§19. Development of New High Field and High Current Density Superconductors for Fusion Devises

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New Nb_3Sn superconductors with improved high-field performance can be prepared by ibe Jelly Roll (JR) process using Sn-Ta and Sn-Ti based sheet.[1] In the present study, high-field performance of Sn-Ta and Sn-Ti based sheet wires has been compared. Furthermore, the fabrication of multifilamentary JR wires has been attempted.

Sn-Ta based alloy buttons with different Sn/Ta atomic ratio and a small amount of Ti and Cu addition were prepared by the melt diffusion process among constituent element powders at 780℃ for 10h. The effect of Hf addition instead of Ti addition was also studied. The Sn-Ta based buttons were then pressed into a plate ～3mm in thickness. Meanwhile, Sn-2wt%Ti-5wt%Cu alloy plates with the same thickness were sliced from an ingot prepared by the melt and cast process. The Sn-Ta and Sn-Ti based plates were rolled into sheets ～90 μ m in thickness. The resulting sheet was laminated with a commercial Nb sheet, and wound into a JR composite. The composite was encased in a Nb-3.3at%Ta sheath, and fabricated into a wire 1.4mm in diameter by grooved rolling and subsequent wire drawing. Some of the JR composites were clad with a Cu stabilizer and hydrostatically extruded followed by the wire drawing down to 1.0mm in diameter.

The Sn-Ta based buttons show an unique behavior in which their shape does not show any change even if they are heated up to a much higher temperature than the melting point of Sn. A small amount of Ti addition produces a more tightly shrunk button. Sn-Ti particles distribute around Ta particles, which may improve the bonding between Ta particles and Sn matrix. It was found that Nb diffuses into the Sn-Ta based sheet from the Nb sheet at the heat treatment of JR wires. Thus Nb_3Sn layers are synthesized by the mutual diffusion between Sn-Ta and Nb sheets without the formation of voids.

Table 1 summarizes the non-Cu J_c of different Sn-Ta based sheet wires in high-fields at 4.2K, as well as the qualitative evaluation of the structure of button, sheet and wire. 3at%Ti addition increases the thickness of Nb_3Sn layer in the wire, resulting the increase of non-Cu J_c by ～50%. Table 1 indicates that the 4/1 (Sn/Ta)-3Ti-3Cu composition is the most favorable among Sn-Ta based sheets. However, since non-Cu J_c's of ～250A/mm^2 and ～150A/mm^2 are obtained at 20T and 22T, respectively, in the wide composition range, high-field performance of the wire is not sensitive to the sheet composition. The Hf addition improves the non-Cu J_c of the wire similar to the Ti addition does. In Table 1 , non-Cu J_c of 16wt%Sn bronze processed Nb_3Sn wire which is the best practical high-field conductor is listed.[2] Present JR wires show much better high-field performance than the 16wt%Sn bronze Nb_3Sn wire.

Fig.1 illustrates the non-Cu and JR part J_c of the Sn-Ta and Sn-Ti based sheet wires, both are fabricated by the hydrostatic extrusion. The JR part J_c of Sn-Ta based sheet wire fabricated by the grooved rolling is also illustrated by a dashed line. Non-Cu J_c versus magnetic field curves of Sn-Ta and Sn-Ti based sheet wires cross each other at ～ 20T; in fields higher than 20T the former shows better performance, while in fields lower than 20T the latter shows better performance. Fig.1 also indicates that the hydrostatic extrusion yields better JR part J_c than the grooved rolling at the initial stage of the fabrication. The hydrostatic extrusion results a more beautiful and dense JR structure than the grooved rolling.

A 54 filament JR wire was fabricated using 3/1 (Sn/Ta)+2.5wt%Cu sheet. The outer diameter of the second stack billet was 46mm, which was finally fabricated into a wire 1.4mm in diameter. A small insert coil was made using the multifilamentary wire. Although Sn-Ta based sheet wires exhibit slightly superior high-field performance, the Sn-Ti based sheet is attractive due to its easiness of mass production. Present new JR processed Nb_3Sn wire is promising as a high-field conductor for the next generation.

Table 1 High-field performance of Sn-Ta based sheet wires @ 4.2K and qualitative evaluation of sheet and wire structure (full marks: 5). Heat treatment: 725℃ × 120h or 750℃ × 100h.

Sn/Ta	Ti (at%)	Cu (wt%)	non-Cu J_c (A/mm^2)@4.2K 20T	22T	Button Solidification	Sheet Workability	Nb_3Sn Layer Formation
7/3	-	2.5	~170	~90	3.5	3.5	3
3/1	-	2.5	~180	~100	3.5	3.5	3
3/1	4(3~5)	2.5,3	~250	~150	4	4.5	5
3/1	4	0.8	~230	~150	4	4.5	5
4/1	3(3~5)	3	~260	~150	5	5	5
6/1	4	3	~240	~140	4	4.5	5
9/1	5	5	~260	~150	3	5	5
3/1	3Hf	3	~240	~150	4	4	5
16%Sn Bronze Nb_3Sn Wire			145	79	–	–	–

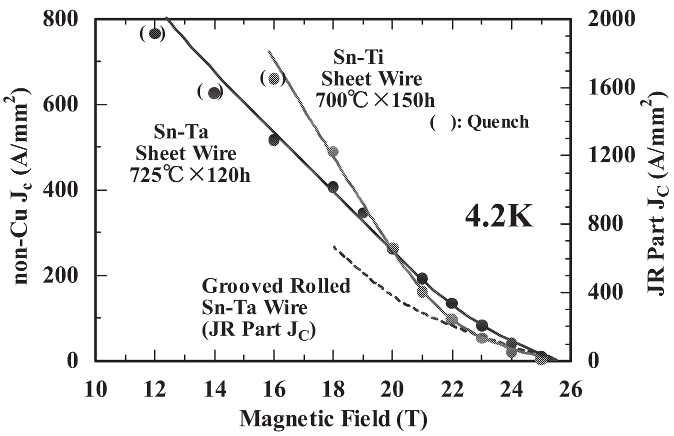

Fig.1 Non-Cu Jc and JR part Jc versus magnetic field curves of Sn-2wt%Ti-5wt%Cu and 3/1(Sn/Ta)-3at%Ti+3wt%Cu sheet wires fabricated through hydrostatic extrusion . Wire diam. : 1.0mm.

Reference
1) Tachikawa, K. et al.: Abstract of CSJ Conference, Vol 76 (May 2007, Chiba) 189.
2) Miyazaki, T. et al.: IEEE Trans. Appl. Supercond., Vol 14, No1(2004) 975.