§29. Effect of Cu Addition on Superconducting Properties of V3Ga Low Activation Superconducting Wires through the PIT Process Using TiGa3 Compound


In the typical magnetic confinement machines, highly energetic 14 MeV neutron and alpha particles are produced during the burning plasma reaction between deuterium (D) and tritium (T). The advanced reactors beyond ITER such as the DEMO and fusion power plants will premise the steady-state and long term D-T reaction. And the induced radioactivity and neutron irradiation properties on all reactor components will be one of the important factors to realize higher social receptive fusion reactors. Especially, the decay time of the induced radio-activity will control the reactor safety, the maintenance scenario and shutdown schedule including the total cost on the fusion reactor. The decay times of the V-based compounds, V3Ga, V3Si and C15 Laves phase compound, are within 1 year, making it desirable as candidate low activation materials. Specifically, it is well known that V3Ga wire contributed to the fabrication of superconducting magnet generating 17.5 T which is the world record in 1976 [1], and V3Ga will be one of desirable materials to realize “low activation and high field superconducting magnets” for the future fusion reactors. However, Jc-B properties of V3Ga wire are lower than that of Nb-based wires such as Nb3Sn and Nb3Al. Jc-B enhancement on the V3Ga wire is necessary in order to meet the requirements of fusion magnets. In the previous study, we fabricated mono-cored V3Ga using TiGa3 compound, and confirmed that Hc2 values were estimated to be about 22 T [2]. In this study, we investigated effect and optimum Cu addition in V3Ga multifilamentary wire using TiGa3 compound in order to improve superconducting property.

TiGa3 compound buttons were made by arc-melting method TiGa3 ingots were crushed and ground into fine powders by hand-milling. Cu additions to the TiGa3 compound were carried out using high purity Cu fine powder; the Cu-added compositions were 10, 30 and 50 wt.%Cu. TiGa3 compounds with several Cu additions were packed tightly into a high purity vanadium sheath tube. The hexagonal precursor TiGa3/V mono-cored wires were fabricated through the Powder-In-Tube (PIT) process. The precursor wires were cut in short piece and fifty-five short pieces of mono-cored wires were restacked into high purity metal Ta tube. The TiGa3/V/Ta multifilament restacked composite was also carried out wire drawing to 1.04 mm without wire breakage. TiGa3/V/Ta precursor wires were sintered at various temperatures for 50 hours under vacuum.

In order to evaluate the transport critical current density (Jc) values at 4.2 K and various magnetic fields, DC I-V curves were measured using four-probe method at the Tsukuba Magnet Laboratory of NIMS. Transport Ic criterion was 1 μA/cm. The critical current density (Jc) values reported here are the V3Ga layer values (Ic value divided by the cross-sectional area of V3Ga phase), and will be referred to as the “Layer Jc”.

Layer Jc value of Cu addition sample was higher than that of non-Cu addition sample, and 30 wt.%Cu addition sample sintered 650 °C showed about 550 A/mm2, which was about twice higher compared with non-Cu addition sample (250 A/mm2). We believe that the optimum Cu addition was obtained to be 30 wt.% and the lowering melting point by the Cu addition might result in the formation of the V3Ga phase at lower sintering temperature, and that it was also effective in restricting the coarsening of the V3Ga grains. The Jc-B performances of the TiGa3/V wire with Cu addition sintered at optimum sintering conditions are also shown in Fig. 1. Layer Jc degradation with increasing magnetic field in the Cu addition wire was clearly smaller than that for the non-Cu addition wire. The Kramer plots for the TiGa3 wire with and without Cu addition, calculated based on Jc-B performances shown in Fig. 1, were estimated. For the non-Cu addition TiGa3/V wire, the Hc2 value was estimated to be about 21.5 T, whereas Hc2 value for the TiGa3/V with 30 wt.%Cu addition wire was estimated to be above 24.2 T. This Hc2 value was about 3 T higher than practical bronzed processed V3Ga wires.