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Effect of the different Sr dopant contents on NiO ceramic

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Abstract

Sr - doped NiO ceramic was studied. The effect of composition variation of $\text{Ni}_{(1-x)}\text{Sr}_x\text{O}$ where $x = 0, 0.01, 0.02, 0.03, 0.05$ and 0.10 mole % was prepared by using solid state method. The calcination temperature used at $950\text{ }^\circ\text{C}$ for 4 hours and the sintering temperature used at $1200\text{ }^\circ\text{C}$ for 3 hours. The results depict the microstructures increase in grains size ($0.43 - 3.30\text{ }\mu\text{m}$) by increase of Sr dopant contents. The density and porosity testing support the result of microstructures analysis. The larger grains size led to increase in density and lower in porosity. The dielectric properties is observed in a wide frequency range of ($1 - 1\ 000\text{ MHz}$). The increase of dielectric constant is associated with the decrease of dielectric loss. The optimum composition was obtained for the $x = 0.03$ mole % sample with highest dielectric constant (3.24×10^3) and lowest dielectric loss (1.42) at 1 MHz.

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1. Introduction

The interest in using a dielectric materials keep increasing each day due to having applications which attributes to high dielectric constant and low dielectric loss. The potential applications in electronic such as capacitors and memory devices required an improvise efforts for miniaturization of electronic components. Therefore, high demand in the search for new materials with a very high dielectric constant and low loss is very competitive.

Recently, monovalent alkali and transition metal doped NiO systems have attracted much attention from the researchers due to the observation of an extraordinarily high dielectric constant. Wu et al. have reported a giant low-frequency dielectric constant ($> 10^5$) near room temperature, observed in (Li, Ti) - doped NiO,¹ (Li, Al) - doped NiO,² and (Li, Co) - doped NiO.³ These ceramics are a new type of high dielectric permittivity oxide which is nonperovskite, lead - free and non - ferroelectric. Zheng et al.⁴ stated that the minimal addition of Sr considerably reduces the temperature of maximum shrinkage, therefore indicating its strong promotion of the sintering behavior in the system of ceria based ceramics. Ding et al.⁵ on his report added that increasing Sr concentration up to 30% heavily suppresses the Curie temperature and saturation moments.

In the present work, the effects of Sr^{2+} on the microstructures, the XRD patterns, densities and dielectric characteristics of $\text{Ni}_{(1-x)}\text{Sr}_x\text{O}$ ceramics, where $x = 0, 0.01, 0.02, 0.03, 0.05$ and 0.10 mole % have been investigated, where the role of dopant contents are emphasized. The different of Sr^{2+} dopant contents will affects the microstructure of ceramics, as well as grain size, uniformity of grains and boundary structure thereby, affecting its dielectric properties.

2. Experimental methods

In this work, NiO (99.9 %) and SrCO_3 (99.9 %) were employed as starting raw materials. The $\text{Ni}_{(1-x)}\text{Sr}_x\text{O}$ ceramics with different Sr^{2+} dopant concentrations, $x = 0, 0.01, 0.02, 0.03, 0.05$ and 0.10 mole % were prepared by solid - state reaction. The raw materials was mixed together with acetone and then the mixtures was milled for 24 hours using zirconia ball as the mixing medium. Then, the mixtures were dried at room temperature and grounded using agate mortar. The dried powder was calcined at $950\text{ }^\circ\text{C}$ for 4 hours. The calcined powders were then compacted into a mold of 6 and 13 mm shape using hydraulic pressing of 250 MPa. Sintering process was done at of $1200\text{ }^\circ\text{C}$ for 3 hours using Electrical Carbolite Furnace CWF 1400 with heating rate $5\text{ }^\circ\text{C}/\text{min}$. Density and porosity testing were done by using Archimedes principle. The samples were characterized using Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD). The measurement of dielectric properties was done using the Impedance Analyzer (model: RF Impedance/Material Analyzer 4291B Hewlett Packard).

3. Result and Discussions

Fig. 1 (a) indicate the XRD patterns of all the $\text{Ni}_{(1-x)}\text{Sr}_x\text{O}$ ceramics samples with different Sr^{2+} concentration. All peaks were identical to a crystalline phase of NiO with Miller index (hkl) of (111), (200), (220), (311) and (222), which fall into ICSD Data File Card No. 98 - 009 - 0203 and it could be assigned to a cubic cell with space group of Fm - 3m (no. 225). Results indicated that the addition of Sr^{2+} (0.112 nm) dopant did not change the cubic structure of NiO. Fig. 1 (b) depict peaks of $\text{Ni}_{(1-x)}\text{Sr}_x\text{O}$ which correspond to (200). The trend shows the peaks to shift slightly from the undoped NiO. These behaviour was attribute to the fact that the incorporation of Sr^{2+} (0.112 nm) into NiO (0.069 nm) crystallite led to change in lattice parameter and crystallite size. Manna and De⁶ reported that the dopant tends to substitute the parental atom of crystal structure due to the difference in size between the dopant and the parental atom of NiO.

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