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Microstructural Changes and Enhanced Current Density in Nano-sized HfO_2 Added ($Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_{10}$)/Ag Superconductor Tapes

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The ($Bi_{1.6}Pb_{0.4}$)$Sr_2Ca_2Cu_3O_{10}$/Ag superconductor tapes have great potential for power transmission application. At relatively high temperatures, the transport critical current density (J_c) is limited by the weak pinning of magnetic flux lines. Movement of the flux lines as a result of the Lorentz force leads to the dissipation of energy and the appearance of electrical resistance. Improvement in the microstructure and addition of suitable impurities can prevent the flux from moving [1]. The objective of this work was to investigate the effect of nano-sized HfO_2 on the microstructure and the critical current density of Ag sheathed Bi-2223 superconductor tapes.

The ($Bi_{1.6}Pb_{0.4}$)$Sr_2Ca_2Cu_3O_{10}$(HfO_2)$_x$/Ag tapes (x = 0 and 0.10 wt. %) were prepared by powder-in-tube (PIT) method. The ($Bi_{1.6}Pb_{0.4}$)$Sr_2Ca_2Cu_3O_{10}$ powders were prepared by the acetate co-precipitation method. These powders were added with 0.10 wt. % HfO_2 (60-80 nm) and then packed into a 4.35 mm inner diameter and 6.35 mm outer diameter silver tube (99.9 % metals basis, Alfa Aesar). The amount of 0.10 wt. % of HfO_2 was chosen based on our initial study on nano-sized HfO_2 added pellet samples. The tube was drawn to a 1 mm diameter wire and then pressed into 1.53 mm wide and 0.30 mm thick tape. The tape was cut into sections of 2-3 cm and sintered at 845 °C for 50 and 100 h.

The size of HfO_2 (Nanoshel, 99.9+% purity) was confirmed by a Philips transmission electron microscope (TEM) model CM12 that showed that the size of the starting HfO_2 was between 60 and 80 nm (Figure 1). The microstructure was observed by a Zeis VPSEM (Leo 1450). The distribution of nano HfO_2 was determined using an Oxford Instrument energy dispersive X-ray analyzer (EDX) model INCA mics. The J_c of the tapes was measured by the four-probe method using the 1 μV/cm criterion from 30 K to 77 K.

Figure 2 shows J_c of the (Bi, Pb)-2223(HfO_2)$_x$/Ag (x = 0 and 0.10 wt. %) tapes sintered for 50 and 100 h from 30 to 77 K. For tape sintered for 50 h, J_c at 30 K was 8104 and 12470 A/cm^2 for non-added and HfO_2 added tapes, respectively. The HfO_2 added tape sintered for 100 h showed the highest J_c between 30 K and 70 K. J_c at 30 K for tape sintered for 100 h was 10820 and 17810 A/cm^2 for non-added and HfO_2 added tapes, respectively. The high J_c is caused by the strong alignment of grains attained by pressing and rolling of the tapes [2,3] and longer sintering time [4].
The SEM micrographs of the non-added and HfO_2 added tapes sintered for 50 and 100 h showed plate-like grains (Figure 3). Longer plate-like grains in Figure 3(b) for HfO_2 added tape sintered for 50 h as compared to the non-added tape is observed (Figure 3(a)). The white dots in Figure 3(b) indicate the distribution of Hf in the tape.

A non-linear drop in $J_c(T)$ was observed in the non-added tape sintered for 50 h. However, an almost linear drop in $J_c(T)$ was observed in the non-added tape sintered for 100 h. This shows that a change in flux pinning mechanism occurred with increasing sintering time.

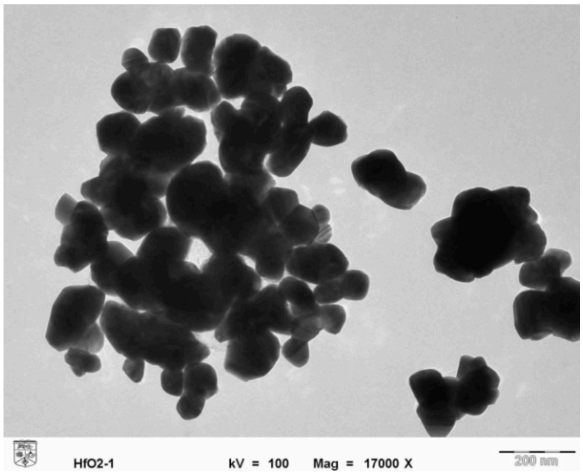


Figure 1. (a) TEM micrograph of HfO_2 with particle size 60-80 nm

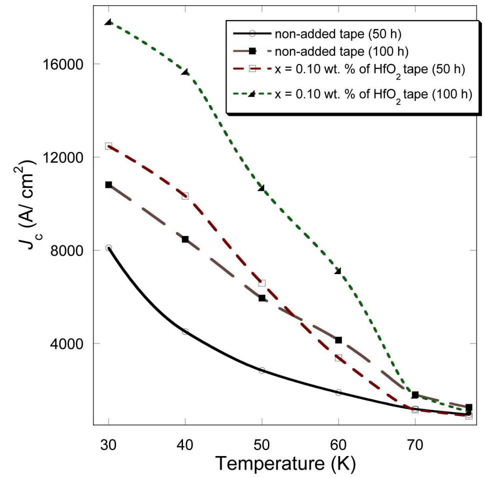
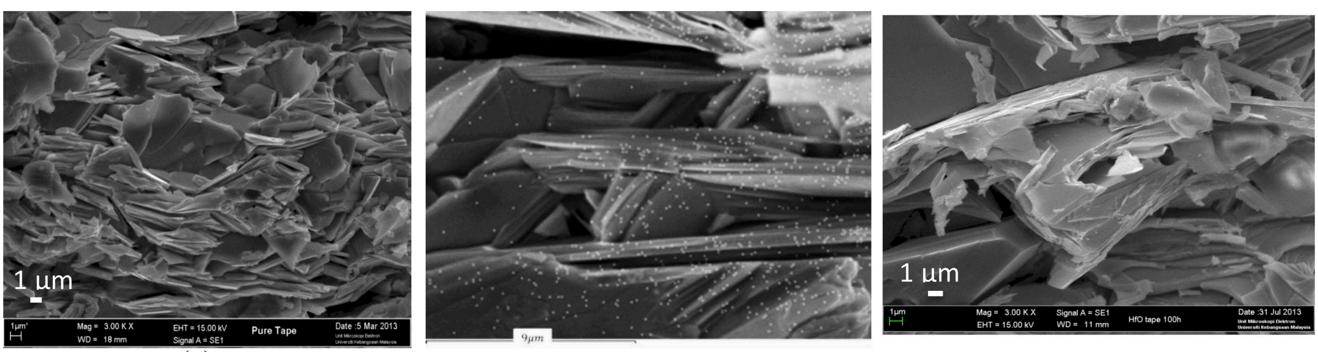


Figure 2. J_c versus temperature of Bi-2223(HfO_2)/Ag tapes



(a) (b) (c)

Figure 3. (a) SEM micrograph of non-added tape, and (Bi, Pb)-2223$(HfO_2)_{0.1}$/Ag tapes sintered for (b) 50 and (c) 100 h

In conclusion, changes in the microstructure due to nano-sized HfO_2 addition in (Bi, Pb)-2223/Ag tape led to the enhancement of J_c. SEM of the tapes showed the plate-like microstructure and the size of the grains increased with increasing sintering time. EDX microanalysis showed a homogeneous distribution of Hf in the tapes. There was not much difference in J_c between the HfO_2 and non-HfO_2 added tapes at 77 K. However, at 30 K the tapes with nano HfO_2 sintered for 100 h showed the highest J_c. Nano HfO_2 improved the microstructure and enhanced J_c at low temperatures (< 70 K).

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