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Synthesis of wide band gap nanocrystalline NiO powder via a sonochemical method

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A sonochemistry-based synthesis method was used to produce nanocrystalline nickel oxide powder with ~20 nm average crystallite diameter from $Ni(OH)_2$ precursor. Ultrasound waves were applied to the primary solution to intensify the $Ni(OH)_2$ precipitation. Dried precipitates were calcined at 320 °C to form nanocrystalline NiO particles. The morphology of the produced powder was characterized by transmission electron microscopy. Using sonochemical waves resulted in lowering of the size of the nickel oxide crystallites. FT-IR spectroscopy and X-ray diffraction revealed high purity well-crystallized structure of the synthesized powder. Photoluminescence spectroscopy confirmed production of a wide band-gap structure.

1. Introduction

Nanocrystalline oxides of transient metals, showing astonishing properties suitable for alternative applications, have opened attractive horizons for advanced materials development [1–3]. Nickel oxide (NiO) is a p-type semiconductor of wide band gap (3.6–4.0 eV) class [4,5]. Excellent electronic, optical and catalytic properties recommend NiO nano-crystalline powder for employment as raw material for p-type transparent films, gas sensing units, pollutant clean-up catalysts, alkaline battery cathodes, dye-sensitized solar cells and solid oxide fuel cells (SOFC) [4–11]. Also, nanocrystalline NiO powder shows superparamagnetism effect; then which can be used for drug delivery and MRI agent [12].

Various methods such as sol–gel [11,13], chemical precipitation [4,7], microwave assisted method [14] and anodic arc plasma technique (AAPM) [8] have been developed to produce NiO nanocrystalline powder [15,16]. Sonochemical methods have recently been acknowledged as a promising route for preparation of various nanocrystalline materials including metallic and ceramic particles [17–22].

Power ultrasound induces its effects via cavitation bubbles. Compression and rarefaction cycles are created when ultrasound waves propagate through the liquid media. During rarefaction cycles, tiny micro-bubbles are created due to the low pressure region produced in the liquid. Throughout compression cycle, as micro-bubbles collapse intensely, instantaneous increases in temperature (>5000 °C) and pressure (>500 atm) are locally produced [23,24].

Excessive temperature and pressure due to cavitation result in morphological changes during preparation of nanocrystalline particles. The actual mechanism of cavitation, however, is not completely understood [23]. Irradiation of ultrasonic waves has advantages like acceleration of reaction, reduction of driving force, reduction the number of reaction steps, altering the reaction pathway and elimination the need to additives for initiation of the production [24].

A few reports are available on ultrasound utilization for obtaining nano-sized nickel oxide powder. Saghatforoush et al. [25] used, for example, a nano-sized nickel(II) Schiff base complex synthesized via hydrothermal and sonochemical routes. They used a novel complex precursor for production of the powder; but they did not characterize their product in details [25]. Gandhi et al. [26] produced nano-sized nickel oxide powder by one-pot sonochemical method and characterized the semi-crystalline structure of the synthesized powder by emphasizing on the surface catalytic activity of the produced NiO nanoparticles. They studied the effect of nano-sized NiO on PVA structure of NiO–PVA composite prepared during their research [26].

The aim of the present study is synthesis of a wide-band gap nano-crystalline nickel(II) oxide powder by a sonochemical method. Nickel hydroxide was used as the raw material. The crystallite size of the product was compared with the conventionally synthesized one. The product was characterized by transmission electron microscopy, X-ray diffraction, FT-IR and photoluminescence spectroscopy analyses.

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