International Journal of Current Science, Engineering & Technology
ISSN : 2581-4311
Original Research Article | Open Access | AMCT 2017 Malaysia | *Special Issue*

AC Susceptibility of the Magnesium Diboride (MgB_2) Added on $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_\delta$ Superconductor

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ABSTRACT. This study have used ac susceptibility technique to measure the transition through the whole volume of the MgB_2 added on $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_\delta$ superconductor for additions at x= 0.00, 0.02, 0.04, 0.06, 0.08 and 0.10 wt.%. Transition curve can be divided into two parts which are real part, χ' and imaginary part, χ''. From the real part, χ' found that two steps transition corresponds to the temperature of onset diamagnetism, $T_{C\text{-}ON}$ and phase lock-in temperature, T_{CJ}. The results indicate that the transition have optimum value with x= 0.02 wt.% addition at 109 K ($T_{C\text{-}ON}$) and 107 K (T_{CJ}). From these results displays allows the determination of Josephson current, *Io* at 92.37 Ampere. The smaller range between $T_{C\text{-}ON}$ and T_{CJ} indicate higher *Io* corresponds to intrinsics properties of grains. While imaginary part, χ'' showed two peaks of coupling peak temperature, T_p related to the magnitude or strength of the pinning force. As the fields increases, T_p decreases for the lower temperature when applied ac field from 0.05 O_e to 2.00 O_e. The decreasing temperature attributed to the absorption of magnetic energy of the superconductor from the AC field. These results indicate the optimum T_p for pure sample belonging to displays the good coupling effect between the grains.

Keywords: *AC susceptibility, Real part, Imaginary part and diamagnet;*

Received: 15.10.2017, Revised: 15.12.2017, Accepted: 30.02.2018, and Online: 20.03.2018;

DOI: *10.30967/ijcrset.1.S1.2018.215-219*

Selection and/or Peer-review under responsibility of Advanced Materials Characterization Techniques (AMCT 2017), Malaysia.

1. INTRODUCTION

Intrinsic and extrinsic properties are the nature contains grains, grain boundaries and coupling between grains can be measured using ac susceptibility techniques. This technique offered additional advantages because the samples is contactless and the whole are measures. The curve can provide information on coupling diamagnet shielding for intrinsic and feature of coupling losses which common extrinsic behavior [1]. AC susceptibility measurement have been widely used to study flux dynamics of high temperature superconductors since this contactless measurement revealed a detailed information on critical current density, pinning strength, flux creep, activation energy, volume fraction of the grain etc. [2]. In this paper, ac susceptibility measurement as a function of temperature and ac field and its effect on the coupling of the grains were discussed. Nikolo and Goldfard [3] were discussed on the Aderson flux creep model that ac loss peak shift to higher temperature shown the flux creep enhance the critical current density. The major limitation of inter and intra granular capability is the flux pinning capability need to improve by overcome the rapid decrease in the critical current density. The addition could produce such defects within superconducting grains as dislocations or stacking faults, which enhance the flux pinning and critical current density [4]. The aims of this work were studied the intrinsic and extrinsic properties on the MgB_2 added with $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_\delta$ using applied fields dependence AC susceptibility. We have also determined the Josephson current, I_o based on equation (1) effectively controlled the grains morphology and thus the grain coupling and hence the superconducting properties.

2. MATERIALS AND METHODS

Samples $(Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_\delta)_{1-x}(MgB_2)_x$ were prepared by solid state reaction method. Samples with the nominal ratio Bi_2O_3, PbO, $SrCO_3$, $CaCO_3$, and CuO powder was mixed. Then the powders were milled using ball for 24 hours. The mixture was first calcined at 800 ^oC for 20 hour, followed by calcined at 820 ^oC for 10 hours and finally calcined at 840 ^oC for 4 hours with intermediate grinding to ensure homogeneity. The $(Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_\delta)_{1-x}$ $(MgB_2)_x$ with x= 0.00, 0.02, 0.04, 0.06, 0.08 and 0.10 wt.% added then the powder were pressed into pellet and sintered at 845 ^oC for 96 hours and annealing at 830 ^oC for 30 hours. AC susceptibility of the entire volume of the samples were measured using CryoBIND (Cryogenic Balanced Inductive detector) SR830 lock in amplifier at frequency of 240 Hz with driving fields range from 0.05 O_e to 5.00 O_e to investigate coupling peak temperature, T_p, onset temperature of onset diamagnetism, $T_{C\text{-}ON}$; Phase lock-in temperature, T_{CJ} of the materials.

3. RESULTS AND DISCUSSION

Typical AC susceptibility curves were observed for all samples which are the two drops in real part, χ' accompanied by bell-shape in imaginary part, χ'' can be seen in Fig. 1, its shows the temperature dependence curves for pure samples. In polycrystalline high temperature superconductor, normally real part χ' depicts diamagnet shielding of the samples while imaginary part χ'' indicates the hysteric losses due to vortex motion. The real part depicts the diamagnet shielding currents in intra and inter granular superconducting region. The imaginary part indicates losses for intra and inter granular vortices [5].

All the summarize data of coupling peak temperature (T_P), onset temperature of onset diamagnetism ($T_{C\text{-}ON}$), phase lock-in temperature (T_{CJ}) and Josephson current (I_o) in Table 1 extract from the graph real part, χ' and imaginary part, χ'' of susceptibility versus temperature for samples $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_\delta$ added with $(MgB_2)_x$ at x= 0.00, 0.02, 0.04, 0.06, 0.08 and 0.10 wt.%. The temperature of onset diamagnetism, $T_{C\text{-}ON}$ was observed at 107 K, 109 K, 108.5 K, 108.3 K, 108.1 K and 108.0 K for addition MgB_2 at x= 0.00, 0.02,0.04,0.06,0.08 and 0.10 wt.%. The second drop from χ' which reflected to phase lock-in temperature, T_{CJ} occurred at lower temperature was observed at 105.5 K, 107 K, 105.2 K, 104.5 K and 103 K for samples x=0.00-0.08 wt.%. There was no superconducting behavior for sample with x=0.010 wt.% thus indicating that the samples have lost their superconductivity. This might be related to the quality of the grain [6].

From the imaginary part χ'' showed the integranular coupling peaks, T_p shifted towards lower temperature when increasing the field from 0.05 O_e to 1.00 O_e and with increasing additions of MgB_2. The decrease of the temperature is proportional to the magnitude or strength of the pinning forces [7]. The result for addition with x= 0.02 wt.% showed the highest temperature at 107 K, 105.5 K, 101.0 K, 95 K and 90 K at different applied fields for 0.05 O_e, 0.10 O_e, 0.5 O_e, 1.00 O_e and 2.0 O_e. These explained by apply lower fields, magnetic penetration into the sample at higher temperature however when apply higher fields the magnetic start expels the field from the interiors known as Meissner effect. By increases the additions also show the coupling slightly decreases the temperature.

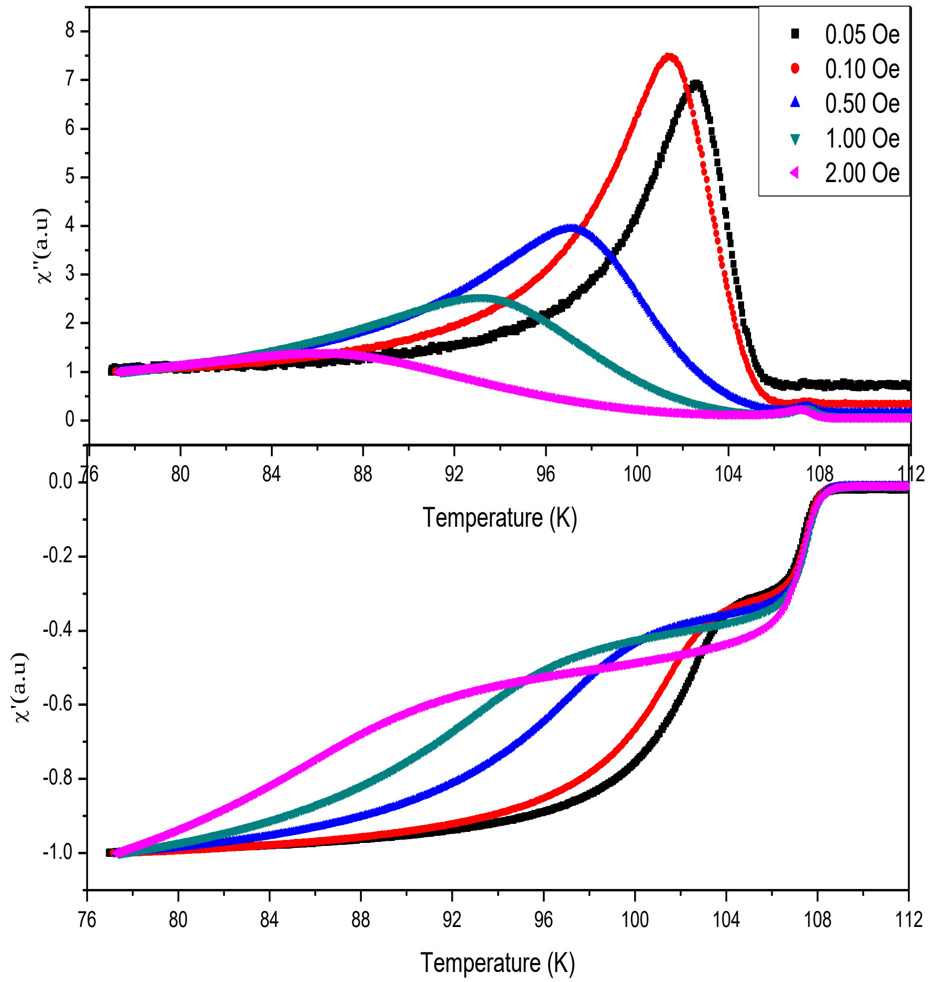

Fig.1 Real part, χ' and imaginary part, χ'' of susceptibility versus temperature, T at various magnetic fields for $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_\delta$

The results plotted in Fig. 2 shown the variation of the superconducting diamagnet ($T_{C\text{-}ON}$), phase lock-in temperature (T_{CJ}) and Josephson current (I_o) versus amount of MgB_2 additive. The width between $T_{C\text{-}ON}$ and T_{CJ} narrow for pure $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_\delta$ but for addition with 0.02 wt.% while the width slightly wide for addition 0.04 wt.% till 0.10 wt.%. Wide separation of $T_{C\text{-}ON}$ and T_{CJ} loss peaks showed poor coupling between the grains. The variation of *I*o decreased as addition increases at 119.83 μA, 93.27 μA, 56 μA, 48.46 μA and 35.97 μA for all samples. The higher of *I*o indicates a good links and hence the good coupling between the grain occur due to the layer consist polycrystalline phase. For samples with Bi-2223 phase dominancy the weak link is probably S-N-S types will correspond to higher I_o, whereas lower *I*o in the Bi-2212 phase dominancy the weak link is probably S-I-S types, respectively [8]. As we can see from Table 1, the Josephson current, I_o calculated based on eqn. (1) [9]

$$I_o = 1.57 \times 10^{-8} (T_{C\text{-}ON})^2/(T_{C\text{-}ON} - T_{CJ}) \quad (1)$$

The strong dependence of coupling T_P with the various amount of applied field are observed in Table 1 was found that the result is shifted toward lower temperature. The amount of shifted to lower temperature as the higher applied fields is proportional to the magnitude or strength of the pinning force. The large of the shifted of the temperature, the weaker pinning force and hence the smaller intergranular critical current density [10].

Table 1 Summarize data of coupling peak temperature (T_P), onset temperature of onset diamagnetism ($T_{C\text{-}ON}$), Phase lock-in temperature (T_{CJ}) and Josephson current (I_o)

Sample x / Applied Field (O_e)	0.00	0.20	0.40	0.06	0.08	0.10
	T_P (K)					
0.05	105.0	107.0	105.0	101.0	97.0	-
0.10	104.0	105.5	103.5	99.0	95.0	-
0.50	101.0	101.0	99.0	92.0	88.0	-
1.00	99.0	95.0	93.0	86.0	80.0	-
2.00	95.0	90.0	88.0	-	-	-
$T_{C\text{-}ON}$ (K)	107.0	109.0	108.5	108.3	108.1	108.0
T_{CJ} (K)	105.5	107.0	105.2	104.5	103.0	-
I_o(μA)	119.83	93.27	56.00	48.46	35.97	-

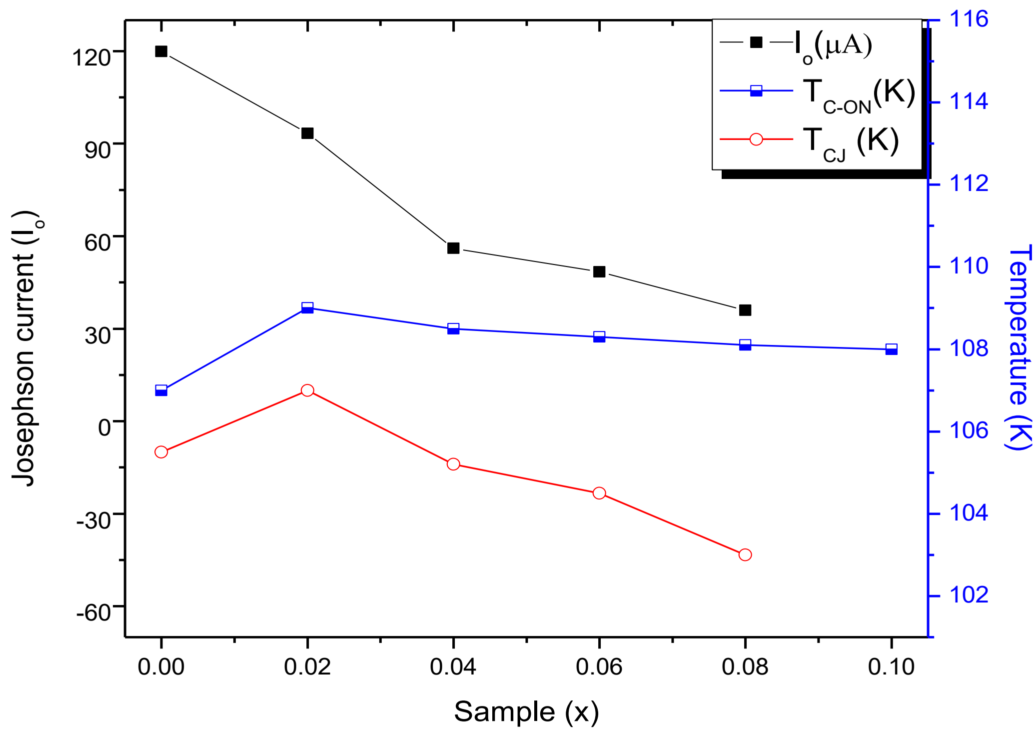

Fig. 2 The variation of the superconducting Diamagnet ($T_{C\text{-}ON}$), Phase lock-in temperature (T_{CJ}) and Josephson current (I_o) dependence on sample (x) wt.% of MgB_2

SUMMARY

Polycrystalline superconducting samples of $(Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_\delta)_x\,(MgB_2)_{1-x}$ were applied various fields and the AC susceptibility studies carried out the important properties of these materials. We demonstrated that AC susceptibility technique are powerful tools to study wider aspects of superconductor, by investigated the role of superconducting grain and their coupling in bulk polycrystalline samples. Nature of the grain boundaries and flux pinning mechanism through remain same. The grain boundary was very much required to unleash the potential of high temperature superconductor.

ACKNOWLEDGEMENTS

The authors wish to thank to the Superconductivity and Thin Film Laboratory, Department of Physics Universiti Putra Malaysia for aiding experiment and special thanks to University Malaysia Kelantan to support the SGJP Grant R/SGJP/A08.00/00356A/001/2016/000344.

REFERENCES

[1] S. A. Halim, S.B. Mohamed, H. Azhan, Khawaldeh, H.A.A. Sidek, Effect of barium doping in Bi-Pb-Sr-Ca-Cu-O ceramics superconductors, Physica C, 312 (1999) 78-84.

[2] A.I. Malik, S. Celebi, S.A. Halim, AC susceptibility study in $Bi_{1.6}Pb_{0.4}Sr_2(Ca_{1-x}Nd_x)_2Cu_3O_\delta$ ceramic superconductors, Physica C, 377 (2002) 421-430.

[3] M. Nikolo, R.B. Goldfarb, Flux creep and activation energies at the grain boundaries of Y-Ba-Cu-O superconductors, Phy. Rev. B., 39 (10) 6615.

[4] M. Annabi, A. M'chirgui, F.B. Azzouz, M. Zouaoui, M.B. Salem, Addition of nanometer Al_2O_3 during the final processing of (Bi, Pb)-2223 superconductors, Physica C, 405 (2004) 25-33.

[5] K. H. Müller, AC susceptibility of high temperature superconductors in a critical state model, Physica C, 159 (1989) 717-726.

[6] A. Arlina, S.A. Halim, M.A. Kechik, S.K. Chen, AC Losses in YBCO-Added $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_\delta$ Superconductor, J. Supercond. Novel Mag., 28 (2015) 1953-1958.

[7] S. Çelebi, Comparative AC susceptibility analysis on Bi-(Pb)-Sr-Ca-Cu-O high-Tc superconductors, Physica C, 316 (1999) 251-256.

[8] M. Klee, J.W.C.D. Vries, W. Brand, Superconductivity above 100 K in Bi (Pb)-Ca-Sr-Cu-O films made by thermal decomposition of metal carboxylates, Physica C, 156 (1988) 641-648.

[9] I. Hamadneh, S.A. Halim, C.K. Lee, Characterization of $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_y$ ceramic superconductor prepared via coprecipitation method at different sintering time, J. Mater. Sci., 41(2006) 5526-5530.

[10] G. Yildirim, Y. Zalaoglu, M. Akdogan, S.P. Altintas, A. Varilci, C. Terzioglu, Investigation of Gd addition added on magnetic and structural properties of $Bi_{1.8}Pb_{0.35}Sr_{1.9}Ca_{2.1}Cu_3Gd_xO_y$ superconductors by ac susceptibility, J. Supercond. Novel Mag., 24(2011) 2153-2159.