جامعة الاسكندرية
ALEXANDRIA
UNIVERSITY
Faculty of Science

Faculty of Science
Department of Physics

Effect of Nano-$Y_3Fe_5O_{12}$ Addition on the Superconducting and Mechanical Properties of $Cu_{0.5}Tl_{0.5}Ba_2Ca_2Cu_3O_{10-\delta}$ Phase

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science

Presented by

Mennatallah Ahmed Mohamed Mohamed

B.Sc. in (2018)
Faculty of Science

2022

English Summary

The primary goal of this research is to investigate the impact of nano-sized Yttrium iron garnet ($Y_3Fe_5O_{12}$) addition on the microstructure and mechanical properties of the polycrystalline $Cu_{0.5}Tl_{0.5}Ba_2Ca_2Cu_3O_{10-\delta}$ (CuTl-1223) superconductor. Co-precipitation and solid-state reaction methods were utilized to prepare $Y_3Fe_5O_{12}$ nanoparticles and $Cu_{0.5}Tl_{0.5}Ba_2Ca_2Cu_3O_{10-\delta}$ superconductor, respectively. $(Y_3Fe_5O_{12})_x/Cu_{0.5}Tl_{0.5}Ba_2Ca_2Cu_3O_{10-\delta}$ nanoparticle/superconductor composites were formed by adding small contents of $Y_3Fe_5O_{12}$ (x = 0.00, 0.02, 0.04, 0.06, 0.08, and 0.10 wt%) to the CuTl-1223 matrix. The prepared samples were characterized using X-ray powder diffraction (XRD) and scanning electron microscopy (SEM) for phase analysis and microstructure examination, respectively.

The volume fraction percentage of the main phase, CuTl-1223, was increased from 87.9 to 91.4% as x was adjusted from 0.00 to 0.04 wt%. The unit cell parameters (a and c) remained unchanged following the addition of $Y_3Fe_5O_{12}$ nanoparticles to the host CuTl-1223. The porosity percentage (P %) was decreased from 39.1 to 29.4% as x was increased from 0.00 to 0.10 wt%. Thus, the addition of $Y_3Fe_5O_{12}$ nanoparticles has the ability to reduce weak links and voids among the CuTl-1223 superconducting grains. The different elemental compositions were detected by energy-dispersive X-ray measurements (EDX). The analysis shows that, $Y_3Fe_5O_{12}$ nanoparticles do not enter the structure of the CuTl-1223 phase, but rather occupy the interstitial space between the grains.

Vickers microindentation hardness test was employed to study the mechanical strength of the prepared composites. Analysis and modelling of Vickers hardness (H_v) versus test load (F) were done through various models. Meyer's empirical law showed that all the prepared composites follow normal indentation size effect behaviour. Hays and Kendall model clarified that the applied test load was sufficient to produce both elastic and plastic deformation for the investigated samples. The elastic/plastic deformation model indicated that the prepared samples contain an elastic relaxation portion that recovers after withdrawing the test load. The proportional sample resistance and modified proportional sample resistance models confirmed the HK model findings. Moreover, the HK model was found to be the most suitable model for describing the microhardness results of the prepared samples. Furthermore, the elastic modulus (E), yield strength (Y), fracture toughness (K) and brittleness index (B) for the prepared composites were calculated as function of $Y_3Fe_5O_{12}$ addition. As the amount of $Y_3Fe_5O_{12}$ in the samples was increased, elastic E, Y, K and B of the samples were improved. These

enhancements are thought to be due to the presence of $Y_3Fe_5O_{12}$ particles, which can encourage compressive stresses in the superconducting matrix and resist crack propagation by pinning the propagating cracks.