§6. Development of Tantalum Matrix RHQT Processed Nb_3Al Superconductors

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In a tokamak-type fusion reactor, magnet systems are composed of a toroidal field (TF), a poloidal field (PF), and central solenoid (CS) coils. Among these, the TF coils are placed at the nearest position from the plasma, and their structure and composition are affected by neutron irradiation depending on the spectrum and the fluence. The CS coils next to the TF coils are also possibly affected by the neutron irradiation. Superconducting materials, such as NbTi, Nb_3Sn and Nb_3Al, are considered for use in ITER and commercial reactors. However, Nb produces long half-life radioactive nuclide-like ^{94}Nb ($T_{1/2} = 2x10^4$y) under heavy irradiation conditions. It is therefore important to suppress the excess use of Nb in these conductors; diffusion barrier and matrix materials, except for superconducting filament materials.[1)]

Since Nb_3Al shows much better strain tolerance than Nb_3Sn does, many attempts have been made to fabricate the multifilamentary and stoichiometric Nb_3Al conductor, of which aspects are key issues to be solved for its commercialization. Such a Nb_3Al conductor can be fabricated by the so-called RHQT technique; the multifilamentary Nb/Al precursor is subjected to joule heating at 1900-2000°C, quenching to a molten Ga bath around 50-100°C to form the metastable supersaturated-solid solution $Nb(Al)_s$ filaments embedded in a Nb matrix, and then transformation annealing at 800°C to form the stoichiomatric Nb_3Al filaments in a Nb matrix.

In the present study, we have replaced Nb matrix with Ta which has an advantage of a shorter half-time of induced-radioactivity when irradiated with neutrons. Ta seems to have additional advantages[2)]: (1) excellent tolerance to uniaxial and transverse stresses at a low temperature to be caused by a huge electromagnetic force, (2) higher mechanical strength at elevated temperature to suppresses undesirable creep deformation in the reel-to-reel joule-heating of the wire, (3) less reactivity with Ga to suppress the formation of Ga-rich compound on the surface of wire, like a chain of islands, during RHQ operation, (4) non-superconductive matrix in fields to suppress the magnetic instability like flux jumps of wire.

In order to examine the drawability of such Ta matrix precursors, we have prepared three kinds of Ta matrix JR Nb/Al precursors that have different volume ratios of Ta as substitution for Nb. Fig. 1 shows schematic illustrations of the three designs of Ta matrix JR precursors manufactured. The cross-sectional structure of a Ta sheath and Ta dummy filaments in the multi-strand is common to all cases, but, according to the Ta matrix design, we have changed the material species of the inter-filament barrier and the intra-filament core from Nb to Ta. Both of the barrier and the core are changed to Ta for the 1st design, only the core for the 2nd design, and neither of them for the 3rd design. The 0.2% yield stress of Ta at room temperature (170 MPa) is much larger than that of Nb (45 MPa), the extrusion ratio was consequent as adjusted so that it was smaller than that used for conventional Nb matrix precursors. Contrary to our expectations, all the Ta matrix JR precursors could be extruded and drawn down to 0.8 mmϕ without any breaking, where Al layer thickness is adjusted to the same value of the conventional Nb matrix precursor.

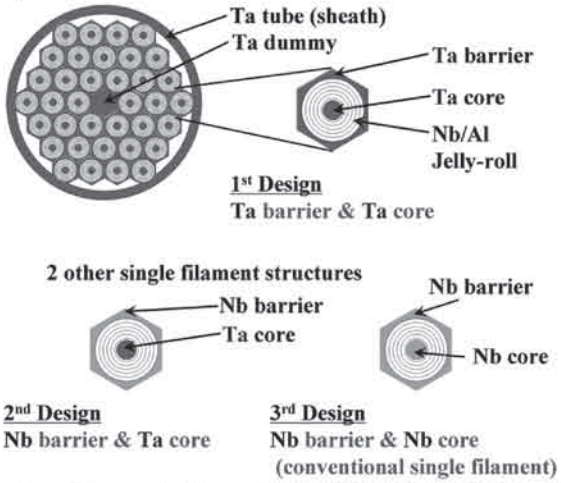

Fig. 1. Schematic illustrations of the three designs of Ta matrix JR precursor manufactured.

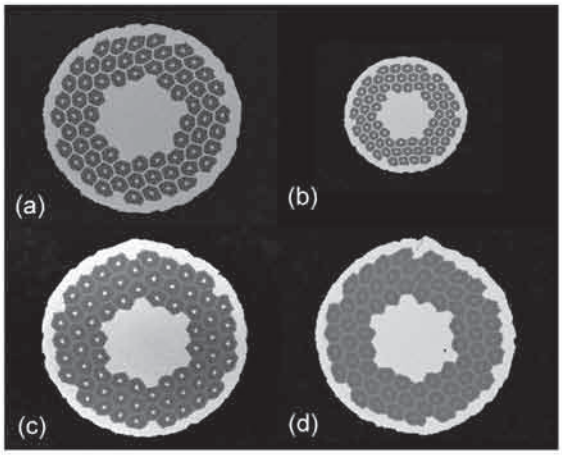

Fig. 2 Finished cross-sections of (a) the Design 1 precursors (0.8 mmϕ), (b) the Design 1 at 0.5 mmϕ, (c) the Design 2 at 0.8 mmϕ, and (d) the Design 3 at 0.8 mm ϕ.

Fig. 2 shows the finished cross sections of the Ta matrix precursors manufactured. Since the 1st design Ta matrix precursor (all Ta) exhibited the best workability at least until 0.8 mm in diameter, we have further drawn it down to 0.5 mm in diameter. The JR filament diameter is reduced to about 40 μm for this 0.5 mmϕ wire as shown in Fig. 2 (b).

Reference

1) Noda, T. et al, J. Nuc. Mat., **329-333** (2004) 1590
2) Takeuchi, T. et al, IEEE Trans. Appl. Supercond. **15** (2005) 3372