§23. Studies on Advanced Superconductors for Fusion Device

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i) Fabrication of New Nb_3Sn Superconductors for High-Field Use

Nb_3Sn superconductors with upper critical field Bc_2 exceeding 25T at 4.2K has been prepared through a new process starting from an intermediate Nb_6Sn_5 compound [1]. Nb_6Sn_5 powder can be easily produced by a melt diffusion process at 900℃ using Nb and Sn powders. The pre-reaction between powders of Nb_6Sn_5 and Nb by mechanical mixing promotes the formation of A15 Nb_3Sn in the subsequent heat treatment. The fabrication of tape specimens from mixed powder using Ta sheath has been performed without intermediate annealing. Third element can be added either to the Nb_6Sn_5 compound or to the mixed powder.

Nb_3Sn tapes prepared by the present process show Tc about 0.5K higher than that of bronze-processed Nb_3Sn. A Bc_2 of 24.7T has been obtained even in pure Nb_3Sn tape at 4.2K as illustrated in Fig.1. The Bc_2 is still enhanced by Ti doping, where 2 at% Ti addition produces the best high-field performance. The Jc of Nb_3Sn core exceeds 3.3×10^4 A/cm^2 at 20T and 4.2K after the heat treatment at 900℃ as shown in Fig.1. Table I indicates the normal state resistivity ρ_n of present and bronze-processed Nb_3Sn specimens. The ρ_n value of present Nb_3Sn is much larger than that of bronze-processed Nb_3Sn. The high Bc_2 obtained in the present pure Nb_3Sn specimen seems to be originated to the large ρ_n value, since Bc_2 is dependent on ρ_n in type-II superconductors. A small amount of Cu addition to the mixed powder decreases the optimum reaction temperature to 850℃. Present Nb_3Sn may be promising for high-field use as well as for refrigerator-cooled superconducting magnets.

ii) Investigation on the Present Status of Nb_3Sn Superconductors.

Nb_3Sn conductors have been developed with great expectation as an advanced high-field superconductor to be used in fusion devices of next generation. We summarized manufacturing procedures, superconducting performances and applications of Nb_3Sn conductors fabricated through different processes in different countries [3]. More detailed subjects included in this report are high-field properties, AC properties, conductor for fusion with large current capacities, stress-strain effect and irradiation effect as well as standardization of critical current measurement method regarding to Nb_3Sn conductors. The comprehensive grasp on the present status of Nb_3Sn conductors provided by this report will act as a useful data base for the future planning of fusion devices.

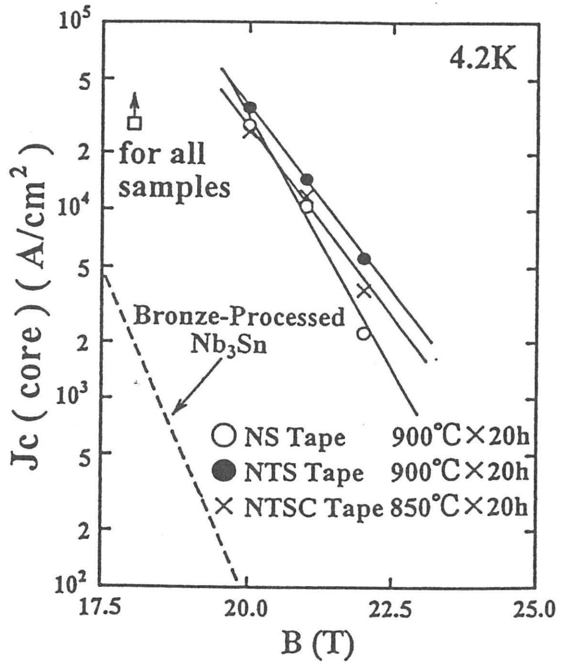

Fig.1 Critical current density Jc versus magnetic field B at 4.2K for present Nb_3Sn specimens. NS: pure Nb_3Sn, NTS: NS with 2 at% Ti addition, NTSC: NTS with 10 wt% Cu addition.

Table I Normal state resistivity just above Tc in different Nb_3Sn specimens. Data of bronze-processed Nb_3Sn are taken from reference [2]

Present Process	ρ_n ($\mu\Omega\cdot$m)
Pure Nb_3Sn	0.29
NTS (2at%Ti)	0.39
Bronze Process	**ρ_n ($\mu\Omega\cdot$m)**
Pure Nb_3Sn	0.08
1.60at%Ti in Nb_3Sn	0.33
2.71at%Ti in Nb_3Sn	0.41

References

1) Tachikawa, K., Natsuume, M., Kuroda,Y. and Tomori, H., Cryogenics, 36 (1996) pp 113-117.
2) Sekine, H., Itoh, K., and Tachikawa, K., J. Appl. Phys., 63 (1986) pp 2167-2170.
3) Tachikawa, K. and Yamamoto, J., Research Report NIFS-MEMO-20 (March, 1996) pp 1-77.