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A Study on Nano-Dimensional Mixed and Doped Ferrites

[1]Narender Kumar, [1]Anil Kumar, [2]Sunil Kumar

[1]Department of Physics, SunRise University, Alwar, Rajasthan, India

[2]Department of Physics, Chaudhary Ranbir Singh University, Jind, Haryana, India

**** Corresponding author*** *Tel: +919236780000, E-mail: nk.physics15@gmail.com*

Abstract:

Nano-dimensional ferrite material is a multiphase solid material whose one of the phases has one, two, or three dimensions is less than 100 nanometres (nm). The idea behind Nano-dimensional is to use building blocks with dimensions in the nanometre range to enhance the physical properties of materials and to design new materials having outstanding flexibility. Recently, researchers are more attracted to Mixed/Doped ferrite due to their properties like high magnetic coercivities, high magnetic saturation, high structural stability, better electromagnetic performances, and improved conductivity values. Mixed/Doped ferrite contains a compound with the formula $A_xB_{1-x}Fe_3O_4$, where A and B are transition metals of the eighth group Mixed/Doped ferrite can exert the harmonious effect of transition metal ions, due to which stability and magnetic performance with broad potential window are improved. Currently, in Magneto electronic devices and electromagnetic types of equipment the mixed/Doped ferrite, Like $CoFe_2O_4/SiO_2$, $Mn/ZnFe_2O_4$, and $Co/ZnFe_2O_4$ play an important role. Mixed/Doped ferrite also plays an important role in the electronic industry, solid-state physics, high-frequency devices, and mobile communication of information technology.

Keywords: Multiphase material, Nano dimensions, Mixed/Doped ferrite.

Introduction

At present, due to the special properties of nano dimensional metal ferrites, like structural, chemical, physical, etc. scientists have great interest in it. These properties are expanded from insulating to semiconductors and conductors [1]. The field of nano-dimensional ferrite is large, but this field expands more in the case of Mixed/Doped ferrite, where extra attractive properties are existent. Because of a diversity of potential applications in many areas, research on nano dimensions of Mixed/Doped ferrite is an area of deep scientific activity. The Mixed/Doped nano-dimensional ferrites are among the widest-used manufactured materials due to their distinctive properties [2]. There are many properties of nanophase structure like higher ductility, sensitivity, special catalytic and super-paramagnetic behaviour, selective activity, and cold-welding properties which make it an essential tool in modern nanotechnology. For example, in the case of the identical composition of bulk material and nanosized material, the melting point is lower for the nanosized material [3]. At the same time, Nano-dimensional shows fast diffusivities and surprising adsorptive properties and in critical conditions, some nano-dimensional ferrites are found unstable [4].

The electronic, chemical, and magnetic properties of Mixed/Doped ferrites are of size-dependent, which depends on the size of the specimen. The distinct physical and chemical properties of nano dimensional mixed/Doped metal ferrite are assigned to the high density and limited size of corners and edges on their surface [5]. Scientists; with considerable interest in electronics, materials chemistry, agriculture, energy, medicine, catalysis, environment, information technology, optical, and biomedical field are attracted to nano dimensional Mixed/Doped ferrite, because of their potential technological applications [6]. The number of surface and interface atoms increases with a decrease in size which leads to stress/strain and adjoining structural perturbations. The specific size of the Nano-dimensional can change the chemical, magnetic, electronic, and conducting properties [7]. The magnetic properties of Nano-dimensional ferrites can be changed with their shape and size due to which they gained much interest. The authors of the article dare to state that through this study they are in a state to represent a brief account of Nano-dimensional mixed/doped ferrite, which may be useful to scholars working in the field of technological magnetic materials.

Applications:

Materials scientists show interest in the Mixed/Doped Nano-dimensional Iron ferrites because they are attached through a series of potential applications, extending from magnetic storage devices (MSD) to magnetic resonance imaging (MRI) contrast agents. The γ-Fe_2O_3 nanoparticles show Size-dependency, the ferromagnetic behaviour of nanoparticles at 55nm changes into super-paramagnetic behaviour without hysteresis at 12 nm [8]. The total magnetic anisotropy also decreases with a decrease in particle

size while inducing the change to super-paramagnetic. To attain electronic, chemical, and magnetic properties, easy and Innovative methods of producing required sized Nano-dimensional metal ferrite are necessary. Electrical properties i.e. conductance is a property that depends on the size of these particles mainly using ferrites like $CoFe_2O_4/SiO_2$ and $Co/ZnFe_2O_4$in gas sensing applications [9]. Mixed/Doped Nano dimensions ferrites have many approaching applications for upgrading magnetic switches and many other fields of magneto-electronic [10]. Electrical or ionic conductivity is that property of Mixed/Doped ferrite which needs to adjust to discover the utility in the field of photo-Voltic, Opto-electronics, or highly used sensors. At high temperatures Mixed/Doped Nano dimensions ferrites $Co/Ni/Zn/Fe_2O_4$ are best known for their low dielectric loss, large permeability, high electric resistivity, and unique magnetic structure. Due to these properties, they are widely used in electronic devices such as magnetic heads, magnetic resonance imaging, filters, gas sensors, supercapacitors, and fuel cells. Hence it is very difficult/challenging to prepare magnetic nanoparticles with bulk magnetic properties. Moreover, ferrite nanostructures highly depend on the preparation process in which the annealing temperature of synthesis directly affects magnetic and electric properties. To eliminate gaseous air pollutants like CO, CO_2, SO_x, and NO_x Mixed/Doped ferrites like $Co/ZnFe_2O_4$, and $Mn/ZnFe_2O_4$with nano-dimensions are used as a material for scrubbers in various chemical industries [11]. Nano-dimensional Mixed/Doped metal ferrite is also use [12]. At low temperatures, for new optical and electronics applications the Mixed/Doped ferrite catalyst having CuO doped with CoFe2O4 is used in surface-catalyzed systems. Similarly, Ga2O3 doped with ZnFe2O4 is used in broad bandgap catalysts and provides a wide range of light emissions. To utilize the potential of β-Ga2O3 for optoelectronic applications it is recently doped in CoFe2O4[13].

In photoconductive, photothermal, and many oxidation processes applications CuO nanoparticles are doped with CoFe2O4 and used as a redox catalyst [14]. Mixed/Doped $ZnO/CoFe_2O_4$ with Nano dimensions are used in many industrial applications like photocatalysis to eliminate pollutants as well as in engineering& material science[15].

In many chemical reactions within the lattice, oxygen storage capacity & mobility of cubic fluorite type CeO_2 is high, due to which cerium-doped ferrite shows great catalytic activity. Cerium easily changes between Ce^{3+} and Ce^{4+} states. Bulk pure ceria shows lower catalytic performance and poor morphology [16] but CeO_2 doped with ferrite Like ($CoFe_2O_4/SiO_2$ and $Co/ZnFe_2O_4$) shows better properties [17].

Mixed/DopedCeO_2/Y_2O_3Nano dimensions are used in many fields like gas sensing, catalysis, electrochemistry, material chemistry, and the biomedical field. On irradiation of UV/visible light degradation of cationic dye Rhodamine- B dye takes place due to which photocatalytic decomposition effect of Mixed/DopedCeO_2/Y_2O_3Nano-dimensional enhanced.

Because of the mixing/doping mentioned above, nano-dimensional ferrite offers higher thermal stability, improved structural properties, low-temperature redox functionality, oxygen storage capacity, and better magnetic properties.

Currently, sensor technology is the most influential technology having applications that grow continuously in both private and government sectors. It could be on top as a future technology for the coming decades.

Gas sensors

In gas sensing research, for scientist, it becomes a priority to develop a reliable and high-performing gas sensor that can monitor accurately at room temperature. In past, due to properties like low cost, easy handling, the broad range of target gases, fast response, and longer lifetime of metal ferrite semiconductors, these are commonly used as sensing materials. But they also have some disadvantages like lower selectivity and higher energy consumption. To overcome these disadvantages of ferrite semi-conductors Mixed/Doped ferrite is used.

Mixed/Doped metal ferritelike$CoFe_2O_4/MnFe_2O_4$ have properties like large surface-to-volume ratios, more surface-active sites, and high specific surface areas having surface reactivity very high. Because of these properties, $CoFe_2O_4/MnFe_2O_4$ are applied toward gas sensing. The number of reactive surface sites and adsorption of oxygen species define the mechanism of gas sensors which further increase the number of surface reactive sites. Surface conductivity is increased by oxygen vacancies and decreases with absorbed ions, this makes the dependency on the surface conductivity of the Mixed/Doped ferrite on surface stoichiometry. At present time there are many fields in which Gas sensing is receiving collective consideration. For example, Biomedical applications, industrial production in hospitals, and environmental monitoring. High sensitivity, low energy consumption, rapid lower response time, signal stability, good reproducibility, and long-term monitoring are some factors that show the great performance of gas sensors.

Batteries

In the past time, due to environmental concern scientist does not consider rechargeable batteries worthy but presently scientists found rechargeable batteries are good scope in energy applications. Lithium-ion batteries have long life cycles and energy density high due to which LIBs are massively used in electric & hybrid vehicles and in the field of portable electronic devices. For future energy storage devices, advanced electrode materials are the best option. To increase the LIBs performance, scientists developed novel electrode material with nano Mixed/Doped ferrite. However, some Mixed/Doped nano metal ferrite anodes have electrical conductivity or cycling performance low which can be improved by mixing them with electrolytes.

For lithium-ion batteries, Mixed/Doped metals ferrites are good alternative anode materials because of their high theoretical specific capacity. The Mixed/Doped metal ferrite CuO-ZnO has good chemical stability, is environment friendly, non-toxic, and has good theoretical capacity making this Mixed/Doped metal ferrite a good option in energy applications. But there are some drawbacks of Mixed/Doped CuO-ZnO Nano-dimensional like large irreversibility, expansion, and rate limitations which restricted its development in some fields. To control drawbacks like these we need to improve the performance of Mixed/Doped CuO-ZnO

Nano- dimensional ferrites and nanostructure design, by controlling morphology and composite preparation are some methods which increase the performance of Mixed/Doped CuO-ZnO based ferrites

Solar cells

In solar cells, conductive material absorbs light, and charge carriers are generated. Transmission of electricity takes place when charge carriers are separated from a conductive material Mixed/Doped ferrite has exceptional flexible properties which make Mixed/Doped ferrites tunning material for new-generation photovoltaics. Several Mixed/Doped ferrites are used as photo-harvesters due to their broad bandgap energy range and high tunability. Due to exclusive properties & functionality, the Mixed/Doped ferrite are used as transparent electrodes, light absorbers, and transport layers in photovoltaics.

The energy loss can be minimized by using p-type materials CuO&Cu2O because they have low-lying valence bands. However, CuO and Cu2O are not appropriate for window layer materials in solar cells because they have narrow band-gap due to which light absorption of the photoactive layer is affected. To overcome these drawbacks, we need a low-temperature solution-processable Mixed/Doped metal ferrite and copper-chromium Mixed/Doped metal ferrite to meet expectations.

In solar cells, the Mixed/Doped metal ferrite of copper-chromium is used because they have a wide bandgap as compared to the copper ferrite. Nano-dimensional of copper-chromium Mixed/Doped metal ferrite has a suitable energy level for hole transporting and electron blocking. At low temperatures, to gain high power conversion efficiency in solar cells copper-chromium Mixed/Doped metal ferrite hole transport layer is used.

Antennas

Antennas are used to convert electromagnetic radiation into electrical current in space. In past decades, rigid metals without impurities are good conductors. Although metals were oxidized, which is the major problem to use metals in antennas. For electric antennas, few conductive materials attain effective parameters but they also have some drawbacks like non-transparency & it's tough to integrate on malleable carriers. So scientists are searching for alternative source which overcomes these drawbacks and they found that the mixed/Dopedferrite are stable enough to be used as antennas. Au/VO2 Mixed/Doped metal ferrite is an effective material for antennas. Vanadium ferrite (VO2) has the property that it can changes into a conductor from an insulator instantaneously. Au coupled with VO2 is a Mixed/Doped metal ferrite that behaves as a metamaterial which is efficient in controlling electromagnetic waves.

Conclusion

In many fields like agriculture, food, medicine, energy conversion, catalysis, magnetic storage media & textile Nano-dimensional Mixed/Doped ferrite became a remarkable component. Due to nanoarchitecture and ordered structure of Nano-dimensional of Mixed/Doped ferrite, they became worthy to design batteries, gas sensors, solar cells, and antennas with improved properties. With time as nanotechnology has grown up, many excellent applications of Nano-dimensional of Mixed/Doped ferrite in fields of optical imaging, antennas, data storage, energy conversion, etc. appear. There is a huge number of advantages in many fields because of a vast number of different Mixed/Doped ferrite & their excellent properties. Some important (gas sensors, batteries, solar cells, and antennas) are discussed herein. The importance of nanotechnology increases rapidly in technical and scientific fields day by day and for researchers who are working on devices with novel designs, this study could be beneficial.

References

1. Akther Hossain AKM, Mahmud ST, Seki M, Kawai T, Tabata H J MagnMagn Mater 312:210–219,2007
2. Bahgat M, Farghaly FE, Abdel Basir SM, Fouad OA J MaterProcess Technol 183:117,2007
3. D. K. Sar, P. Nayak, and K. K. Nanda, "Thermodynamic model for the size-dependent melting of prism-shaped nanoparticles," *Physics Letters A*, vol. 372, no. 25, pp. 4627–4629, 2008.
4. W. S. Galvão, D. M. A. Neto, R. M. Freire and P. B. A. Fechine, Super-Paramagnetic Nanoparticles with Spinel Structure: A Review of Synthesis and Biomedical Applications, *Solid State Phenom.*, 241, 139–176, 2015
5. Deraz NM and Alarifi "A Structural, morphological and magnetic properties of nanocrystalline zinc substituted cobalt ferrite system"*Journal of analytical and applied pyrolysis*94 pp 41–47,2012
6. Chand, P.; Vaish, S.; Kumar, P. Structural, optical and dielectric properties of transition metal (MFe2O4; M = Co, Ni and Zn) nanoferrites. Phys. B Condens Matter, 524, pp 53–63, 2017
7. A. Ali, H. Zafar, M. Zia, I. UlHaq, A.R. Phull, J.S. Ali, A. Hussain, "**Synthesis, characterization, applications, and challenges of iron oxide nanoparticles"** Nanotechnol. Sci. Appl., 9, pp. 49-67, 2016
8. Gubin S.P., Koksharov Y.A., Khomutov G.B., Yurkov G.Y. "Magnetic nanoparticles: Preparation, structure and properties". *Russ. Chem. Rev.*74:489–520,2005.
9. Chand, P.; Vaish, S.; Kumar, P. "Structural, optical and dielectric properties of transition metal (MFe2O4; M = Co, Ni and Zn) nanoferrites". Phys. B Condens Matter, 524, 53–63,2017.
10. Gupta, R.; Sagade, A.A.; Kulkarni, G.U. "A low cost optical hydrogen sensing device using nanocrystalline Pd grating". Intl. J. Hydr. Ener, 37, 9443–9449,2012.
11. P. Sivakumar, R. Ramesh, A. Ramanand, S. Ponnusamy, and C. Muthamizhchelvan, "Synthesis and characterization of $NiFe_2O_4$ nanosheet via polymer assisted co-precipitation method," *Materials Letters*, vol. 65, no. 3, pp. 483–485, 2011.

12. Taylor R, Coulombe S, Otanicar T, Phelan P, Gunawan A, Lv W, Rosengarten G, Prasher R, Tyagi H "Small particles, big impacts: a review of the diverse applications of nanofluids". Appl Phys 113:011301, 2013
13. C. Janowitz, V. Scherer, M. Mohamed, A. Krapf, H. Dwelk, R. Manzke, et al., " Experimental electronic structure of In 2 O 3 and Ga 2 O 3 ", *New J. Phys.*, vol. 13, pp. 085014, Aug. 2011.
14. S.A. Abouelmagd, F. Meng, B.-K. Kim, H. Hyun, Y. Yeo, "Tannic acid-mediated surface functionalization of polymeric nanoparticlesACSBiomater". Sci. Eng. p. 6b00497, 2016.
15. A. Kusior, J. Klich-Kafel, A. Trenczek-Zajac, K. Swierczek, M. Radecka, and K. Zakrzewska, "TiO_2–SnO_2 nanomaterials for gas sensing and photocatalysis," *Journal of the European Ceramic Society*, vol. 33, no. 12, pp. 2285–2290, 2013.
16. S. Jafari, B. Tryba, E. Kusiak-Nejman, J. Kapica-Kozar, A. W. Morawski, and M. Sillanpää, "The role of adsorption in the photocatalytic decomposition of Orange II on carbon-modified TiO_2," *Journal of Molecular Liquids*, vol. 220, pp. 504–512, 2016.
17. Lu AH, Salabas EL, Schüth F. Magnetic nanoparticles: synthesis, protection, functionalization, and application. AngewChemie Int Ed. 2007;46(8):1222–44