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Synthesis and Characterization of MnO_2 Nanoparticles using Co-precipitation Technique

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Abstract

The thrust to develop eco-friendly procedures for the production of nanoparticles arises from the extremely recent nanotechnology research. MnO_2 nanoparticles were synthesized by co-precipitation method using green chemistry. The size, structure and morphology of MnO_2 nanoparticles were characterized by UV-Visible, X-Ray diffraction (XRD), FTIR techniques. The average particle size of manganese oxide nanoparticles was calculated from the XRD study. The average particle size of MnO nanoparticles was 25-30 nm. MnO_2 nanoparticles thus synthesized have large number of potential applications in the field of pharmaceutical industries, sensors, piezoelectric crystals, fuel cell electrodes and catalysis etc.

Keywords: MnO_2 nanopartilces, co-precipitation method, nanotechnology, XRD, FTIR.

1. Introduction

Over the last three decades nanoparticles have received an increasing amount of research interest. This is due to unique size dependent properties of nanaoparticles, which are often thought as a separate and intermediate state of matter lying between individual atoms and bulk material (Schnid, 2004). Nanoparticles consisting of a large range of transition metals and metal oxides have found to exhibit advantageous size dependent catalytic properties and are being investigated intensively (Stowell, 2005; Narayanan et al, 2004; Subramamian et al, 2006; Cuenya et al, 2003; Schaaff, 2002; Sau et al, 2001; Frank et al, 2000; Rice et al, 2000; Heiz et al, 1998; Somorjai, 1997).

Physical vapor deposition, chemical vapor deposition, aerosol processing, Sol-Gel process, reverse micelle method, mechanical alloying/ milling, are some of the commonlyused methods by which nanoparticles can be synthesized. Among the

various wet chemical methods to synthesize nanoparticles, hydrothermal (Yanagisawa et al, 2000; Xu et al, 2000), microemulsion (Sujata et al, 2002; Kim et al, 2000) and sol-gel (Shukla et al, 2004), conventional co-precipitation method is commercially widely used because of its cost-effective (Nam et al, 2001; Kim et al, 2006; Kim and Park et al, 2006; Praminik et al, 2002; Seo et al, 2006; Kim et al, 2002).

Co-precipitation method offers advantages like, simple and rapid preparative method, easy control of particle size and composition can be made in this method and also, there are various possibilities to modify the particle surface state and overall homogeneity. Co-precipitation of various salts (nitrates, sulphates, chlorides, perchlorates etc.) under a fine control of pH by using NaOH or NH_4OH solutions yields corresponding spinel oxide nanoparticles.

In the present study, MnO_2 nanoparticles were synthesized by co-precipitation method. As an important functional metal oxide, manganese oxide nanoparticles are one of the most attractive inorganic materials because of its physical and chemical properties and wide applications in catalysis, ion exchange, molecular adsorption, biosensor, and particularly, energy storage (Qi et al.1999; Shen et al., 1993; Cao & Suib, 1994).

Present work reports synthesis of MnO_2 nanoparticles and its characterization by UV- Visible spectroscopy, FTIR and XRD techniques.

2. Experimental

2.1 Materials and Method

All chemicals used in the experiment were of AR grade. The co-precipitation method was performed by using maganese salts of two different anions which are manganese (II) sulphate and manganese oxalate. Both salts of equal concentration i.e., 0.2M are mixed with continuous stirring at a constant temperature of 60°C. While stirring, NaOH solution was added till the pH of the solutions become 12. The stirring was continued for 1 hour at constant temperature of 60°C. Brown precipitates formed was then filtered and washed with ethanol. Precipitates were dried for overnight at 100°C. Than the precipitates was kept in muffle furnace at 500°C for 4 hrs.

2.2 Characterization Technique

The properties of formed MnO_2 nanoparticles were determined by the aid of UV-Visible spectroscopy (Systronic-2203) in the wavelength range 200-1000 cm^{-1}, Fourier Transform Infra-Red spectroscopy (FTIR) (Thermo-USA, FTIR-380) in the wavelength range 400-4000 cm^{-1} and X-ray Diffraction (XRD) (Rikagu Mini-2 using CuKα1, λ=0.15406 nm radiations).

3. Results and Discussion

3.1 X-Ray Diffraction

Figure 1 shows X-ray diffraction study of manganese oxide metal nanoparticles synthesized by co-precipitation method. From the XRD pattern it is clear that

manganese oxide metal nanoparticles synthesized were purely crystalline in nature. Average particle size of manganese oxide nanoparticles was found to be 25.0 to 30.0 nm. Size of MnO_2 nanoparticles corresponding to 100 percent intensity peak correspond to 29.07 as calculated using Scherrer equation.

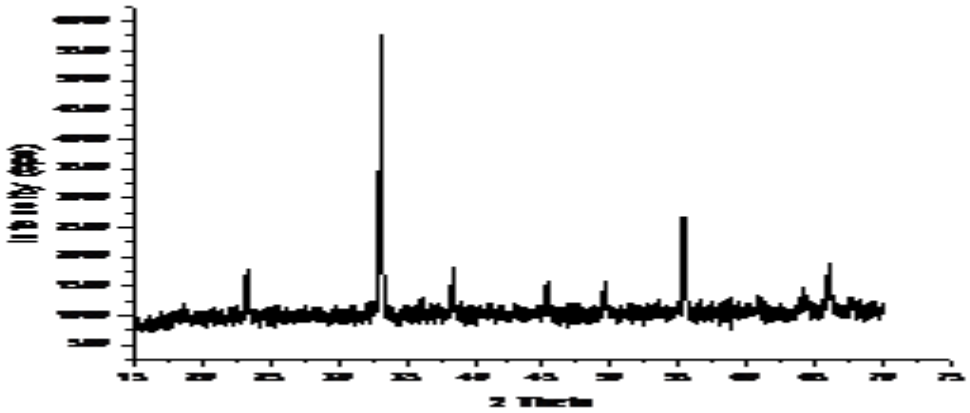

Figure 1: X-ray diffraction pattern of manganese oxide metal nanoparticles synthesized by co-precipitation method.

3.2 FTIR Spectroscopy

Figure 2 shows FT-IR spectra of manganese oxide metal nanoparticles synthesized by co-precipitation method. FTIR spectroscopy was carried out in order to ascertain the purity and nature of manganese oxide metal nanoparticles as synthesized by co-precipitation method.

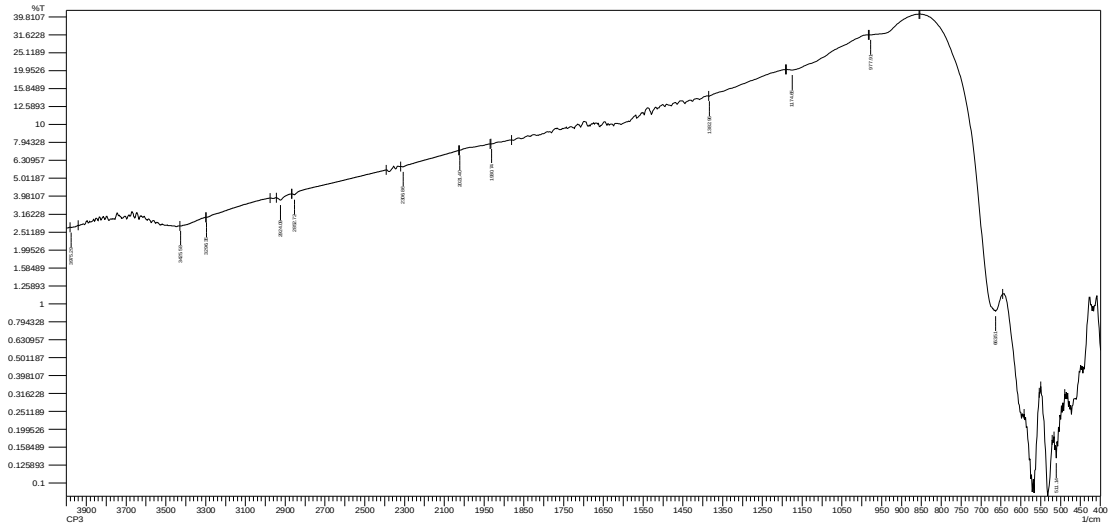

Figure 2: FT-IR spectra of manganese oxide metal nanoparticles synthesized by co-precipitation method.

Oxides and hydroxides of metal nanoparticles generally gives absorption peak in the finger print region i.e. below wavelength of 1000 nm arising from inter-atomic vibrations. The bands at 515 and 480 cm^{-1} correspond to the Mn–O bond (Kang et al, 2007;Li et al, 2007; Potter and Rossman, 1979). From the above result we conclude that the synthesized nanomaterial is manganese oxide. Absorption peak observed at 2924.09 cm^{-1} may be due to -CH_3 stretching vibrations. The absorption peaks at 2852.72 cm^{-1}, 2021.40 cm^{-1} and 1382.96 cm^{-1} may be due to –CH_2 stretching, =C-H stretching and –C-H stretching vibrations.

3.3 UV- Visible Spectroscopy

Figure 3 shows UV-Visible spectra of manganese oxide metal nanoparticles synthesized by co-precipitation method as a function of wavelength. The UV-visible absorption shows sharp absorption at 339.60 nm due to manganese oxide metal nanoparticles.

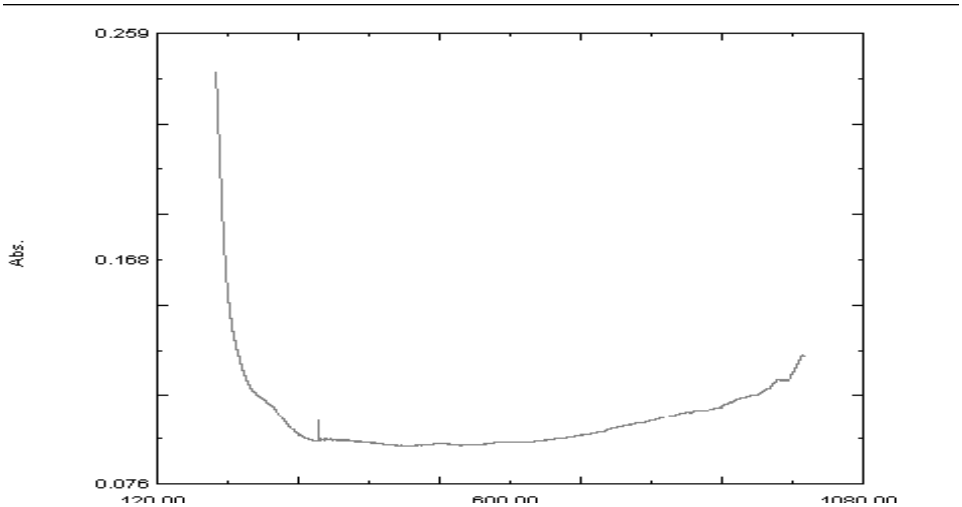

Figure 3: UV-Visible spectra of manganese oxide metal nanoparticles synthesized by co-precipitation method.

4. Conclusion

MnO_2 nanoparticles of simple cubic structure were synthesized by co-precipitation method using green chemistry. The FT-IR spectral analysis reveals the characteristics peaks of Mn-O stretching. The UV-visible absorption shows sharp absorption at 339.60 nm due to metal nanoparticles. XRD spectra predict the average size of 25-30 nm. There are large numbers of potential applications of MnO_2 metal nanoparticles such as in the field of electrode materials in different rechargeable batteries, biosensors, coatings, nanofibres, nanowires and also in specific biogenic and bioscience applications.

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