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AC loss reduction of TFA-MOD coated conductors in long length by laser scribing technique

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Abstract

TFA-MOD process is expected to be promising for future applications since it can produce high performance YBCO coated conductors with low cost. Applying YBCO coated conductors to the power electric devices such as transformer, cable, motors, reduction of AC loss for long wire is necessary. Multifilamentation, which is one of the effective approaches for AC loss reduction, has been developed by the scribing process. YBCO coated conductors produced by our standard TFA-MOD process delaminated into two parts by the laser scribing. The delamination was clarified to occur within the superconducting layer caused by the defects such as pores in the superconducting layer. In order to reduce the defects in the superconducting layer, we modify the heat treatment profile performed on the decomposed precursor films by applying the interim annealing(550-600 ℃) before crystallization heat treatment(740-770 ℃). The interim annealed samples had much less and smaller pores than the standard processed ones. The peel strength measured by transverse tensile test was as high as the PLD derived coated conductors which was successfully scribed into five filaments resulting in 1/5 AC loss. A 50m long YBCO coated conductor with the characteristics of 398A/cm-width was obtained and cut into 5mm width, followed by the laser scribing process into five filaments. The multifilamentation process was successfully performed without delamination throughout the wire. The hysteresis loss was down to 1/N (N: number of filaments), as we aimed. The I_C properties of the filaments were 29±4A, indicating the wire was uniformly fabricated.

Keywords: YBCO; TFA-MOD; Delamination strength; AC loss

1. Introduction

YBCO coated conductors with high critical current density (J_C) under the self-fields as well as the external magnetic fields would be expected for applications of electric power devices such as power cables, Superconducting Magnetic Energy Storage (SMES) and transformers. The metal-organic deposition (MOD) method using the starting solution containing trifluoroacetate (TFA) salts of yttrium, barium and copper is one of the most promising methods for fabrication of long YBCO tapes with high property cost-effectively. High critical current (I_C) characteristics, long length, high production rate, low AC loss and low cost are required for YBCO coated conductors. YBCO coated conductors composed of narrow filaments have low AC loss which is strongly required in the applications such as

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"transformers" , "power cables". Therefore uniform I_C characteristics in transverse direction is also necessary as well as the technology of filamentation.

In our previous work, the uniformity in transverse direction was improved by reducing a tube diameter in dip-coating. We have developed a filamentation technique of laser scribing [1] , however, TFA-MOD derived coated conductors were difficult to be scribed due to delamination mostly occurred within the superconducting layer.

We investigated the delamination and found that many pores existed in the superconducting layer. We inferred that the pores caused the delamination of the superconducting layer. In this work, we investigated the influence of the interim annealing in order to reduce the number/size of the pores for fabrication of long YBCO coated conductors which can be laser scribed to reduce AC loss.

2. Experimental

The starting solution was prepared by dissolving TFA salts of Y and Ba, and Cu-Octylate with a cationic ratio of Y : Ba : Cu = 1:1.5:3 into the organic solvent [2]. The starting solution was dip-coated/decomposed on the buffered metal substrates with the architecture of CeO_2/$LaMnO_3$/IBAD-MgO/GZO/Hastelloy^{TM} using the multi-turn Reel-to-Reel (RTR) system and the process was repeated to obtain desired thickness. These decomposed samples were interim annealed at 575℃ for 3 hours in a dry Ar gas atmosphere. Finally these samples were heated to 765 °C in a mixed humid gas of nitrogen and oxygen under reduced total pressure.

The microstructure of these samples was observed by scanning electron microscopy (SEM). The peel strength was measured by transverse tensile test [3].The crystallized YBCO films were cut into filamentations by YAG laser scribing technique[1]. The hysteresis loss was measured by the pickup coil method [4]. I_C values of these YBCO films were measured by a conventional four-prove DC transport method with a criterion of 1μV/cm.

3. Results and Discussion

Transverse tensile test was performed on the samples prepared with and without the interim annealing. The delaminated surface of the interim annealed sample was rarely the superconducting layer and mostly the YBCO/CeO_2 boundary. Fig.1 shows the results of the transverse tensile test of the interim annealed films comparing with those without the interim annealing and PLD films. The minimum peel strength increased from 10MPa to 30MPa due to interim annealing as high as that of PLD derived coated conductors. The laser scribing into 5 filaments (5mm in total width) has been successfully performed using 50m long PLD coated conductors, therefore, the improvement was considered to be enough for the same scribing.

According to the other report [5], many pores exist in the superconducting layer of no interim annealed sample. On the other hand, the number and size of pores in the superconducting layer of the interim annealed sample were reduced and the superconducting layer was densified. It can be a reason for improvement of the peel strength. We also recognized that I_C performance was improved partly because of the densification of the superconducting layer [6].

Based on the above results, a 50m long YBCO coated conductor was produced by new process including the interim annealing. The conductor with the I_C characteristics of 398A/cm-width was obtained and standard deviation of Ic distribution in longitudinal direction was 6.4A (2%) as shown in Fig. 2. The produced conductor was quite uniform. Then the YBCO conductor was cut into 5mm width and divided into five filaments by the laser scribing technique. The scribing process was successfully performed without the delamination of the superconducting layer. We measured the hysteresis loss by the pickup coil method, which is the imaginary parts of AC susceptibility of the long wire before and after the scribing (Fig. 3). The imaginary part of AC susceptibility is proportional to hysteresis loss. Therefore, we recognized that the hysteresis loss was down to 1/5 by the scribing because the imaginary part of AC susceptibility was down to 1/5 as shown in Fig. 4. Fig. 5 shows the *I-V* curves of the scribed wire. All filaments showed almost the same I_C performances. The total critical current of five filaments was 143.7(A) and I_C value was 199.5(A) before scribing, so the ratio of I_C change was 28%. The amount of the superconducting layer loss estimated from the filament width and groove width was 19%, so the ratio of I_C degradation due to damaging by scribing process was less than 10%. It indicated that both conductor production process and laser scribing process were successfully performed. We think that the uniformity in transverse direction after scribing process was improved due to reduction of the pores in the superconducting layer and development of the laser scribing technique. We have also tried to divide into ten filaments using a short sample. In this sample, no delamination was observed.

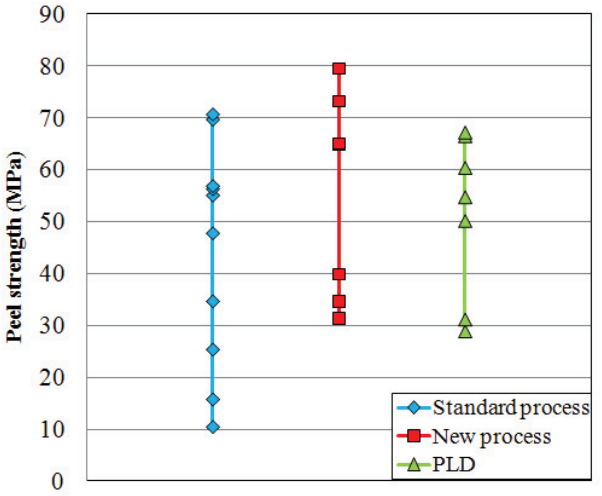

Fig. 1. The results of the transverse tensile test.

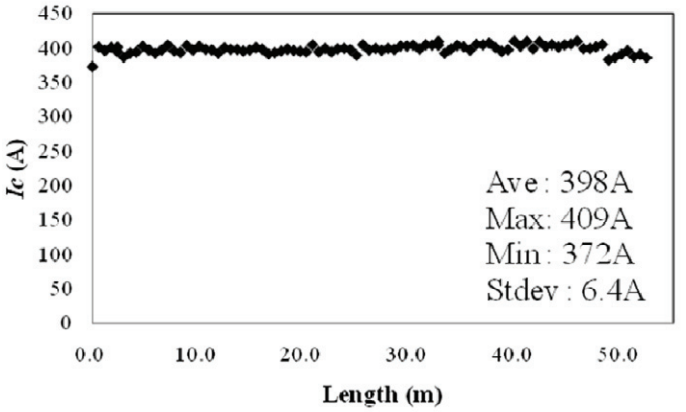

Fig. 2. The I_C distribution in longitudinal direction of the 50m YBCO conductor.

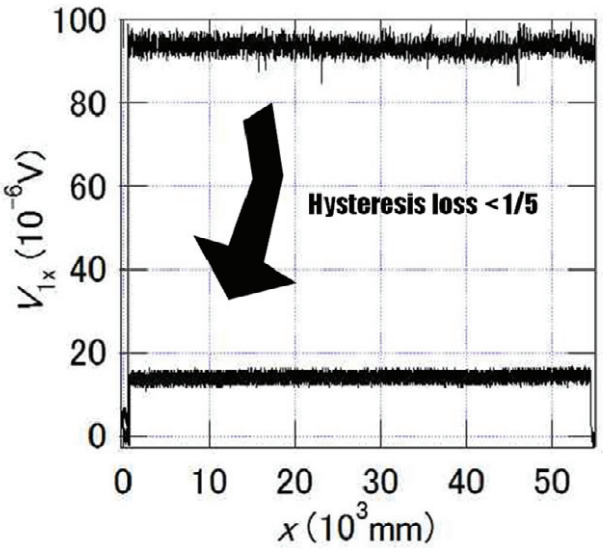

Fig. 3. The result of the hysteresis loss measurement (The imaginary parts of AC susceptibility).

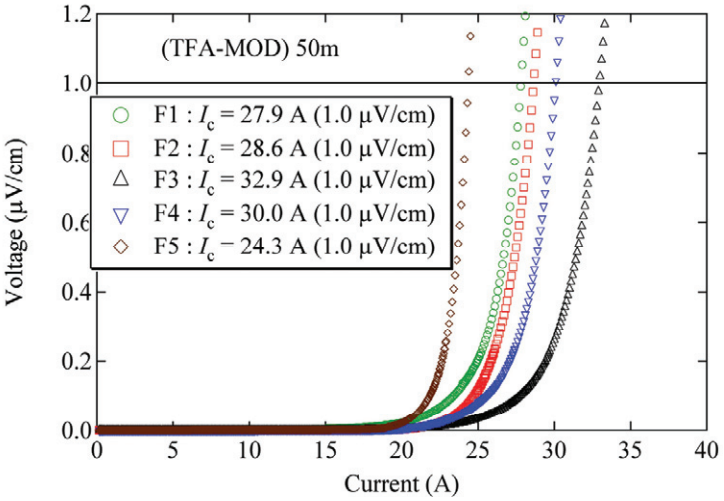

Fig. 4. The results of the filaments I_C measurement.

4. Conclusion

The interim annealing was adopted to reduce the number/size of the pores in superconducting layer which caused delamination by the laser scribing process. We found that the number/size of the pores were reduced by adopting the interim annealing and the superconducting layer was densified. As a result, the peel strength increased enough to be scribed. A 50m long YBCO coated conductor was produced by the new process including the interim annealing. The YBCO conductor was divided into five filaments by the laser scribing technique. The scribing process was successfully performed without delamination in whole length and the ratio of I_C degradation was less than 10%. And the hysteresis loss was reduced down to 1/5 (1/the number of filaments). We have also succeeded in dividing a short sample into ten filaments without delamination.

Acknowledgement

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