

Fabrication of Oxide Thick Film for Renewable Electrical Energy Storage Technology

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(Received March 25 2005, Accepted May 11 2005)

We have fabricated superconducting HTSC ceramic thick films by chemical process. c-axis oriented HTSC thick films have been attempted bi-axially textured Ni tapes. The x-ray diffraction pattern of the HTSC thick films contained superconducting phase crystal. The critical temperature and critical current density was 110 K.

Keywords : High Tc superconductor, Thick film

1. INTRODUCTION

Significant effort has been directed towards developing high current superconducting wire technologies.

Much of this work has focused on achieving the crystallographic texture needed in high temperature superconductor (HTS) wire or tape in order to realize the high critical current density (J_c) at 77 K.

When compared to the first generation Bi based HTS tapes, $YBa_2Cu_3O_7$ (YBCO) coated conductors have higher critical current densities of 1 MA/cm^2 at 77 K. J_c values of YBCO thin films grown epitaxially on single crystals exhibit above 1 MA/cm^2 , while randomly oriented polycrystalline high Tc superconductors shows a few hundred A/cm^2 .

This large difference is related to the weak link behavior due to the high misorientation angle above 10 at the grain boundaries. To obtain high J_c values, the high Tc superconductors tapes should possess high grain alignments of both in-plane and out-of plane over the entire conductors.

High temperature superconductors (HTS) are of interest in electrical power applications where their unique properties can make them economical if they can be optimized and produced repeatably.

Commercial applications of superconducting electric power device and systems based on HTSC require long lengths of flexible, high current and high field tape conductors.

HTSC coated superconducting tapes hold out the promise of both a high zero field critical current density, J_c (77 K) 10^6 A/cm^2 , and excellent magnetic field performance[1-6].

Researchers have been studying the thin film growth of high-Tc superconducting materials using several methods, RF diode sputtering, EB sputtering, ICB deposition, laser devices that operate at liquid-nitrogen temperature.

A high Tc superconductor consists of an aligned high Tc superconductor film and buffer layers on a metal substrate. The buffer layers are needed to prevent the chemical reaction and compensate for the lattice mismatch between the high Tc superconductor film and the metal substrate.

The degree of the alignment of the high Tc superconductor film is dependent on the alignments of the buffer layers.

A template with aligned buffer layers can be made by two well-known processes, named ion beam assisted deposition and rolling assisted bi-axially textured substrate.

The metal substrate of the former process does not need a texture structure due to the directional oxide decomposition by the ion beam, while the metal substrate of the latter process should have a texture structure.

In both process, ceria and yttria stabilized zirconia are widely used as buffer layers for the high Tc superconductor tapes.

In the process, the textured Ni tape can be fabricated by rolling and recrystallization. The well-known buffer layer structure is ceria/YSZ/CERIA/Ni tape.

Ceria is good material to compensate for the lattice mismatch, and TSZ has been widely used as a diffusion barrier. The buffer layers like ceria and YSZ have been mainly deposited by physical vapor deposition methods using e-beam evaporation or sputtering for textured substrates, or ion beam assisted deposition method for

textured substrate.

Typically, a superconducting tape is fabricated depositing HTS film on base metal substrate that has been pre-coated with an oxide buffer layer.

The oxide buffer layer is biaxially aligned and acts as a diffusion barrier to the metal species and as a template to facilitate the epitaxial growth of c-axis tape conductor.

High J_c (10^6 A/cm²) values can be achieved if the in plane grain misalignment in the tape conductor film is 15.

Since this misalignment is controlled by the texture of the buffer layer, it is very important that the buffer layer has a very high degree of biaxial alignment. Meng *et al.* have already reported high J_c tape conductor.

We fabricated 1223 phase HgBaCaCuO superconducting thick film by chemical process. This paper discusses the chemical process and the characteristics of HgBaCaCuO thick films.

2. EXPERIMENTAL PROCEDURE

The calcined powder of nominal composition Ba₂Ca₂Cu₃O_y precursor, which was prepared from mixed powders of BaCO₃, CaCO₃, and CuO, was mixed with HgO, and then sintered at 900 °C for 20 h in a sealed quartz ampoule.

Obtained HgBa₂Ca₂Cu₃O_y 1223 pellets were grounded and used as starting powder of the thick film. The Hg-containing pellets as Hg vapor source were prepared with nominal compositions of HgBa₂Ca₂Cu₄O_y in the similar way.

In the case of the Ni substrate, 1223 thick film was formed on the substrate by painting method using a slurry containing calcined powder of 1223.

NiO layer was prepared by oxidizing the surface of the Ni foil at 900 °C in air.

The thick films were put into Al₂O₃ tube, and then sintered at various temperatures in a sealed quartz ampoule together with Hg-containing pellets.

The microstructure of the tape surface was observed by a scanning electron microscope. The electrical transport properties of the tapes were measured by the conventional four probe method T_c .

3. RESULTS AND DISCUSSION

HgBa₂Ca₂Cu₃O_y 1223 thick films were obtained with the Ni substrates, when pellets of HgBa₂Ca₃Cu₄O_y used as Hg vapor source. In addition, platelet crystals of HgBa₂Ca₂Cu₃O_y 1223 were grown on the substrate by sintering at 870 °C.

HgBa₂Ca₂Cu₃O_y 1223 tapes could be synthesized reproducibly and Fig. 1 shows a typical X-ray diffraction pattern of the tape. In the case of Ni substrate, strongly

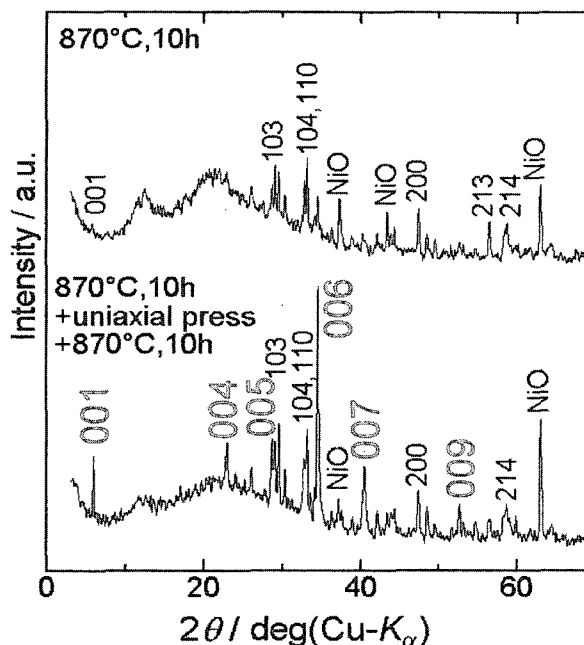


Fig.1. The x-ray diffraction pattern for Hg1223/Ni thick film.

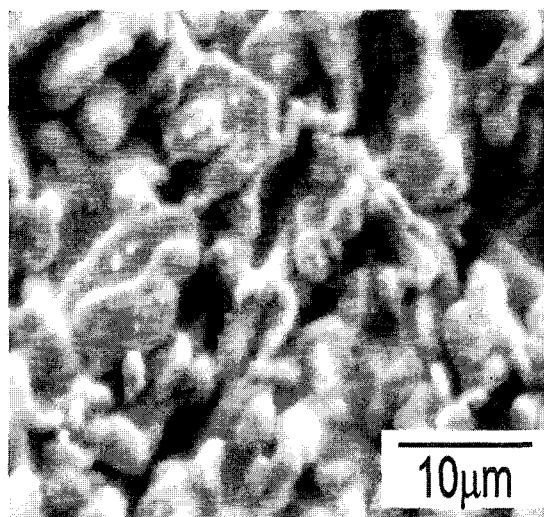


Fig. 2. SEM image of Hg1223 thick film.

c-axis oriented Hg1223 thick film was fabricated by sintering at 870 °C with an intermediate uniaxial pressing.

Hg1223/Ni thick film could be synthesized reproducibly and the surface morphology was found as shown in Fig. 2.

The oriented thick film exhibited $T_c=135$ K under zero magnetic field as shown in Fig. 3. These results indicate that the Ni substrate is more preferable for Hg1223 thick film.

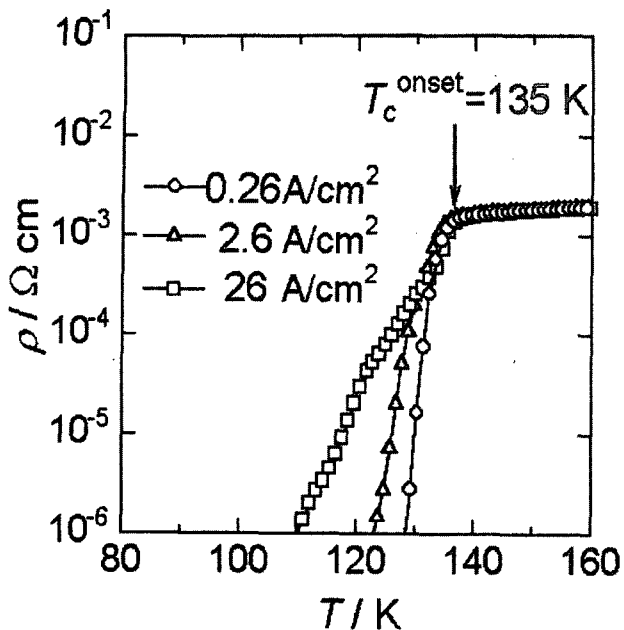


Fig. 3. Temperature dependence of the resistivity of Hg1223/Ni thick film.

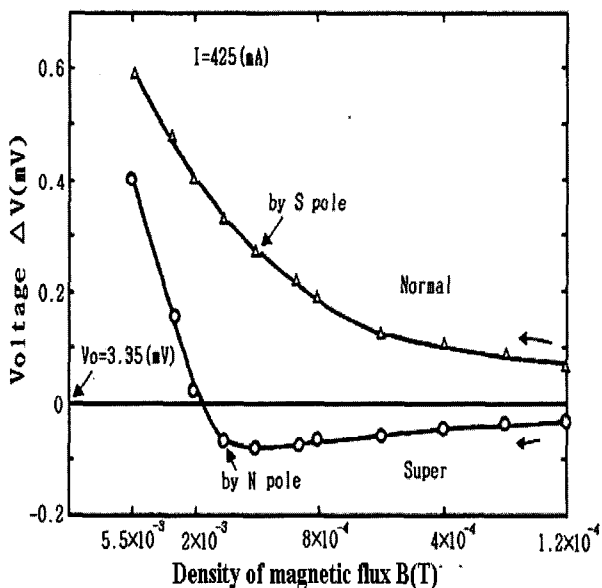


Fig. 4. The change in the voltage across the sample memorized by N pole as a function of external magnetic flux density.

The electric characteristic is attributed to flux pinning and slow flux creep. In polycrystalline high T_c superconductors, there are many pinning centers, such as grain boundaries, defects, oxygen deficiency, and the existence of non-superconducting impurity phase.

Such a strong pinning effect gives rise to hysteresis in magnetization of type-II superconductors.

V_{MAG} and V_{MEM} are the voltages appeared across the HTS sample after the removal of the external magnetic field and the voltage in the memorized state, respectively. It is found that V_{MEM} is negligibly small below $B=2 \times 10^{-3}$ T.

The V-B characteristics of the superconducting magnetic sensor memorized by N pole of permanent magnet were measured.

By approaching N pole (or S pole) of a magnet to the HTS magnetic sensor, it is evident that the HTS magnetic sensor can differentiate the polarity and the magnitude of external magnetic field with respect to the initial voltage, V_0 , of field cooled sample. The decrement of voltage $-\Delta V$ is attributed to the external magnetic flux of N pole, and $+\Delta V$, due to the external magnetic flux from S pole.

The amount of such decrement (increment) was found to be varied with the distance of N (or S) pole of permanent magnet, as shown in Fig. 4.

The sign of ΔV only corresponds to the change of the number of flux trapped into the sample. In the same manner as the behavior, the decrease (increase) of the trapped flux leads to the decrease (increase) of resistance, corresponding to the negative (positive) ΔV .

Because of the spatial gradient of flux density into the sample, the trapped flux is given by a spatial integral of the gradient B over the volume of the sample. In general, it strongly depends on the shape and size of the magnet and the superconducting samples as well as the distance between them.

4. CONCLUSION

Hg1223 thick films were fabricated on the Ni substrates. The c-axis oriented Hg1223/Ni tapes were reproducibly fabricated by sintering at 870 °C with an intermediate uniaxial pressing.

We have fabricated superconducting HTSC ceramic thick films by chemical process. c-axis oriented HTSC thick films have been attempted bi-axially textured Ni tapes.

The x-ray diffraction pattern of the HTSC thick films contained 1223 phase crystal. The critical temperature and critical current density were on set $T_c = 135$ K.

The electric properties in Hg1223 superconductor were studied. In the measurement of current-voltage characteristics, a voltage across the superconducting sample was observed on applying an external magnetic field.

The voltage continues to be observed after the removal of the magnetic field. The appearance of the voltage is ascribed to the trapping of magnetic flux.

Depending on the direction of applied magnetic flux, the voltage in the magnetized sample increases or decreases. The possibility that the superconducting materials can be used as magnetic sensors has been examined.

From the experiments, it was found that the memorized superconductor can detect both magnitude and polarity of the coming magnetic flux. The knowledge from this principle of electric properties shows that the same polarity of the coming external magnetic flux and the memorized magnetic flux will cause to decrease the resistance of the superconductor, that is, the voltage across the superconductor is decreased.

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