§2. Investigation of the Cross-sectional Configuration of Ag Sheath Material for High Strength Bi-2212 Superconducting Wire

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Critical current density (J_c) improvement under the high magnetic field and higher mechanical strength for the large electromagnetic force is one of the key issues to realize an advanced fusion reactor beyond ITER. On the other hands, it is known that Y and Bi systems high T_c oxide superconducting wires have higher J_c property under the high magnetic field above 20 T compared with A15 compound superconducting wire as Nb_3Sn and Nb_3Al.

Especially, $Bi_2Sr_2CaCu_2O_x$ (Bi-2212) oxide superconducting wire is easy to make round-shape wire, so that Bi-2212 wire is easy to apply for the large Cable-in Condit (CIC) conductor of the fusion magnet system. However, mechanical strength of the Bi-2212/Ag wire is remarkably lower than A15 compound superconducting wire because the sheath material of the Bi-2212 superconducting wire must be used only Ag and/or Ag based alloy in order to obtain the high J_c performance. In addition, Bi-2212 compound is brittle material as a consequence of ceramic. In this study, we carried out reconsideration of the wire configuration of the Bi-2212 round wire to realize higher mechanical strength for the large electromagnetic force without decreasing of J_c performance.

Generally, mechanical strength of Bi-2212/Ag round wire can be improved by the making Ag-Cu and/or Ag-Mg alloy as sheath materials. Bi-2212/Ag round wire was heat-treated by the "partial melting-slow cooling process" because of the forming of highly c-axis oriented and dense microstructure. Investigating the mechanical strength improvement in Bi-2212/Ag round wire, the composite material for high mechanical strength metal is required to higher melting point compared with Bi-2212 compound. We approached the higher mechanical strength of the Bi-2212/Ag round wire using the composite of the metal Ni-based alloy such as Cu-Ni. Furthermore, we also investigated the cross-sectional configuration to retain the Bi-2212 highly c-axis oriented structure using metal Ni composite. Fig.1 shows the conceptual wire configuration designs of the high mechanical strength Bi-2212/Ag round wire using Cu-Ni alloys. The final diameter of all samples is 1.04 mm. Sample A is the conventional Bi-2212/Ag round wire via Powder-In Tube (PIT) process. Sample B is the Bi-2212/Ag wire (Sample A) cladding the Cu-Ni alloy to the outer side of Ag sheath. Sample C is the multifilamentary wire composed of eight Sample B wires. We found that all of sample wires had the good workability without wire breaking during wire deformation. Critical temperature (T_c) values of all samples were obtained to be about 90 K. This value is as same as that of conventional Bi-2212/Ag wire. It suggested that composite using Cu-Ni alloy was not lowered T_c property.

We investigated about the bending strain dependence of the J_c property on Bi-2212 composite round wires (sample A, B and C) in order to evaluate the mechanical strength. Fig. 2 shows that the jig block and mechanism to apply the bending strain for Bi-2212 composite round wires. The jig blocks to apply the bending strain were made by aluminum and they had various curvatures from 25 mm to 500 mm. The sample was set on the jig block along the curvature. The roller was moved on the Bi-2212 round wire in order to apply bending strain homogeneously. The bending strain was calculated by the following equation;

$$\text{Bending strain} \quad \varepsilon = (D/2R) \times 100$$

where D is the diameter of wire and R is curvature of jig block. In this study, we would apply bending strain from 0.104 % (D = 500 mm) to 2.08 % (D = 25 mm). Critical current (I_c) value before applying of bending strain was defined I_{c0} as basis of I_c degradation by bending strain. I_{c0} value was measured by the four probe method under 4.2K@12T. I_c criterion (generating electrical voltage) is 1 μV/cm. Estimating I_c degradation of Bi-2212 composite wire is undergoing (Degradation factor $F=(I_c/I_{c0})\times 100$).

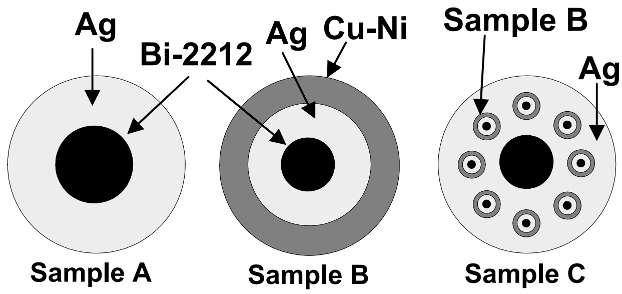

Fig. 1 Typical cross-sectional configuration of high mechanical strength Bi-2212 round wire using Cu-Ni alloys.

Fig. 2 Typical jig block and mechanism to apply the bending strain for Bi-2212 composite round wires