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Solution deposition planarization for IBAD-MgO texture template

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Abstract-- **In this work, the optimized process condition of chemical solution deposition which is used to planarize the surface of the metal tape (which is used to grow IBAD-MgO texture template) was investigated. Y_2O_3 films were dip-coated on the surface of the unpolished metal tape as the seed and barrier layer. The effects of Y_2O_3 concentration of the solution (0.5wt.%, 1.3wt.%, 2.8wt.%, 5.6wt.%) and the number of coatings on the surface morphology and barrier capability against the diffusion from the metal tape were examined. The surface morphology and the thickness of the film were observed using the scanning electron microscope and the atomic force microscope. The presence of elements in metal tape on the film surface was analyzed using the auger electron spectroscopy. The Y_2O_3 film thickness increases with increasing the Y_2O_3 concentration in the solution, and the surface became smoother with increasing the number of coating cycles. The best result was obtained from the Y_2O_3 film coated 4 cycles using 2.8wt.% solution.**

1. INTRODUCTION

To achieve high critical currents in coated conductor (CC), using ion-beam assisted deposition (IBAD) texture template, the roughness of the substrate surface and the texture of the buffer layer are important factors [1-4]. The substrate used for the IBAD consists of multiple layers, which include metal tape, barrier and seed layer. The diffusion barrier capability and the surface roughness of the buffer layers have an important influence on the performance of the CC fabricated on them. In order to obtain buffer layer with smooth surface, electro-polishing process of metal tape is used. The electro-polishing process which is used to improve the smoothness of the metal surface, however, needs a lot of energy and produces large amount of acid waste. In addition, for large-scales application of CC in power electric devices, the performance per cost is also important. The solution deposition planarization (SDP) has been used to smooth the rough surface of the metal tape and make it ready for IBAD processing [1]. SDP can replace the electro-polishing and the physical vapor deposition of the barrier/seed layer.

The advantage of SDP include low production cost, simple and environmentally-friendly process, no need to electro-polish metal tape and compatibility with many alloys [5, 6].

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In SDP, the deposited layer should perform the important roles as a diffusion barrier and a seed layer Y_2O_3 solution is a promising candidate for the SDP layer.

In this paper the optimized process condition of SDP was investigated.

2. EXPERIMENTAL

Various concentrations of Y_2O_3 solutions (0.5, 1.3, 2.8, 5.6wt.%) made by NanoM company were used. Fig. 1 shows the process for synthesizing Y_2O_3 solutions. The precursor solutions were dip-coated on unpolished metal tapes, and then the films were heated at 350°C for drying. The coating and drying process, namely a cycle of coating process, was repeated several times to obtain smooth surface. The surface morphology and the thickness of the films were observed using the scanning electron microscope (SEM: JSM-6330F) and the atomic force microscope (AFM: SPA-400). To investigate the effectiveness of the chemical solution deposited layer as the diffusion barrier, the Y_2O_3 film on metal tape was heat-treated at 880°C for 10 min, and the presence of elements in the metal tape on the film surface was analyzed using auger electron spectroscopy (AES: PHI 660).

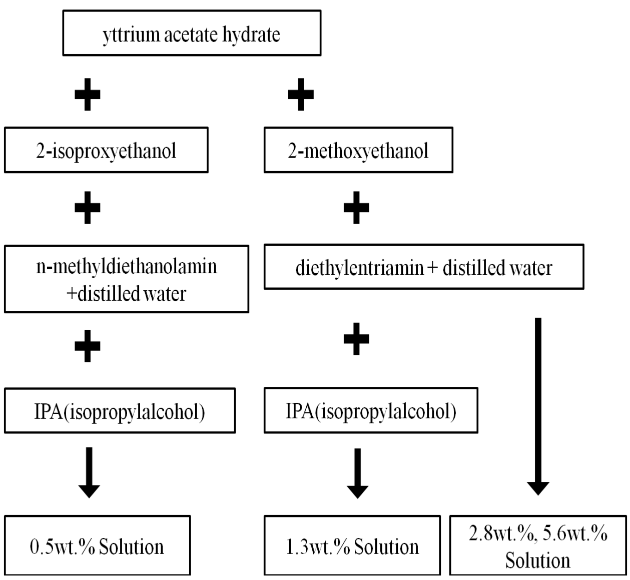

Fig. 1. The process for synthesizing Y_2O_3 solution.

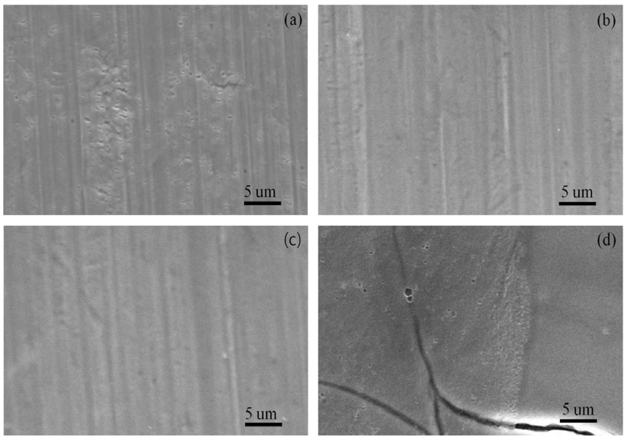

Fig. 2. SEM images of the surface morphology of (a) the bare metal tape, (b) tape with 10-cycle Y_2O_3 coating using 1.3wt.% solution, (c) tape with 4-cycle using 2.8wt.% solution, (d) tape with 3-cycle using 5.6wt.% solution.

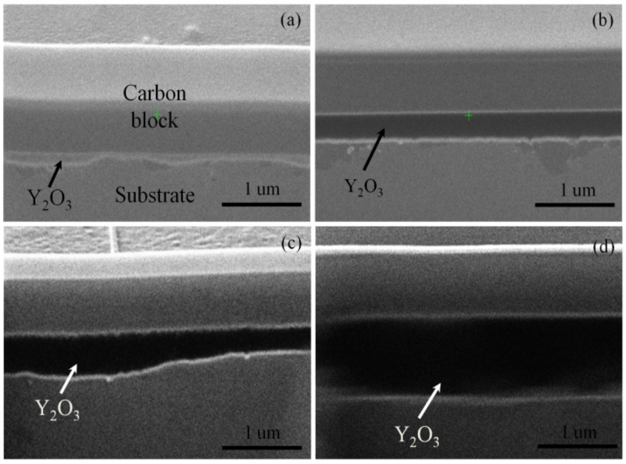

Fig. 3. 45 degrees tilted cross sections of (a) 10-cycle Y_2O_3 films using 0.5wt.% solution, (b) 10 cycle Y_2O_3 using 1.3wt.% solution, (c) 4 cycle Y_2O_3 using 2.8wt.% solution and (d) 3 cycle Y_2O_3 using 5.6wt.% solution.

3. RESULTS

In order to optimize the process condition of the chemical solution deposition, the four Y_2O_3 solutions (0.5, 1.3, 2.8, 5.6wt.%) with different concentrations were used to form thin films, and the number of coating cycles was varied from 1 to 20.

Fig. 2 shows the SEM micrographs of the surface morphology of the bare metal tape and the tapes with Y_2O_3 coating. As seen in Fig. 2 (a), the surface of the bare metal tape has many holes and lines that can come from the tape manufacturing process. Instead, the tapes with Y_2O_3 coating show surface smoother than that of the bare metal. Thu numbers of the coating process and the concentrations of solutions for the samples can be found in the figure caption. In case of the highest concentration solution, 5.6wt.%, the pores and cracks on the surface were observed which is very usual for the chemical solution deposited films with high concentration solutions [8].

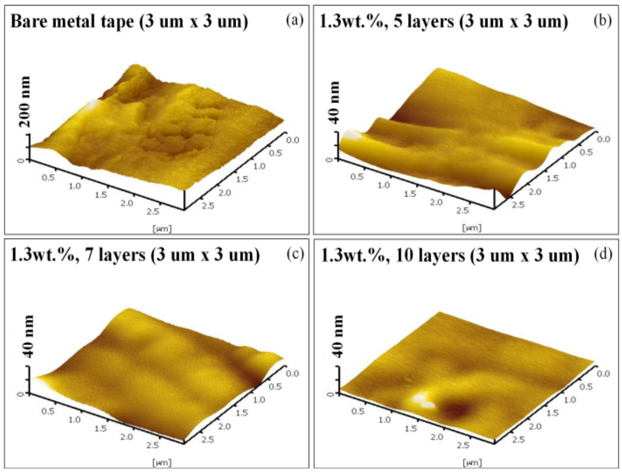

Fig. 4. AFM images of (a) the bare metal tape, (b) the surface of 5-cycle Y_2O_3 coating, (c) that of 7-cycle coating, and (d) that of 10-cycle coating, using 1.3wt.% solution.

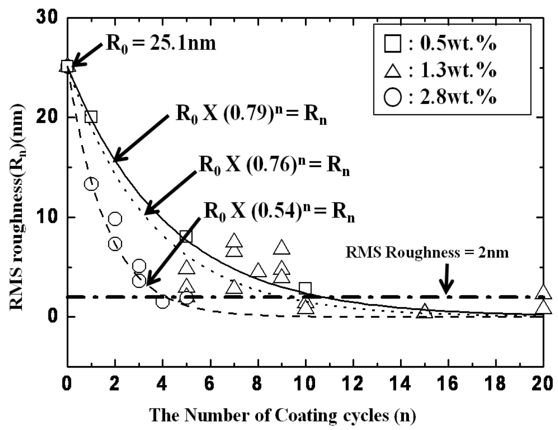

Fig. 5. The roughness values of the samples as a function of the number of the coating cycles.

Fig. 3 shows FIB cross-sections of the Y_2O_3 layers coated on the metal tapes. The thickness was estimated from the Fig. 3 using a multiplication factor of $\sqrt{2}$ because the pictures were taken at 45 degrees with respect to the normal vector of the cross section. The Y_2O_3 layer thicknesses of Fig. 3 (a) ~ (d) are 35-115 nm, 250-265 nm, 275-600 nm, and 960-980 nm, respectively. The large variation of the thicknesses on each sample was due to the roughness of the bare metal tape. The largest number of the thickness was taken from the deepest point of the metal tape surface. Generally, the film thickness increases with increasing Y_2O_3 concentration in the solution. The planarization of the metal tape by the solution deposition process can be clearly observed in Fig. 3 (c).

AFM images of the surface coated using a 1.3wt.% Y_2O_3 solution are shown in Fig. 4 for 5, 7, and 10 coating cycles. The root mean square roughness (R_{rms}) value of the bare metal surface was 25.1 nm at 3 um x 3 um while that of the surface 10 cycles coated was 1.4 nm at 3 um x 3 um. The similar R_{rms} values were obtained for the tape surface coated more than 4 cycles using a 0.5 and 2.8wt.% Y_2O_3 solutions.

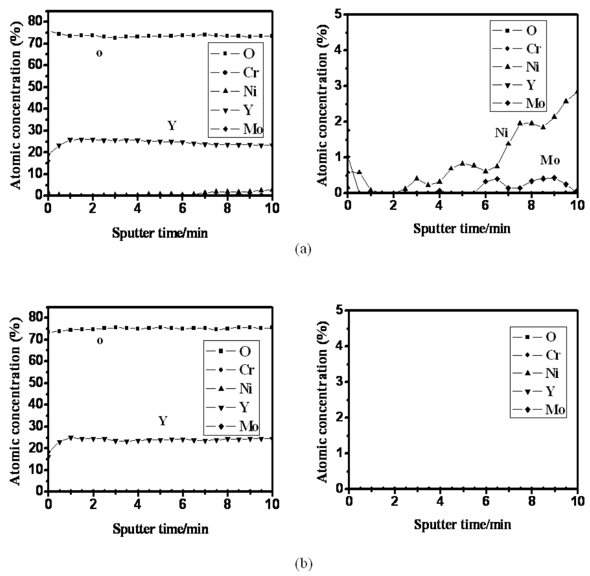

Fig. 6. Auger electron spectroscopy depth profiles of the (a) Y_2O_3 Film with coating 10 cycles using 1.3wt.% solution and (b) that with 4 cycles using 2.8wt.% solution.

The R_{rms} roughness values for the samples are plotted in Fig. 5 as a function of the number of coating cycles. The data were fitted by the equation $R_0 * A^n = R_n$ where R_0 is the roughness of the uncoated substrate. A is the shrinkage rate, n is the number of coating cycles and R_n is the R_{rms} after n-cycles coating [5-7]. Here the shrinkage rate (A) is the fitting parameter which is shown in Fig. 5. As the concentration of the solution increases, the shrinkage rate decreases.

The surface became smoother with increasing the number of the coating cycles. However, as shown in Fig. 2 (d), cracks were observed on the surface coated using a 5.6wt.% solution, which can be a problem for barrier capability against the diffusion from the metal tape. The Y_2O_3 layers coated for 10 cycles using 1.3wt.% solution and for 4 cycles using 2.8wt.% solution showed good performance for the planarization of the rough surface of the bare metal.

To investigate the effectiveness of the chemical solution deposited layer as the diffusion barrier, the Y_2O_3 film on the metal tape was heat-treated at 880°C for 10 min which is similar to the high temperature condition the IBAD-MgO template will go through during the CC manufacturing process. The auger electron spectroscopy depth profiles of the heat-treated Y_2O_3 layers are shown in Fig. 6. The metal elements (Ni, Mo) diffused from the metal tape were observed on the surface of Y_2O_3 film with 10-cycles coating using 1.3wt.% solution (Fig. 6 (a)), while any of them were not observed on the surface with 4-cycles using 2.8wt.% solution. The latter Y_2O_3 layer prevented the metal element from diffusing from the metal tape.

4. CONCLUSION

This paper has presented the detailed investigation on the solution deposition planarization for the bare metal tape using the four Y_2O_3 solutions (0.5, 1.3, 2.8, 5.6wt.%) with different concentrations. The planarized surface of the bare metal tape after the solution deposition process was observed at the cross section of the sample coated for 4 cycles using a 2.8wt.% solution. Generally, Y_2O_3 film thickness increases with increasing the Y_2O_3 concentration in the solution, and the surface became smoother with increasing the number of the coating cycles [5, 9]. The smooth surface ($R_{rms} < 2$ nm) of the Y_2O_3 films deposited for 10 cycles using a 1.3 wt. % solution and 4 cycles using a 2.8wt.% solution was obtained. However the Y_2O_3 film deposited for 10 cycles using a 1.3wt.% solution did not prevent the metal element from diffusing from the metal tape. In this work, the best result was obtained from the Y_2O_3 film coated 4 cycles using 2.8wt.% solution.

ACKNOWLEDGMENT

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