YBCO 박막도체의 비틀림 변형률에 따른 임계전류 열화거동

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I_c Degradation Behavior in YBCO Coated Conductors under Torsional Strain

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Abstract: The I_c degradation behavior of YBCO CC tapes due to torsional deformation has been investigated. Particularly, the influence of torsion angle on the I_c in HTS tapes was examined at 77K (self-field). At low torsional angles or shear strains, the I_c degradation was small and gradual. Also, a good consistency of the I_c degradation behaviors was found along the longitudinal direction under torsion when multiple voltage terminals were adopted for investigating the homogeneity of the I_c degradation.

Key Words : YBCO, Coated conductor, Torsional shear strain, Critical current, n-value

1. Introduction

YBCO coated conductors (CC) are now commercially available for electric power applications. In cable applications, high temperature superconductors (HTS) tapes are subjected to different kinds of deformation or loads including twisting [1]. Therefore in this paper, the I_c degradation behavior and its homogeneity along the longitudinal direction under torsional deformation in YBCO CC tapes were investigated. It is meaningful to investigate if the I_c degradation behavior at each section along the longitudinal direction of tapes would be gradual and consistent, similar to the case of the Bi-2223 tapes [1].

2. Experimental Procedures

A YBCO CC manufactured using the Metal Organic Deposition (MOD) on a RABiTS substrate, which has the structure of Ag/YBCO/CeO_2/YSZ/Y_2O_3/Ni-5at.%W was used. The tape was laminated on both sides with hardened copper for stabilization. The critical current, I_c, of the tape is over 70 A. Fig. 1 shows the enlarged view of the cross-section of the sample used.

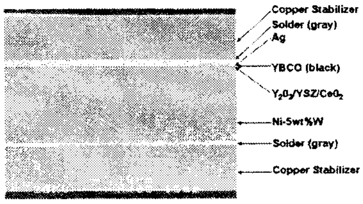
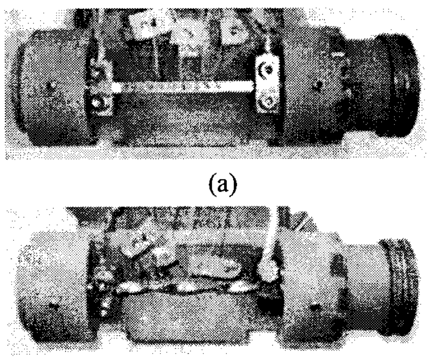


Fig. 1 Enlarged view of the cross-section of the YBCO CC sample.



(a)

(b)

Fig. 2 Appearance of sample mounted to holders during testing at the twisting angle of (a) 0°, and (b) 450° respectively.

Fig. 2 (a) shows the set-up for the torsion test of YBCO CC. The theory and test procedures are given in Ref [1]. The only difference with the set-up given in the reference is that the fixing of the CC tape was changed from soldering to mechanical contact. Fig. 2 (b) shows the appearance of the sample twisted at θ = 450°. The turning of the knob was conducted at RT to give a specific torsion angle to the YBCO CC sample, and then the sample holder was cooled to 77 K to measure I_c. After I_c measurements at 450°, the torsion angle was returned to θ = 0°.

The maximum torsional shear strain, ε_t, which occurred at the midpoint of the width side of the cross-section, can be evaluated based on [2],

$$\varepsilon_t = t\theta/L \qquad (1)$$

where t is the thickness of the sample, θ is the twisting angle usually expressed in radians and L is the gauge length of the sample subjected to torsional deformation, 60 mm.

I_c was measured using the four probe method and defined by a criterion of 1 μV/cm. In order to investigate the homogeneity of I_c degradation induced by torsional strains along the longitudinal direction in YBCO CC tapes, the 30 mm part of the gauge length was divided into six sections, 5 mm apart. Seven voltage terminals designated as A-G were soldered to the tape to measure I_c at each section. From the current-voltage (I-V) curve obtained, the n-value was also calculated by a linear fitting in the voltage range of 0.2-5.0 μV/cm.

3. Results and Discussion

Fig. 3 shows $I_c/I_{c0}(\theta)$ behavior obtained through the torsion test of the YBCO CC tape at 77 K (self field). The I_c measured was normalized by the I_{c0} obtained at θ and $\varepsilon_t = 0$. For the 30-mm region (A-G) shown with the dotted line, I_c almost had a constant value up to 180° (corresponding to ε_t = 0.94%), and then it began to degrade slowly up to 300°. At 300° (ε_t = 1.6%), the I_c degradation was gradual and small (below 5%). This gradual I_c degradation behavior is a characteristic feature of YBCO under torsional loading which is similar to the I_c degradation in Bi-2223 under bending [1].

When the torsional angle exceeded 300°, I_c degraded rapidly with the increase of the torsional angle. At 360°, the I_c showed a 10% I_c degradation. From 360°~450°, I_c degraded sharply and eventually to below 60% of I_{c0}. When the torsional strain was released, about 10% of the I_c was recovered. But when the torsional angle of 450° was applied again, more degradation of I_c occurred. When the torsional strain was again removed (0°), more degradation of I_c occurred.

Fig. 3 also shows that all the sections measured along the longitudinal direction showed a similar I_c degradation with the 30-mm voltage tap separation (A-G), showing high consistency and uniformity. This consistent I_c degradation behavior along the longitudinal direction is a characteristic feature of HTS tape under torsion [1].

The torsion angle dependencies of the n-value is shown in Fig. 4. The n-value of the sample in the untwisted state (θ=0) is about 28. It can also be found that the n-value behavior is similar to the I_c degradation behavior with torsional angle as shown in Fig. 3.

4. Conclusions

The I_c degradation in YBCO CC tape under torsion strains occurred gradually which is a characteristic feature of CC tape under torsion.

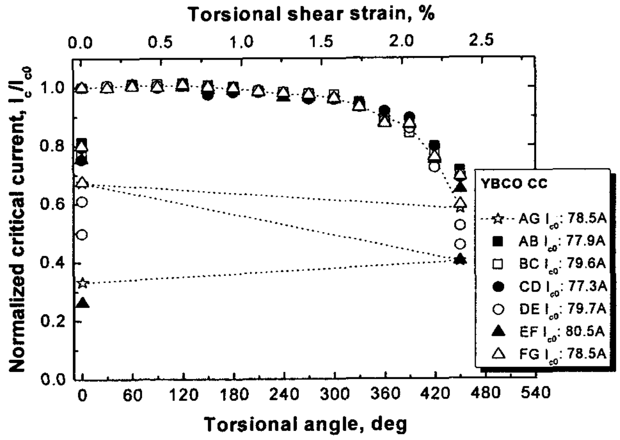


Fig. 3 $I_c/I_{c0}(\theta)$ behavior obtained at each region during torsion test of YBCO CC.

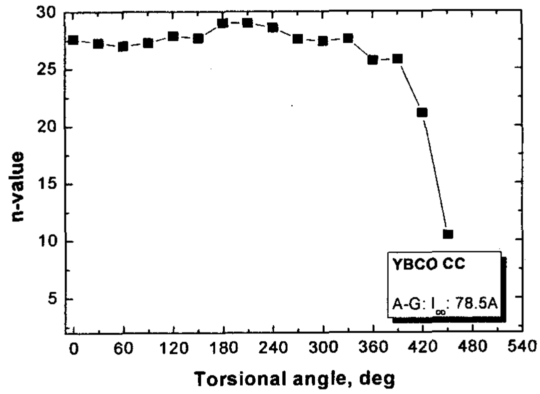


Fig. 4 Normalized n-value(θ) behavior obtained during torsion test of YBCO CC.

Through I_c measurements using multiple voltage tap separations, a uniform torsional deformation can be observed in the tape. The n-value behavior of the YBCO CC tape is similar with the I_c/I_{c0} behavior.

Acknowledgments

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