§2. Development of Low Activation Compound Superconducting Wires for Fusion Reactor

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The burning plasma experiments between Deuterium and Tritium were planned in the ITER project. There will be fear that degradations of superconducting properties in coil conductors are caused by radiations such as streaming neutrons in the advanced fusion reactor. In the case of advanced fusion reactor such as DEMO or commercial fusion plants, there is problem that the streaming of radiation dose over the ITER level seems to become larger with increasing fusion power. We considered that it is necessary to develop the superconducting conductor which is "low activation" compatible with "high magnetic field". V-based compound superconductors are suitable for applying as a high field conductor for advanced fusion reactors, because they show neutron irradiation resistance and low activation in the fusion reactor compared with those of Nb-based A15 wires. Therefore, we started to develop the V_3Ga compound which was one of the V-based superconducting materials.

Though the rapidly heating and quenching (RHQ) processing has been applied until now to various A15 compounds such as Nb_3Sn, Nb_3Ga, Nb_3Ge and $Nb_3(Al,Ge)$ wires, supersaturated solid solution filament like the Nb_3Al wire can not have been formed in each case. In this study, the RHQ process was applied at the V_3Ga compound which existed by stabilizing the V-25at%Ga solid solution in the high-temperature region above 1300℃. We focused and observed that the stacking fault was formed in the V_3Ga phase transformed from supersaturated solid solution as well as Nb_3Al compound.

V_3Ga compound powder was produced to grinding by hands using Arc-melted V_3Ga compound button. We confirmed composition of V_3Ga compound powder using XRD and ICP analysis. Prepared V_3Ga compound powder was packed into Nb tube having 20 mm outer diameter and 10 mm inner diameter, and then this composite was cold rolled with a grooved and the wire drawn a diameter of about 2.00 mm through Powder-In-Tube method. This mono-cored wire was cut into short piece, and they were stacked into Nb tube. The number of stacked mono-cored wire was 55 pieces. The stacked composite was cold-rolled with a grooved roller and drawing machine to wire of about 0.74 mm diameter. This multifilamentary wire was set into RHQ apparatus, and it was applied to the RHQ treatment in a dynamic vacuum chamber with moving at 0.4 m/sec of velocity. Then some of as-RHQ wires were additionally post-annealed at 800℃ for 12 hours in vacuum.

Fig.1 shows that typical SEM image on the cross-section of the V_3Ga/Nb multifilamentary wire. This composite has good workability without breaking of wire during wire deformation, and average diameter of V_3Ga filament is about 20 μ m. Fig.2 shows that the relationship between heating energy density and T_c value of as-RHQ samples. The heating energy density J (J/mm^3) indicate normalized heating condition regardless of diameter and moving velocity of wires, and J value is given by

$$J = V \times I \times (L \times A)^{-1}$$

where V is applied voltage (V), I is current (A), L is length of heating area (mm) and A is the cross-sectional area of wire (mm^2), respectively. The heating temperature during RHQ treatment was increased with increasing of J value, and this tendency agreed well the change of maximum heating temperature measured by radiation thermometer shown in Fig.2. In the case of V_3Ga wires, T_c values of pure Nb within 9 K appeared remarkable lower heating energy region compared with that of Nb_3Al wire, and V-Ga supersaturated solid solution was formed at lower heating temperature (above 1300 ℃) compared with Nb-Al supersaturated solid solution (above 2200 ℃). This result is agreed well with V-Ga equilibrium diagram.

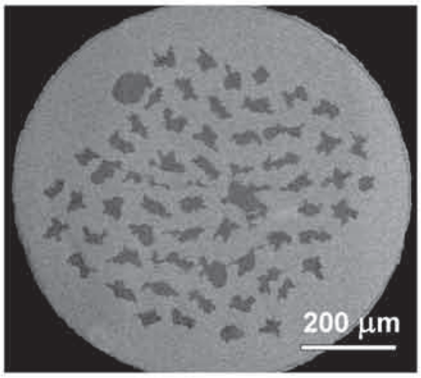

Fig. 1 Typical SEM image on the cross-section of the V_3Ga/Nb multifilamentary PIT wire.

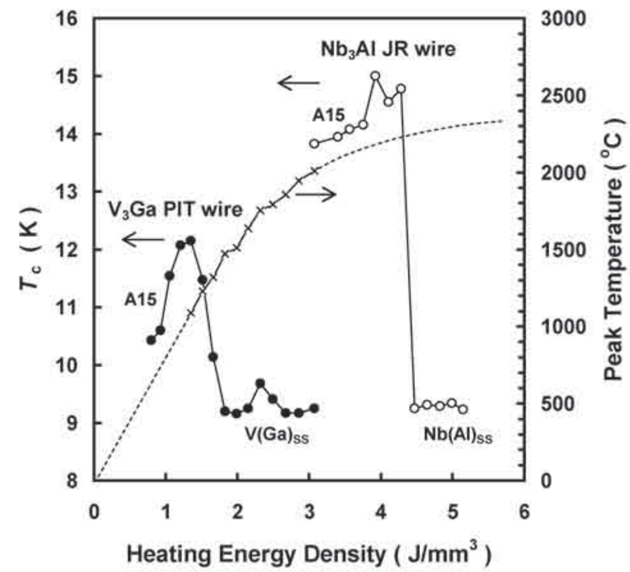

Fig. 2 Relationship between Tc and heating energy density on rapid-heating/quenching treatment for V_3Ga PIT wire and Nb_3Al JR wire.