c-axis Texturing of $Bi_4Ti_3O_{12}$ Thick Film

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Introduction

This paper focuses on the texturing of $Bi_4Ti_3O_{12}$ (BiT) thick film. It is well known that preferential orientation appears in the thin film in order to minimize surface energy or to release internal stress. So that one dimensional texture appears on the film deposited on the glass substrate or on the polycrystalline substrate. On the other hand, preferential orientation of thick film is uncertain.

Thick film technology is based on sintering of powdered materials which is similar to that of bulk materials; however, the influence of the substrate is significant. One of the distinctive features of thick film densification is that there is little shrinkage in the in-plane direction during sintering, which is caused by constraint of substrate. This constraint is enough to cause shear deformation, which may bring particle rotation. Hence preferential orientation may emerge for the particles of anisotropic shape.

To demonstrate the nature of texture evolution in thick film, equiaxed particles of BiT as starting material were prepared by co-precipitation and its paste was coated by screen-printing on substrates, resulting in randomly oriented films. During subsequent heating, the morphology of the particles transforms from the original to platelet. Here we report the progress of preferential orientation of these films in connection with film shrinkage.

Experimental procedures

Coprecipitation method was used to synthesize BiT particles. The powder was then mixed with α-terpineol and methyl cellulose, which was subsequently used as a paste for screen printing. The film thickness after drying was found to be 20–50 μm. Sintering was carried out in the temperature range of 800 – 1050 °C, in a lidded crucible of alumina. To compensate any Bi loss by evaporation during sintering, BiT powder was also settled in the crucible.

The pole-figure profiles were observed using the Schulz reflection method. The profiles were analyzed based on the March-Dollase function after eliminating background and defocusing effects. The density of films was measured from the film weight divided by the film volume. The surface profile of the films measured by a confocal LASER scanning microscope was used to obtain the film volume.

Results and discussion

The progress of texturing was also confirmed by pole-figure profile as shown in Fig. 1. Here, the distribution of (006) diffraction intensity was monitored; where ϕ is the angle of tilt from the plane normal to the substrate surface. It is clear that the c-axis orientation gradually emerged in the out-of-plane direction (ϕ=0) as the film density increased. In order to analyze

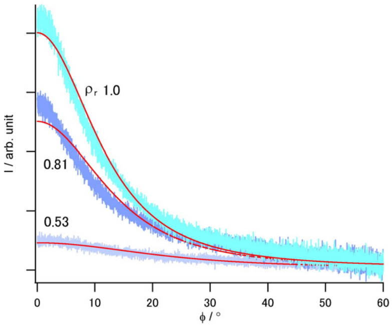

Fig. 1 Orientation distributions of BiT thick films with a various relative density (ρ_r).

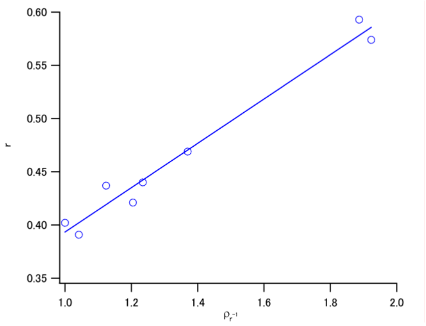

Fig. 2 The relation between March coefficient (r) and relative density (ρ_r).

the progress of texturing qualitatively, these profiles were fitted to the March-Dollase function. This distribution function is as follows:

$$\left(r^2\cos^2\phi + r^{-1}\sin^2\phi\right)^{-\frac{2}{3}} \qquad \text{Eq.1}$$

This function was derived for the development of preferred orientation as a result of rigid-body rotation of platy or rod-shaped grains upon linear sample deformation. The March coefficient, r, characterizes the strength of the preferred orientation and is related to the amount of sample deformation. For platy crystallites the relation is $r=d/d_0$, where d_0 is the thickness of an original (hypothetical) sample showing uniform pole density and d is the sample thickness after axial extension or compaction. The solid line in Fig. 1 indicates fitted curves using the March-Dollase function, and reasonable fitting to the experimental data is found.

In the curve fitting, the March coefficient was used as the fitting parameter, and the obtained parameter, r, was plotted against the inverse of density as shown in Fig. 2. There is a good linear relation between them. Remembering that the film density linearly increased with thickness reduction, it is found that the inverse of relative density increased in proportion to film thickness. In addition, the March coefficient also has a linear relation with deformed thickness. Hence, the linear relation between them indicates that the preferential orientation during the film sintering originates in the reduction in the film thickness without in-plane shrinkage.

Biographical Sketch

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Dr. Kinemuchi received his PhD degree in materials science at Nagaoka University of Technology. He is currently a research scientist of the Advanced Sintering Technology group of AIST. He is also a visiting associate professor of Nagaoka University of Technology.

His research is focused on the basic understanding of sintering phenomenon including nano particles, constrained sintering and texturing.