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# Homo-epitaxial growth of YBCO bulk by using YBCO/MgO thin-film seed

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## Abstract

Using YBCO/MgO thin films as seeds, the homo-epitaxial growth of YBCO bulk by a cold-seeding process was reported. The grown bulk was revealed to possess an in-plane alignment, which is the same as the seed film. A small percentage of *a*-axis oriented grains, which may strengthen the stability of the seed film, were detected by Raman spectrum. The influence of processing on the superheating behavior of the seed film was discussed. The in-plane alignment of the YBCO thin film was determined by XRD pole figure. It was found that the alignment of seed film played a key role in the growth of YBCO bulk.


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*Keywords:* Melt-texture; Superheating; Y123/MgO thin film; Seed

## 1. Introduction

The top-seeding melt texture growth (TSMTG) technique is widely used in the preparation of block-type superconductor materials. Because of the anisotropic structure of the $REB_2C_3O_x$ (REBCO, RE = rare earth), a suitable seed crystal plays a key role in TSMTG technique. Up-to-date, only hereto-seeds are used in the cold-seeding process in $YBa_2Cu_3O_x$ (YBCO) system. The most popular seeds are MgO [1], other RE123 in the form of single crystal, MT bulk, thin film or thick film [2–5]. However, all those seeds have some inevitable disadvantages. That's because hereto-seeds may induce other elements, which suppresses the superconducting properties of the grown bulk. Recently, the finding of superheating phenomenon opens a new gate for homo-seeding YBCO bulk growth.

Superheating phenomenon has the great potential in clarifying the melting process of crystalline materials. Many studies have been devoted due to the scientific and practical concern [6–8]. In 2002, Yao et al. reported the superheating phenomenon of YBCO/MgO thin film in YSNG (YBCO-seeded $NdBa_2Cu_3O_x$ growth) process [9]. Furthermore, the *in situ* observation of YBCO thin film by high-temperature optical microscope (HTOM) was reported recently, which presented the direct evidence of the superheating phenomenon [10]. This becomes the start point of our work in this paper. If only the degree of superheating of YBCO/MgO thin film is larger than the temperature difference between the highest process temperature ($T_{max}$) and the $T_p$ of YBCO, the film may act as a seed for the MT bulk growth. REBCO/MgO homo-seed can be used even in the cold-seeding process, offering a possible universal seed for all REBCO systems.

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## 2. Experimental

The YBCO/MgO thin films were prepared by the pulsed laser deposition (PLD). The in-plane alignment was tested by XRD (D8 Discover GADDS, Bruker AXS) and the out-plane orientation was probed by Raman spectrum (Jobin Yvon LabRAM HR 800 UV–VIS–NIR micro-Raman system) with $z\ (x,\ x')\ z'$ scattering geometry. The components of YBCO pellet was prepared in a molar ratio of Y:Ba:Cu = 1.7:2.35:3.35, which is a ratio of Y123: Y211 = 1:0.35 in the final bulk. The initial raw powders are $Y_2O_3$, $BaCuO_3$ and CuO. After mixed and ground in an agate mortar, the powders were calcined for 48 h at 900 °C. In order to optimize the size and distribution of Y211 particles, the ground-calcined circle was run three times. Then the powders were uniaxially pressed into precursor pellets. One seed film, about 2 mm × 2 mm in size, was placed at the center of the top surface of the pellet.

The thermal circle contained steps as following: (1) heating to 960 °C in 2 h and held for 1 h; (2) heating to 1045 °C in 2 h and dwelling for 1.5 h; (3) rapid cooling to 1010 °C within 15 min; (4) slowly cooling to 1000 °C in 20 h and quenching.

## 3. Results and discussion

Seeded by an YBCO/MgO homo-seed, YBCO melt-texture bulk was successfully obtained through the cold-seeding process. Viewed from the top surface of the grown bulk (Fig. 1), a single grain growth without any self-nucleation was acquired. The grain is square, which represents a typical *c*-axis orientation. It's easy to find that the $\langle 100 \rangle$ plane of YBCO bulk is parallel to the $\langle 100 \rangle$ plane of MgO. The $\langle 100 \rangle$ plane of the YBCO thin film is also parallel to the $\langle 100 \rangle$ plane of MgO. The orientation relation between the grown bulk and the thin film can be concluded as $\langle 100 \rangle_{film} \| \langle 100 \rangle_{bulk}$, which is a reasonable deduction since both the bulk and the seed film have the same orientation relation with the MgO substrate. In a previous study of MgO seeded YBCO reported by Cai et al. [1], there are two possible results of grown bulks, which varied with the undercooling degree: one is multi-grain growth and the other is single grain growth with a 45° rotation about the $\langle 100 \rangle$ plane of MgO. However, both results are different from ours. It's valid that the YBCO thin film withstood the high processing temperature and worked as a seed. Noticing that the $T_{max}$ is 1045 °C, which is 35 °C higher than the $T_p$ of YBCO, and the duration is 1.5 h, a further study in understanding the superheating mechanism of YBCO thin film attracts our interest.

Fig. 2 shows the $\theta$–$2\theta$ scan result of the seed film, which shows clearly set of $\langle 00l \rangle$ peaks. The strong *c*-axis orientation could be another evidence of the epitaxial growth of bulk from the seed film. No such grain with other orientations is observed from the XRD measurement. Nevertheless, the micro-Raman spectrum (Fig. 3) provides some

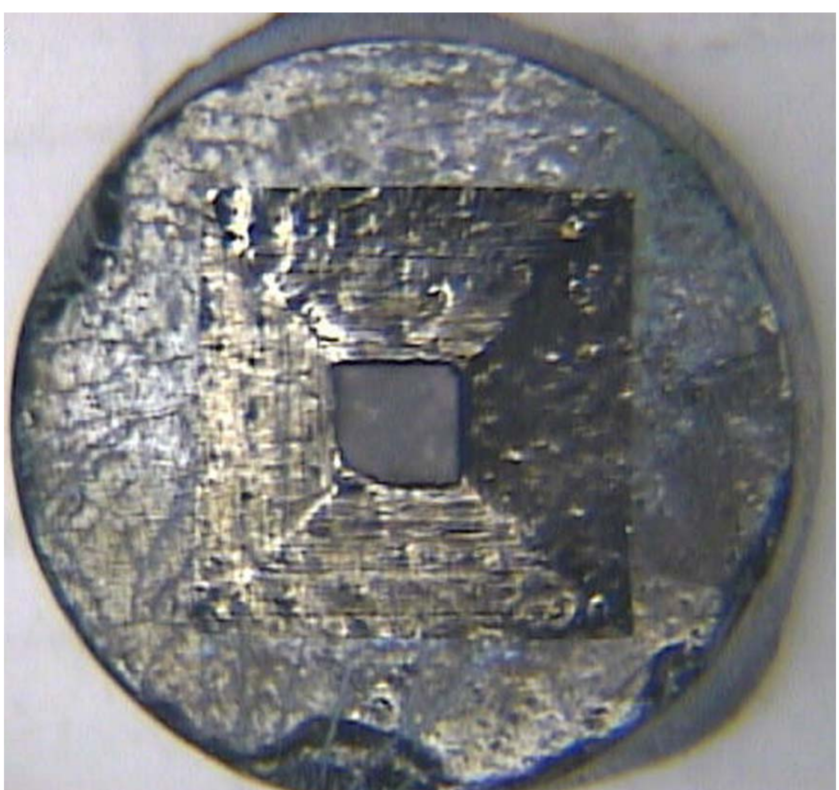

Fig. 1. Optical image of single grain YBCO bulk, seeded by YBCO/MgO thin film.