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SUPERCONDUCTING PROPERTIES OF $Y_2Ba_5Cu_8O_\delta$ (Y258) POROUS AND NON- POROUS STRUCTURE

(Sifat Superkonduktor $Y_2Ba_5Cu_8O_\delta$ (Y258) Struktur Berliang dan Tidak Berliang)

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Abstract

Solid state reaction method was applied to produce porous and non-porous ceramic materials through a series of heating and grinding. This study revealed the distinguish properties of Y258 in terms of their porous and non-porous structure. The bulk material usually loses its high temperature features due to increase in critical current density. Therefore, it is essential to investigate the porous structure that influences the superconducting properties. The electrical properties of superconductor due to critical temperature, T_c and critical current density, J_c were determined using Resistivity Measurement System (RMS). The morphological structure of superconductor material was analysed by using Scanning Electron Microscopy (SEM). The grain boundary of porous structure is significant to induce higher conductivity without detriment the critical temperature of the superconductor. The higher J_c recorded for porous Y258 was 1.59 A/cm^2 at 50 K. The J_c value was higher compared to non-porous optimal structure which is 1.42 A/cm^2. The $T_{c\ zero}$ for porous and non-porous sample gives the same value which is 78 K for both samples. Results of Y247 doped with Ca were determined for comparison.

Keywords: porous, non-porous, critical temperature, current density, morphology

Abstrak

Kaedah tindak balas keadaan pepejal telah diaplikasikan bagi menghasilkan seramik berliang dan tidak berliang melalui siri-siri pembakaran dan kisaran. Kajian yang telah dilakukan adalah berkisar kepada perbandingan sifat superkonduktor Y258 berliang dan tidak berliang. Bahan pukal kebiasaannya hilang bersifat suhu tinggi disebabkan peningkatan dalam ketumpatan arus. Oleh yang demikian, adalah satu keperluan bagi mengkaji sifat struktur berliang dalam mempengaruhi sesuatu sifat superkonduktor. Sifat elektrik superkonduktor melalui suhu genting dan ketumpatan arus genting adalah ditentukan menggunakan Sistem Pengukuran Rintangan (RMS). Struktur permukaan superkonduktor dianalisis melalui Mikroskop Imbasan Elektron (SEM). Sempadan butiran bagi struktur berliang adalah penting bagi mempengaruhi kekonduksian yang lebih tinggi tanpa menjejaskan nilai suhu genting superkonduktor. Dapatan tertinggi J_c melibatkan Y258 berliang adalah 1.59 A/cm^2 pada suhu 50 K. Nilai J_c adalah tinggi dibandingkan dengan struktur optimum tidak berliang sekitar 1.42 A/cm^2. $T_{c\ sifar}$ bagi sampel berliang dan tidak berliang memberikan nilai suhu yang setara pada 78 K melibatkan kedua-dua sampel. Dapatan Y247 yang di dopkan Ca turut dijadikan sebagai rujukan serta perbandingan bagi teras kajian yang dilakukan.

Kata kunci: berliang, tidak berliang, suhu genting, ketumpatan arus, morfologi

Introduction

Materials in foam and porous structures can be considered as a novel class among bulks, films and single crystal since this materials have specific properties that has potentially high critical temperature as well as critical current density (J_c) [1]. A porous high temperature superconductor material can be considered as an aggregate of single crystals that are spatially separated and attach each other predominantly through their faces [2]. Materials containing tailored porosity exhibit special properties and features that usually cannot be achieved by their conventional dense counterparts [3]. The high specific surface of foam makes porous high temperature superconductor (HTSC) attractive for various practical applications. However, the influence of porosity on critical current is still unclear [4]. The porous structure also could be highly favourable for good oxygenation and better cooling for an efficient heat extraction from the superconducting element. This is used to overcome the typical hot-spot phenomena commonly observed in superconducting fault current limiters [5]. Moreover, many papers concerning the synthesis of bulk superconductor ceramics since fabrication of open-pores superconductive ceramics. It was found that crystalline sucrose was the best filler in order to obtain a homogeneous localization of free spaces [6]. Filling of crystalline sucrose does not destroy the superconductive properties yet it enables the fabrication of samples with good mechanical properties. Superconducting porous with small open porosity can be easily and continuously reinforced in order to improve their mechanical properties hence can overcome the forces encountered in levitation and quasi-permanent magnet applications [7].

Materials and Methods

Two distinguish structured porous and non-porous sample were prepared for Y258 and Ca doped Y247. Each series comprise four identical structures which were Y258 porous, Y258 non porous, Ca doped Y247 porous, and Ca doped Y247 non porous. Bulk samples were prepared by considering the relevant amount of high purity chemicals of Yttrium Oxide (Y_2O_3), Barium Carbonate ($BaCO_3$), Copper Oxide (CuO) and Calcium Carbonate ($CaCO_3$) for each series $Y_2CaBa_4Cu_7O_\delta$ and $Y_2Ba_5Cu_8O_\delta$ respectively. The powder and ethanol were mixed in alumina jar and milled about 24 hours in order to have homogeneous mixture. The mixture was dried in an oven at 120 ^oC for 6 hours. Then the mixture was pulverized using an agate mortar to ensure the chemicals were homogenously mixed and become fine powder. The powder was pre-sintered in the box furnace at 850 ^oC for 5 hours before pulverizing it again [11, 12]. For non-porous, 2g of powder was pressed to form a pellet while 1.8 g of powder and 0.2 g of sucrose was mixed together to obtain a porous pellet. The pellet and porous powder that mixed with sucrose was sintered at 400 ^oC for 2 hours before the execution of final sintering at 920 ^oC for 5 hours. The resistivity measurement system (RMS) was done to determine the critical temperature, T_c and critical current density, J_c. The crystallographic structures and lattice parameter were identified using X-Ray Diffraction (XRD). The surface morphology of the samples was observed by Scanning Electron Microscopy (SEM) [13]. Analysis of Y247 with Ca-doped was carried out for comparison.

Results and Discussion

The electrical resistivity analysis was performed to investigate the effect of porosity on superconducting properties of $Y_2Ba_5Cu_8O_\delta$ samples. The normalized resistance at room temperature as a function of temperature between 20 and 100 K with addition of crystalline sucrose as filler to Y258 and Y247 Ca-doped powders are shown in Figure 1(a). The curve indicated a metallic behaviour for all samples at normal state with a single step of superconducting transition. Both samples (porous and non-porous) for Y258 showed the same value of $T_{c\ zero}$ that is 78 K while sample of Y247 Ca-doped shows decreasing in $T_{c\ zero.}$ The Y258 for both structures possess highest T_c but for non -porous Ca doped Y247 has least T_c as shown in Table 1. The decline in T_c value is justified by the orthorhombicity properties of the samples. XRD results in Figure 2(b) shows that, the orthorhombicity of the system degraded varied to the doping level of Ca [8]. The porosity of Ca doped Y247 also indicates that the possibility of T_c reduction via orthorhombicity detrimental.

Table 1 also shows the critical current density, J_c value for the samples. The value of J_c was increased for samples with low density that has been created by introducing pores. This enhancement of J_c is due to the grain alignment of the porous structure [9]. In addition, the increase of J_c for porous sample might be due to the good electrical contact within the porous ceramic body rather than one just on the surface as in a dense sample [4].

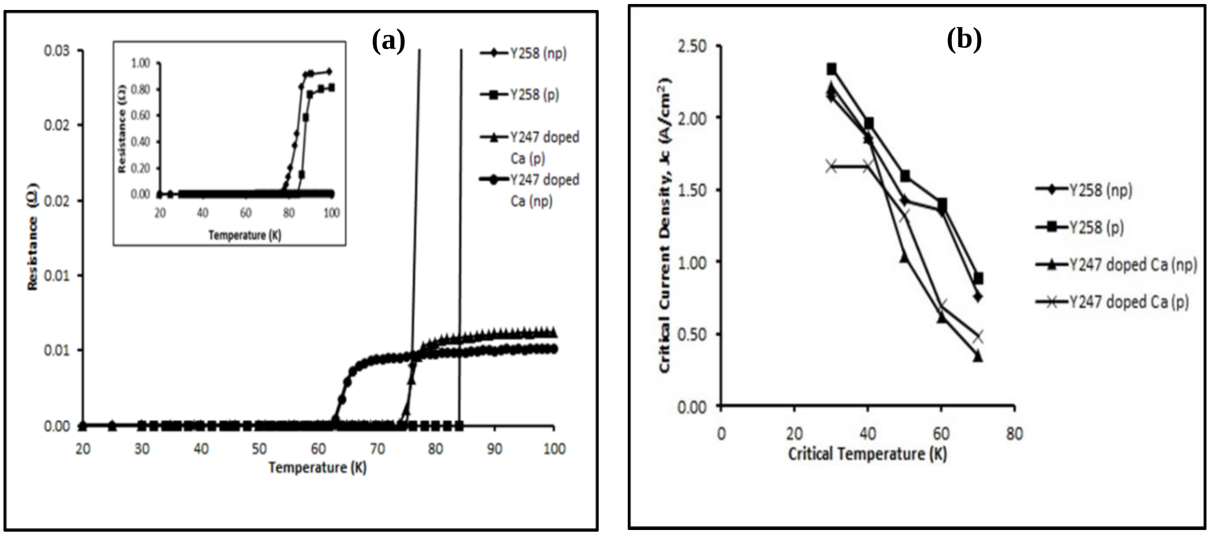

Figure 1. (a) Normalized resistance versus temperature of the samples (b) Critical current density versus temperature

Table 1. Lattice parameter, critical temperature and critical current density of the samples.

Sample	Lattice parameter (Å)			Volume (Å)^3	T_C (K)	Critical Current Density, J_C (A/cm^2)	
	a	b	c			50 K	60 K
$Y_2Ba_5Cu_8O_\delta$ non-porous	3.89	3.84	11.79	174.47	78.0	1.42	1.35
$Y_2Ba_5Cu_8O_\delta$ porous	3.89	3.84	11.79	174.47	78.0	1.59	1.41
$Y_2CaBa_4Cu_7O_\delta$ non-porous	3.83	3.88	50.80	754.51	75.0	0.62	0.35
$Y_2CaBa_4Cu_7O_\delta$ porous	3.90	3.88	49.81	752.84	62.9	0.69	0.48

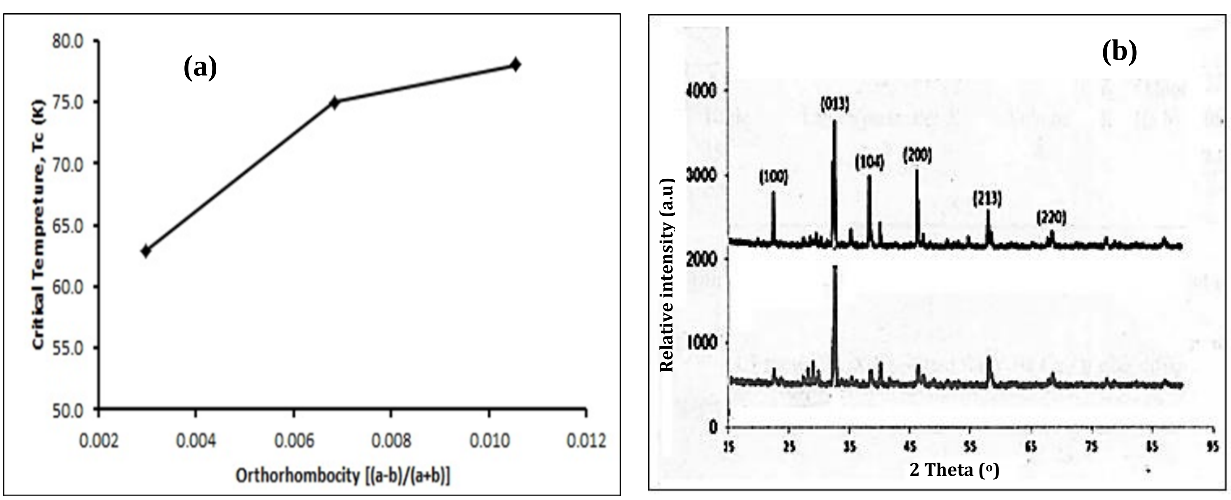

Figure 2. (a) Critical temperature versus orthorombicity (b) X-ray diffraction pattern of samples

Figure 3 shows the SEM micrograph of the samples. Morphology of the samples from SEM images revealed that the porous Y258 sample had the larger average grain size compared to non-porous structure. Larger grain size manifests the lessen of grain boundaries [8, 10]. The grain boundaries are significant to influence the current density in the polycrystalline form. Optimal sintering time is essential to increase the superconducting volume fraction as well as grains connectivity for better current transport. Short sintering period can produce smaller grain size, resulting in weak connectivity between grains. Longer sintering period possibly lead to phase decomposition but decreasing the superconducting phases can weaken the weak links [14]. Larger grain size will enhance the grains continuity, lessen the porosity thus-increased the J_c value. Smaller grain size and irregular grain shape in non-porous Y258 system decrease the J_c value.

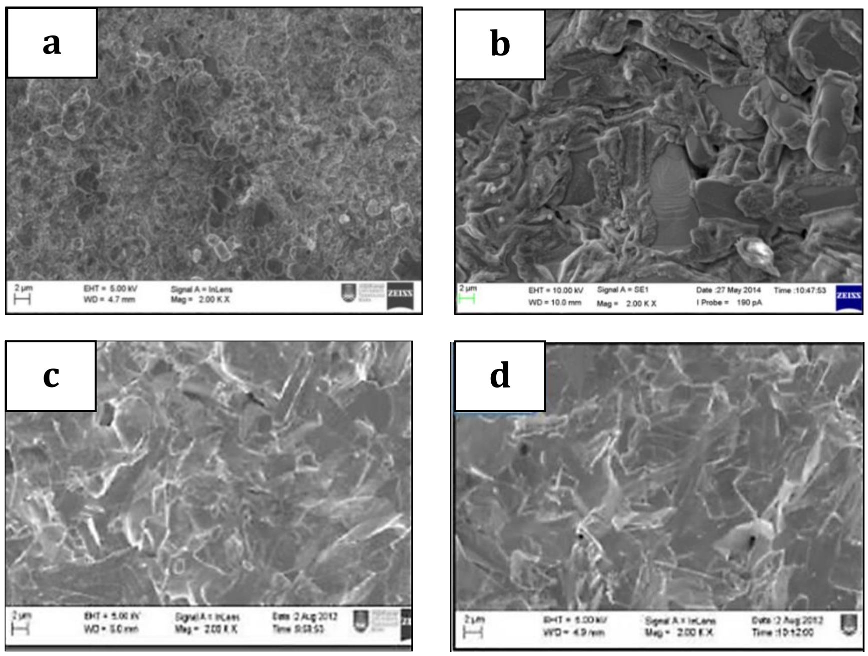

Figure 3. SEM photograph of samples (a) $Y_2Ba_5Cu_8O_\delta$non-porous (b)$Y_2Ba_5Cu_8O_\delta$porous (c)$Y_2CaBa_4Cu_7O_\delta$non-porous (d)$Y_2CaBa_4Cu_7O_\delta$ porous

Conclusion

The effect of porosity on the morphological of microstructure and the electrical resistance characteristics of Y258 porous structure were investigated in this study. The porous sample of YBCO 258 was successfully synthesized using solid state reaction method. It is found that the crystalline sucrose that used as filler does not affect the superconductive properties of the porous structure Y258 but changed the electrical properties which give lower critical current density, J_c than porous YBCO sample. Furthermore, it is found that the value of $T_{c\ zero}$ of porous Y258 is 78 K which is the same as non-porous sample.

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