Experimental Results of Various Optical Fibers Encapsulated HTS Tapes Under Impulse Currents for the SFCL Application

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Introduction

1) In high temperature superconducting (HTS) applications, especially for HTS magnets, quench detection is very important to protect the magnets from burning out. As a potential candidate method, the technology based on distributed temperature sensors (DTS) using optical fibers is proposed in recent years, and some progress is shown in HTS quench detection.

2) In present study, the feasibility of quench detection method based on DTS system has been demonstrated. In that work, the combination method between optical fibers and HTS tapes is immobilizing optical fibers on the turn by turn surface of the HTS coil by using epoxy. However, it is inapplicable to HTS applications using long length tapes.

3) In this study, we proposed a novel HTS tape with two encapsulated optical fibers along the two sides to make good contact between the optical fibers and HTS tapes. Three kinds of optical fibers encapsulated HTS tapes (OF-tapes) with various optical fibers are fabricated. The structure of the OF-tape is introduced and critical currents, resistance at room temperature and impulse current withstand capability of this novel HTS tapes are tested.

Sample fabrication

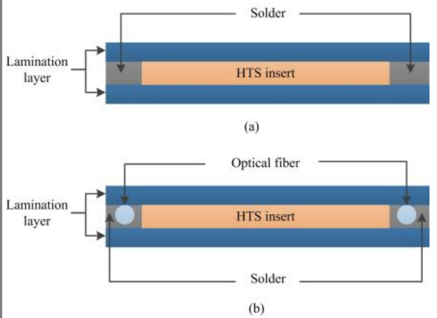

Fig. 1. The cross-sectional view of a typical HTS tape (a) and an OF-tape (b).

TABLE I
PARAMETERS OF ENCAPSULATED OPTICAL FIBERS

Type	A	B	C
Diameter	95 µm	170 µm	250 µm
Fiber mode	Multi	Single	Single
Coating material	Polyimide	Acrylate	Acrylate

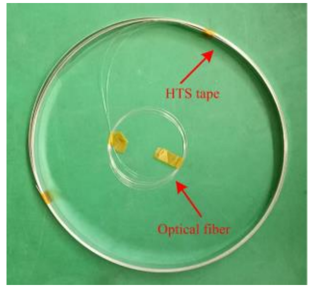

Fig. 2. Photo of OF-tapes.

TABLE II
SPECIFICATIONS OF OPTICAL FIBERS ENCAPSULATED HTS TAPES

Type	Tape-95	Tape-170	Tape-250
Diameter of fibers	95 µm	170 µm	250 µm
Thickness of OF-tape	0.272 mm	0.299 mm	0.361 mm
Critical current	The same 500±10% A		
Width of OF-tape	The same 12 mm		
Width of insert tape	The same 10 mm		
Thickness of insert tape	The same 55 µm		
Width of lamination tape	The same 12 mm		
Thickness of lamination tape	The same 80 µm		
Type of lamination material	The same stainless steel		

- **Average fabrication velocity of the OF-tapes is 0.4cm/s.**
- **Temperature of the liquid solder is 469K during the fabrication process.**

Experiment

A. Resistance test platform

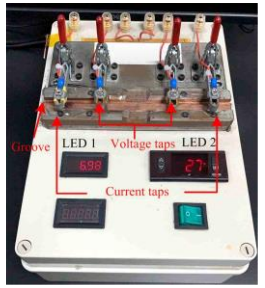

Fig. 3. The platform of measuring the room temperature resistance of OF-tapes.

- **The measurement principle is based on four-probe method.**
- **A DC current was applied on the OF-tapes.**
- **LED 1 and LED 2 show the per unit length resistance and the temperature of the sample.**

B. Experimental setup of impulse tests

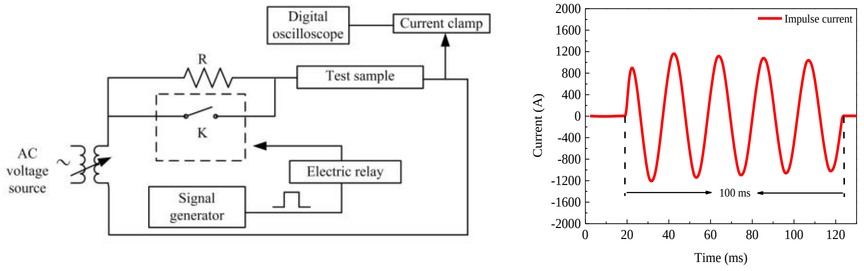

Fig. 4. Circuit diagram of impulse tests (a) and the typical waveform of impulse currents (b).

- **When the switch K is turned on, an impulse overcurrent will flow through the OF-tape.**
- **The frequency of the applied impulse currents is 50 Hz, and the duration is 100 ms.**
- **For each type of OF-tape, from sample 1 to sample 11, preset peak values of impulse currents energized to the tapes are 500, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, and 1900 A, respectively.**

Experiment Results and Analysis

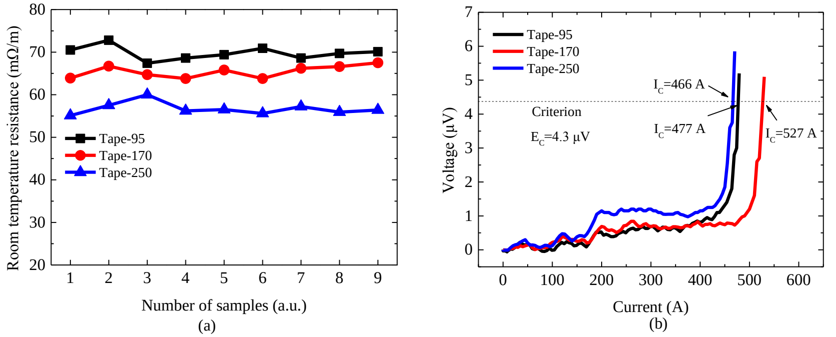

Fig. 5. Room temperature resistance (a) and critical currents of three kinds of OF-tapes (b).

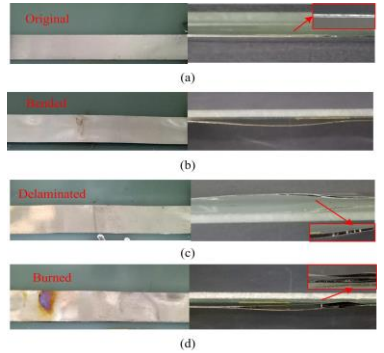

Fig. 6. Photos of OF-tapes after impulse tests. (a) original, (b) bended, (c) delaminated, and (d) burned.

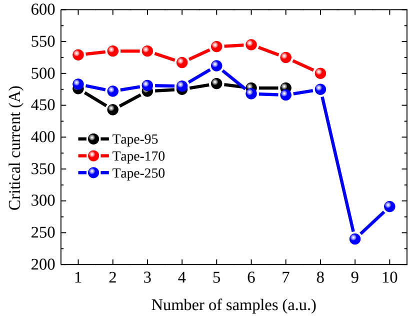

Fig. 7. Comparison of critical currents for each sample of three types of OF-tapes after impulse current tests.

TABLE III
MINIMUM PEAK VALUE OF THREE DAMAGED CASES FOR DIFFERENT SAMPLES AFTER IMPULSE CURRENT TESTS

Type	Min. value of bended case	Min. value of delaminated cases	Min. value of burned cases
Tape-95	1510 A	1590 A	1810 A
Tape-170	/	1610 A	1740 A
Tape-250	/	1720 A	1920 A

Conclusion

1) In this study, we introduced the structure of the OF-tapes and fabricated three types of OF-tapes with various optical fibers, 95, 170, and 250 µm.

2) Per unit length resistance at room temperature increases with the decrease of the diameter for optical fibers and critical currents of three types OF-tapes are similar.

3) Performances of three kinds of OF-tapes after suffering impulse overcurrent are a little different. With the increase of diameter of optical fiber, the impulse current withstand capability of OF-tapes becomes better.

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