Structural and Electrical Properties of YBCO Added with Nd_2O_3, Gd_2O_3 and Sm_2O_3 Nanoparticles

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STRUCTURA ED WITH Nd_2O_3, Gd_2O_3 AND Sm_2O_3 NANOPARTICLES

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Lihat Sebelah

September 2015

To my Father & Mother:

Haji Ramli Abu Bakar & Hajah Safiah Mohd Yusof

My beloved Husband & Children:

Mohd Najmuddin Ibrahim, Nur Alesya, Muhammad Naufal & Nur Athirah

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STRUCTURAL AND ELECTRICAL PROPERTIES OF YBCO ADDED WITH Nd_2O_3, Gd_2O_3 AND Sm_2O_3 NANOPARTICLES

By

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It is well known that the superconducting properties are strongly dependent on the synthesis technique and processing conditions. Coprecipitation method is frequently used in sample synthesis and thus, chosen in this project due to high homogeneity, low reaction temperature, fine and uniform particle size with non-agglomerate particles, easy set-up and economical, and time saving processing. The Yttrium Barium Copper Oxide (YBCO) samples have been prepared by coprecipitation of metal ion oxalates method added with Nd_2O_3, Gd_2O_3 and Sm_2O_3, x = 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 wt%. Phase formation and volume fraction of each sample were examined using X-ray diffraction and Rietveld refinement technique. All samples show predominantly Y-123 with non-superconducting phase, Y-211 and impurities, Nd_2O_3, Gd_2O_3 and Sm_2O_3 with orthorhombic structure and *Pmmm* space group. The volume fractions of non-superconducting phase, Y-211 abruptly increase in all systems, might be due to the local differences in the size of Y-211, thus, affect the T_c and J_c in the Y123 system. The microstructure scanning electron microscope (SEM) revealed that the average grain sizes calculated from the Image J, decreased in all systems as the addition of magnetic nanoparticles, Nd_2O_3, Gd_2O_3 and Sm_2O_3 increased indicating that the poor grain connectivity due to the porosities and weak links. The transport measurement of resistance dependence, $T_{c\text{-onset}}$ was measured by using standard four point probe technique. T_c for pure sample is about 92 K. However, T_c decreased to 74 K, 80 K and 88 K for Nd_2O_3, Gd_2O_3 and Sm_2O_3, respectively. The suppression on $T_{c\text{-onset}}$ was attributed to the lowering oxygen content in samples. Since YBCO is granular in nature, AC susceptibility is used as an effective tool to characterize granular of this system. The inter-granular vortex was investigated with different applied field, H_{ac}, 0.005 – 3.0 Oe at fixed frequency 123 Hz. The matrix critical current density, J_{cm} was calculated in the framework of Bean's critical state model. Flux creep activation energy is determined in vortex dynamics exhibited by frequency dependence of AC susceptibility in the range of 123 – 6000 Hz. Sample with x = 0.6 wt% Nd_2O_3 shows maximum value of J_{cm}, 5.77 x 10^{-5} A/cm^2 and E_a, 9.212 x 10^{-19} J indicating at this point it has a optimum pinning centre. As a conclusion, Nd_2O_3 nanoparticles acting as flux pinning centres in matrixes of superconductors Y123 which gave the best result in term of J_{cm} value as compared to Gd_2O_3 and Sm_2O_3.

Abstrak thesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

SIFAT STRUKTUR DAN ELEKTRIK BAHAN YBCO DICAMPUR NANOZARAH Nd_2O_3, Gd_2O_3 DAN Sm_2O_3

Oleh

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Telah diketahui bahawa sifat mensuperkonduksi sangat dipengaruhi oleh teknik sintesis dan keadaan pemprosesan. Maka, kaedah pemendakan logam sentiasa digunakan dan dipilih di dalam kajian ini disebabkan oleh kehomogenan yang tinggi, suhu tindakbalas yang rendah, saiz butiran yang halus dan sekata tanpa sebarang gumpalan, mudah untuk disediakan dan murah serta menjimatkan masa pemprosesan. Kesemua sampel Yttrium Barium Copper Oxide (YBCO) disediakan melalui kaedah pemendakan ion logam oxalate ditambah dengan Nd_2O_3, Gd_2O_3 dan Sm_2O_3, x = 0.0, 0.2, 0.4, 0.6, 0.8 dan 1.0 peratus berat. Pembentukan fasa dan peratusan pecahan isipadu setiap fasa sampel dikaji dengan teknik Pembelauan Tenaga Sinar-X dan pemurniann Rietveld. Kesemua sampel menunjukkan pra-mendominasi fasa Y-123 dan fasa tidak mensuperkonduksi, Y-211 dengan kewujudan bendasing Nd_2O_3, Gd_2O_3 dan Sm_2O_3, dengan struktur ortorombik dan kumpulan ruang *Pmmm*. Pecahan isipadu fasa mensuperkonduksi, Y-211 maningkat secara mendadak adalah disebabkan oleh perbezaan saiz penempatan Y-211 yang mempengaruhi T_c dan J_c di dalam sistem Y-123. Struktur mikro daripada Mikro Pengimbas Elektron mendedahkan bahawa saiz zarah yang dikira melalui Imej J berkurangan apabila penambahan nanozarah bermagnet Nd_2O_3, Gd_2O_3 dan Sm_2O_3 meningkat, menunjukkan bahawa bahan tersebut mempunyai ikatan butiran yang lemah berikutan kewujudan keadaan berliang dan lohong. Pengukuran perubahan rintangan dilakukan dengan teknik penduga empat titik. Tc untuk sampel tulen ialah 92 K. Walaubagaimanapun, T_c semakin berkurangan kepada 74 K, 80 K dan 88 K masing-masing untuk Nd_2O_3, Gd_2O_3 and Sm_2O_3 Didapati $T_{c\text{-onset}}$ semakin berkurangan disebabkan oleh kandungan oxigen yang semakin rendah di dalam sampel. Memandangkan superkonduktor YBCO bersifat butiran secara semulajadi, pengukuran keupayaan arus ulang alik digunakan sebagai alat yang efektif untuk mencirikan sifat butiran dalam sistem ini. Vorteks antara butiran diukur dengan medan yang dikenakan antara 0.005 Oersted hingga 3.0 Oersted pada frekuensi tetap, 123 Hz. Manakala ketumpatan arus kritikal matriks, J_{cm} dikira berdasarkan rangka Model Keadaan Kritikal Bean. Pengaktifan tenaga pergerakan fluks, E_a pula ditentukan di dalam dinamik vortex yang bersandarkan perubahan frekuensi di dalam keupayaan arus ulang-alik iaitu di dalam rangkuman 123 Hz hingga 6000 Hz. Sampel dengan nilai peratusan berat, x = 0.6 Nd_2O_3 mempunyai nilai J_{cm}, 5.77 x 10^{-5} A/cm^2 dan E_a, 9.212 x 10^{-19} J yang maksimum menunjukkan sampel ini mempunyai pusat pengepinan yang

optimum. Sebagai kesimpulan, nanozarah Nd_2O_3 bertindak sebagai pusat pengepinan fluks di dalam matriks superkonduktor, telah memberikan keputusan yang terbaik di dalam J_{cm} jika dibandingkan dengan system Gd_2O_3 dan Sm_2O_3.