

High Temperature Electrical Resistivity Studies of Pure and Strontium-doped NiO Nanoparticles

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Abstract - NiO and Strontium-doped NiO nanoparticles are prepared by co-precipitation method. The electrical resistivity measurements by applying high temperature on pure and Strontium-doped NiO nanoparticles were reported. The electrical resistivity values decrease with an increase of temperature when the pressure is kept constant. Also the temperature dependence of electrical resistivity studies clearly indicates the absence of pressure-induced phase transitions. The activation energy of the samples under pressure up to 8 GPa reveals that the energy is decreasing for both high and low regions of temperature.

Keywords – Electrical resistivity, Activation energy, Co-precipitation, Nanoparticles, High Temperature

I. INTRODUCTION

In the recent years, Nanoscale materials have fascinated the scientific community because of their physical and chemical properties. One of the most commonly used transition metal oxides for a wide range of application is NiO. It is a p-type antiferromagnetic semiconductor with a wide bandgap of 3.6 to 4.0 eV. This paper emphasis the high temperature electrical resistivity studies of pure and strontium-doped nickel oxide nanoparticles. A number of new techniques have been developed for measuring the electrical resistivity of samples under high temperature. Electrical resistivity studies play an important role in order to understand the electrical nature of material properties. The resistivity of these materials depends upon the physical parameters like pressure, temperature, magnetic field etc. This manuscript explains the structural and high temperature electrical resistivity studies of pure NiO and copper-doped NiO Nanoparticles.

II. EXPERIMENTAL FLOWCHART

2.1 Preparation technique –

Pure NiO and strontium-doped NiO nanoparticles are synthesized by co-precipitation method. All the chemical reagents used in our experiments are of analytical grade. NiO nanoparticles were successfully synthesized by Nickel nitrate hexahydrate ($\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$) and Strontium III Nitrate of various concentrations (1mol%, 3mol% and 5mol%) were dissolved in 40 ml of distilled water under constant stirring. The NaCl solution was added dropwise into the above solution over 15 minutes. Subsequently, green precipitate was filtered out. And stirring process was done in room temperature until pH approaches 7. Finally, the end product was separated by centrifugation and washed thoroughly with de-ionized water, ethanol and acetone consecutively. After drying at ambient temperature for 24 hours, the powder was calcined at 400°C for 2 hours. For synthesis of pure NiO nanostructure, the same procedure was followed without Strontium III Nitrate solution as mentioned above.

The purity and crystallinity of the as-synthesized pure NiO and strontium-doped NiO nanoparticles are examined by using powder X-ray diffraction (XRD). XRD pattern was taken from the BRUKER D5 phaser. High temperature electrical resistivity studies were carried out by Bridgman opposed anvil device by introducing a thermocouple.

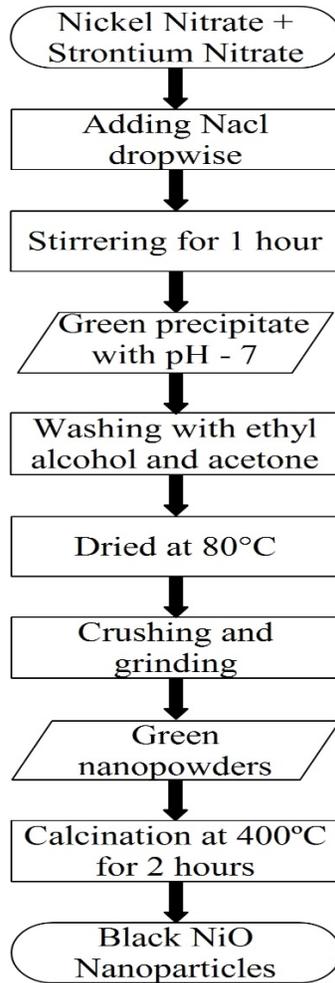


Figure 1. Preparation mechanism of Strontium-doped NiO Nanoparticles

III. EXPERIMENT AND RESULT

3.1 Phase analysis-

Powder X-ray diffraction pattern of chemically precipitated pure NiO and Strontium-doped NiO nanoparticles are calcined at 400 °C for 2 hours are shown in Figure 2. It clearly indicates the formation of face centered cubic NiO nanostructure with the space group of Fm-3m. The crystallite size of pure NiO and strontium-doped NiO are determined using Debye-Scherrer's relation [1-3]. The Debye-Scherrer's relation is given by

$$D = k\lambda / \beta \cos\theta \quad (1)$$

where β denotes the full width half- maximum value of the high intensity peak, k denotes the shape factor ($k = 0.9$), θ denotes the angle of diffraction and λ denotes the wavelength of the X – ray source used in the XRD. The crystallite size of the pure NiO nanoparticles are in the range of 7.906 nm. Table 1 shows the lattice parameter of the pure NiO and Strontium-doped NiO nanoparticles. It is clear that the size of the crystalline samples decreases with the doping concentration of strontium [4-6]. Also it is clear that the van der Waal's forces are responsible for the agglomeration of ultrafine strontium nanoparticles. The crystal structures of the samples are face centered cubic. The Lattice parameter of the samples are $a = 4.17 \text{ \AA}$. From the XRD pattern, the most intense peak was observed at $2\theta = 43.33^\circ$. Also no impurity peaks were observed.

Table -1 Lattice parameter and the crystal structure of pure NiO and Strontium-doped NiO Nanoparticles

Sample	Crystal Structure	Lattice parameter (a) Å
Pure NiO	FCC	4.172
1 mol % Sr / NiO	FCC	4.177 ± 0.005
3 mol % Sr / NiO	FCC	4.181 ± 0.009
5 mol % Sr / NiO	FCC	4.185 ± 0.013

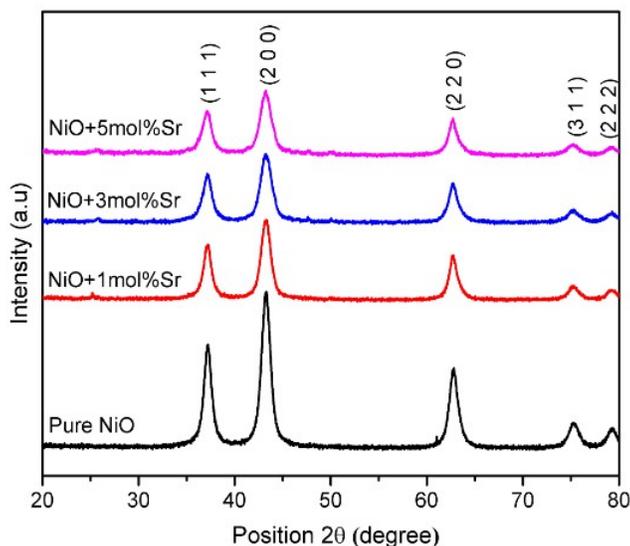


Figure 2. Powder X-ray diffraction pattern of pure NiO and Strontium-doped NiO nanoparticles

3.2 Electrical resistivity studies under high temperature

The temperature dependence of the electrical resistivity of pure NiO and Strontium-doped (1 mol %, 3 mol % and 5 mol %) NiO nanoparticles at various pressures are shown in Figure 3. The electrical resistivity versus temperature studies are used to investigate the defect or impurity properties of the pure NiO and Strontium-doped NiO nanoparticles. The temperature dependence of the samples is measured for different pressures (2 GPa, 4 GPa, 6 GPa and 8 GPa). It is clear that the electrical resistivity values decrease with an increase of temperature when the pressure is kept constant [7-9]. At low pressures, the samples follow a structure of face-centered cubic (FCC) and are bounded

together by means of van der Waal's forces. However, with increasing applied pressure the molecules are individually bounded together into pairs or larger clusters by covalent intermolecular bonds. It makes the electron transport easier. Thus the pressure-induced polymerization is the possible cause of the steep pressure-dependent decrease in electrical resistance observed in Figure 3. Due to compression, the electrical conduction of the samples is dominated by electrons, impurity level or other levels in the gap such as strain-induced level [10-13]. Both pressure-induced band gap shrinkage and strain-induced level are the major reason for decrease of electrical resistivity of the pure NiO and Strontium-doped NiO nanoparticles from ambient pressure to 8 GPa. The results indicate that there is no sign of pressure-induced phase transition.

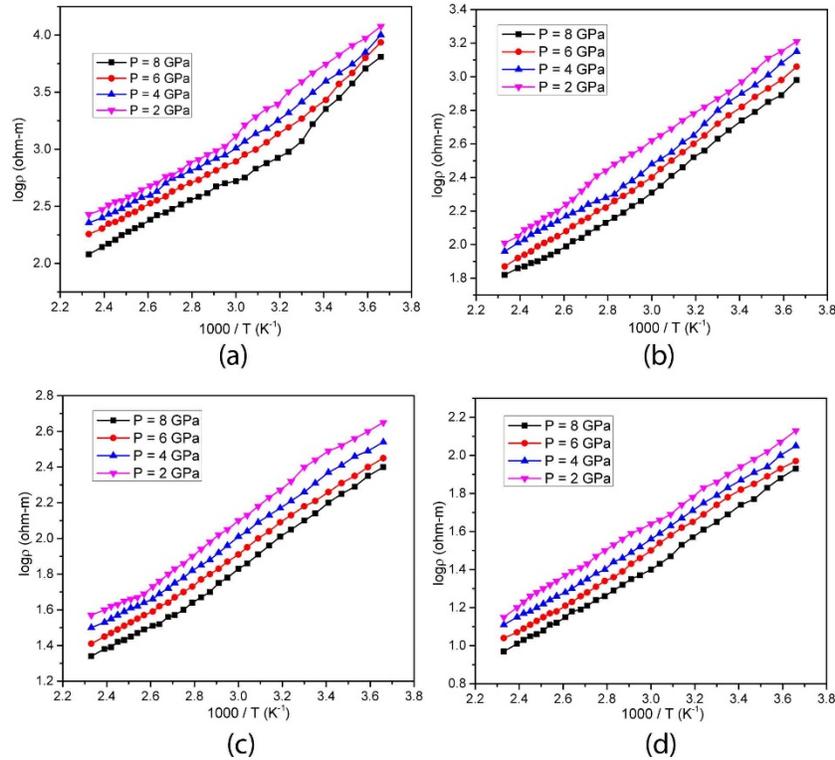


Figure 3. Temperature dependence of the electrical resistivity of pure (a) and 1 mol% (b), 3 mol% (c) and 5 mol% (d) Strontium-doped NiO nanoparticles at various pressures

IV. CONCLUSION

Pure NiO and Strontium-doped NiO nanoparticles are prepared by using a novel Co-precipitation method for various concentrations. The structural and electrical resistivity studies were carried out. From the XRD pattern, it is clear that the prepared samples contain highly homogeneous pure NiO and Sr-doped NiO nanoparticles. There is no identification of impurities or any other secondary phases. NiO nanoparticles have a space group of Fm-3m with a face-centered cubic crystal structure. From the temperature dependence of the samples, it is clear that the electrical resistivity values decrease with an increase of temperature when the pressure is kept constant. Also the temperature dependence of electrical resistivity studies clearly indicates the absence of pressure-induced phase transitions. The activation energy of the samples under pressure up to 8 GPa reveals that the energy is decreasing for both high and low regions of temperature.

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