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FTIR SPECTROSCOPIC CHARACTERIZATION OF MANGANESE DOPED NICKEL OXIDE: UNDERSTANDING FUNCTIONAL GROUP MODIFICATIONS FOR DRUG DELIVERY

Amina Noor
Faculty of Sciences, The Superior University, Lahore, Pakistan.
Kanwal Akhtar*
Faculty of Sciences, The Superior University, Lahore, Pakistan.
Ayesha Younus
Department of Physics, Government College Women University, Faisalabad, Pakistan.
Yasir Javed
Department of Physics, University of Agriculture, Faisalabad, Pakistan.
Fayyaz Ahmad
Faculty of Sciences, The Superior University, Lahore, Pakistan.
Shehr Bano
Department of Physics, University of Agriculture, Faisalabad, Pakistan.
Umbar Zulfiqar
Faculty of Sciences, The Superior University, Lahore, Pakistan.
Tehseen Abbas
Faculty of Sciences, The Superior University, Lahore, Pakistan.
Muhammad Sohail Zafar
Faculty of Sciences, The Superior University, Lahore, Pakistan.
Muhammad Talha Naseer
Faculty of Sciences, The Superior University, Lahore, Pakistan

Article Info

Abstract

Nickel oxide doped manganese extends various biocompatible and biological interaction capacities, which results in superior stability. As such, Nio nanoparticles exhibit remarkable optical, electrical as well as magnetic properties that make them suitable for several biomedical applications. Further, additives enhance cosmetic properties of the particles, minimize toxicity while facilitating extended drug delivery. Hydrothermal technique enables the synthesis of Mn-doped Nio nanoparticles which are then analyzed through Fourier transform FTIR. FTIR spectra indicated molecular structure and bonding.

Keywords:
Nickel oxide, Hydrothermal method, Biomedical applications, targeted drug delivery, Biosensing, tissue engineering, Surface modification.

INTRODUCTION

Nanotechnology has affected every aspect of our lives, including biomedicine. The food, pharmaceutical, manufacturing, packaging, cosmetic, and agricultural industries have all made use of nanoparticles because of their unique electrical and physicochemical properties and their small size. Nanomaterials utilized for a variety of biomedical purposes are discussed, including metallic, nonmetallic/inorganic, and biodegradable materials. Nanotechnology has affected every facet of biomedicine, including tissue engineering, regenerative medicine, nano formulations and drug inject systems for treatments and imaging diagnostic techniques. Through the detection of many analytes in complex biological fluids including blood or blood-related substances, urine, saliva, and breath, smart nanoprobes that can diagnose diseases both inside and outside the body utilizing noninvasive and minimally invasive techniques. Numerous nano-based drug delivery technologies, such as liposomes, dendrimers, nanoparticles made of polymers, and made up of carbon nanocarriers, are being employed for targeted drug delivery. Drugs can be targeted passively or actively using nanocarriers that have been functionalized with different surface ligands. Oral, trans follicular, and pulmonary modalities are among the noninvasive drug delivery methods that have been established. Additionally, nanotechnology has made a substantial contribution to advancements in regenerative medicine and tissue engineering [1, 2].

Transition metal doping enhances the ferromagnetic behavior at room temperature of a NiO thin film by enhancing the valence defects within its lattice. Doping is one of the numerous changes used to enhance its physicochemical characteristics. Manganese (Mn) is an oxalate compound belonging to the 3d series. It is a hard and brittle transition metal and is isomorphous in nature. Manganese also has high melting and boiling points. Due to these specific characteristics of Mn, its doping in oxides of semiconductors can alter their material and structural properties. For this reason, Mn has been widely utilized as a dopant in the preparation of metal oxide semiconductor thin films [3].

Manganese is a chemical element with the atomic number 25 and the symbol Mn. This silvery, hard, and brittle metal is commonly found in minerals along with iron. Manganese resembles iron and is a silver-gray metal. It is difficult to melt but readily oxidized because to its hardness and brittleness.[4]. Nickel oxide is the chemical compound having the chemical formula Nio It is nickel's principal oxide. Nio is frequently non-stoichiometric, which means that the Ni:O ratio is not precisely 1:1, such as many other binary metal oxides. Melting point will be 1,955 °C **[5].**

The advanced characteristic of NPs is keeping their particle size, structure, sharing, and morphology in mind, which are reliable based on the preparation method. The different preparative methods have been modernized to synthesize NPs such as the sol–gel method, solvothermal method, electrochemical routes, hydrothermal reaction, and precipitation method are the most utilized methods for synthesizing the NPs. The hydrothermal synthesis-produced nanomaterials may become unstable at increasing temperatures [6, 7].

Doped nanoparticles have been produced using a variety of physical, chemical, and biological methods. The top-down strategy, which breaks down more visible precursors into smaller bits, and the bottom-up method, which makes up smaller units to make nanosized materials, are the two main ways to synthesize nanomaterials. The top-down approach used decomposition techniques, while the bottom-up approach use solvothermal processes. [8, 9] [10-12]. In the present research, nickel doped manganese nanoparticles were synthesized through hydrothermal process because it is low cost and simplest method. For the functional group analysis, FTIR was used for characterization analysis.

Experimental Section

Materials

Nickel (III) chloride hexahydrates ($NiCl_3 \cdot 6H_2O$), Manganese (II) chloride ($MnCl_2$) and sodium hydroxide ($NaOH$). Other analytical-quality solvents were bought from reliable vendors and utilized exactly as supplied, requiring no additional processing.

Method to prepare Manganese dopped Nickel Oxide

The hydrothermal process was used to prepare manganese-doped nickel oxide by following the given steps.

Preparation of Precursor Solutions

To make the precursor solutions, Manganese Chloride is first added to a beaker having distilled water and then stir for 12 minutes until a total dissolution takes place. After that, Nickel Chloride is also added in the same beaker and well-stirred to prepare a uniform mixture. Sodium hydroxide is added to distilled water in a different beaker, green color solution is obtained, and the mixture is stirred for 20 minutes to obtain dissolution and homogeneity.

Synthesis of Manganese-Doped Nickel Oxide

Then add the Sodium Hydroxide solution in first beaker drop wise through ppt. The mixture is stirred for 15 minutes to ensure complete dissolution. The solutions are now ready for further treatment, like mixing and Hydrothermal treatment, for synthesizing Manganese-doped Nickel Oxide. Check PH of the sample through PH paper .PH of pure Manganese dopped Nickle Oxide is 8. Manganese-doped nickel oxide (Mn-Nio) is synthesizing by way of a hydrothermal method by subjecting the solution to steam pressure in an autoclave. The synthesis makes it possible to create nanoparticles of Mn-Nio through enhancement of its crystallinity, decontaminating and also by controlling its particle size. Upon autoclaving, autoclave allows natural cooling down, or a helper may hasten this step. Upon coolness, a sample is gingerly taken from the autoclave with extra caution not to cause damage or contamination.

Post-Autoclaving Treatment

Manganese-doped nickel oxide nanoparticles are subjected to post-autoclaving treatment. This involves washing in distilled water or a suitable solvent to eliminate impurities and centrifugation to purify the solid product from the liquid. The purified manganese-doped nickel oxide nanoparticles are taken to a crucible and dried overnight in an oven to yield a dried sample. The sample is then grind to fine powder, that can be used for further analysis.

Results and Discussion

Fourier Transform Infrared (FTIR) spectroscopy was conducted to determine the functional groups and confirm the structural integrity of Mn dopped Nio. FTIR spectra of Mn dopped Nio exhibit characteristic bands in the region 600-700 cm^{-1}, corresponding to Ni–O bending modes, and prominent absorption peaks in the vicinity 1300–1500 cm^{-1}, corresponding to Nitrate groups, Stretching vibrations of nitrate ions (NO_3^-).

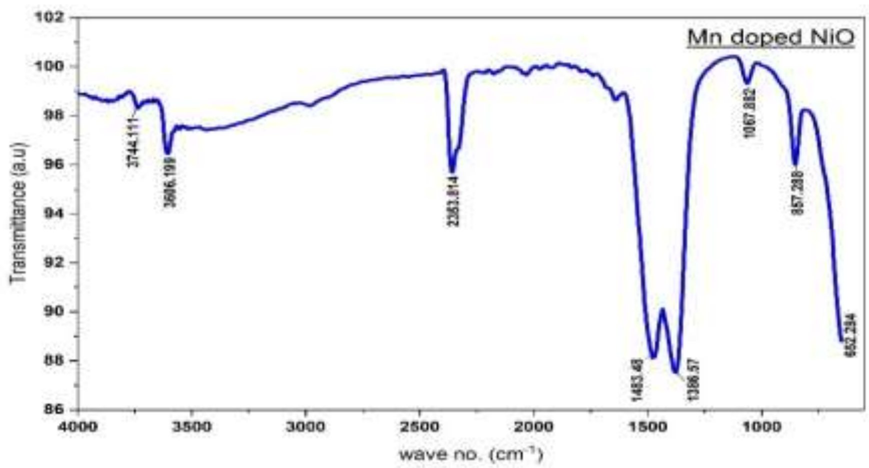

Fig. 1: FTIR graph of Mn dopped Nio

The Fourier transform infrared spectroscopy (FT-IR) method was successfully employed to prove the existence of various functional molecule groups incorporated in the synthesized Mn-doped Nio nanoparticle. With the help of FTIR analysis, the molecular fingerprint of the material was determined. [13]. The peaks in the Mn-doped Nio structure were found at certain wavenumbers, and this proves that Mn ions have been successfully incorporated into the Nio lattice. Mn-Nio has Ni-O and Mn-O bonds between 400-650 cm-1. [14]. FTIR results for Mn-doped NiO show characteristic Ni-O stretching vibrations in the 400-600 cm^{-1} range, confirming the formation of the NiO phase. Doping with Mn can cause a slight shift in these bands towards higher or lower wavenumbers, and the appearance of other peaks related to impurities. The strongest feature in FTIR spectra for Mn-doped Nio is the presence of absorption peaks within the mid-infrared region, usually about 400-650 cm^{-1}. These peaks are ascribed to the stretching vibrations of the Nio Ni-O and Mn-O bonds in the lattice. [15].

Conclusion and Recommendations

Doping is the deliberate addition of foreign elements to an element's vacant crystal lattice to modify that element's properties. It is a widely used technique to enhance the optical, electrical, chemical, biological, and physical properties of nanoparticles. Numerous factors, such as loading capacity, area of the surface, and the efficacy of drug encapsulation, are influenced by the nanoparticle's physicochemical properties. Doping is one of the numerous changes used to enhance its physicochemical characteristics. The dopant materials like cobalt, manganese, silver, nickel, transition and rare earth elements—have an impact on the material's modulation abilities and electrical structure. Certain metals' biological properties, such their antibacterial activity, have been enhanced by doping. Doping is also used to prevent cancer since it can influence the generation of ROS. The nanoparticles can be doped in several ways, including sol-gel, solvothermal, microwave-assisted, green synthesis, and laser ablation. Numerous techniques have been used to dope nanoparticles on different surfaces. Doped nanoparticles have been produced using a variety of physical, chemical, and biological methods. The top-down approach, which breaks down more visible predecessors into lesser bits, and the bottom-up method, which makes up smaller units to make nanomaterials, are the two main ways to produce nanosized materials. The top-down strategy employs decomposition techniques, whereas the bottom-up approach makes use of solvothermal processes. Sol-gel, sonication, dip-coating, laser ablation, burning, and arch discharge are some of the methods that have been used. The sol-gel method has become the popular technology because of its benefits, including the ease of use and the purity of its product. The introduction of Mn ions changes the electronic structure of NiO, which increases conductivity and fine-tunes the optical responses. FTIR spectroscopy confirms the existence of these functional groups and characteristic bonding vibrations, as evidence of the successful incorporation of Mn ions into the NiO lattice as well as the performance of the polymer coatings. This multifunctional nanomaterial shows promise in optoelectronics, energy storage, and biomedicine. Specifically, the synergy coated Mn doped nanomaterials provides a platform for developing advanced materials that present stability, biocompatibility, and improved electronic/optical functionalities.

References

McNamara, K. and S.A.J.A.i.P.X. Tofail, Nanoparticles in biomedical applications. 2017. 2(1): p. 54-88.

Abdalkreem, T.M.J.S.U.o.S. and K. Technology, Optical properties of gold and silver nanoparticles. 2018.

Rekha, K., et al., Structural, optical, photocatalytic and antibacterial activity of zinc oxide and manganese doped zinc oxide nanoparticles. 2010. 405(15): p. 3180-3185.

Choge, p., assessment of levels of selected heavy metals and coliform bacteria in soil and vegetables grown at Eldoret municipal dumpsite. 2015, university of Eldoret.

Sheena, P., et al., Influence of finite size and surface effects on the structural, electrical and magnetic properties of nanostructured nickel oxide. 2020. 31(7): p. 5769-5778.

Perkampus, H.-H., UV-VIS Spectroscopy and its Applications. 2013: Springer Science & Business Media.

Bharathy, G. and P.J.J.o.M.S.M.i.E. Raji, Room temperature ferromagnetic behavior of Mn doped NiO nanoparticles: a suitable electrode material for supercapacitors. 2017. 28(23): p. 17889-17895.

Zhang, D., et al., Dual-functional catalytic materials: magnetically hollow porous Ni-manganese oxides microspheres/cotton cellulose fiber. 2017. 77: p. 311-320.

Pulidindi, K., H.J.I.A.R. Pandey, Regional Outlook, Growth Potential, Price Trend, Competitive Market Share, and Forecast, Nanocellulose market size by product (nano fibrillated cellulose, nanocrystalline cellulose), by application (composites, paper processing, food & beverages, paints & coatings, oil & gas, personal care). 2020. 2026: p. 2020.

Mahmood, A., et al., Polyethylene glycol and chitosan functionalized manganese oxide nanoparticles for antimicrobial and anticancer activities. 2023. 648: p. 907-915.

Bharathala, S. and P. Sharma, Biomedical applications of nanoparticles, in Nanotechnology in modern animal biotechnology. 2019, Elsevier. p. 113-132.

Lucky, S.A., et al., Evolution in Morphological Features, Enhancement of Optical Transparency and Band Gap Broadening in Manganese Doped Nickel Oxide Thin Films for Optoelectronics Applications. 2025: p. 140651.

Thangamani, C., et al., Structural and size dependence magnetic properties of Mn-doped NiO nanoparticles prepared by wet chemical method. 2020. 31(14): p. 11101-11112.

1Vinodhini, P.A., et al., FTIR, XRD and DSC studies of nanochitosan, cellulose acetate and polyethylene glycol blend ultrafiltration membranes. 2017. 104: p. 1721-1729.

Nivedha, P., S. Monika, and S.J.M.T.P. Devikala, synthesis of Manganese (Mn) doped Nickel oxide nano particles, its antibacterial activity. 2022. 50: p. 380-383.