

## §22. Development of New High Field and High Current Density Superconductors for Fusion Devices

Tachikawa, K., Koyata, Y., Nakaze, T. (Faculty of Engr., Tokai Univ.), Mito, T.

Excellent high-field performance capable of generating ~20T at 4.2K has been reported for  $(\text{Nb,Ti})_3\text{Sn}$  conductors fabricated by bronze process and internal tin process. However, in these processes residual bronze reduces the overall critical current density  $J_c$  of the conductors. Improved overall  $J_c$  might be expected when a  $\text{Nb}_3\text{Sn}$  conductor could be fabricated from a Sn-based alloy/Nb composite. Present authors recently revealed that a Sn-Ta alloy with ductility can be synthesized by reacting a mixture of Sn+Ta powder containing ~30at%Ta. Then  $(\text{Nb,Ta})_3\text{Sn}$  wires with attractive performance at 22T and 4.2K were fabricated through a Jelly Roll(JR) process using Sn-Ta(-Cu) and Nb sheets<sup>1)</sup>. Ta in the Sn-Ta sheet is incorporated into the  $\text{Nb}_3\text{Sn}$  layer improving the high-field performance, while a small amount of Cu addition to the sheet reduces the reaction temperature of the wire. In the present study, the relation between  $J_c$  in high fields and structure of the  $(\text{Nb,Ta})_3\text{Sn}$  wires has been studied. Subsequently a preliminary study for the fabrication of long-length  $(\text{Nb,Ta})_3\text{Sn}$  wires through the JR process has been performed.

Sn-Ta alloys with Sn/Ta ratio of 7/3 and 3/1 with 2.5wt% and 5wt%Cu addition were melted at 800°C for 10h in vacuum. The melted Sn-Ta-Cu button, typically 30gr. in weight, was pressed into a plate and flat rolled into a sheet 100 $\mu\text{m}$  in thickness. For the fabrication of longer length wire bar-shaped alloys, 180gr. in weight, have been prepared. Fig.1 illustrates Sn-Ta-Cu specimens of different form prepared in the present study. The Sn-Ta-Cu sheet was laminated with a Nb sheet of the same thickness, and wound around a Nb-3.3at%Ta rod. The resulting JR composite was encased in a Nb-3.3at%Ta tube and then fabricated into a wire 1.40mm in diameter. The resulting wires were heat treated at 700-800°C for 80h in vacuum.

Fig.2 shows the critical current  $I_c$  and non-Cu  $J_c$  versus heat treatment temperature of the 7/3+2.5Cu sheet wire at different magnetic fields. At 22T the maximum  $I_c$  is obtained after the reaction at 775°C. A non-Cu  $J_c$  of ~100A/mm<sup>2</sup> is achieved at 22T and 4.2K. The reaction temperature where the maximum  $I_c$  is obtained is lowered with decreasing applied field reaching 725°C at 16T. Then, average grain size of  $(\text{Nb,Ta})_3\text{Sn}$  was evaluated in parallel (parallel to the diffusion direction, i.e. perpendicular to the sheath) and perpendicular direction by scanning electron microscope study. These are 0.66 $\mu\text{m}$  and 0.53 $\mu\text{m}$  at 725°C, and 0.99 $\mu\text{m}$  and 0.61 $\mu\text{m}$  at 775°C, respectively. The grain boundaries are considered to be major flux pinning centers at lower fields in

A15 phase. The shift of the optimum reaction temperature with decreasing field shown in Fig.2 may be related to the change of  $(\text{Nb,Ta})_3\text{Sn}$  grain size.

For practical application, superconducting wires should be embedded in a Cu stabilizing matrix. Then a preliminary study was performed for fabricating the JR composite where a Cu tube was used instead of a Nb-3.3at%Ta tube described before. The reaction between the Cu stabilizer and the Sn-Ta(-Cu) sheet during the heat treatment may be avoided when an extra Nb sheet is wound in the outer-most layer of the JR composite. The resulting JR composite with outer Cu stabilizer has been successfully fabricated providing a positive prospect for producing long-length practical  $(\text{Nb,Ta})_3\text{Sn}$  wires.

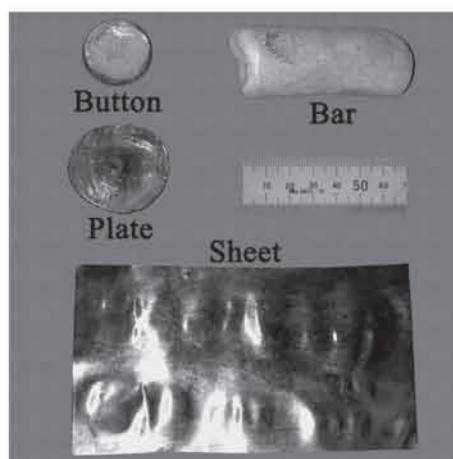


Fig.1 Sn-Ta-Cu specimens in different forms.

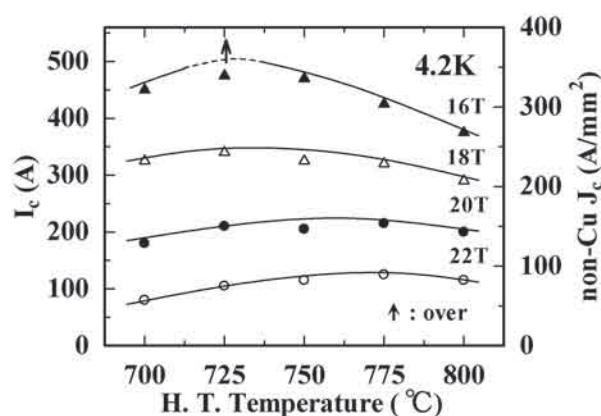


Fig.2  $I_c$  and non-Cu  $J_c$  versus heat treatment temperature of the 7/3+2.5Cu sheet wire at quoted magnetic fields.

### Reference

1) Tachikawa, K. et al: Fabrication of High-Field  $(\text{Nb,Ta})_3\text{Sn}$  Conductors through Jelly Roll Process, Adv. Cryogenic Engineering, Vol.50(2004) pp387-394.