§29. Effect of Cu Addition on Superconducting Properties of V_3Ga Low Activation Superconducting Wires through the PIT Process Using $TiGa_3$ Compound

Hishinuma, Y.,
Kikuchi, A., Iijima, Y., Takeuchi, T. (NIMS),
Murakami, S., Matsuda, K. (Univ. Toyama),
Taniguchi, H. (Osaka Alloying Works Co., Ltd)

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, V_3Ga, V_3Si and C15 Laves phase compound, are within 1 year, making it desirable as candidate low activation materials. Specifically, it is well known that V_3Ga wire contributed to the fabrication of superconducting magnet generating 17.5 T which is the world record in 1976 [1], and V_3Ga will be one of desirable materials to realize "low activation and high field superconducting magnets" for the future fusion reactors. However, J_c-B properties of V_3Ga wire are lower than that of Nb-based wires such as Nb_3Sn and Nb_3Al. J_c-B enhancement on the V_3Ga wire is necessary in order to meet the requirements of fusion magnets. In the previous study, we fabricated mono-cored V_3Ga using $TiGa_3$ compound, and confirmed that H_{c2} values were estimated to be about 22 T [2]. In this study, we investigated effect and optimum Cu addition in V_3Ga multifilamentary wire using $TiGa_3$ compound in order to improve superconducting property.

$TiGa_3$ compound buttons were made by arc-melting method $TiGa_3$ ingots were crushed and ground into fine powders by hand-milling. Cu additions to the $TiGa_3$ compound were carried out using high purity Cu fine powder; the Cu-added compositions were 10, 30 and 50 wt.%Cu. $TiGa_3$ compounds with several Cu additions were packed tightly into a high purity vanadium sheath tube. The hexagonal precursor $TiGa_3$/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 $TiGa_3$/V/Ta multifilament restacked composite was also carried out wire drawing to 1.04 mm without wire breakage. $TiGa_3$/V/Ta precursor wires were sintered at various temperatures for 50 hours under vacuum.

In order to evaluate the transport critical current density (J_c) 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 I_c criterion was 1 μV/cm. The critical current density (J_c) values reported here are the V_3Ga layer values (I_c value divided by the cross-sectional area of V_3Ga phase), and will be referred to as the "Layer J_c".

Layer J_c 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/mm^2, which was about twice higher compared with non-Cu addition sample (250 A/mm^2). 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 V_3Ga phase at lower sintering temperature, and that it was also effective in restricting the coarsening of the V_3Ga grains. The J_c-B performances of the $TiGa_3$/V wire with Cu addition sintered at optimum sintering conditions are also shown in Fig. 1. Layer J_c 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 $TiGa_3$ wire with and without Cu addition, calculated based on J_c-B performances shown in Fig. 1, were estimated. For the non-Cu addition $TiGa_3$/V wire, the H_{c2} value was estimated to be about 21.5 T, whereas H_{c2} value for the $TiGa_3$/V with 30 wt.%Cu addition wire was estimated to be above 24.2 T. This H_{c2} value was about 3 T higher than practical bronzed processed V_3Ga wires.

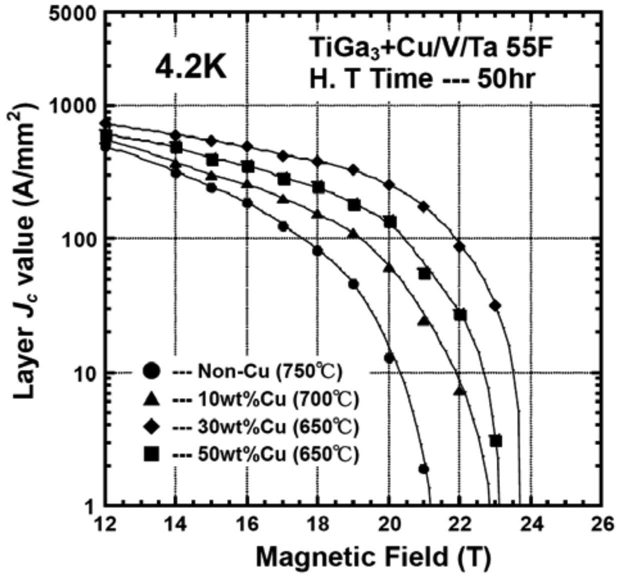

Fig.1 *J_c-B* performance in higher magnetic field region of $TiGa_3$/V/Ta multifilamentary wire with and without Cu addition sintered at optimum temperature for 50 hrs.

1) Tachikawa, K. et al., TEION KOGAKU, **11**, 252 (1976).
2) Hishinuma, Y., et al., IEEE Trans. Appl. Supercond., **21**, 2525 (2011).