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Comparison of The Using of Silver and Stainless Steel 316 Tubes on Fabricating (Bi,Pb)-Sr-Ca-Cu-O Superconducting Wires by PIT Method

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ABSTRACT

Research on $Bi_{1.6}Pb_{0.4}Sr_2Ca_{2-x}O_xCu_3O_y$ monofilment superconducting wires using Ag-sheated and Stainless Steel 316 to reach higher critical temperature (T_c) have been done. Samples were prepared via powder-in-tube method. Powders of Bi_2O_3,PbO_2, $SrCO_3$, $CaCO_3$ and CuO were mixed in stoichiometric ratio.After being mixed, the monofilament billet rolling with diameter (d = 8mm, 6mm, 5mm, 4mm, 2.5mm) were replaced inti the furnance and sinterizeded in air at temperature 850 ^{0}C for about (t = 30h, 24h, 9h) then cooled in a furnace. The samples were submitted to X-Ray Diffraction to determine their crystalline structure. The diffraction pattern of sample BPSCCO monofilament superconducting wires using Ag-sheated shows that the occurrence of phase formation (Bi, Pb) -2223, (Bi, Pb) -2212, CuO and the crystal structure formed on BPSCCO wires sheated Ag is Orthorombic. For the superconducting monofilament BPSCCO sheathed Stainless Steel 316 is amorphous due to the impurity of CuO and the composition of the Stainless Steel tube to the base superconductor material Bi. The surface morphology studied by SEM show that the BPSCCO monofilment superconducting wires using Ag-sheated and Stainless Steel 316 through morphological analysis seen the existence of crack due to the rolling process on the wire, the homogeneity of the sample already looks quite good although the resulting grains melted and distributed randomly. The resistivity analysis, the sample of the BPSCCO monofilament superconducting wires using sheated - Ag (Sample A1) around $T_{c,\ onset}$ = 98 K and $T_{c,\ zero}$ = 72 K and the sample of BPSCCO monofilament superconducting wires using sheathed Stainless Steel 316 (Sample B1) has $T_{c,\ Onset}$ 107 K and $T_{c,\ zero}$ 49 K and Sample B2 indicate only possible T_c, the onset of the wire is about 80 K. So that the superconducting wire of sheated Stainless Steel 316 can replace the sheated-Ag because the price of Ag cover is relatively more expensive.

Keywords: BPSCCO superconducting monofilament wires, Silver tube, Stainless Steel 316 tube, PIT Method

I. INTRODUCTION

BSCCO-based high temperature superconductor (HTS) have been done to increase the critical temperature of superconductors with a critical transition temperature of superconductivity (T_c) of about 110 K. It is well known that the one of the most promising superconducting applications in the energy is the superconducting wire where its use is in the electrical distribution network [8]. High Superconducting cable is expected as one of the solutions for the shortage of transmission capacity in metropolitan areas. Its merits are as follows; large transmission capacity in compact dimension, small transmission loss, no leakage of electro-magnetic field to the outside of the cable, and small impedance. These features are effective for the improvement of reliability and economical competitiveness of electrical networks. Recently, a lot of demonstration projects have started around the world in order to accelerate the application of superconducting cable to the real network systems and its commercialization. In superconducting cables, the electrical resistance is zero at temperatures below the critical temperature, so its transmission loss is very small [9]. In this bismuth-based superconductor the problem arises is the effort to increase the critical temperature and minimize the degree of material fragility. Thus, it is necessary to increase the critical temperature through various temperature variations at the time of superconducting formation and the variation of the process of cooling the superconducting material while inside the heating furnace [1]. In the sheated-Ag to obtain the characterization properties of the high temperature superconductors therein are usually mixed with one or more other metals to improve the mechanical properties of the wire [4] [5]. BSCCO itself is a ceramic that has fragility, but the use of a 10 μm long-thick filament and a length of 200 μm-on the Ag matrix reduces the crack form and critical strain at about tenths of percent [3]. Stainless Steel 316 tube is a type of austeitic Stainless Steel containing elements Carbon C 0,08% Max, Chromium Cr 16-18%, Nickel Ni 10-14%, Silikon Si 1% Max, Molybdenum Mo 2-3% Max, Mangan Mn 2% Max, Fosfor P 0,045% Max, Sulfur S 0,03% Max (Simply Bearings Ltd). The austenitic alloy has excellent corrosion resistance properties, but also has additional inventory properties as well as easy of fabrication including being able to alter the metal [6].

The stability of the structure by doping the superconducting material by substitution of Pb [2] [10]. Additionally, Pb doping can increase the critical temperature of BSCCO superconductors by 106.42 K and 107 K because they have physical and chemical properties similar to the Bi element so can substitute the Bi position in the BSCCO crystal system[11] [12]. Multi-filamentary silver sheathed Bi2223 wires were prepared by using the PIT method because it has a laminate structure that contains superconductors Bi2223 wire has been expected to be used for various cryogenic applications. Sumitomo Electric Industries, LTD. (SEI) has manufactured Bi2223 wires by using powder-in-tube (PIT) method because it can produce easily a long wire due to the inherent features as mentioned above [7].

II. METHODS AND MATERIAL

The samples were prepared using highly pure powders of Bi_2O_3 (purity 98%), PbO_2 (purity 97%), $SrCO_3$ (purity 96%), $CaCO_3$ (purity 98%) and CuO (purity 99%). BPSCCO monofilment superconducting wires using Ag-sheated and Stainless Steel 316 made by powder-in-tube (PIT), method commonly used for fabrication of cable and cassette. The PIT process in situ ie, the mixture of its elements is inserted into the metal tube and the reaction is carried out in the wire or tape after the deformation process. The presence of porosity is a problem inherent in the powder metallurgy process.The main advantage of this method is that it is capable of carrying a high critical current density and capable of removing the defects caused by the sheathed [13].

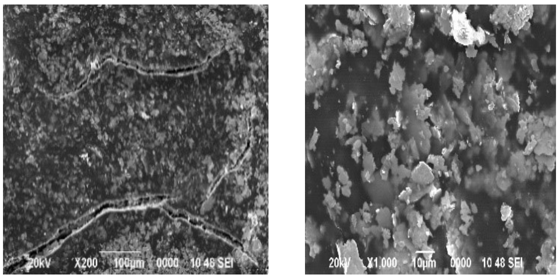
Table 1. Sampling of BPSCCO monofilament superconducting wire with Ag-sheated and Stainless Steel 316 tubes Using powder-in-tube (PIT) Method with T = 850 ^{0}C

No	Tube	Time Sintering (hours)	Diameter (mm)	Code Sample
1	Ag	30	5	A1
		9	2,5	A2
2	Stainless Steel 316 (Insitu)	9	6	B1
		30	4	B2

The materials are weighed according to stoichiometric calculations. Early mono-filament billet with diameter of 8 mm is then in rolling to obtain wire with a diameter according to the table on each sample. The recrystallization process is further sintered in the furnace at a constant temperature of 850^{0}C for a time t = 30 h ; 24 h ; 9 h ago cooled in a furnace. It is known that sintering temperature increase is effective in controlling morphological grains and grains coupling to improve the properties of superconductors such as T_c, J_c and F_p. For all samples the resistivity and critical temperature tests on the BPSCCO superconducting monofilament wire samples were measured by the four-probe (Cryogenic Cryotron FR Oxford) method, the structure properties using X-Ray Diffraction (XRD Rigaku Mini Flex 600), and to investigate the surface of the sample microstructure using Scanning Electron Microstructure (JEOL SEM type JSM-6390A).

III. RESULTS AND DISCUSSION

The grain size and microstructure morphology of the samples were identified using Jeol Scanning Elecron Microscope JSM-6390A.



(a) (b)

Figure 1. SEM images for Sample A1 with t = 30h, d = 5 mm with different magnification : (a) 200x and (b) 1000x

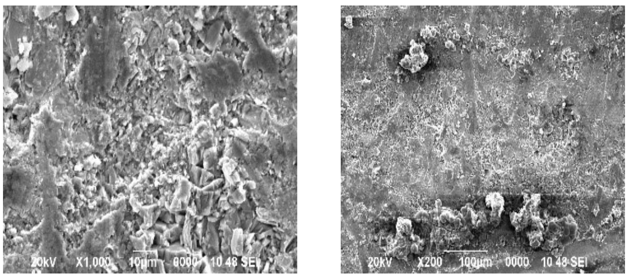
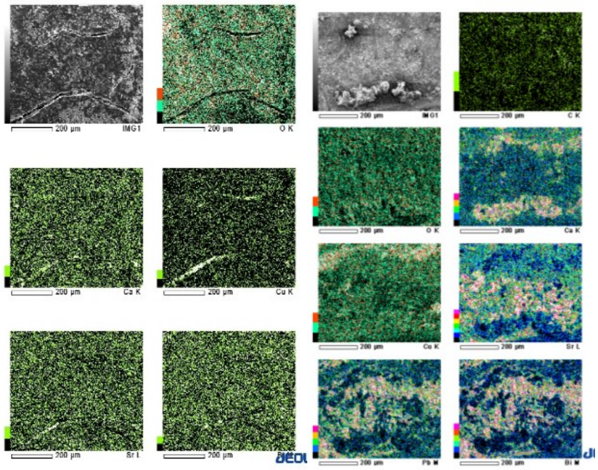


Figure 2. SEM images for Sample A2 with t = 30 h, d = 2,5 mm with different magnification : (a) 1000 x and (b) 200 x



(a) (b)

Figure 3. Sample Mapping A1 (t = 30 h, d = 5mm) and Sample A2 (t = 30 h, d = 2,5 mm)

In **Figure 1** and **Figure 2** shows the SEM images of BPSCCO monofilament superconducting wires d = 5 mm with sintering temperature 850^{0}C, for 24 h shows that the presence of crack caused by rolling process on wire, sample homogeneity has been quite good, although the resultant grain melt and each grain grows in random directions. From the result of mapping in **Figure 3** Sample A1 shows that the elements of Bi, Pb, Sr, Ca, Cu, O, C have value of wt of 4.75%, 0%, 1.84%, 13.67%, 0.72%, 79.02% 17.52%. For element O high concentration and unequally distributed, Bi, Sr, Ca, Cu, C Pb have low concentration and evenly distributed. In Sample A2 shows that the elements of Bi, Pb, Sr, Ca, Cu, O, C has values %of wt respectively of 26.77%, 9.77%, 26.01%, 3.82%, 10.31 %, 10,02% and 13,31%. For element Bi, Sr, C, O have high enough concentration with evenly distributed. Elements of Pb, Ca, Cu, have low concentrations and are unevenly distributed.

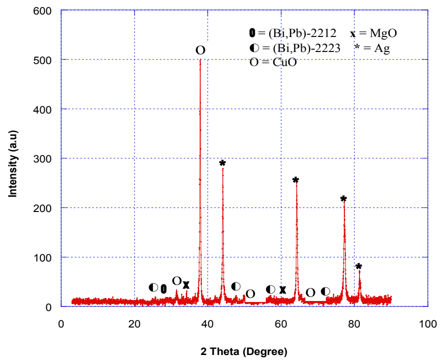


Figure 4. XRD patterns for Sample A1 with t = 30 h and d = 5 mm

X-ray diffraction patterns of BPSCCO monofilament superconducting wires using Ag-sheated sample A1 are shown in **Figure 4** with sintering treatment of 30 h. Shows that the occurrence of phase formation (Bi, Pb) -2223, (Bi, Pb) -2212, and CuO. The optimum phase of (Bi, Pb) -2223 is 2θ = 28.56° with an intensity of 45.16 count second (cts) while the phase (Bi, Pb) -2212 is optimum at an angle of 2θ = 53.70° with an intensity of 15, 97 cts. The CuO phase is present at 2θ = 37.57° with an intensity of 990.32 cts. The Ag phase is at an angle of 2θ = 44.26° with an intensity of 551.61 cts. The CuO phase is the impurity phase of the sample $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_{10+\delta}$. the result of the formation of these two impurities phases can reduce the critical temperature of the sample [11].

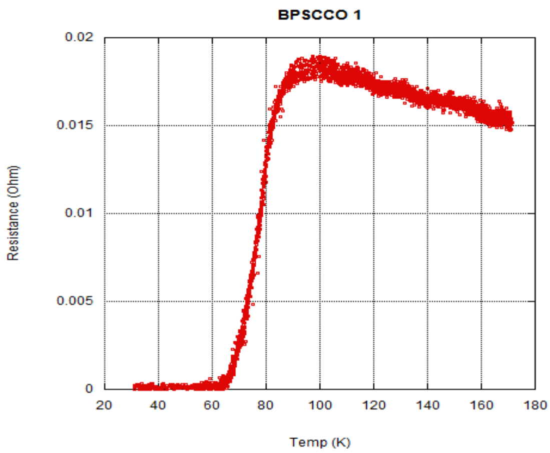


Figure 5. Resistance to Temperature for Sample A1

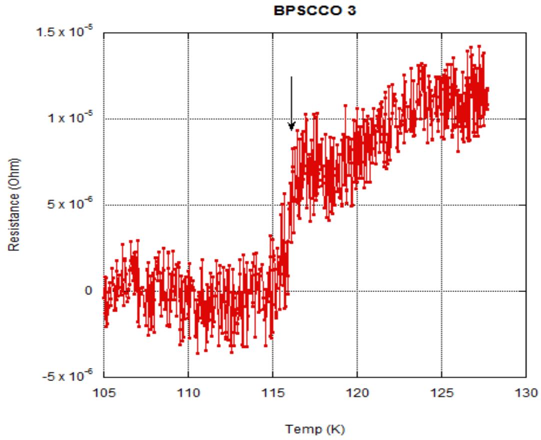


Figure 6. Resistance to Temperature for Sample A2

The electrical resistivity of the prepared samples was measured by the conventional four-probe technique from room temperature down to the zero superconducting transition temperature (T_0) via closed cryogenic refrigeration system employing helium gas as a working medium. In **Figure 5** is the result of identification of resistivity of sample A1 with sintering time 30 h and d = 5 mm. Shows that $T_{c,\,onset}$ = 98 K and $T_{c,\,zero}$ = 72 K. This is because there are still many impurities phases in the sample. **In Figure 6** Sample A2 with d = 2 mm after heating 4 times did not show $T_{c,\,onset}$ and $T_{c,\,zero}$. This is because there are still many impurity phases in the sample, such as CuO. This impurity phase will certainly affect the properties of the sample superconductivity.

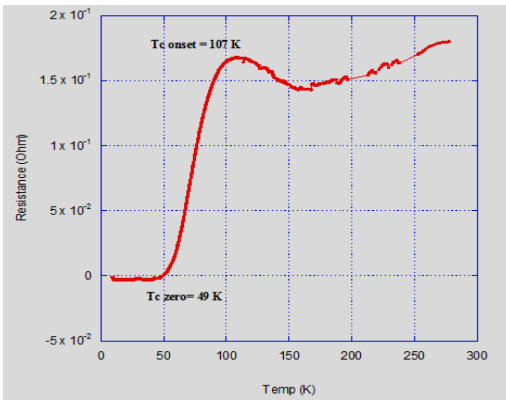


Figure 7. Resistance to Temperature for Sample B1

In **Figure 7** the above result is the resistivity curve to temperature for sample B1. The superconducting wire is subjected to sintering treatment at 860 °C for 24 h and after rolling the wire diameter to 5 mm.

The pure superconducting wire without the dopant samples B1 has $T_{c,Onset}$ 107 K and $T_{c, Zero}$ 49 K. This is because of impurities (impurities) so that T_c is shifted or the difference is far enough.

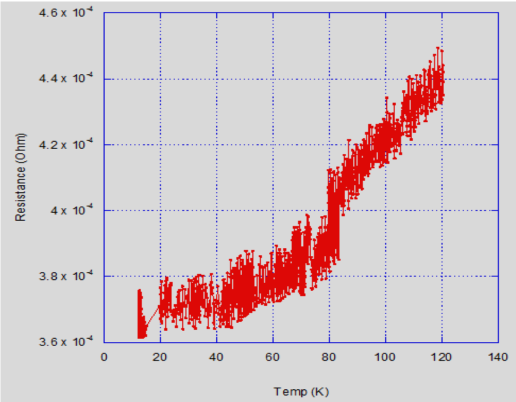


Figure 8. Resistance to Temperature for Sample B2

In **Figure 8** The above result is the temperature resistivity curve for the superconducting B2 wire sample. The superconducting wire is given 2nd sintering treatment with 860°C for 24 h and after rolling the wire diameter to 4 mm, the result indicates that there is only chance of T_c, the onset of the wire is about 80 K. This is because of the impurity or the phase change so that T_c changes.

IV. CONCLUSION

$Bi_{1.6}Pb_{0.4}Sr_2Ca_{2-x}O_xCu_3O_y$ monofilment superconducting wires using Ag-sheated and Stainless Steel 316 show that the crystal structure formed on the BPSCCO sample of Ag-sheated and Stainless Steel sheath is amorphous due to the impurity of CuO and the composition of the Stainless Steel 316 to the base superconductor material Bi.

The SEM images of BPSCCO monofilament superconducting wires using Ag-sheated and Stainless Steel 316 show that the presence of crack caused by rolling process on wire, sample homogeneity has been quite good, although the resultant grain melt and each grain grows in random directions.

The resistivity analysis, the BPSCCO monofilament superconducting wire using Ag-sheated and Stainless Steel 316 have point $T_{c, Onset}$ and $T_{c, Zero}$ so that stainless steel can replace the tube Ag which is relatively more expensive.

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