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

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In a magnetic confinement fusion test reactor such as ITER, 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. At the present, high J_c Nb_3Sn is 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 compared with Nb_3Al. The development of a new Nb_3Sn wire production process which improves 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)]. Zn would be 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 approached the high strength of Nb_3Sn wire by the Zn including commercial Cu-Sn-(Ti) alloys with high Sn content from 10 to 13.5 mass% for the bronze matrix. In the previous report, we investigated the Nb_3Sn phase formation mechanism by the diffusion reaction between Nb and Cu-Sn-Zn matrix[2)]. In this report, we fabricated Nb_3Sn multifilamentary wires using various Cu-Sn-Zn ternary bronze matrices via the conventional industrial workability.

The nominal mass% compositions of the various Zn addition bronze alloys were already indicated[2)]. Typical SEM image of the cross-sectional area in Nb_3Sn multifilamentary wire using Cu-Sn-Zn ternary bronze matrix. We found that Nb_3Sn multifilamentary wire using Cu-Sn-Zn ternary bronze matrix was easily fabricated without wire breakage, and several Cu-Sn-Zn ternary alloys showed excellent workability at room temperature.

The comparisons of J_c-B performance between various Nb_3Sn multifilamentary wires using Cu-Sn-Zn ternary bronze matrix was shown in fig.2. These samples were heat-treated at 700 $^oC\times100h$. For comparisons, the Nb_3Sn wires using conventional bronze matrix were also prepared. As well as the conventional bronze processed Nb_3Sn wire, we found that J_c property of Nb_3Sn multifilamentary wires using Cu-Sn-Zn ternary bronze matrix was increased with increasing the nominal Sn composition of Cu-Sn-Zn ternary bronze matrix. Furthermore, J_c values below 10 Tesla were higher than that of the reference Nb_3Sn wire. This is because the lowering of the reaction temperature by Zn addition may produce small Nb_3Sn grains, and small grain formation yields larger J_c in lower magnetic fields.

However, J_c-B performances of the Nb_3Sn multifilamentary wires using Cu-Sn-Zn ternary bronze matrix above 12 Tesla were lower than that of the reference wire. We thought that reconsidering the heat treatment process, such as two-stage heat treatment, was necessary to improve the J_c-B performance.

1) Flükiger, R. et al.: Adv. in Cryo. Eng. (materials), **30** (1984) 851.
2) Kikuchi, A. et al.: Annual Report of NIFS, **2014-2015** (2016) 265.

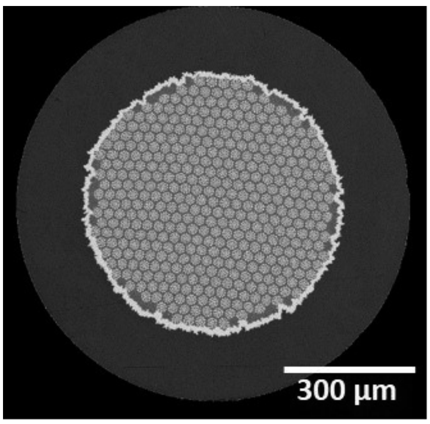

Fig. 1 Typical SEM image of the cross-sectional area in Nb_3Sn multifilamentary wire using Cu-Sn-Zn ternary bronze matrix.

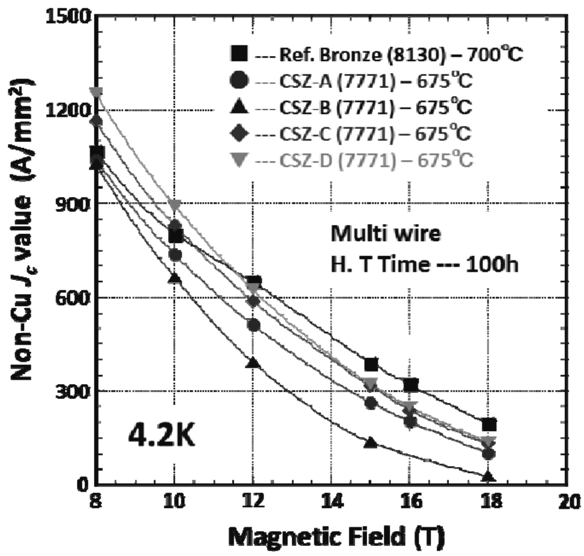

Fig. 2 The comparisons of J_c-B performance between various Nb_3Sn multifilamentary wires using Cu-Sn-Zn ternary bronze matrix