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Review on-Hydrothermal Synthesis of Nickel Ferrite and its Applications

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Abstract

In this paper, one attempt has been made to review on hydrothermal synthesis of nickel ferrite and its application. Hydrothermal route is one of the most commonly used techniques owing to its economics and high degree of compositional control. This does not require extremely high-processing temperature or sophisticated processing. This method has very simple reaction setup. This method gives uniform crystallization ferrite. This does not require extremely high-processing temperature or sophisticated processing. With the doping with different metal ions, properties of nickel ferrite can be greatly improved. Nickel ferrite has many applications.

Keywords: hydrothermal synthesis, nickel ferrite, substituted/mixed nickel ferrite, characterization technique, applications.

Introduction

Ferrite is soft magnetic material having formula MFe_2O_4 (M is divalent metal ion like Ni, Zn, Co, Cu etc.). It is most attracting class of materials due to their interesting and important properties as low melting point, high specific heating, large expansion coefficient, low saturation magnetic moment and low magnetic transition temperature etc 1-2]. Because of these properties, they have many applications as photoelectric device, catalysis, sensors, nano devices, microwave devices and magnetic pigment [3-8].

Properties of ferrites depend upon nature of ions, charges and their distribution among tetrahedral and octahedral sites [10]. Nickel ferrites are one of the versatile and technological important soft ferrite materials due to their typical ferromagnetic properties, low conductivity and low eddy current losses, high electrochemical stability, catalytic behavior, abundance in nature etc [8]. This is inverse spinel in which eight units of $NiFe_2O_4$ go into a unit cell of the spinel structure. Half of ferric ions preferentially fill the tetrahedral sites (A-sites) and others occupy octahedral sites (B-sites) [11]. They can be represented by formula $(Fe^{3+})_A [Ni^{2+}Fe^{3+}]_B O_4^{2-}$ [12].They are prepared by various chemical methods such as hydrothermal, son chemical, sol-gel methods, microwave plasma, co-precipitation, micro emulsion methods, citrate precursor techniques and mechanical alloying for fabrication of stoichiometric and chemically pure spinel ferrite nanoparticles [10, 13-19]. Hydrothermal route is one of the most commonly used techniques owing to its economics and high degree of compositional control.

In this paper, one attempt has been made to review on hydrothermal synthesis of nickel ferrite and its applications.

Methodology

In this method; an aqueous mixture of precursors (Metal salts) is heated in a sealed stainless steel/Teflon lined autoclave above the boiling point of water, and consequently, the pressure within the reaction autoclave is dramatically increased above atmospheric pressure. The synergistic effect of high temperature and pressure provides a one-step process to produce highly crystalline materials without the need of postannealing treatments.

It has formula $NiFe_2O_4$. For synthesis,1 mmol of nickel salt and 2 mmol of ferric salt dissolve in 80 ml deionized water follow by vigourous stirring to form uniform dark brown transparent solution. pH is maintained basic more than 8, mostly 12 or 13. Molar ratio 1:2 for the reaction with or without surfactant.

Fig. - Hydrothermal Autoclave (Teflon-lined)

In most cases surfactant like cetyltrimethylammonium bromide (CTAB), hexamethylenetetramine (HMT) etc. is added. Then solution is injected teflon lined/steel autoclave and put in an furnace at temperature more than 100°C to 220°C for required hours. After that it allows to cool naturally. Product collected and rinsed with copious amount of ethanol and deionized water for several times followed by vaccum drying in oven. Then it allows sintering at temperature 400-800°C for desired time in the electrical furnace. Zallite *et al*. [20] prepared nickel ferrite at different temperature 200-250°C, 1-3 hr, p=17-17.5 Mpa. After hydrothermal treatment, precipitate was filtered with water jet pump using 5 µm membrane filter and washed with distrill water, dried in oven at 40°C. Its particle size was found to be 22nm [20]. Nejati and Zabihi [21] prepared nickel ferrite at different temperature 45, 80, 100, 130 and 150°C for 18 hour. They maintained pH 10 with help of 5M triethylamine in ethylacetate solution. A product was dried at vaccum oven at 70°C for 3 hour. They used glycerol and sodium dodecyl sulfate as surfactant for preparation of ferrite, particle size is found to be 50-60nm. Miroslaw *et al*. [22] prepare nickel ferrite at pH 12 and with 240°C temperature for 8 hr then product were dried 60°C for 24 hr. Then it sintered at 1200°C for 1 hr, particle size is found to be 44.1nm. Dias *et al*. [23] prepared nickel ferrite at 175°C for 4 hr at pH 7.5. Product is washed with water and ethanol, centrifuged at 4000 rpm for 5 min then dried at 60°C. Hua *et al*. [24] prepared hexamethylenetetramine (HMT) assisted nickel ferrite by maintaining pH 13 at different temperature 140,160,180 and 200°C for 12 hr, particle size is found to be 81,69,63 and 46nm respectively. Hua *et al*. [25] prepared hexamethylenetetramine (HMT) assisted nickel ferrite by maintaining pH 13 at different temperature 140,160,180 and 200°C for 12 hr, particle size is found to be 81,69,63 and 46nm respectively.

Characterization Techniques

Ferrites are characterization and their property studied by using X-ray diffraction analysis (XRD), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Fourier transform infrared spectroscopy (FT-IR), Vibrating sample spectroscopy (VSM), UV-VISIBLE Spectroscopy, Cyclic Voltametry (CV), Electrochemical Impedance Spectroscopy (EIS).

Application

Nickel ferrite acts as catalyst in photocatalytic water oxidation using $[Ru(bpy)_3]^{2+}$ as a photosensitizer and $S_2O_8^{2-}$ as a sacrificial oxidant. Pourshojaei *et al*. [26] used nickel ferrite nanoparticles as magnetically recyclable nanocatalyst for synthesis of 4H-Chromene derivatives. They used 5 mole% catalyst with different solvents and different temperature and found yield upto 96%. Nickel ferrite also shows antibacterial activity. Vijay *et al*. [27] used nickel ferrite nanoparticles as photocatalytic degradation of irgalite violet dye. They found that dye was degraded completely within 60 min in presence of 0.15g of catalyst. Koli *et al*. [28] used modified Ni-Ferrite films as an effective sensor for industrial and environmental gas pollutant detection like LPG, Ammonia, ethanol, methanol, nitro, petrol vapours. Talukdar *et al*. [29] used nickel ferrite as inherent multiple fluorescence properties covering whole visible region and catalytic activity application. They found it is to be efficient in cell imaging. T also found that it has goog catalytic and photocatalytic activity in degradation of biologically and environmentally toxic pigments [billirubin and methylene blue]. Ana *et al*. [30] studied magnetic liposomes based nickel ferrite nanoparticles for biomedical application. Nickel ferrite is also used as catalyst in C-O bond formation in organic synthesis reactions.

Conclusion

Hydrothermal synthesis occurs with dissolution, precipitation, particle growth and structural reording. Hydrothermal synthesis gives magnetic nanomaterials with very high crystallinity because of its high-temperature and high-pressure reaction conditions. But in this method, it gives low yield of products. This method gives uniform crystallization ferrite. This does not require extremely high-processing temperature or sophisticated processing. Nickel ferrite has many applications such as catalyst in photocatalytic water oxidation, photocatalytic degradation, gas sensor, C-O bond formation in organic synthesis reactions, biomedical application etc.

Conflicts of interest: The authors stated that no conflicts of interest.

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