§5. Research and Development of New Intermetallic Compound Superconductors

Tachikawa, K., Ikeda, Y., Koyata, Y. (Faculty of Engr., Tokai Univ.)

Generation of high magnetic field in superconducting state is required in the development of fusion, NMR and other advanced facilities. Present author has revealed that a Sn-Ta ally with ductility can be prepared by melting a mixture of Sn+Ta powder when the Ta concentration is between 25~30at%[1]. In the present study, new $(Nb,Ta)_3Sn$ conductors have been fabricated through Jelly Roll(JR) and filamentary process using ductile Sn-Ta or Sn-Ta-Cu matrix. No intermediate annealing is required for the fabrication, and thick and uniform $(Nb,Ta)_3Sn$ layers are synthesized after the reaction. Ta in the Sn-Ta sheet is incorporated into the Nb_3Sn layer, improving the high-field performance of Nb_3Sn.

In the present study, Sn-Ta alloy with Sn/Ta ratio of 7/3 and 3/1 with or without 2.5wt% and 5wt%Cu addition were melted at 800°C for 10h in vacuum. The melted Sn-Ta button, typically 50gr. in weight, was pressed into a plate and flat rolled into a sheet 100μm in thickness. In the JR process the Sn-Ta or Sn-Ta-Cu sheet was laminated with a Nb sheet of the same thickness, and wound around a Nb-4at%Ta rod. In the filamentary process, the Sn-Ta or Sn-Ta-Cu sheet was wound around thirteen Nb-1at%Ta rod(core) and wrapped around 13 components. The resulting JR or filamentary composite was encased in a Nb-4at%Ta tube and then fabricated into a wire 1.40mm in diameter. The resulting wires were heat treated at 775°C - 900°C for 80hr in vacuum.

The EDX composition mapping of the Sn-Ta-Cu sheet with a Sn/Ta ratio of 7/3 and 2.5wt%Cu addition is composed of a matrix with a dispersion of white and black particles 1-10μm in diameter. The matrix is Sn containing a small amount of Ta and Cu. The white particle is based on Ta, the approximate composition being $Ta_3(Sn_{0.7}Cu_{0.3})$. The black particle is richer in Cu of which composition corresponds roughly to Cu_2Sn containing a small amount of Ta. The Sn-Ta-Cu alloys with such a macrostructure have an appropriate workability to be fabricated into a thin sheet.

The 2.5wt%Cu addition and 5wt%Cu addition to the Sn-Ta sheet decreases the optimum heat treatment temperature to 800°C and 775°C, respectively, from 900°C. Transition temperature of the wires is almost independent on the Sn/Ta ratio and amount of Cu addition to the sheet, the midpoint of the transition being ~18.0K.

Fig.1 is the critical current, I_c and non-Cu critical current density, J_c versus magnetic field curves of the JR wires. The measurement at 2.1K was made under reduced pressure atmosphere. The 7/3 wire reacted at 900°C for 80h shows a non-Cu J_c of $100A/mm^2$ at 4.2K and 23T, and at 2.1K and 25T. The J_c-magnetic field curve shifts to higher field by about 2T by reducing the temperature from 4.2K to 2.1K. The upper critical field of the wire reacted at 900°C extrapolated by the Kramer plot reaches 28.5T at 2.1K. The 7/3 JR wire with 2.5wt%Cu addition shows a non-Cu J_c of $100A/mm^2$ at 4.2K and 22T, and at 2.1K and 24T. The present wires exhibit a few Tesla better high-field performance than the bronze-processed $(Nb,Ti)_3Sn$ wire, as indicated in Fig.1, which is the best commercial high-field superconductor. Furthermore, present wires exhibit fairly large n values, e.g. the 7/3 JR wire shows a n value of 30 at ~23.5T and ~25.7T at 4.2K and 2.1K, respectively. This indicates the potentiality of the present $(Nb,Ta)_3Sn$ wire in high magnetic fields.

Figs.2 (a) and (b) illustrate cross-sectional configuration of the 13-core filamentary wire, and EPMA composition mapping of the wire after the section at 800°C, respectively. Residual Nb-1at%Ta core(orange) and surrounded thick $(Nb,Ta)_3Sn$ layer(yellowish green) are observed in Fig.2(b). Some Nb is incorporated into the Sn-Ta matrix. The 13-core filamentary wire with a sheet composition of 7/3+2.5Cu and reacted at 800°C shows nearly the same non-Cu J_c and n value as those of JR wires in high magnetic fields.

In conclusion, new $(Nb,Ta)_3Sn$ wire with promising high-field performance have been successfully fabricated through Jelly Roll process and filamentary process using ductile Sn-Ta(-Cu) sheet.

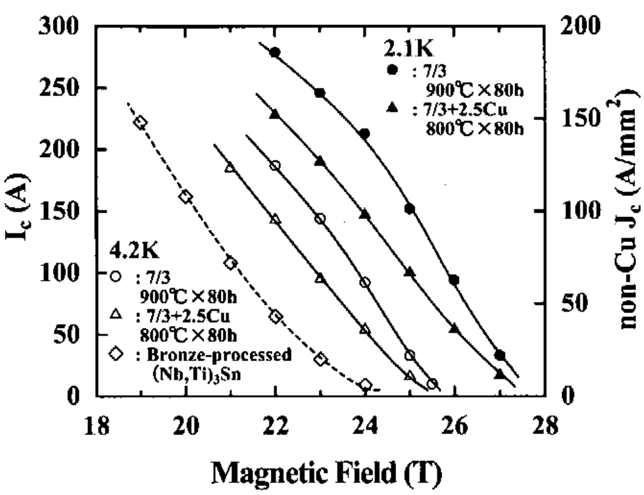

Fig.1 I_c and non-Cu J_c versus magnetic field curves of JR-processed $(Nb,Ta)_3Sn$ wires at 4.2K and 2.1K.

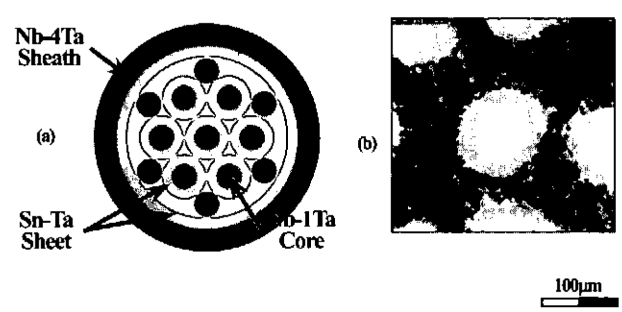

Fig.2 (a) Cross-sectional configuration of 13-core filamentary wire. (b) EPMA composition mapping of the filamentary wire reacted at 800°C for 80h.

Reference

1) Tachikawa,K., Kato,R., Aodai,M., Izawa,H. and Takeuchi,T. : IEEE Trans. Appl. Supercond.,Vol13, No2(2003) p.3438-3441.