§18. Development of V-Ti and V-Ti-Ta Superconducting Alloy Conductors

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Superconductors in the practical fusion reactors will be exposed to heavy neutron irradiation during a long term. The use of Nb and Ag-based superconductors in the practical fusion reactor may force us to keep the superconducting materials in custody for a long term of more than several hundreds years in order to reduce their radioactivity below a safety level after the used fusion reactor shutdown. For avoiding the radioactivity problem we had better avoid the use of Nb and Ag. For the practical fusion reactor we should not use Nb_3Sn, Nb_3Al, Nb-Ti, Bi-2223, and Bi-2212 superconductors, which are the present commercialized superconductors or the next generation practical ones. Therefore the developments of new practical superconductors without Nb and Ag are required for the future practical fusion reactors.

For the superconductors of practical fusion reactor, we selected ductile V-Ti and V-Ti-Ta alloys, and have been developing them as the superconducting wires, because their good ductility can be expected to withstand the large electro-magnetic force in the fusion reactor. In addition their radioactivity problem is relatively small by using the alloys. In the studies at 2005 and 2006, we studied on the cold-workability and the superconducting properties for the simple binary V-Ti alloys. α-Ti particle deposition at temperatures above 400°C and cold-drawing after the deposition are very effective to improve J_c of the binary alloy. The binary alloy showed the highest B_{c2} at 50-55 at%Ti. In 2007 we began to study on the V-Ti-Ta ternary alloy, which has higher B_{c2} than that of V-Ti binary alloy. Considering the composition shift to Ti-poor side in matrix due to the α-Ti deposition, at first we studied the ternary alloys including 60 at%Ti, which are expected to have the highest B_{c2}.

In this study arc-melted V-60at%Ti-3at%Ta, V-6at%Ti-6at%Ta and V-60at%Ti-9at%Ta alloy ingots were arc-melted and then cold-drawn into the long V-Ti-Ta wires with diameter of 3.1 mm and then inserted into the Cu-10at%Ni alloy pipes. The V-Ti-Ta/Cu-Ni composite wires were cold-drawn into the thin V-Ti-Ta/Cu-Ni wires with heat treatments of 400°C or 500°C (for the α-Ti deposition) at various wire diameters, and then T_c, B_{c2} and J_c were measured in order to evaluate the superconducting properties of the V-Ti-Ta/Cu-Ni composite wires.

As shown in Fig. 1, B_{c2} of the ternary alloys are increased rapidly with decreasing temperature below 4.2 K. With the increase of Ta content, the B_{c2} increase below 4.2 K becomes larger. In addition the α-Ti deposition at 400-500°C caused the both improvements of T_c and B_{c2} as shown in Fig. 1. The improvement effect due to the α-Ti deposition is higher for 500°C than that for 400°C. On the other hand, the most effective deposition temperature for Nb-Ti alloy is reported to be about 350°C. Comparing the phase diagrams of V-Ti binary alloy to that of Nb-Ti binary alloy, the α-Ti deposition temperature of V-Ti alloys is higher by 100 to 200°C than that of Nb-Ti alloys, which should cause the increase of optimized α–Ti deposition temperature.

The V-Ti-Ta ternary alloy showed the 100 times larger J_c through the combination of α–Ti deposition and cold-working after deposition. In order to obtain practically interesting V-Ti-Ta ternary ally wire with much larger J_c, however, more optimization investigations are necessary on the deposition conditions (the temperature and the duration time) and the cold-drawing ratio after deposition. In the practical Nb-Ti alloys, the studies for optimizing the α–Ti deposition conditions have been performed more than 30 years obtaining the present large J_c values.

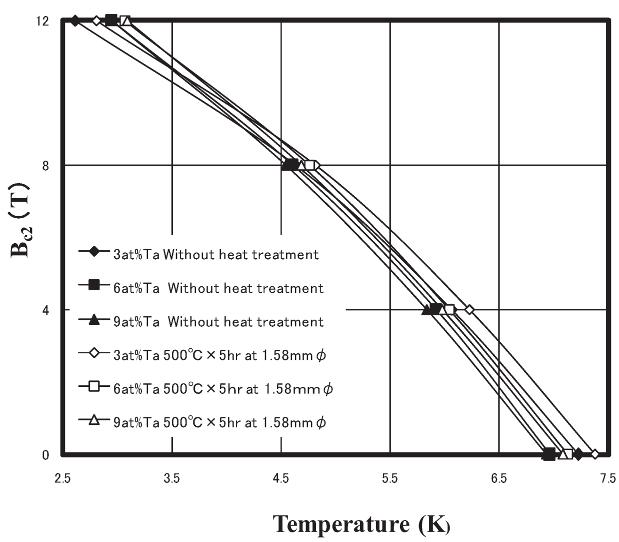

Fig. 1. B_{c2} vs. temperature curves for V-60at%Ti-3at%Ta, V-6at%Ti- 6at%Ta and V-60at%Ti-9at%Ta ternary alloy wires with and without heat treatment at 500°C for 5 hrs. The heat treatments were performed at wire diameter of 1.58 mm.