Study of Fluctuation Induced Conductivity and Magnetic Properties of Nano-Metal Oxide Doped MgB_2 Superconductors

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The discovery of superconductivity in the binary boride, MgB_2 at the high temperature of 39 K has generated considerable interest because of the apparent simplicity of its chemical composition, crystal structure and electronic properties. MgB_2 shows a lower anisotropy, large coherence lengths and better current flow across the grain boundaries than the cuprate superconductors, making this compound a vivid candidate for practical applications. MgB_2 possesses a simple hexagonal structure (AlB_2-type, space group P6/*mmm*) comprising graphite-type B layers interleaved with Mg layers. The lattice parameters are a = 3.086 Å and c = 3.524 Å. The bulk samples were synthesized using high purity powders of Mg and B doped with nano ZnO and nano Al_2O_3, separately. The resistivity measurements were carried out in the temperature range of 12-300 K using standard four-probe geometry on a close cycle refrigerator. Chemical substitutions at specific crystallographic sites that lead to a variety and richness in the high temperature superconductors is not easily possible in MgB_2. Presently, various approaches are achieved in understanding of its physical properties and enhance the pinning behavior in MgB_2 materials, such as chemical doping using different elements and nanoparticle addition that seems to be the best and most practical route due to form a high density of nano-inclusions in MgB_2 matrix. Al substitution has resulted in a decrease in T_c.

We have successfully synthesized nano-Al_2O_3 doped $Mg_{1-x}Al_xB_2$ (x = 0%, 2%, 4% and 6%) and nano-ZnO doped $Mg_{1-x}Zn_xB_2$ (x = 0%, 2%, 4% and 6%), separately and investigated the doping effect of nanoparticles on the superconducting properties of MgB_2 bulk material. We have observed that the lattice parameter, cell volume and T_c decreased monotonically with increasing doping level for nano-Al_2O_3 doped $Mg_{1-x}Al_xB_2$. Result clearly shows that the J_c value of all the $Mg_{1-x}Al_xB_2$ samples increases at all the temperatures and higher magnetic fields, among which $Mg_{1-x}Al_xB_2$ at x = 2% sample exhibits the excellent J_c-H properties. The irreversibility line H_{irr} and critical current density J_c are systematically enhanced by doping nano-alumina. Nano-particle inclusions observed by SEM are proposed to be responsible for the slight enhancement of flux pinning at all temperatures and higher magnetic fields. Slight decrease in lattice parameters of nano-ZnO doped $Mg_{1-x}Zn_xB_2$ endorses that Zn is successfully substituted in Mg site. The impurity phase MgO might arise during the solid-state reaction of the starting materials and increases with the doping level in both nano-Al_2O_3 and nano-ZnO powder doped samples. Lattice parameter and cell volume of the samples slightly decreases as the doping level increases for nano-ZnO doped $Mg_{1-x}Zn_xB_2$. Reduction of the transition temperature observed from the temperature dependence of resistivity plot of nano ZnO doped MgB_2. Results explicate that magnetization for nano-ZnO doped MgB_2 sample appears to be more stable in comparison with nano-Al_2O_3 doped MgB_2 sample for all temperature and doping level. We analyzed that x = 2% $Mg_{1-x}Zn_xB_2$ sample shows the higher J_c value in comparison with other doped and undoped samples. We observed that irreversibility line, H_{irr} for nano-ZnO doped MgB_2 sample become less inclined in comparison with nano-Al_2O_3 doped MgB_2 sample.

In the present work, we recognized the fluctuation induced conductivity (FIC) in the vicinity of transition temperature of polycrystalline MgB_2 superconductor. Temperature dependence of resistivity at 6T and 8T are distinct to each other. The peaks obtained in $d\rho/dT$ vs. T plot clearly explained the anomalous behaviour of temperature dependence of resistivity at 6T and 8T by T_c^{mf} (mean field critical temperature). As magnetic field increases the T_c and T_c^{mf} decreases. We employed the modified Aslamazov and Larkin (AL) equations for polycrystalline MgB_2 system. It is evident that anomalous fluctuations of the resistive transition have been observed in several high temperature cuprate superconductors, which are electronically and structurally much more complex than MgB_2. The experimentally estimated effective coherence length in this paper is roughly matched with the previous reported experimental work.

The summary of the present work is described in underneath chapters:

Chapter 1 deals with the common characteristics and basic building block of high temperature superconductors. History of the superconductors is discussed in details after the discovery of K. Onnes. This chapter also consists of the differences between Type I and Type II superconductors.

Chapter 2 describes the crystal structure of high temperature superconductors and review of basic properties of MgB_2 system.

Chapter 3 elaborates the sample preparation and their characterization through different techniques *viz.* x-ray diffraction, electrical resistivity, magnetic measurement and scanning electron microscopy.

Chapter 4 & 5 referred to different characterization of nano-alumina and nano-zinc oxide doped MgB_2 superconductors. The effect of the substitution of nano-alumina and nano-zinc oxide in superconducting MgB_2 is discussed in details in these chapters. Electrical transport and magnetic properties of the prepared samples are exclusively discussed in these chapters.

Chapter 6 gropes the fluctuation-induced conductivity (FIC) in polycrystalline samples of pristine MgB_2 in presence of anomalous magnetic field (H = 0T, 6T and 8T).

Chapter 7 purports the future opportunities and challenges of the recent discover MgB_2 superconductor in the different arena.