



Electrodeposited Ag-Stabilization Layer for High Temperature Superconducting Coated Conductors

Preprint

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ELECTRODEPOSITED Ag-STABILIZATION LAYER FOR HIGH TEMPERATURE SUPERCONDUCTING COATED CONDUCTORS

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ABSTRACT

We developed a non-aqueous based electrodeposition process of Ag-stabilization layer on YBCO superconductor tapes. The non-aqueous electroplating solution is non-reactive to the HTS layer thus does not deteriorate the critical current capability of the superconductor layer when plated directly on the HTS tape. The superconducting current capabilities of these tapes were measured by non-contact magnetic measurements.

INTRODUCTION

The development of high- T_c superconductors has created the potential of economically feasible development of superconductor components and other devices in the power industry, including applications for power generation, storage, distribution power cables, transformers, and fault current interrupters/limiters. In addition, other benefits of high-temperature superconductors in the power industry include a factor of 3-10 increase of power-handling capacity, significant reduction in the size (i.e., footprint) and weight of electric power equipment, reduced environmental impact, greater safety, and increased capacity over conventional technology. While such potential benefits of high-temperature superconductors remain quite compelling, numerous technical challenges continue to exist in the production and commercialization of high-temperature superconductors on a large scale. Among the challenges associated with the commercialization of high-temperature superconductors, many exist around the fabrication of a superconducting tapes. A first generation of superconducting tape includes Bi(Pb)-Sr-Ca-Cu-O (BSCCO) high-temperature superconductor. This material is generally fabricated in form of discrete filaments, which are embedded in a matrix of noble metal, typically silver. Although such conductors may be made in extended lengths needed for implementation into the power industry (such as on the order of a kilometer), its widespread commercially feasibility is limited due to materials and manufacturing costs. Accordingly, a great deal of interest has been generated in the so-called second-generation HTS YBCO tapes that have superior commercial viability¹. However, to date, numerous engineering and manufacturing challenges remain prior to full commercialization of such second generation-tapes. These tapes typically rely on a layered structure, generally including a flexible substrate that provides mechanical support, buffer layers overlying the substrate, an HTS YBCO layer overlying the buffer film, and an electrical stabilizer layer around the entire structure. In the following section we will discuss the importance and development of low-cost stabilizer layer.

High temperature superconducting (HTS) coated conductors have possibilities to be quenched due to several factors, e.g., local defects in the conductors, over-load operation, a failure in power supply and cooling system, etc. Quench produces excessive temperature or voltage in the coil winding, and overheating may cause the conductor to meltdown or high voltage to cause a dielectric break down²⁻⁶. Coated conductors that are made by deposition of thin HTS YBCO film on Hastelloy tapes or textured Ni based substrates become highly resistive when they are quenched. Therefore to manufacture reliable and safe HTS coil, conducting layers such as Cu and Ag are necessary to attach to the HTS tapes to stabilize and protect the conductors from damage due to quenches. The stabilizer layers also serve as a protection layer against harsh environmental conditions. The stabilization layers are generally dense, thermally and electrically conductive, and

bypass electrical current in case of failure of the superconducting layer or if the critical current of the superconducting layer is exceeded. It has been found that a capping Ag layer at least 1 micron in thickness is needed between the superconductor layer and the Cu-stabilizer layer to avoid interfacial reaction and reduction in the critical current capability of the superconductor layer. At present, the capping Ag-stabilization layer is fabricated by sputtering techniques. Sputtering techniques are suitable for large-area deposition; however, they require expensive vacuum equipment and suffer from low material utilization. Non-vacuum electrodeposition techniques have the potential to prepare large-area uniform films using low-cost source materials and low-cost capital equipment. We are developing a non-aqueous based Ag-stabilization layer which is non-reactive to the HTS layer. While the content of silver in 2G HTS wire is small ($< 2 \mu\text{m}$), silver deposition is an important constituent of wire cost as well as production capacity.

EXPERIMENTAL

Electrodeposition of Ag on YBCO superconductor tape was performed from a bath containing AgNO_3 dissolved in organic solvent. A Fisher Scientific (FB300) power supply was used to electrodeposit Ag films. The electrodeposited Ag films were prepared by employing a two-electrode cell in which the counter electrode was Pt gauze and the working electrode (substrate) was YBCO tape.

Critical current measurements were conducted using non contact technique. A hall-probe-based measurement was used for the non contact technique with a spatial resolution of 1 mm.

RESULTS AND DISCUSSION

Electrodeposition uses electrolysis to deposit a coating of the desired form on conducting substrates from a solution ("bath") containing the ions of interest (e.g., Ag^+). In cathodic electrodeposition, when the potential of the substrate (electrode) is moved from its equilibrium value toward negative potentials, the cation will be reduced and metal film will be deposited on the substrates. In a solution containing Ag^+ , when the potential is sufficiently negative, the deposition of Ag on electrode surface takes place, corresponding with the following Nernst equation.



$$E = E^0_{\text{Ag}} + \frac{RT}{F} \ln [\text{Ag}^+] = 0.799 + 0.0591 \log [\text{Ag}^+] \quad (2)$$

where E is the electrode equilibrium potential with respect to the standard hydrogen electrode (SHE); and E^0_{Ag} is the standard electrode potentials of Ag. F is Faraday's constant equal to 96,485 Coulomb/mole.

The electrodeposited Ag thin film morphology and thickness were evaluated by the scanning electron microscopy (SEM). Figure 1(a) and 1(b) show the SEM of the electrodeposited Ag film deposited from an organic solvent on glass/Mo substrates. The surface morphology of the electrodeposited film shown in Fig.1a indicates the deposition of dense polycrystalline Ag film. The cross-sectional view of an electrodeposited Ag film deposited for 2 minutes is shown in Fig.2b. The SEM cross sectional image shows the film thickness is about 3.5 microns with a deposition rate of about $1.75 \mu\text{m}/\text{min}$. The surface morphology of the bare YBCO tape and electrodeposited Ag film deposited on YBCO tape for 2 minutes are shown in Fig.2(a) and 2(b). The SEM images indicate that electrodeposition of Ag is strongly influenced by the surface topography of YBCO tape.

Figure 3(a) and 3(b) show I_c of two YBCO tapes with electrodeposited Ag-stabilization layer. The I_c of bare YBCO tape does not change after the electrodeposition of Ag thin film. The I_c improves slightly after annealing the tape with electrodeposited Ag. Figure 4 shows the results obtained from YBCO tape with sputtered Ag. Figure 5 shows the results obtained from the bare YBCO tape. The annealing process does not have any effect on the YBCO tape coated with sputtered Ag and also for bare YBCO tape. YBCO tapes with electrodeposited Ag-stabilization layer, YBCO tape with sputtered Ag and bare YBCO tape were annealed together. The I_c improvement of the annealed electrodeposited Ag-coated YBCO tape is not clearly understood at this time, but

could be due to the electrochemical reduction reactions which can change the stoichiometry/oxygen of the YBCO tape.

CONCLUSION

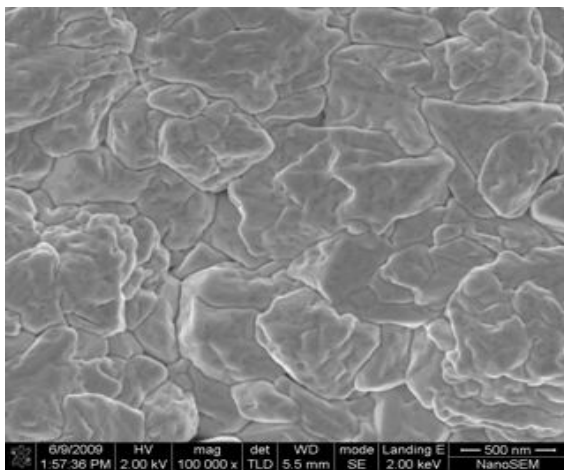
We developed a non-aqueous based electrodeposition process of Ag-stabilization layer on YBCO superconductor tapes. We demonstrated that direct Ag plating on YBCO tapes from the non-aqueous solvent does not destroy the superconducting YBCO layer. Overall, it is seen that the critical current of YBCO tape stays at the similar level after each step indicating no degradation in the tape quality after the electrodeposition and oxygenation processes.

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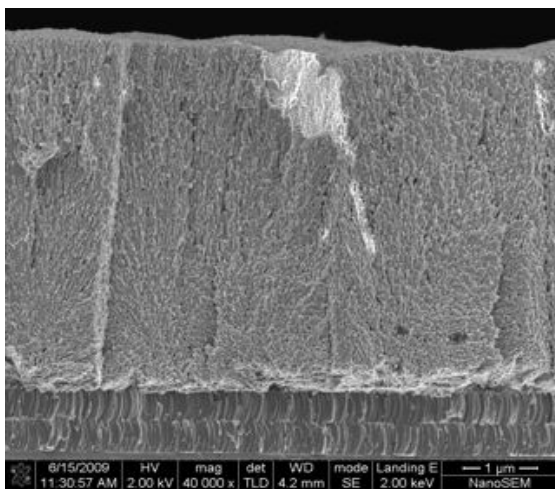
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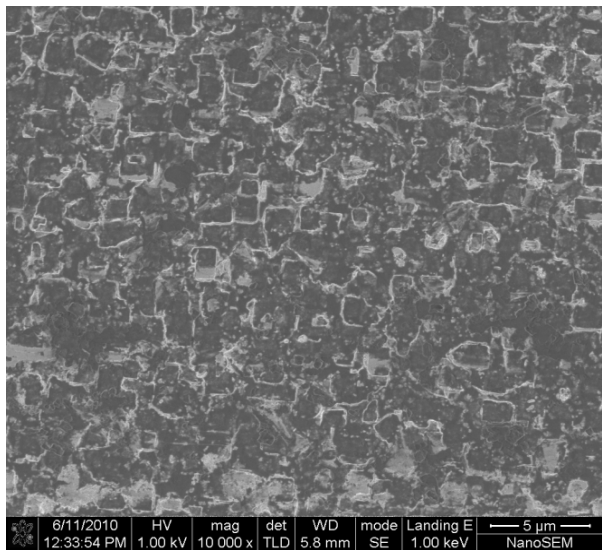


(a)

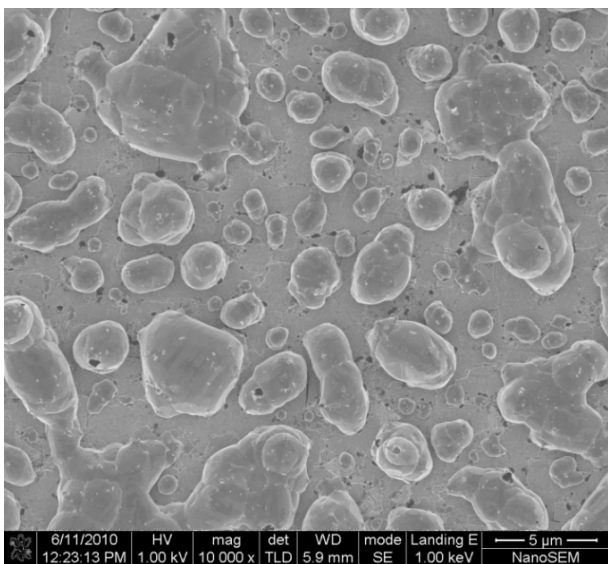


(b)

Figure 1. (a) SEM surface morphology of an electrodeposited Ag film on Mo/Glass; (b) SEM cross-section of a film deposited for 2 minutes on Mo/Glass.

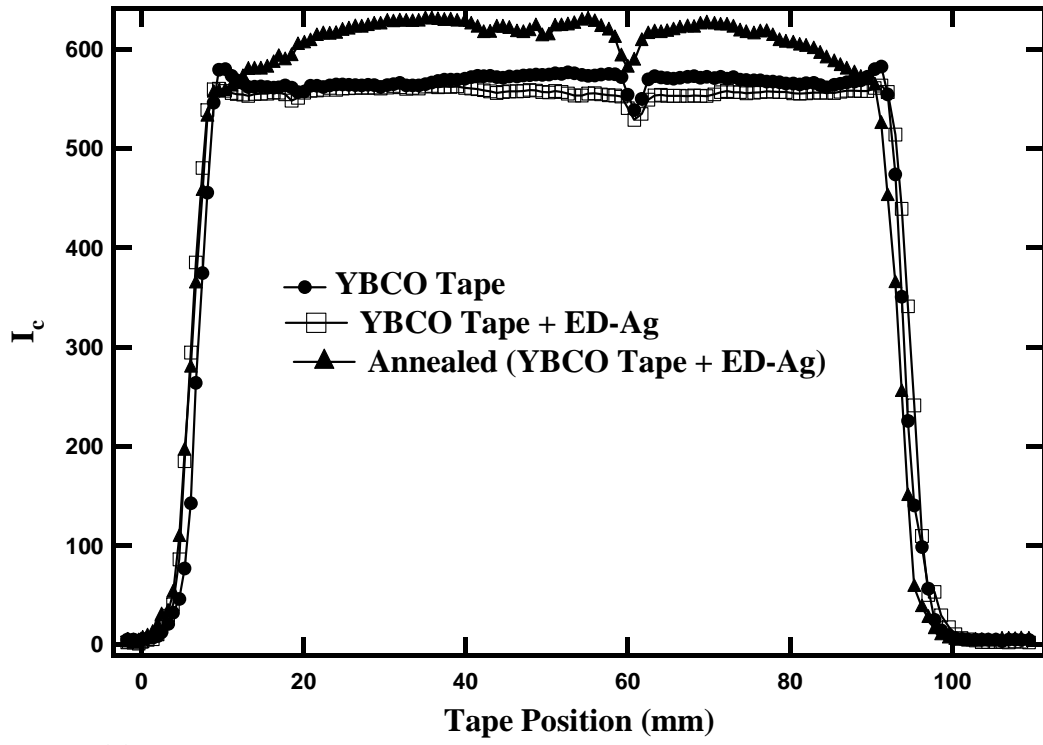


(a)

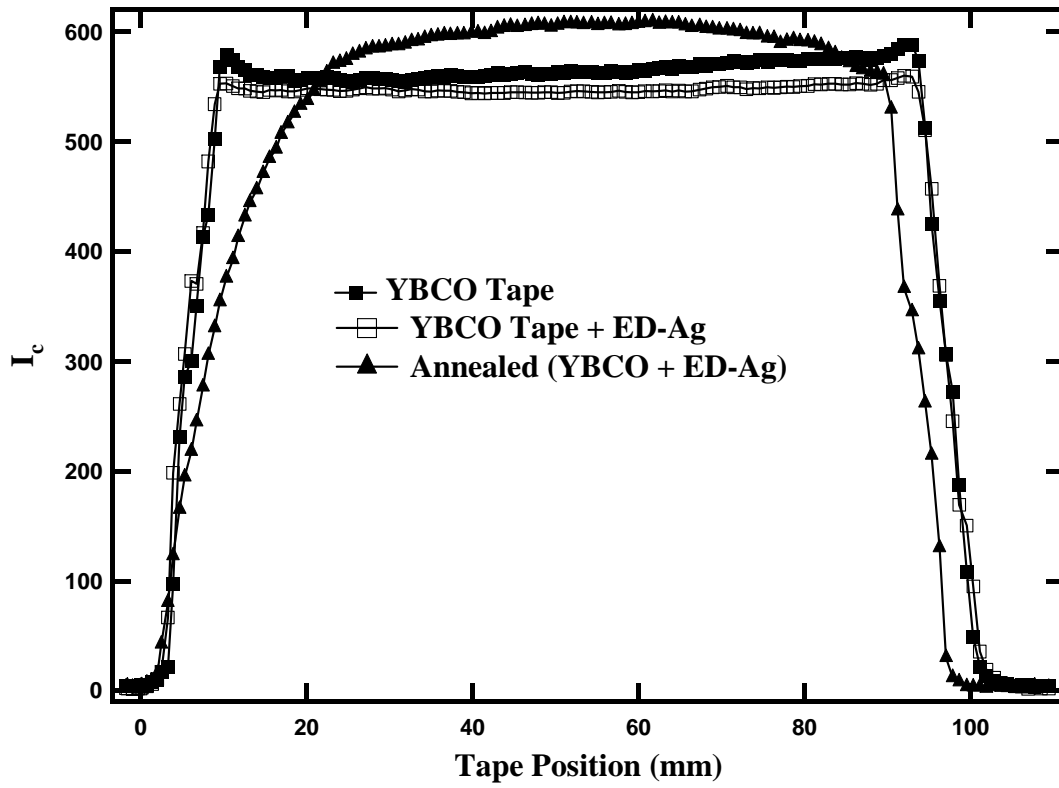


(b)

Figure 2. SEM surface morphology of (a) YBCO tape and (b) YBCO tape with electrodeposited Ag thin film.



(a)



(b)

Figure 3(a) and (b). I_c of two 10 cm YBCO tapes with electrodeposited Ag-stabilization layer (before and after annealing). The I_c results are compare with bare YBCO tape

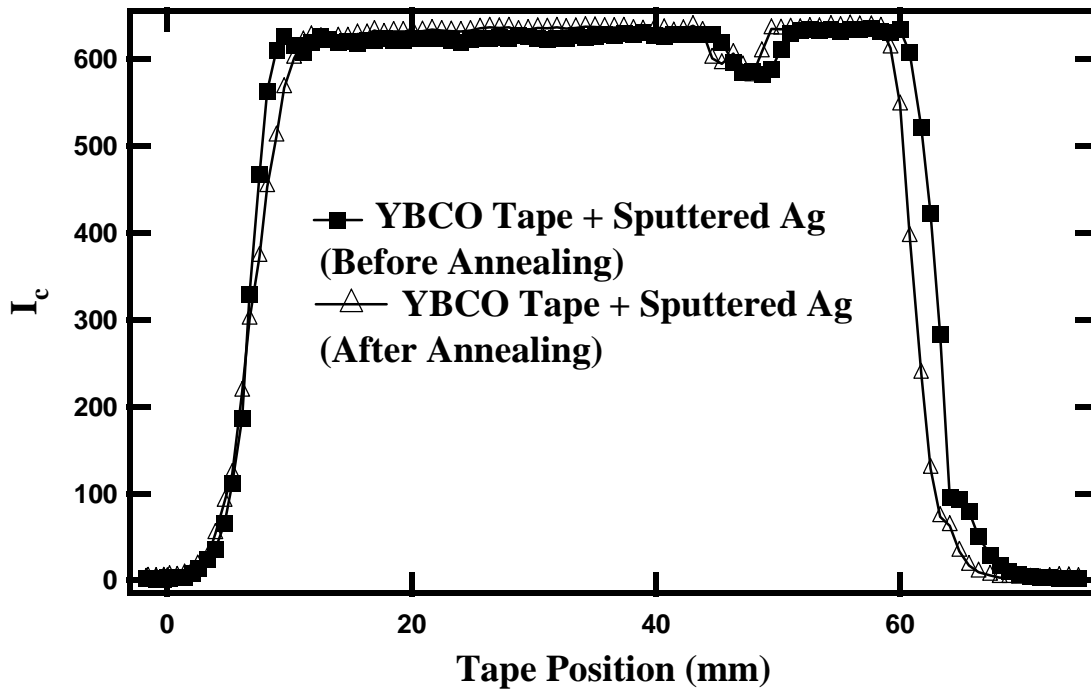


Figure 4. I_c results obtained from YBCO tape with sputtered Ag (before and after annealing).

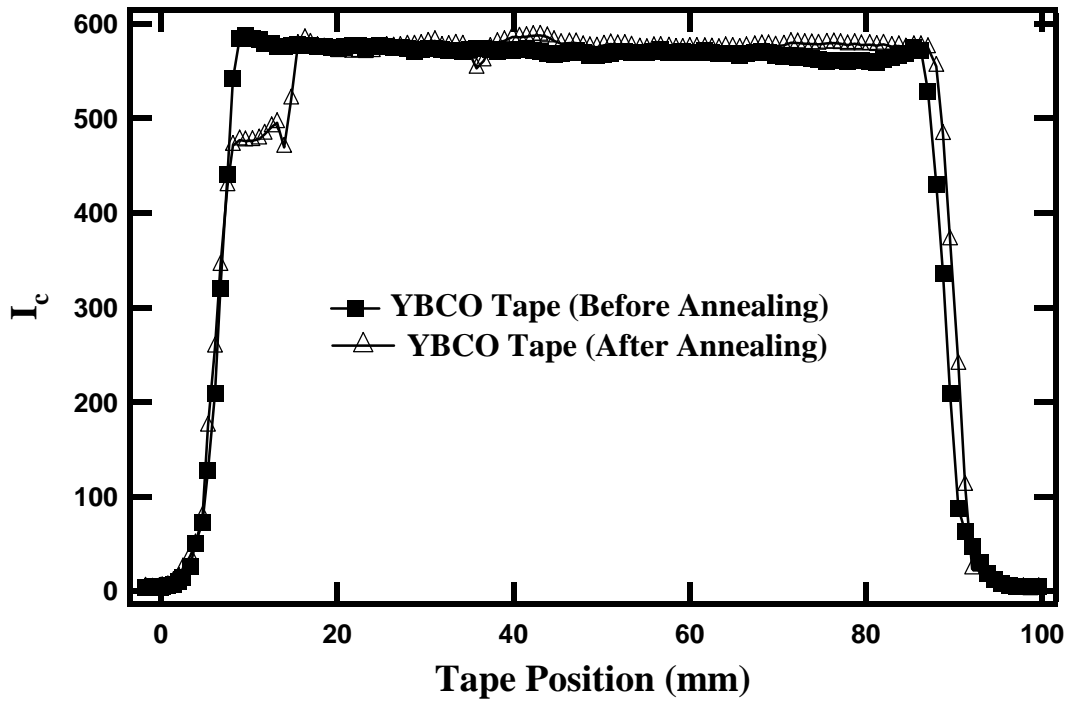


Figure 5. I_c results obtained from the bare YBCO tape (before and after annealing).

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