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Effect of Sintering Temperature on the Microstructure and Electrical Properties of $Y_3Ba_5Cu_8O_{18}$ Superconducting Material

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Abstract

In the present work, the influence of various sintering temperatures on the microstructural and electrical properties of the new $Y_3Ba_5Cu_8O_y$ (noted Y-358) superconducting material was investigated. Samples were prepared through the solid-state reaction method. The structure and microstructure of the various synthesized samples were investigated by X-ray diffraction (XRD) and scanning electron microscope (SEM). The measurements of the electrical resistivity as a function of temperature were also performed and examined.

Key words: $Y_3Ba_5Cu_8O_y$ superconductor, Structure, Morphology, Transport properties.

1. Introduction

In the nature, it exists as different types of materials, such as semiconductors [1], magnetic nanoparticles [2-20] that are used in diverse applications. The high temperature superconductor (HTS) materials are one of the most intensively studied and attractive systems owing to their higher superconducting performances and diverse applications [21-25]. $YBa_2Cu_3O_7$ (Y-123) is the first HTS material discovered with the transition temperature (T_c) of 91 K. The important aim in the field of superconductivity is to enhance the electrical and magnetic properties.

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In previous studies, various techniques such as high energy ball milling technique [26-33] and chemical doping and additives including metal, semiconducting, insulator and magnetic nano-entities [34-40] have been employed to act as artificial pinning centers inside the superconducting materials, which lead to enhance the superconducting properties, particularly the magnetic properties and the critical current densities. In other hand, numerous investigations have been made on the YBCO family with various stoichiometries in the aim to enhance their superconducting properties. Recently, a new Y-based superconducting material labeled Y-358 has been discovered [41-47]. This compound exhibits the highest T_c among the different compounds of the YBCO family. In the present work, we report the impact of sintering temperatures on the microstructural and electrical transport properties of the Y-358 system.

2. Experimental

The Y-358 samples were synthesized using the standard solid-state reaction (SSR) method. Appropriate stoichiometric ratios of powders of copper oxide (CuO, 99.9 %), yttrium oxide (Y_2O_3, 99.9 %) and barium carbonate ($BaCO_3$, 99.9 %) were mixed and ground in an agate mortar. The mixed powders were pressed into pellets and heat-treated at 950°C for 12 h. This step of calcination was repeated two times with intermediate grinding and pelletization. The obtained precursor powders were grounded in the agate mortar and pressed into pellets. The obtained pellets have been heat treated under oxygen atmosphere at various sintering temperatures ranging between 930 and 970°C for 48 h. The morphology was investigated using a FEI Nano Lab 200scanning electron microscope (SEM). The measurements of electrical resistivity versus temperature ρ(T) were performed using the standard dc four-probe technique in a DMX-19 SCC cryostat system.

3. Results and Discussion

Figure 1 presents the SEM images of the sintered samples at 930°C, 950°C and 970°C. The microstructure of the various sintered samples exhibits a granular structure with grains oriented randomly in all direction. It is obvious that the grains size increases on increasing the sintering temperature. The sample sintered at 970°C is consisted of large grains and impurities.

Figure 2 illustrates the variations of the electrical resistivity as a function of temperature ρ(T) for samples prepared at various sintering temperatures. All sintered samples display metal-like behavior in the normal state and a superconducting transition to zero resistance. The sample sintered at 970°C has the highest normal state resistivity. It is known that the resistivity in the normal state greatly depend on the porosity, impurities and te grain boundaries. The sample sintered at 950°C has the lowest normal state resistivity, indicating that the porosity, the disorder and the impurity scattering in the CuO_2-planes in this product are the lowest and that the connectivity between grains is the best. Products sintered at 930°C and 950°C showed a one-step superconducting transition. Nevertheless, the ρ(T) measurements showed two rapid resistivity drops for the product sintered at 970°C. The existence of a double superconducting transition can be assigned to the presence of additional phase resulting from the chemical reaction. The onset transition temperatureT_c^{onset} values extracted from the ρ(T) curves are 93.5, 95.5and 92 K for samples sintered at 930°C, 950°C and 970°C respectively. These values are higher than the values for the Y-123 superconductor. On the other hand, the zero-resistance temperature T_{co} were determined to be 88, 93.5 and 78.5 K for samples sintered at 930°C, 950°C and 970°C respectively. The highest values of T_c^{onset} and T_{co} for the sample sintered at 950°C indicate the better intragranular and intergranular properties compared to the two other samples.

Figure 3 shows the XRD pattern of the optimal Y-358sample sintered at 950°C. All observed peaks correspond to the orthorhombic phase of Y-358 compound with Pmm2 symmetry. The lattice parameters are determined and are found to be a = 3.81 Å, b = 3.88 Å and c = 31.13 Å.

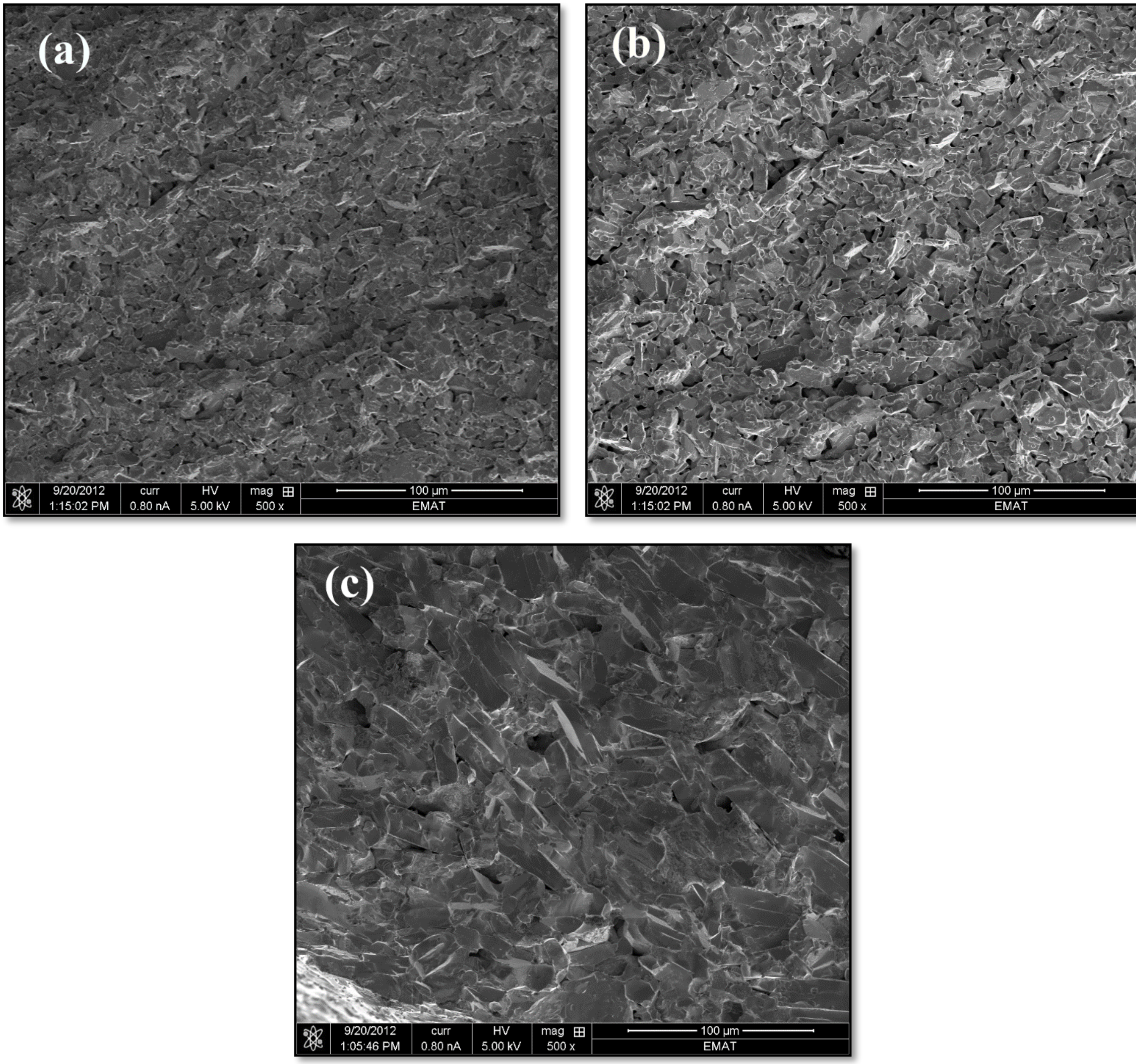

Figure 1. SEM images of samples sintered at (a) 930°C, (b) 950°C and (c) 970°C.

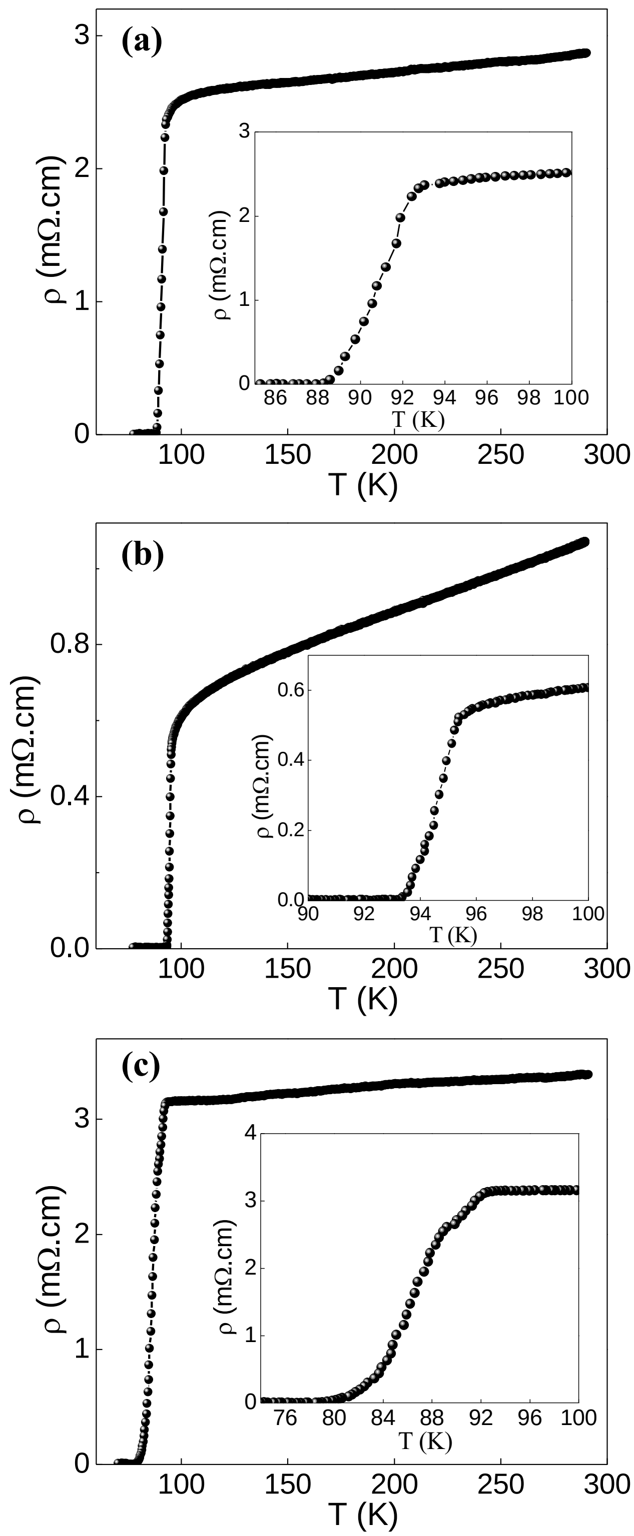

Figure 2. Temperature dependences of the electrical resistivity, ρ(T), for samples sintered at diverse temperatures: (a) 930°C, (b) 950°C, (c) 970°C. The inset shows a closer look of the superconducting transition.

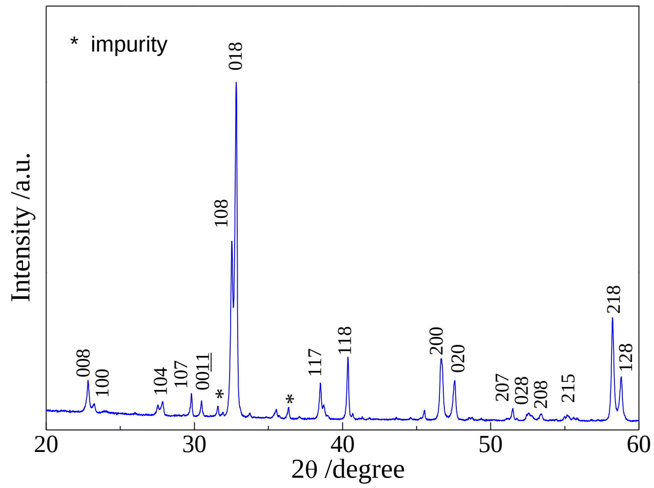

Figure 3. XRD pattern of Y-358 sample sintered at 950°C.

4. Conclusion

In this work, we have investigated the influence of various sintering temperatures on the superconducting properties of Y-358 compound. It was concluded that the temperature of 950°C leads to obtaining the best superconducting parameters. For this sample, the onset superconducting transition temperatureT_c^{onset}started at 95.5K and thevalue T_{co} was reached at 93.3 K. Additionally, the optimal sample prepared at 950°Cexhibited the lowered resistivity in the normal state.

5. Conflicts of Interest

The author(s) report(s) no conflict(s) of interest(s). The author along are responsible for content and writing of the paper.

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