impurity addition but the impurity materials.

2. Nanorod formation and stress fields

The particular plan-view TEM image as shown in Fig. 4 is observed. This image is obtained by the observation of curved nanorods inside a superconducting film from top-view. The elongated nanorods do not randomly distribute but are aligned on one line. That is, nanorods are selectively grown on the underlying nanorods. It is suggested that the crystal stress affects the position of nanorod formation since the way in which nanodots align along the film thickness direction in layer structure of semiconducting films depends on the crystal stress.

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Future Developments

Some parameters controlled the nanorod morphology and distribution could be understood. At present, the nanorod introduction into the high-Tc superconducting tape wires has been already started. It is expected that the high-Jc superconducting tape wires will be developed and they will be applied to the superconducting electricity equipments.

Main Researcher: Ataru Ichinose, Ph. D.,
Senior Research Scientist, Applied High Energy Physics Sector, Electric Power Engineering Research Laboratory

Reference

A. Ichinose, et al., "Microstructures of $REBa_2Cu_3O_y$ adding $BaZrO_3$ or $BaSnO_3$", Physica C 468, p.1627, 2008

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*1：$REBa_2Cu_3O_y$ superconducting films (RE: rear eathe elements); Yttrium is usually applied as a rear earth element.

*2：A pulsed-laser deposition technique is a fabrication technique of superconducitng tape wires. Target materials are deposited on substrates using a pulsed-laser.

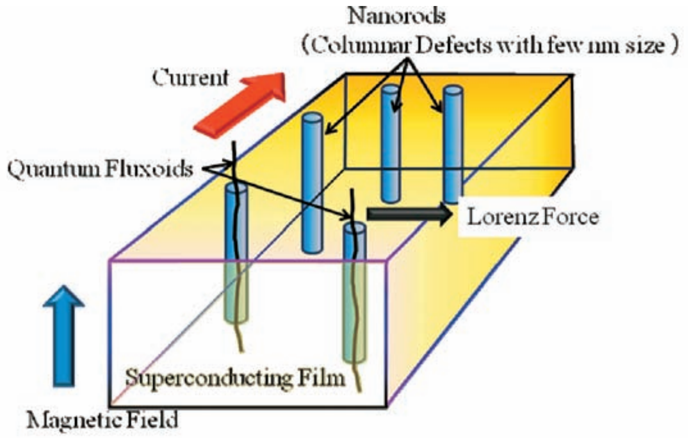
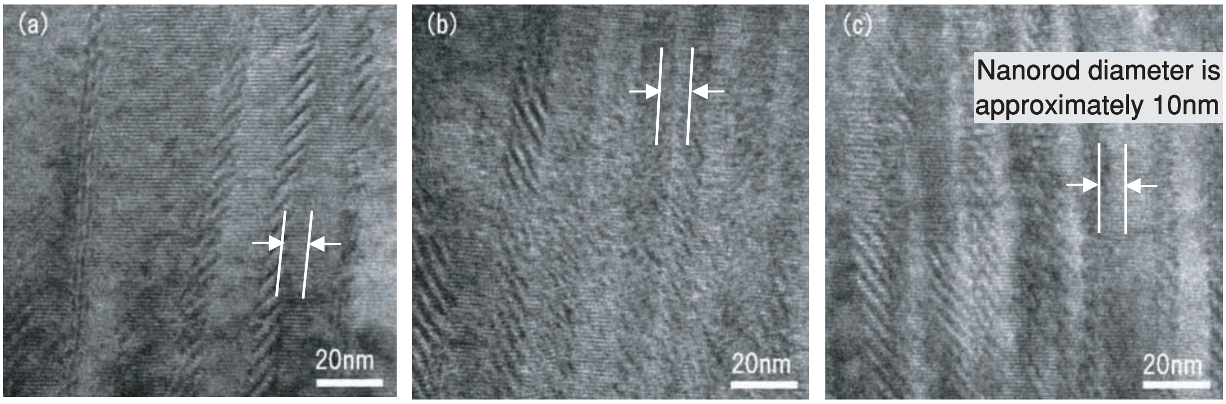


Fig.1 Conceptual configuration of nanorods as pinning centers



Impurity addition: 4 wt% Impurity addition: 6 wt% Impurity addition: 8 wt%

Fig.2 Cross-sectional TEM images of YBCO superconducting films with various impurity amounts.

Nanorods indicate the inclined or vertical stripes gone through from bottom to top sides. It is found that the number density of nanorods increases without changing diameter in various impurity additions.

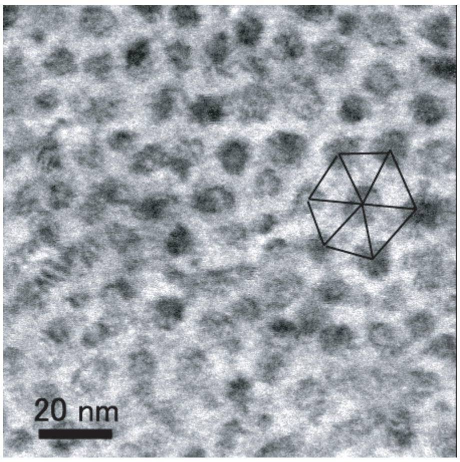


Fig.3 Plan-view TEM image of $YBa_2Cu_3O_y$ film contained 10 wt% $BaZrO_3$.

This image is observed from the elongated nanorod direction and each dark circle indicates nanorods. Nanorods form a triangle lattice shown in this figure, and a quantum fluxoide is trapped in a nanorod.

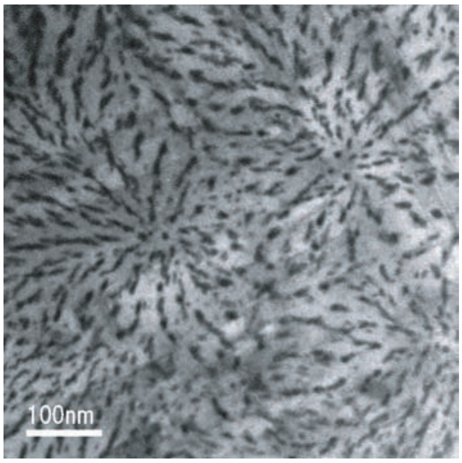


Fig.4 Plan-view TEM im age of the particular structure of $YBa_2Cu_3O_y$ film contained $BaZrO_3$.

This image is also observed in the same direction as Fig. 3. The elongated nanorods radiate form various points and these nanorods form a number of almost straight line. The radiation diameter is approximately 400 nm. The central points indicate that the nanorods grow straight and the surrounded area indicates that the tilted nanorods grow