§26. Development of V_3Ga Conductors Fabricated through Composite Precursor Wires with Ga-coated V Wires

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Superconductors in the practical fusion reactors will be exposed to heavy neutron irradiation during a long term operation. 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 hundred 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. Therefore the developments of new practical superconductors without Nb and Ag are required for the practical fusion reactors.

For the superconductors of practical fusion reactor, we selected V_3Ga A15 compound. The V_3Ga wires were investigated eagerly about 40 years ago because of their superior high field superconductivity to those of Nb_3Sn wires. However, it was found that high-field superconductivity of Nb_3Sn wire can be improved with the addition of Ti or Ta. The investigation of V_3Ga wire decayed due to high costs of V and Ga. However, excellent superconducting properties can be obtained for the V_3Ga wire. In addition the radioactivity problem of V_3Ga is very small. Therefore we selected V_3Ga as the superconducting materials for fusion reactor.

The diffusion process for fabricating V_3Ga wire was investigated eagerly 40 years ago. In this time we studied an RHQT(rapid-heating/quenching/transformation) process for making V_3Ga wire through the transformation from supersaturated bcc V-Ga alloy to A-15 compound. The process was developed recently for producing Nb_3Al wire.

Specimen Preparations and Measurements

In the fabrication of the precursor wire for rapid-heating/quenching (RHQ) treatment, a vanadium wire with 9 mm diameter was coated with Ga through the RHQ treatment. Then the coated Ga was transformed to VGa_3 through the diffusion reaction at 500°C for 1 hr. The VGa_3-coated wires of 57 or 63 were inserted into Ta pipes (O. D. of 20 mm, I. D. of 6 mm) to make composite wires. The composite wires were cold-drawn into the fine wires with 0.81 mm diameter (RIT process).

In comparison with them, we made another processed precursor wire using V_3Ga powder. V_3Ga powder with about 5mm diameter was packed into a Ta pipe (O. D. of 20 mm, I. D. of 8 mm). The wire was also cold-drawn into a fine wire with 0.81 mm diameter (PIT process).

These precursor wires were heat-treated by resistive heating with moving 0.75 m/s between electric terminals 300 mm apart, and quenched to room temperature by passing through Ga-bath. The maximum temperatures during the RHQ-treatment (from 1560°C to 2650°C in this study) are controlled by changing the voltage between the electric terminals. The RHQ-treated wires were heat treated at 600-800°C for transformation. T_c and I_c of the wires were measured by the 4-probe resistive methods

Results and Discussions

Just after the RHQ-treatment, T_c of all specimens made by RIT and PIT processes are 7-8 K, which are T_c of Sn-Pb solder. In PIT specimens V_3Ga powders were packed. Therefore, when the maximum temperature during RHQ-treatment were lower than 1300°C, the wire should show T_c = 14 to 15 K of A15 V_3Ga. However, we performed the RHQ-treatment above 1300°C in this study, where supersaturated V-Ga bcc alloys are stable, and their T_c are lower than 5 K. Therefore supersaturated V-Ga bcc alloys should be formed in all cases of this experiment through the RHQ-treatment.

Heat-treatments at 700°C and 800°C caused the transformation from bcc phase to A15 phase, resulting T_c of 14 to 14.8 K. T_c degradation due to the highest RHQ-treatment was observed for the RIT specimen, which may be caused with the Ga diffusion to the pure V part in the wire. The formation of Ga-poor V_3Ga may cause the T_c degradation. Heat-treatment at 600°C causes T_c of 14 to 14.8 K for the PIT wire, and T_c of 7 to 9 K for the RIT wire.

I_c of the RIT wire is 1 to 2 A at 12 T and 4.2 K, which are relatively small. The volume-fraction of V_3Ga in RIT wire is lower than 5%. The small volume-fraction of V_3Ga may be caused by the small amount of Ga-coating at the starting.

The wire heat treated at 700°C showed higher I_c than that of the wire heat treated at 800°C. The heat treatments at 550 to 650°C are interesting for obtaining higher I_c.