§21. Development of V-Ti and V-Ti-Ta Superconducting Wires

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In the practical fusion reactor, superconducting materials will be exposed to heavy neutron irradiation during a long term. Therefore the use of Nb- or Ag-based superconductors for the practical fusion reactor may force us to keep the Nb and Ag in custody for a long term of more than 1000 years in order to reduce their radioactivity below a safety level after the reactor shutdown. For avoiding the radioactivity problem we must avoid the use of Nb and Ag-based superconductors. Then we may not use Nb₃Sn, Nb₅Al, Nb-Ti, Bi-2223, and Bi-2212 conductors for the practical fusion reactor, which are the present practical superconductors or the next-generation practical superconductors.

We planned to investigate V-Ti and V-Ti-Ta alloys as the substitution of the Nb-Ti alloy. We can expect the alloys to have the excellent mechanical properties as well as the Nb-Ti alloy. In a practical fusion reactor a huge electromagnetic force will be induced in the superconductors. In addition, after the heavy neutron irradiation, the required enclosing term is about ten years for the alloys.

At first we made arc-melted V-40, 45, 50, 55, 60, 65, and 70at%Ti alloy ingots, from which many rods were cut and cold-rolled into long V-Ti wires with the outer diameter of 3.1 mm by using a grooved-roll. Then these V-Ti alloy wires were cold drawn into the fine wires with the diameter of 0.8 mm by using cassette roller-dies. Finally, the V-Ti alloy wires were flat-rolled into the thin V-Ti tapes with 0.15 mm in thickness and 1.8 mm in width in order to reduce the flux jumps during I_c measurements.

The effects of α-Ti depositions, with annealing at 573-773 K, were studied for various V-Ti alloys through T_c measurements, I_c measurements, and X-ray diffraction patterns. The α-Ti particles are very effective pinning centers for the V-Ti alloys. T_c and I_c increased with the α-Ti depositions whenever the Ti contents of V-Ti alloy were near 40at%. The maximum T_c of 7.9 K were obtained for the V-40 to 45at%Ti alloys annealed at 673 K for 5 h, while the maximum B_{c2} (4.2 K) of 8.5 T were obtained for the V-50 to 55at%Ti alloys. J_c (4.2 K, and 6.5 T) of 168 A/mm² was obtained for the V-45at%Ti alloy annealed at 723 K for 4 h. The J_c value is relatively high, considering that we have not yet optimize the V-Ti fabrication process. We are now optimizing the cold-reduction ratio before deposition, the deposition temperature, and heat-treatment duration in order to increase J_c of V-Ti alloys.

In order to stabilize the V-Ti alloy wire, we also try to fabricate the V-Ti multifilamentary wire.

![Fig. 1. T_c dependence on Ti content for V-Ti alloys, heat treated at various conditions.](image1)

![Fig. 2. B_{c2} (4.2 K) dependence on Ti content for V-Ti alloys, heat treated at various conditions.](image2)

T_c vs. Ti content curves are shown in Fig. 1 for the V-Ti alloys heat treated at various conditions. These heat treatments were performed after the cold-reduction with 1/15. Excepting the heat treatment at 300°C for 200 h, T_c of V-Ti wire increased a little.

B_{c2}(4.2 K) vs. Ti content curves are shown in Fig. 2. for the V-Ti alloys heat treated at various conditions. Although the heat treatment at 300°C for 200 hr caused much Bc2 degradation, the effect on Bc2 of other heat treatment conditions is not so clear, depending on Ti content.

References: