§4. Fabrication and Superconductivity of V-based Laves Phase Compound Multifilamentary Wires Synthesized by a RHQ Process to PIT Precursors Using a V Tube


V-based Laves phase compounds, \( V_4(Hf, Zr) \), show very attractive superconducting properties a maximum \( T_c = 10.1 \) K, maximum \( H_{c2} \) above 20 T and a insensitivity to mechanical strain. In addition, V-based Laves phase compound shows much higher radiation resistance than that of Nb-based A15 compound wires and tapes. Therefore we thought that Laves phase compound superconductors were promising as low activation and high field conductors for advanced fusion reactors. However, \( V_4(Hf, Zr) \) precursor (Hf-Zr alloy/V matrix) is very hardness and low workability, so we thought that it needed a new process which does not pass through the conventional diffusion reaction between Hf-Zr alloy and V matrix in order to improve workability and superconducting properties. Then, we fabricated the Laves phase compound multifilamentary wire by applying a rapidly-heating and quenching (RHQ) process to the powder-in-tube processed simple precursors (Hf-Zr metal powder mixture/V tube composite) and its microstructures and superconducting properties was investigated.

First, high purity metal hafnium (Hf) and zirconium (Zr) powders were adjusted to have equal molar ratio. This powder was well ground by hand, and then wet ball-mill processing was carried out for 3 hours to homogenise the mixed metal powder. After the ball-mill processing, mixed powder was packed into V tubes. This composite (\( (Hf_{0.6} Zr_{0.4})/V \)) was cold-rolled with a grooved roller and the wire drawn a diameter of about 1.20 mm. Intermediate annealing was carried out several times at 1173 K for 1 hour to soften this composite during this deformation. The (Hf, Zr)/V composite was cut into short pieces, and they were stacked into a tantalum (Ta) tube. The number of stacked (Hf, Zr)/V composite was 55 pieces. This composite (\( (Hf_{0.6} Zr_{0.4})/V/Ta \)) was cold-rolled with a grooved roller and drawing machine to wire of about 0.754 mm diameter as well as (Hf, Zr)/V composite. Fig.1 shows a typical SEM photograph of the cross-sectional structure of the prepared (Hf, Zr)/V/Ta 55 cored multifilamentary wire. The precursor wire was set into RHQ apparatus, and it was applied to the RHQ treatment in a dynamic vacuum chamber. The precursor wire was continuously heated up to the several temperatures with moving at 1.0 m/sec of velocity. The precursor wire was heat treated by resistive-heating during 0.1 sec using dc current. Subsequently, the wire was continuously quenched into the Ga bath at about 320 K from above 2500 K. Then, some of the as-RHQ wires were additionally post-annealed at several temperatures for 10 hours in the vacuum.

\( J_c \) value of sample post-annealed at 873 K was estimated to be about 100 A/mm² at 4.2 K and 10 T. \( J_c \) dependence of magnetic field on the sample post-annealed at 873 K was higher than for the as-quenched sample, and then the \( H_{c2} \) value calculated by Kramer’s formula was 16 T for the sample post-annealed at 873 K. It was also improved compared to the as-quenched sample. On the other hand, the \( J_c \) dependence on magnetic field for the sample post-annealed at 1173 K was lower than for the as-quenched sample as well as its \( H_{c2} \) value. We found that optimum post-annealing temperature in this study was drastically lower than that of temperature on the conventional diffusion process.

ACKNOWLEDGEMENT

We would like to thank for Tsukuba Magnet Laboratory of NIMS for providing us with using high magnetic field magnet facilities for the \( J_c \) measurement.

Fig. 1. Typical SEM photograph of the cross-sectional structure on the prepared (Hf, Zr)/V/Ta 55 cored multifilamentary wire.

Fig. 2. Typical \( J_c - B \) curves of RHQ samples