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Critical Current under Uniaxial Strain on High-Pressure Heat Treatment Bi-2212 Round Wire

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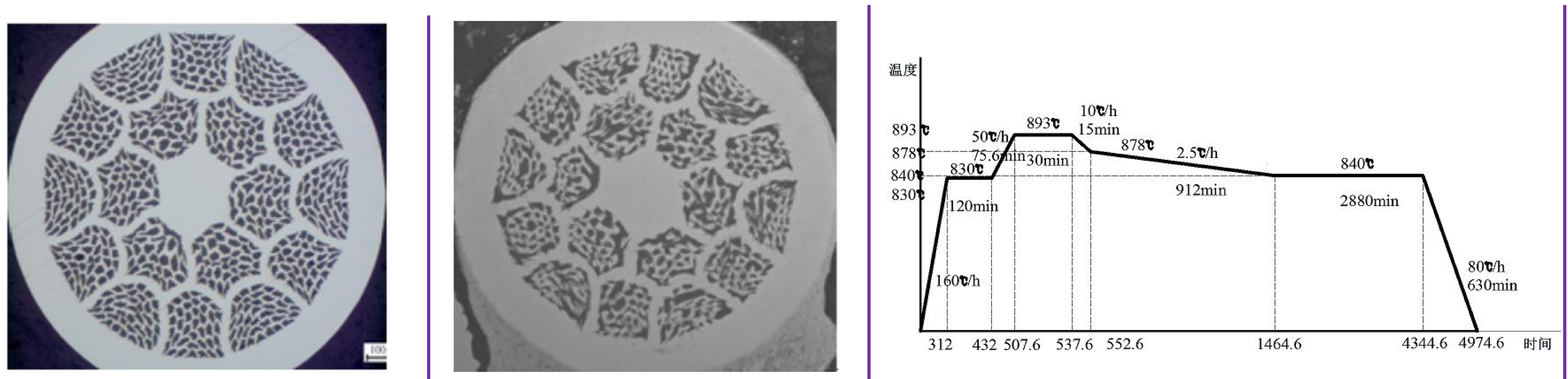
ASIPP USTC

1. Introduction

China Fusion Engineering Test Reactor project (CFETR), the next generation of Tokamak, has been incorporated into the important development of nuclear fusion in the future. Compared to the low temperature superconducting materials, Bi-2212 is one of the most promising superconducting materials due to the high irreversible field and outstanding current-carrying capacity. In particular, its critical properties can be improved dramatically by high-pressure heat treatment, which could enlarge its application range. The critical current performance of Bi-2212 round wire (RW) with high-pressure heat treatment under uniaxial strain are studied at 4.2 K in 12 T background field at Institute of Plasma Physics, Chinese Academy of Science (ASIPP). All samples are provided by Northwest Institute for Non-ferrous Metal Research (NIN) in China with new pcocess. The results showed that samples in 1 bar pressure heat treatment presented a more drastic degradation in compressive and tensile side than that of 30 and 50 bar pressure heat treatment. In order to study the influence of different thermal contraction coefficient between the substrate and sample on the experiment results, two springs with different materials were used in experiment. It was found that Cu-Be alloy spring is more compatible for Bi-2212 RW as substrate than Ti-6Al-4V alloy spring from experiment results. In this paper, the experiment setup and results will be fully presented. This results also can provide experience for superconducting magnet further design and experiment.

2. Experimental setup



(a) (b) (c)

.Figure. 1. Across-section of the 35×18 Bi-2212 RW manufactured by NIN, (a) before high pressure heat treatment, (b) after 50 bar high pressure heat treatmentFig. 2. The structure and operating principle of U-spring device, (c) heat treatment curve

Bi2212 RW were fabricated by the powder-in-tube (PIT) method by Northwest Institute for Non-ferrous Metal Research (NIN) in China. Fig. 1 shows the cross-section of the Bi-2212 RW before and after high pressure heat treatment and the heat treatment cuve. The Bi-2212 RW had 18 bundles of 35 filaments each (35*15 design). The highest Je of 628A/mm2 at 28 T and 4.2 K was obtained in the 1.00 mm diameter round wire tested in French high field laboratory. Parameters of the Bi-2212 RW are shown in Table I.

Table 1 Parameters of the Bi-2212 round wire

Parameter	Value
Material	Ag-alloy sheathed Bi-2212
Fabrication method	PIT
Heat treatment pressure	1 bar、30 bar、50 bar
Bare strand diameter	1.0 mm
Filament configuration	35×18 filaments
Ag-Mg: Ag: Bi-2212	1:1.8:0.9
Ic at 12T, 4.2 K (1 bar)	90A
Ic at 12T, 4.2 K (30 bar)	156A
Ic at 12T, 4.2 K (50 bar)	224A
insulation	N/A

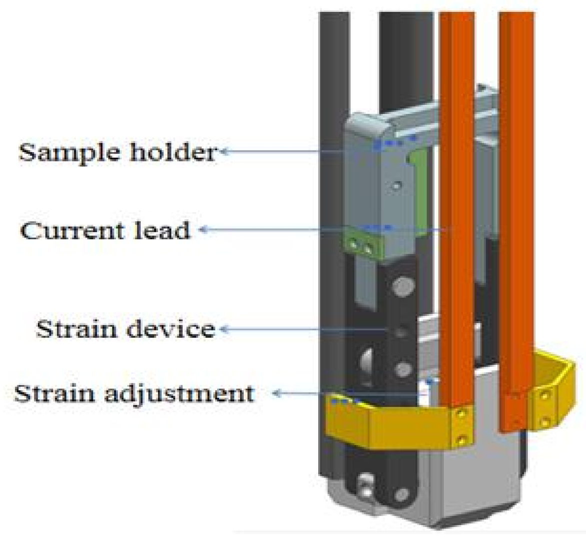


Fig. 2. The structure and operating principle of U-spring device

A reliable high-pressure heat treatment is crucial for enhancing superconducting material properties especially Bi-2212 RW. The Bi-2212 RW requires a modified high-pressure heat treatment process to increase Ic performance. All test samples were heat treated at ASIPP.

3. Results and discussions

$$I_C(T,B)=I_0\left(1-\frac{T}{T_C}\right)^{\gamma}\left[(1-\chi)\frac{B_0}{B_0+B}+\chi\exp\left(-\frac{\beta B}{(B_{C0}\exp(-\alpha T/T_C))}\right)\right]$$

T_C = 87.1 K, B_{C0}= 465.5 T, α = 10.33, β = 6.76, γ = 1.73, χ = 0.33, B_0 = 1.0 T

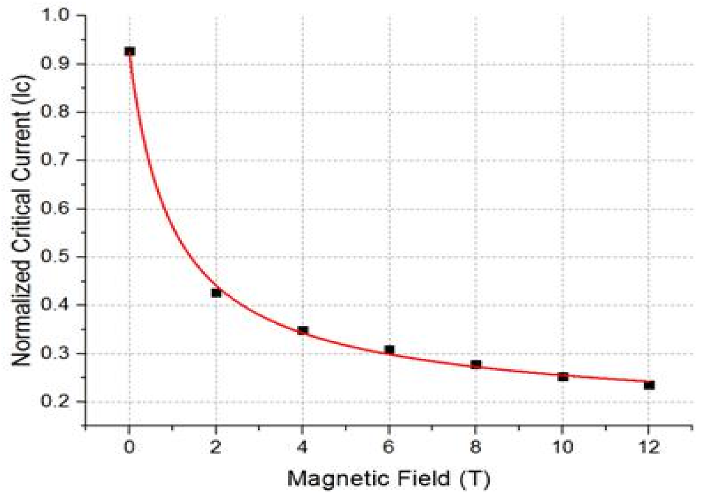


Fig. 3. (Box) Measured critical current of Bi-2212 RW in liquid helium and (solid line) the model given in equation with parameters chosen to fit the experimental data.

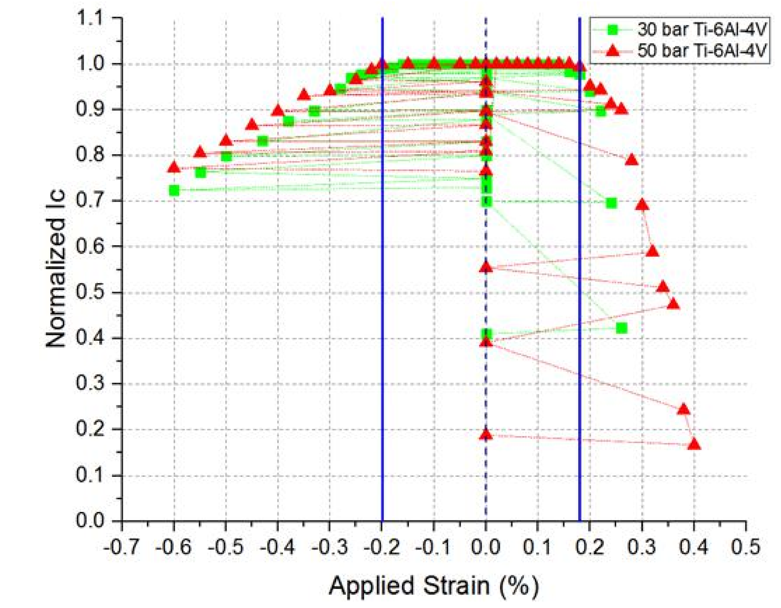


Fig 4. Normalized Ic as a function of applied strain at 4.2 K and 12 T with 30 bar and 50 bar heat treatment

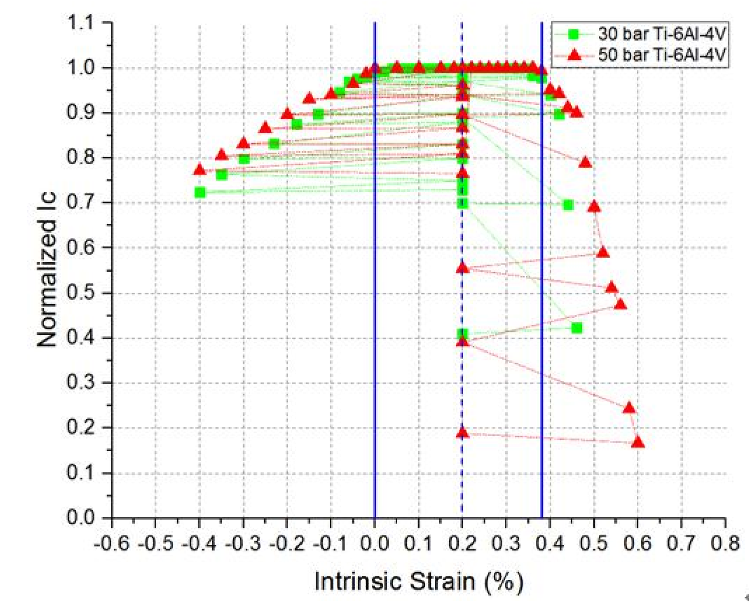


Fig 5. Normalized Ic as a function of applied strain at 4.2 K and 12 T with 30 bar and 50 bar heat treatment after shift strain-axis

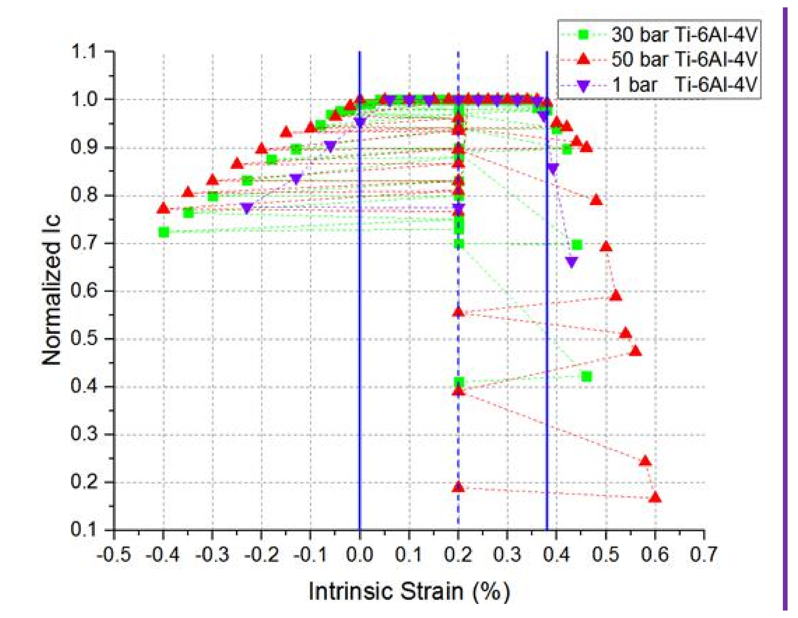


Fig. Normalized Ic as a function of applied strain at 4.2 K and 12 T with 30 bar and 50 bar heat treatment

Table 2 Thermal contraction from 456 K to 4.2K

Material	$\Delta L/L$[%]
Ti-6Al-4V	-0.30
Cu-Be	-0.61
Bi-2212 a-b	-0.29
Bi-2212 c	-0.55
Ag	-0.71
Wire a-b	-0.60

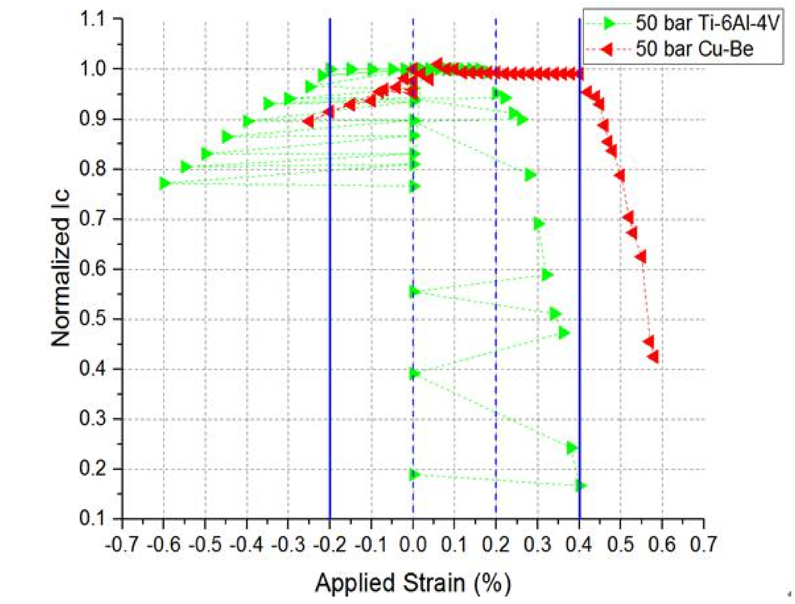


Fig 7. Normalized Ic as a function of applied strain at 4.2 K and 12 T with Ti-6Al-4V and Cu-Be alloy spring of 50 bar heat treatment

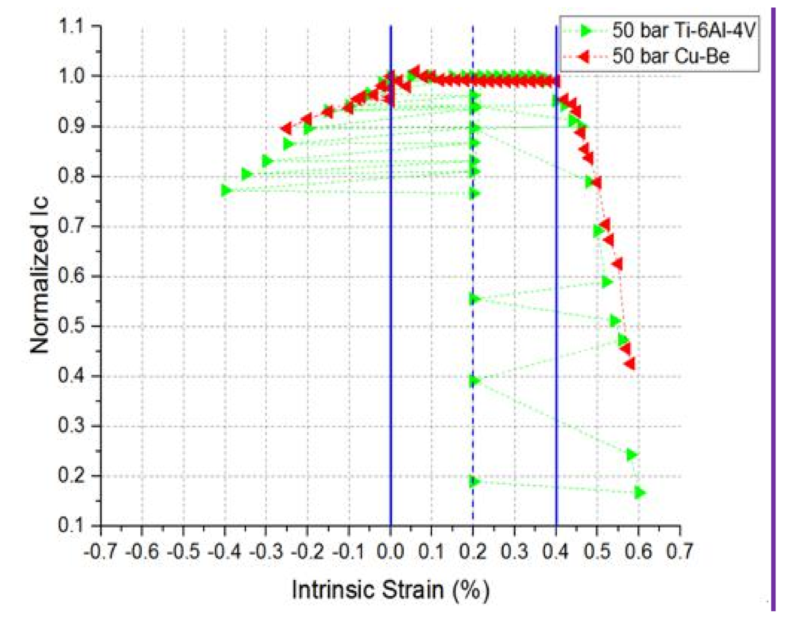


Fig 8. Normalized Ic as a function of applied strain at 4.2 K and 12 T with Ti-6Al-4V and Cu-Be alloy spring of 50 bar heat treatment after shift strain-axis

The results showed that samples in 1 bar pressure heat treatment presented a more drastic degradation in compressive and tensile side than that of 30 and 50 bar heat treatment. It's could be explained by that overpressure heat treatment (OPHT) could densify the filaments and probably enhances *Ic* degradation performance induced by compressive and tensile strain. From Table II, it can be found that the Cu-Be and Bi-2212 thermal contraction is fairly approximate, therefore little relative strain when the Cu-Be substrate cooling from soldering temperature to 4.2 K. Obviously, the two curves almost coincide each other with similar irreversible strain range. The comparison shown in Fig .8. indicates Cu-Be alloy spring perhaps is more suitable for the Bi-2212 RW strain experiment as substrate material.

4. Conclusion

Three heat treatment conditions and two U-shape alloy springs with the Bi-2212 RW were strain tested in both compression and tensile side. All samples followed the same heat treatment progress with 1 bar 、30 bar and 50 bar. The *Ic* degradation of the 50 bar heat treatment Bi-2212 RW is less sensitive to the strain than 30 and 1 bar. The Cu-Be alloy spring showed better adaptability matched with Bi-2212 RW without pre-tension. More overall comparison experiment will be done including three heat treatment condition between Ti-6Al-4V and Cu-Be alloy spring.