Structural and Electrical Properties of Magnesium Oxide Nanoparticles Synthesized By Chemical Co-Precipitation Method

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Abstract

Nanoparticles of magnesium oxide have been successfully synthesized by chemical co-precipitation method using $MgCl_2$ and NaOH as precursors at room temperature. Structural characterizationswere carried out by means of X-ray diffraction and FTIR analysis. X-ray diffraction study confirms polycrystalline nature of MgO. The electrical resistivity of the magnesium oxide material decreases with increase in temperature confirming its semiconducting nature. The electrical resistivity of magnesium oxide at 373 K was found to be 2.79 Ω-cm.

Keywords: Nanoparticles; X-ray diffraction; MgO; Electrical resistivity

1. Introduction

Since last few decades, nanocrystalline metal oxide materials have attracted the significant attention of recent researchers due their potential applications in variety of fields such asbiosensor, cancer therapy, magnetic recording and photovoltaic cell etc. [1- 4]. The nanoparticles of several metal oxides showed novel physical and chemical propertiesthat are very important in various applications [5]. Recently, several nanocrystalline metal oxides such as titanium oxide, zinc oxide, calcium oxide and manganese oxide etc. have attracted the great attentiondue to their stability under harsh process and environmental friendly nature [6]. Amongst them, nanocrystalline magnesium oxide (MgO) has shown promising applications in advanced technologies in view of electronic and photonic devices [7, 8]. Due to its large surface area, magnesium oxide exhibits high activity against bacteria and viruses in aqueous environment [9]. It is also useful in catalysis, toxic waste remediation as additives in paint, refractories and superconducting products etc. [10]. The nanoparticles of magnesium oxide have been synthesized by variety of physical and chemical methods such as sol gel [11], pulsed laser deposition[12], molecular beam epitaxy[13], thermal decomposition [14], chemical vapour deposition [15], sonication method [16] and chemical co-precipitation [17] etc. Among these methods chemical co-precipitation method has various advantages over the other such as nontoxic, environmental friendliness, controlled particle size and easy to synthesis nanoparticles without agglomeration in the yield. In the present work, nanoparticles of magnesium oxide have been synthesized by chemical co-precipitation method at room temperature. The structural characterization was carried out by means of X-ray diffraction and FTIR analysis. The electrical properties of MgO nanoparticles are also discussed.

2 Experimental details

2.1 Preparation of magnesium oxide nanoparticles: For the synthesis of nanostructured magnesium oxide at room temperature, chemical co-precipitation method is employed. In this method $MgCl_2$ and NaOH were dissolved in the deionized water to achieve concentration required.In100ml solution of 1.5M $MgCl_2$,1.5 M NaOH was added drop wise with a rate of 0.2ml per minute with constant stirring. After getting white precipitate, it was filtered out using vacuum filtration assembly and washed several times using deionized water to remove impurities and excess of NaCl. The filtered precipitated was then dried in the vacuum chamber for 2 h at 573K and further grinded in the agate mortar to obtain superfine powder of nanostructured magnesiumoxide. The superfine powder obtained from agate mortar prepared by chemical co-precipitation technique was then used to prepare pellet of required dimensions.

2.2 Characterization Techniques: The structural characterization of prepared material was carried out using D8 Brucker X-ray diffractometer. The Fourier Transform Infra-Red (FTIR) spectrum was carried out using SHIMADZU make IR Affinity FTIR spectrometer in the frequency range from 400 – 4000cm^{-1}. Also the electrical resistivity was measured by using the two probe technique.

3 Results and discussion

3.1 Reaction Mechanism: $MgCl_2$ dissociates in deionized water as,

$MgCl_2 + H_2O \rightarrow Mg^{2+} + 2Cl$ (4)

And NaOH dissociates in deionized water as,

$NaOH + H_2O \rightarrow Na^{+} + OH^{-}$(5)

When NaOH was added into $MgCl_2$,$Mg(OH)_2$ is formed as ,

$Mg^{2+} + OH \rightarrow Mg(OH)_2$ (6)

$MgCl_2 + NaOH \rightarrow Mg(OH)_2 + 2NaCl$ (7)

As prepared $Mg(OH)_2$was further oxidized at 573K to get MgO as,

$Mg(OH)_2 \xrightarrow[573\,K]{\Delta} MgO + H_2O$(8)

3.2 X-ray diffraction study: The X-ray diffraction study of the magnesium oxide powder was performed using the Brucker D8, X-ray diffractometer. The X-ray diffraction pattern was recorded in 2θ degree in the range from 20° to 80° with Cu Kα (λ=1.5406A) as target at an accelerating voltage of 25 KV. Data were collected with a counting rate of 1°/min.The X-ray diffraction pattern of nanostructured Magnesium Oxide prepared by chemical co-precipitation method at room temperature is shown figure 1. The (2 22), (2 1 1), (5 1 1) and (2 2 0) peaks observed in the patterns confirms the formation of polycrystalline magnesium oxide nanoparticles with MgO and MgO_2 phases in accordance with the JCDPS data card

30-0794, 43-1022 and 76-1367. The comparisons of JCDPS data with the observed data of magnesium oxide powder is shown in Table1.

Table 1. Comparison of observed data of magnesium oxide powder with JCDPS data cards.

h k l	Standard		Observed		JCDPS Card no	Phase
	d- value (A^0)	2θ (degree)	d- value (A^0)	2θ (degree)		
2 2 2	2.350	38.470	2.350	38.30	30-0794	MgO
2 1 1	1.985	45.90	1.985	45.71	76-1367	MgO_2
5 1 1	1.565	59.230	1.565	59.01	30-0794	MgO
2 2 0	1.485	62.281	1.485	62.53	43-1022	MgO

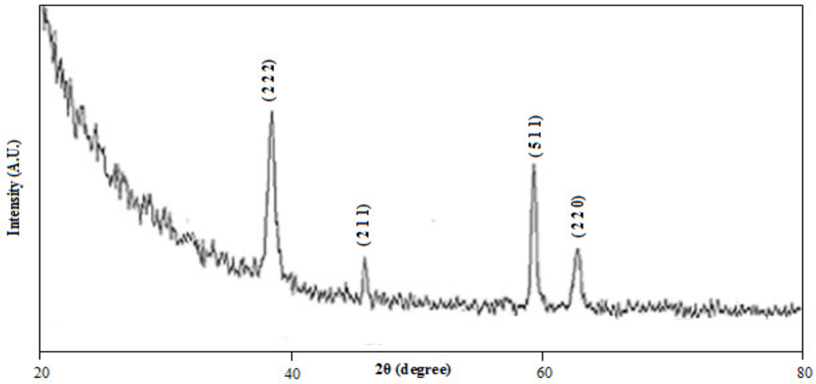

Fig.1: X-Ray diffraction patterns of magnesium oxide nano powder.

The crystallite size of the synthesized magnesium oxide powder was calculated using Debye-Scherrer formula,

$$D = \frac{0.94\lambda}{\beta \cos\theta} \qquad (9)$$

Where D is the crystallite size; λ is the wavelength; β is the full width at half maxima (FWHM) and θ is the angle of diffraction. The average particle size calculated from Debye-Scherrer formula is around 41nm.

3.3 FTIR Measurement: The FTIR spectrum of magnesium oxide is shown in figure2.The spectrum was studied in the range from 400-4000cm^{-1} by using SHIMADZU IR Affinity spectrophotometer.The FTIR spectrum shows the absorption peaks at 428.20, 1066.64 and 1419.61cm^{-1}corresponding to characteristic Mg-O-Mg deformation and stretching vibrations respectively [18]. However, the absorption peaks observed at 2358.94, 2879.72and 3693.68cm^{-1}may be attributed to the O-H stretching vibration of surface adsorbed water molecules. The FTIR spectrum clearly indicates the formation of magnesium oxide.

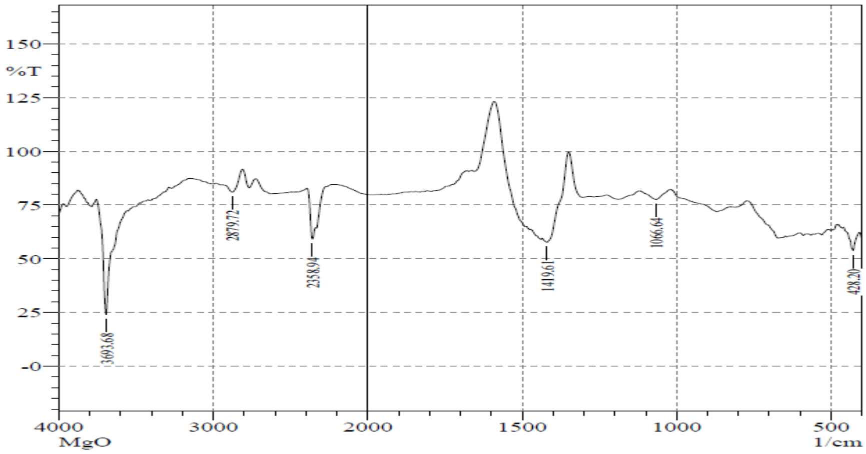

Fig.2: FTIR spectrum of magnesium oxide nanoparticles.

3.4 Electrical resistivity measurements

For measurement of electrical resistivity of magnesium oxide nanoparticles the two-probe resistivity measurement set-up is used. The pelletof magnesium oxide nanoparticles having thickness (t) is 0.417 cm and cross sectional area (A) 0.86 cm^2 is prepared using KBrhydraulic press and 1 cm size die punch. The resistivity (ρ) is calculated using the formula,

$$\rho = \left(\frac{A}{L}\right) \times R \qquad (11)$$

The electrical resistivity of magnesiumoxide nanoparticles was measured in the temperature range 373 – 513 K. It was found that the resistivity decreases from0.604 to 0.575 Ω-cm as temperature increases from 373 to 513 K indicating its semiconducting nature. The plot of variation of resistivity with temperaturefor magnesiumoxide is shown in figure 3.The activation energy was calculated using the relation,

$$\mu - \mu_0 exp(\frac{E_a}{KT}) \qquad (12)$$

where 'ρ' is the resistivity at temperature T, 'ρ_0' is constant; 'K' is Boltzmann constant and 'Ea' is activation energy. The activation energy represents the location of trap levels below conduction band. The activation energy of magnesium oxide is found to be 0.03 eV.

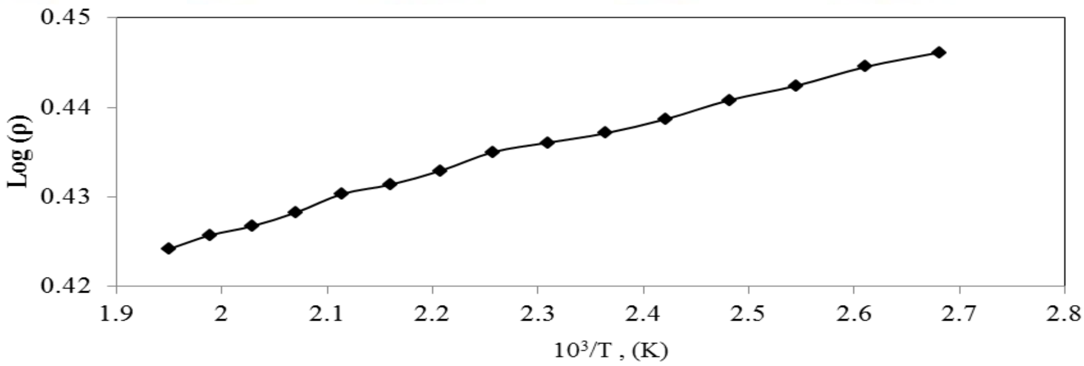

Fig.3: Plot of variation of electrical resistivity versus temperature.

4. Conclusions

Nanoparticles of magnesium oxide have been successfully synthesized by chemical co-precipitation method. The X-ray diffraction studies showed that the prepared magnesium oxide particles are nanocrystalline in nature. The electrical resistivity of magnesium oxide decreases with increase in temperature indicating its semiconducting nature.

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