§15. The Newly Wire Fabrication Process Using High Ga Content Cu-Ga Compound for the V_3Ga Compound Mono-cored and Multifilamentary Wires

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In an advanced magnetic confinement fusion reactor beyond ITER such as DEMO and fusion power plant, superconducting magnet is required to have a higher magnetic field property to confine the steady-state burning deuterium (D)-Tritium (T) fusion plasma and maintain this during the long term operation. Therefore, it is necessary to consider carefully not only superconducting property but also neutron irradiation property in superconducting materials for use in a fusion reactor. V_3Ga compound is desirable as the candidate materials to realize "low activation superconducting magnet" for fusion reactor because the decay times of V_3Ga superconductors are within 10 years and they were shorter than those of Nb-based superconducting wires. However, the present critical current density (J_c) property of V_3Ga compound wire is insufficiency to apply to fusion magnet applications. We investigated a new route PIT process using a high Ga content Cu-Ga compound in order to improve workability and the J_c property of the V_3Ga compound wire.

The various high Ga content Cu-Ga compound ingots were made by the Tammann dissolution in Ar atmosphere using pure metal Cu foil (99.9%) and granular metal Ga (99.999%). Then the ingots crushed and ground by hand-milling into coarse powders. The prepared Cu-Ga compounds were packed tightly into a high pure metal Vanadium (V) sheath tube. The precursor mono-cored wires were fabricated through the Powder-In-Tube (PIT) process. Wire drawing was carried out using grooved roller and cassette roller dies. The multifilamentary wires were also made by the restacking of short pieces of mono-cored wires into V tube. The precursor mono-cored and multifilamentary wires finally have a diameter of 1.04 mm. The PIT precursor wires were heat treated in a vacuum.

The V element distribution mapping and quantitative composition on the cross-sectional region of mono-cored wires is shown in Fig.1. The thickness of diffusion reaction layer was obtained as about 20μm, 40μm and 50μm, and then the increase of the diffusion layer with increasing Ga content was confirmed. In the case of 25at%Ga and 30at%Ga, only a V_3Ga single phase was formed along the boundary between Cu-Ga compound and V sheath. However, the formation of two phases was observed in the case of the 40 at%Ga sample. One was V_6Ga_5 phase, which was formed about 30μm along the Cu-Ga compound core side region, and the other was V_3Ga phase, which was formed about 20 μm along the V_6Ga_5 phase. In both the 25at% and 30at%Ga samples, forming of the single V_3Ga phase was caused by a solid-solid phase reaction, and then Cu element in the Cu-Ga compound promoted the diffusion reaction between Ga and V, just like the conventional "Bronze process". In the 40at%Ga sample, V_6Ga_5 phase was probably formed preferentially due to the excessive Ga component released from Ga-rich liquid phase, and then the V_3Ga phase was formed by the diffusion reaction between V_6Ga_5 phase and V sheath. The typical J_c-B performance of V_3Ga multifilamentary wires is shown in Fig.2. The J_c-B performance was improved by increasing the Ga content of the precursor wires. This J_c improvement was also confirmed for the other high Ga content compound samples. The maximum Layer J_c (J_c value estimated by the cross-sectional area of the diffusion layer) was obtained to be 400 A/mm^2 (4.2K, 20T), and critical magnetic field (H_{c2}) property was about 22.5 T which was 1.5 T higher than that of conventional process without substitution. These suggested that V_3Ga compound superconducting wire had high potential property for an advanced fusion reactor application and the new route processing using high Ga content compound was one of the effective methods to improve superconducting properties of V_3Ga wires.

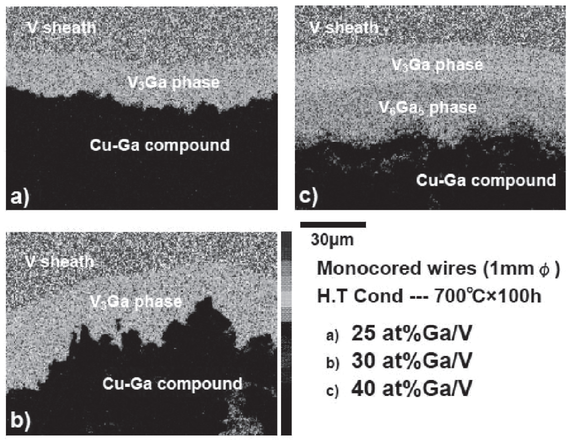

Fig. 1 The V element distribution mapping and quantitative composition on the cross-sectional region of mono-cored wires

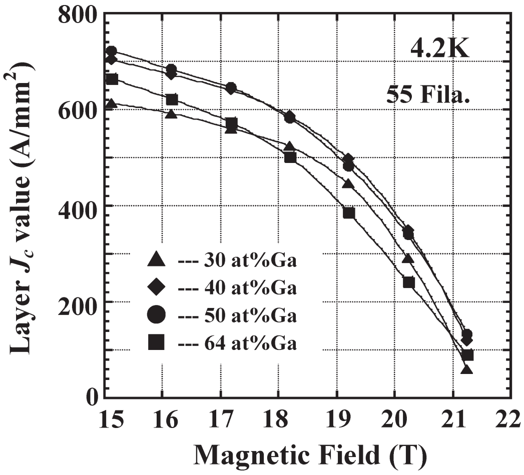

Fig. 2 The typical J_c-B performances of the V_3Ga multifilamentary wires using high Ga content powder