Microstructure of V_3Ga Superconducting Wire Using Cu/V with High Ga Contents*)

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Hishinuma *et al.* has established a new Powder-In-Tube (PIT) process using a high Ga content Cu-Ga compound in order to improve the superconducting property of the V_3Ga compound wire. In this study, we investigated the microstructure of this high Ga content Cu-Ga/V composite superconducting wire. Three different contrasts of the matrix, V-Ga phase and Cu-Ga core were observed by SEM observation in the cross section of 19-multifilament wire. The V-Ga phase was confirmed by SEM mapping. The area fraction of V-Ga phase increased when Ga content increased from 30% to 50%. Thin film sample with V-Ga phase for TEM observation was fabricated by FIB. Selected area diffraction pattern was obtained for V matrix, V-Ga phase and Cu-Ga core. The ratio of V to Ga in V-Ga phase was close to V_3Ga according to the EDS result. The interface between V matrix and V-Ga phase was linear, while the interface between Cu-Ga core and V-Ga phase was not linear. On the other hand, there were some granular grains observed in V-Ga phase around Cu-Ga core.

Keywords: V_3Ga, superconducting wire, TEM, PIT

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1. Introduction

A superconducting wire is used in superconducting magnet system. It is also one of the important components in an advanced magnetic confinement fusion reactor [1]. In previous study, V_3Ga compound wire was mainly investigated the "Diffusion process" between Cu-Ga solid solution matrix within 20 at% Ga composition and V filament [2]. It has been reported that the drastic critical current density (J_C) of Nb_3Sn will be improved by increasing Sn content in the Cu-Sn matrix. Hishinuma et. al. thought that the high Ga content in the Cu-Ga compound material was an effective method to improve J_C of the V_3Ga compound wire, just like the high Sn content Nb_3Sn wires. They tried to develop the new route for the fabrication of V_3Ga compound wire with high Ga content Cu-Ga compound using the PIT processed precursors in order to improve the cold workability and volume fraction of the synthesized A15 phase, and investigated its microstructure and superconducting properties [3,4]. It was confirmed that the thicker V_3Ga layer formed along the interface of Cu-Ga powder core and V matrix compared with previous diffusion processed samples for the multifilamentary wires. Upper critical field (Hc_2) of Cu-Ga compounds was increased with increasing Ga content in Cu-Ga compounds. And Hc_2 showed about 23.0 T for Cu-50at%Ga compound powder, which was 2.0 T higher than bronze processed samples. But there was no report about the microstructure of high Ga content Cu-Ga/V composite superconducting wire. In this work, we investigated microstructures of the superconducting wire with high Ga content to clarify the existence of V_3Ga phase.

2. Experimental Procedures

Cu-Ga compound powders with 30at%Ga and 50at%Ga were filled up a V pipe (ϕ10 mm, internal diameter ϕ6 mm) and drawn into a single filament wire with a diameter of ϕ1 mm. The single filament wire was cut into a proper length. 19 single filament wires were put together in the V pipe again and drown into a 19-multifilament wire with a diameter of ϕ1 mm, which was fabricated without disconnection because of the good workability of the single filament wire. The 19-multifilament wire was heat treated in a vacuum to form the superconducting layer (V-Ga phase). The microstructure of the 19-multifilament Cu-30at%Ga/V and Cu-50%Ga/V, which were called as 30%Ga and 50%Ga wires in this paper, was investigated by

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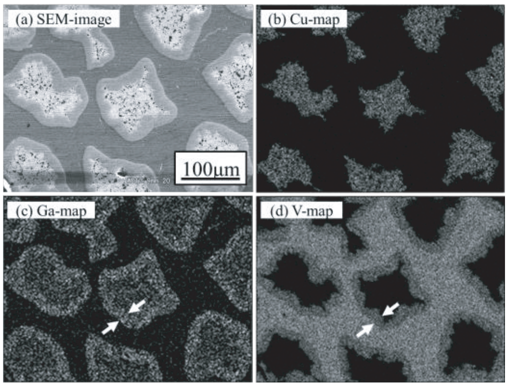

Fig. 1 Cross-section structure for 50%Ga wire: (a) SEM image and (b) Cu-, (c) Ga-, (d) V-map.

SEM and TEM observation. 30%Ga or 50%Ga wire was embedded in the U alloy, which has a low melting temperature, and polished mechanically to prepare the SEM sample. TEM sample was made from SEM sample using FIB method (FB-2100, HITACH). SEM and TEM observation was performed using S-3500H with EDS and EM-002B (TOPCON) with EDS.

3. Results and Discussion

SEM image for the cross-section of 50%Ga wire was shown in Fig. 1 (a). EDS mapping was performed in the same area. Figures 1 (b), (c) and (d) were Cu-, Ga- and V-map, respectively. According to these results, Cu and Ga were detected from Cu-Ga core, V was detected from V matrix. In addition, as illustrated by arrows in Fig. 1 (c) and (d), V-Ga phase existed between Cu-Ga core and V matrix and V:Ga was about 3:1. The area fraction of the V_3Ga phase was calculated as 38% and 53% for 30%Ga and 50%Ga wires, respectively. The thickness of the V_3Ga phase depended on Ga content in the Cu-Ga compound.

Figure 2 showed the TEM bright field image obtained for V-Ga phase/Cu-Ga core in 50%Ga wire. In Fig. 2, the dash line indicated the interface between Cu-Ga core (B) and V-Ga phase (A). And the small area surrounded by the dot line was Cu-Ga core. On the other hand, there were some granular crystal grains in (A). The shape of the interface between Cu-Ga core and V-Ga reaction is complicated.

Figure 3 showed the TEM bright field image obtained for V matrix/V-Ga phase in 50%Ga wire. In Fig. 3, the dash line indicated the interface between V-Ga phase (D) and V matrix (C). There were some vertically elongated crystal grains with long distance direction in (D). The interface between V-Ga phase and V matrix was of linear shape compared to Fig. 2.

EDS analysis was performed for V-Ga phase. The ratio of V to Ga for V-Ga phase in Fig. 2 was 2.8:1, and 3.2:1 in Fig. 3, respectively. So this phase was thought as V_3Ga.

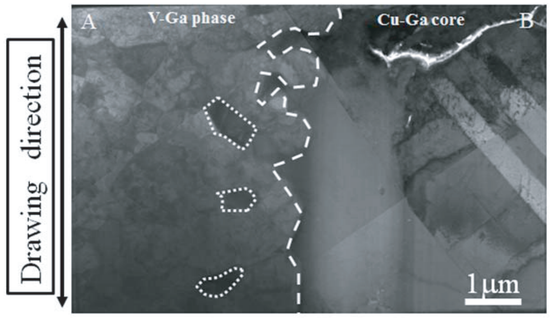

Fig. 2 TEM bright field image of V-Ga phase/Cu-Ga core.

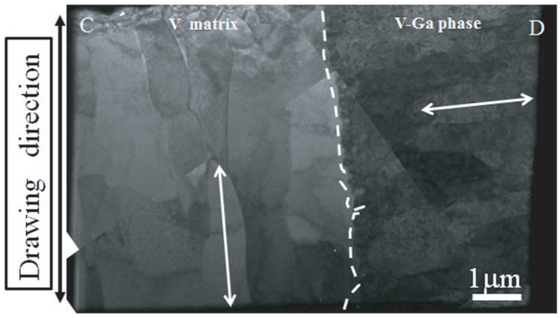

Fig. 3 TEM bright field image of V matrix/V-Ga phase.

4. Conclusions

1. The different contrasts of matrix, V-Ga phase and Cu-Ga core were observed by SEM observation in the cross section of the 19-multifilament wire. V-Ga phase was also confirmed by SEM-EDS mapping.
2. The ratio of V and Ga for V-Ga phase was about 3:1 and the phase was probably V_3Ga according to the EDS result.
3. There was a linear interface between the matrix and V-Ga phase, while the interface between Cu-Ga core and V-Ga phase was not linear. On the other hand, there were some granular grains observed in V-Ga phase around Cu-Ga core.

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