§1. Synthesis of High Performance Nb_3Sn Layers through the New Diffusion Process

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In the present JR (Jelly Roll) process Sn-based alloy sheet, 80 μ m in thickness, is laminated with Nb sheet and wound into a JR composite. The composite is encased in a Nb-based alloy sheath, and then fabricated into a wire. A swift fabrication is possible, and the leak out of Sn is prevented by the holding between Nb sheets at the extrusion and heat treatment. The volume fraction of residual bronze in the JR wire is much smaller than in the bronze and internal Sn processed wires resulting in the increase of non-Cu J_c and the reduction of strain effect.

At the initial stage of the heat treatment at 750℃ Nb_6Sn_5 layers are formed in the JR wire by the reaction between Nb and Sn sheets. The Nb_6Sn_5 layers show a distinct columnar microstructure with an aspect ratio of ~10 owing to the solid / liquid reaction. Then Nb_3Sn layers are formed by the solid state reaction between residual Nb and Nb_6Sn_5. The Nb_3Sn layers show a homogeneous and almost equiaxed microstructure.

The JR processed Nb_3Sn wires show an offset T_c of 18.1K with a transition width of less than 0.1K, which is appreciably higher and sharper transition than other Nb_3Sn wires. Fig. 1 illustrates the relation between offset T_c and applied magnetic field of two JR wires. The B_{c2} increases almost linearly with decreasing temperature, which reaches ~13T at 12K. The result indicates that the JR wires are promising for refrigerator-cooled superconducting magnets capable of generating 10T at 12K. The offset B_{c2} (4.2K) of the JR wires is ~26.5T.

Fig. 2 is non-Cu J_c versus magnetic field curves of Sn-Ta based sheet JR wires with different diameters and Nb sheet thickness. The non-Cu J_c increases with reducing the wire diameter, e.g., 120A/mm^2 for 1.4mm ϕ wire and 180A/mm^2 for 1.0mm ϕ wire at 4.2K and 22T. The thinner wire diameter increases the areal fraction of Nb_3Sn layer as shown in Fig. 2, which may be the main origin of the non-Cu J_c improvement.

The thickness of the Nb sheet produces a drastic change in both the structure and the performance of JR wires. In the wire starting from 100 μ m-thick Nb sheet, the Nb sheet is completely consumed and some Nb_6Sn_5 phase is present in the JR part after the heat treatment. The excess Sn diffuses into the Nb sheath and the central Nb core to form thick Nb_3Sn layers. In the wire starting from 160 μ m-thick Nb sheet, the JR part is composed of equally spaced spiral Nb_3Sn layers. The configuration of the JR part is much improved compared to the previous wires starting from 100 μ m-thick Nb sheet.

The non-Cu J_c of the 160 μ m-thick Nb sheet wire increases much more rapidly with decreasing field below 24T than the 100 μ m-thick Nb sheet wire as shown in Fig.2. The non-Cu J_c at 4.2K and 21T of the 1.4mm ϕ wires is ~160A/mm^2 and ~290A/mm^2 for 100 μ m-thick and 160 μ m-thick Nb sheet wires, respectively. The increase of starting Nb sheet thickness is found to yield much better JR configuration and larger non-Cu J_c in the wire.

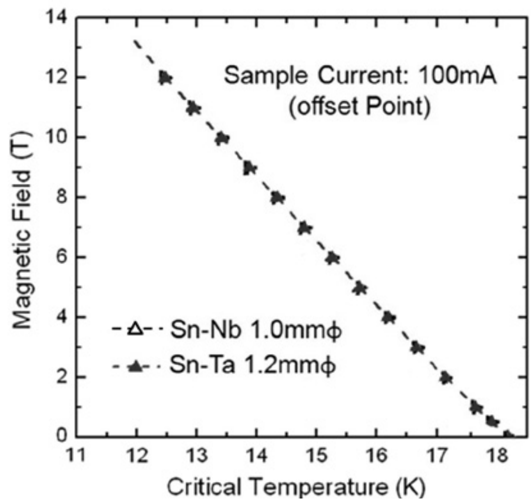

Fig.1 Relation between magnetic field and offset T_c for Sn-Ta and Sn-Nb based sheet JR wires.

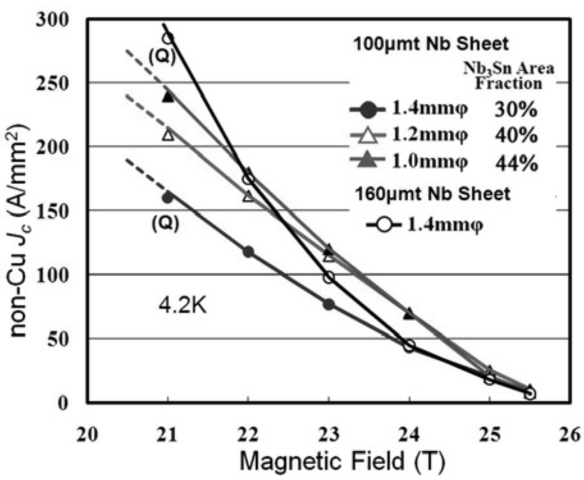

Fig.2 Non-Cu J_c versus magnetic field curves of wires with different diameter and Nb sheet thickness. The areal fraction of Nb_3Sn layers in the 100 μ m-thick Nb sheet wires is inserted in the figure.