§3. Effect of Zn Substitution into the Practical Bronze Material for High-field Nb_3Sn Wires

Kikuchi, A., Iijima, Y. (National Institute for Materials Science),
Hishinuma, Y.

The large high magnetic field superconducting magnet system is one of the main components to confine and maintain a higher volume and steady-state Deuterium-Tritium self-burning plasma for a longer operation time. High J_c Nb_3Sn wire will become the first candidate material for the future fusion reactor due to established industrial mass production and the actual achievement of the ITER project. However, it is well known that commercial bronze and Internal Tin processed Nb_3Sn wires have higher mechanical strain sensitivity on the J_c property. The development of a new Nb_3Sn wire production process which improves both J_c-B performance and the mechanical strain sensitivity is necessary for the advanced fusion magnet system. R. Flükiger et al. reported that the mechanical sensitivity of the Zn and Ni substituted bronze processed Nb_3Sn wire, which was (Nb-(Ni)/Cu-Sn-Zn), was better than conventional bronze processed Nb_3Sn wire[1]. Meanwhile, H. Wada also reported originally that the Zn addition to the lower Sn content bronze matrix drastically accelerated to the Sn diffusion to form the Nb_3Sn phase[2]. Zn was able to become one of the promising additional elements for the Nb_3Sn wires to improve J_c-B property and mechanical sensitivity. In this study, we tried to fabricate the new Zn including commercial Cu-Sn-(Ti) alloys with high Sn content from 10 to 13.5 mass% for the bronze processed Nb_3Sn wire, and the effects of the Zn addition on the microstructure and the Nb_3Sn wire workability were also investigated.

The various Zn addition bronze alloys were casted by the unidirectional solidification process. This process is usually used for the high quality bronze production for the commercial bronze processed Nb_3Sn wire. The nominal mass% composition and the results of the ICP-mass analysis of the various Zn addition bronze alloys are indicated in Table. 1. The reference indicated in Table 1 is a conventional bronze alloy without Zn addition. We confirmed that Zn remained in the Cu-Sn bronze matrix. We also succeeded to fabricate Nb/Zn addition bronze composite wires. The number of the Nb filaments is 19. Typical optical microscope images of the cross-sectional area in bronze processed Nb_3Sn wires using Zn addition bronze alloy is shown in Fig. 1. The composite wires could be fabricated without wire-breaking, and no irregular deformation of Nb filaments and mechanical cracks were observed. We found that Zn addition bronze alloys showed excellent workability at room temperature. The element distributions on the cross-sectional area in the A and D sample wires using EPMA is shown in Fig. 2. In the diffusion layers between Nb filament and two kinds of matrices (A and D), homogeneous diffusion layer both Nb and Sn elements were confirmed. We found that these layers were Nb_3Sn phase by the quantitative analysis indicated. The Zn element remained homogeneously, and distributed in the A and D matrices. We expect that the remained Zn element in the residual bronze will improve the Nb_3Sn wire-handling after the heat treatment. Similar to conventional bronze processed Nb_3Sn, the thickness of the Nb_3Sn layer using the Zn addition bronze alloy increased with increasing Sn content in the matrix.

Table 1 The nominal composition and the results of the ICP analysis of the various Zn addition bronze alloys

Sample	Nominal mass % composition (Cu-Sn-Zn-Ti)	ICP quantitative composition (Cu-Sn-Zn-Ti)			
		Cu	Sn	Zn	Ti
A	Cu-10Sn-10Zn-0.3Ti	79.97	9.73	10.00	0.3
B	Cu-12Sn-6Zn	82.07	11.99	5.94	0
C	Cu-12Sn-6Zn-0.3Ti	82.04	11.75	5.94	0.27
D	Cu-13.5Sn-4Zn-0.3Ti	82.25	13.49	3.98	0.28
Ref.	Cu-14Sn-0.2Ti	----------------------------			

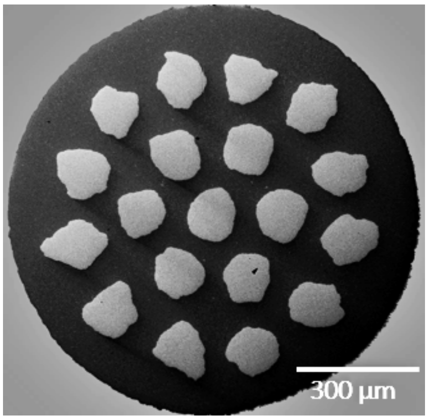

Fig. 1 Typical optical microscope images of the cross-sectional area in bronze processed Nb_3Sn wires using Zn addition bronze alloy (Sample-A)

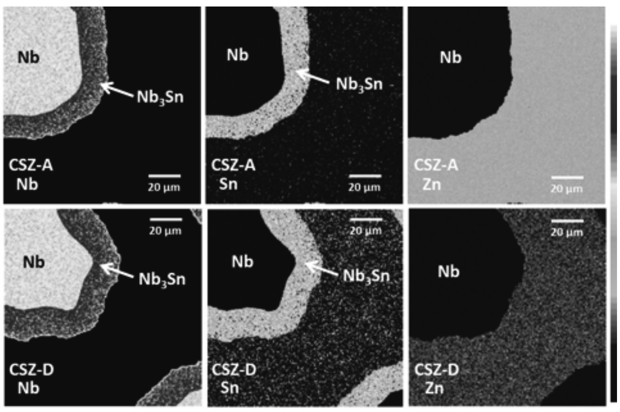

Fig. 2 The element distributions on the cross-sectional area in the A and D sample wires (700 ºC for 200 h)

1) Flükiger, R. et al.: Adv. in Cryo. Eng. (materials), **30** (1984) 851.
2) Wada, H. et al.: J. Mater. Sci., **13** (1978) 1943.