International Journal of Academic and Applied Research (IJAAR)
ISSN: 2643-9603
Vol. 7 Issue 1, January - 2023, Pages: 1-5

Structural Properties of thin film fabricated from Iron Oxide (Fe_3O_4) and Nickel Oxide (Ni_2O_3) Nanoparticles

[1]Adam Mohammed Adam Bakheet, [2]Emtithal Ahmed Jadallah, [3]Al desogi Omer Hamed[3], [4,5]Abdalsakhi. S. Mohammed and [2,4]Mona. A. Abdalrasool

[1]University of Gezira- Faculty of Science - Department of Physics and Astronomy - Madani -Sudan
[2] Sudan University of Science & Technology-College of Science - Department of Physics -Khartoum – Sudan
[3]Kordfan University -Faculty of Science - Department of physics- Alobaid –Sudan
[4]Alneenlen University - Faculty of Science and Technology –Laser and Renewable Energy Department- Khartoum – Sudan
[5]Alneenlen University - Renewable and Alternative Energy Researches Center - Khartoum – Sudan

Abstract: *In this study, Iron oxide (Fe_3O_4) and Nickel oxide (Ni_2O_3) Nano-material samples were prepared by sol-gel method and used for fabricated thin films with different thicknesses (55.25, 78.7, 90.9 144.9 and 263.15) nm. The structural properties were studied using X-ray diffraction technique (XRD). The crystal system of Iron oxide and Nickle oxide were cubic and hexagonal respectively, the structural properties (density, particles size and d-space) increase with thin film thickness increase expect dislocation density which decrease with thickness increase, the density of Iron oxide samples increases by rate (0.00405 mg. cm^{-3}/nm) with thickness increase but for Nickel Oxide increase by rate (0.001129 mg. cm^{-3}/nm), The crystals size of Iron oxide increases by rate 0.04757 and Nickel oxide by rate 0.01577 with thickness samples ,the dislocation density of Iron oxide decreased by rate 0.00184 nm^{-2}/nm but for Nickel oxide decreased by rate 0.00449 nm^{-2}/nm for Iron oxide the d- spacing increased by rate 0.000494 of and or Niekcel Oxide increased by rate 0.002786.*

Keywords: thin film, Nickel Oxide, Iron Oxide, XRD and dislocation density.

Introduction

Nanoscale materials have recently revealed novel applications in a variety of technological fields [1]. Because of their unique, optical, catalytic, electrical, and magnetic characteristics and enhanced physical characteristics such as thermal, or chemical and mechanical, metal oxide nanoparticles are widely employed for many applications like magnetic materials, cosmetics, batteries, pharmaceuticals, catalysts, optical devices, protective coatings structured materials, and biomaterials [2–5]. Thus, the preparation of metal oxide semiconductors with different sizes and morphology has gained significant attention due to their excellent chemical stability and thermal property [6]. Among different nanomaterials, NiO and FeO nanoparticles (NPs) have been extensively employed in many applications such as electro-optical devices, gas sensors, photocatalysts, antimicrobial agents, antibiotics, and electrode materials. Nickel Oxide (NiO) is an important transition metal oxide with cubic lattice structure with wide intrinsic band gap of ~3.6 eV. Among the magnetic nanoparticles, fabrication of nickel nanoparticles (NPS) is often more difficult than that of the other particles, this is because they are easily oxidized. To achieve pure nickel nano-crystals, numerous methods have been conducted in organic environments in order to prevent formation of hydroxide or oxidation [7-9]. Iron oxide nanoparticles (NPs) have attracted much consideration due to their unique properties, such as super paramagnetic, surface-to-volume ratio, greater surface area, and easy separation methodology, it has cubic crystal system and band gap about 2.2 eV. Various physical, chemical, and biological methods have been adopted to synthesize NPs with suitable surface chemistry [10]. Thin films have number of applications in various fields. Few of them are A.R. coating, interference filters, polarisers, narrow band filters, solar cells, photoconductors, IR detectors, waveguide coatings. Temperature control of satellites, photo thermal solar coatings such as black chrome, nickel, cobalt etc., magnetic films, superconducting films, anticorrosive films, microelectronics devices, diamond films, reduction of fabrication through coating or surface modification i.e. epitaxy and heterostructure films, high temperature wear resistance films, hard coatings [11,12]. The aim of this work is to study is study the structural properties of Nickel Oxide and Iron Oxide thin films.

Material and Method

Nickel oxide (Ni_2O_3) and Iron oxide (Fe_3O_4) were prepared from nickel nitrate hexahydrate ($Ni(NO_3)_2.6H_2O$) (6.6 g dissolved in 508 mL deionized water) and Ferric nitrate nonahydrate ($Fe(NO_3)_3.9H_2O$)(40.4 g dissolved in 515 mL deionized water) respectively (0.1M of each),each solution was but in the magnetic stirrer at 700C for 90 min and we were added methanol to accelerate the reaction, after 90 min the colour of Nickel solution was change from dark green to white green however , the Iron solution was change from white yellow to brown. Nickel oxide and Iron oxide thin films were prepared by spread a 0.1 M solutions of nickel nitrate and ferric nitrate onto the pre-heated amorphous glass substrates kept at (390˚C ± 10˚) C using spin coater. Film thickness was measured by using the weight difference method considering the substrate surface area and the density of the bulk Nickel oxide and Iron oxide. As the density of thin films was certainly lower than the bulk density. The structural properties of the films were investigated using X-ray diffractometer (XRD)

Results and Discussion

The crystal structure of all samples characterized at room temperature using a Philips PW1700 X-ray diffract meter (operated at 40 kV and current of 30 mA) and samples were scanned between 10º and 80º at a scanning speed of 0.06 ºC/s using Cu Kα radiation with λ = 1.5418Å.

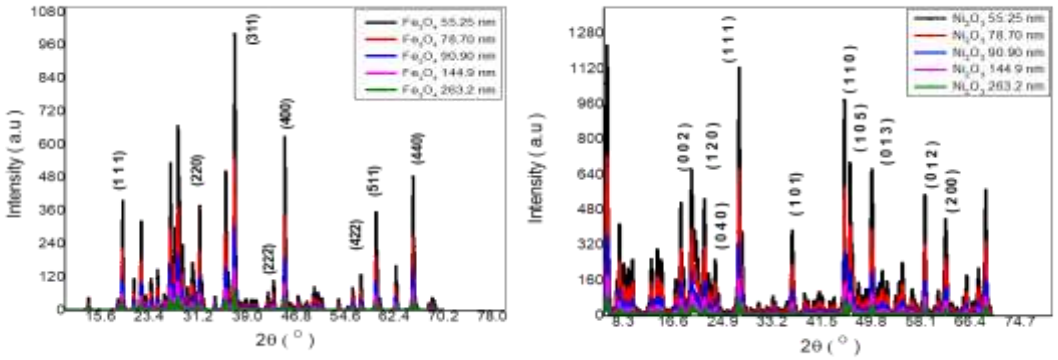

Fig (1): the XRD pattern of Fe_3O_4 and Ni_2O_3 samples

The crystal structure of all samples characterized at room temperature using a Philips PW1700 X-ray diffractometer (operated at 40 kV and current of 30 mA) and samples were scanned between 10^O and 80^O at a scanning speed of 0.06 ºC/s using Cu Kα radiation with λ = 1.5418Å. The representative XRD charts of all samples (Iron and Nickel) Oxide as show in fig (1) and fig (2). The Miller indices of Iron Oxide are (111) at 19.14 ^{O}, (220) at 31.39 ^{O}, (311) at 36.96 ^{O}, (222) at 38.79 ^{O}, (400) at 44.96 ^{O}, (422) at 55.70^O , (511) at 59.4^O and (440) at 65.35 ^{O} , the major lattice planes in the XRD patterns confirms the formation of spinel (Cubic /F-Center), (Cubic /Primitive) and (Cubic /I-Center) while Miller indices for Nickel Oxide are (002) at 17.5 ^{O}, (120) at 19.5 ^{O}, (040) at 22.1 ^{O}, (111) at 27.7 ^{O}, (101) at 36.4 ^{O}, (110) at 45.25^O, (105) at 46.14^O, (013) at 49.69 ^{O} , (012) at 58.4 ^{0} and (200) at 62.38 ^{0} and it is confirms the formation of spinel (Hexagonal/ Primitive) .

Table (1) some crystallite lattice parameter (c-form, a, b, c, β, α, γ, density, Xs (nm) and d – spacing) of all samples that made by five Fe_3O_4 (Iron Oxide) sample.

thickness (nm)	a=b=c (10^{-10}) m	Density ($g.cm^{-3}$)	Particle size Xs(nm)	Dislocation density δ (nm^{-2}) ×10^{-4}	d-spacing (A^o)
55.25	8.09	4.857	55.05	3.299782792	2.0297
78.7	8.39	5.102	56.06	3.181953386	2.21935
90.9	8.39	5.2071	56.10	3.177417459	2.22425
144.9	8.35	5.2071	62.95	2.523530343	2.6007
263.2	9.4	5.808	64.25	2.422443943	3.59315

Table (2) some crystallite lattice parameter (c- form, a, b, c, β, α, γ, density, Xs (nm) and d – spacing) of all samples that mead by five Ni_2O_3 (Nickel Oxide) sample

thickness (nm)	a=b (10^{-10}) m	c (10^{-10}) m	Density ($g.cm^{-3}$)	Particle size Xs (nm)	Dislocation density δ (nm^{-2}) ×10^{-4}	d-spacing (A^o)
55.25	4.61	5.61	5.3175	53	3.55998576	5.3175
78.7	4.61	5.61	5.3175	55.75	3.217438517	5.3175
90.9	4.523	7.36	5.434	56.15	3.171761176	5.434
144.9	2.955	7.227	6.803	57.03	3.074632807	6.803
263.2	2.818	20.56	7.435	57.44	3.030896719	7.435

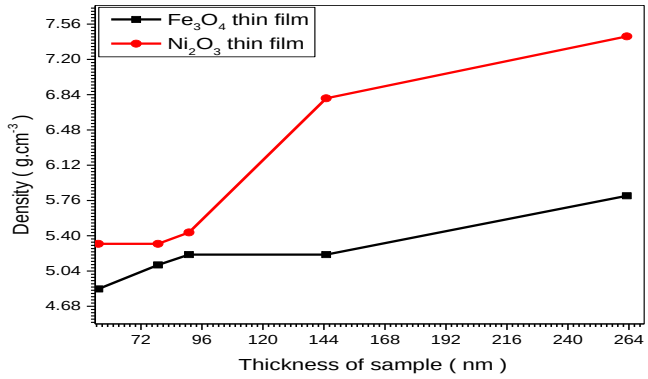

Fig (2) the relationship between thicknesses and density of Fe_3O_4 and Ni_2O_3 samples

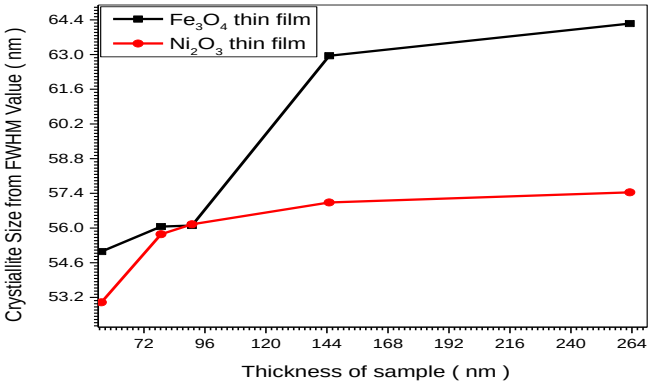

Fig (3) the relationship between thicknesses and crystal size of Fe_3O_4 and Ni_2O_3 samples

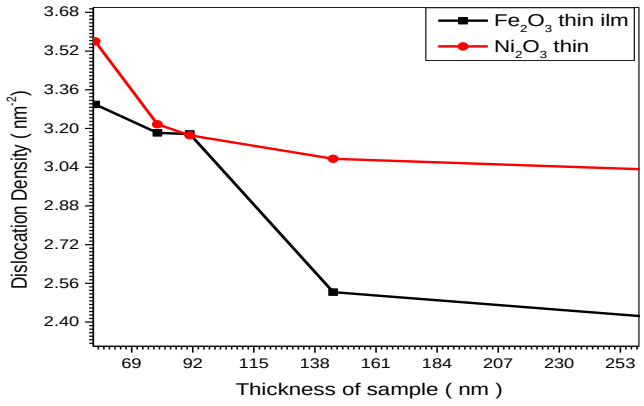

Fig (4) relationship between thicknesses and dislocation density Fe_3O_4 and Ni_2O_3 samples

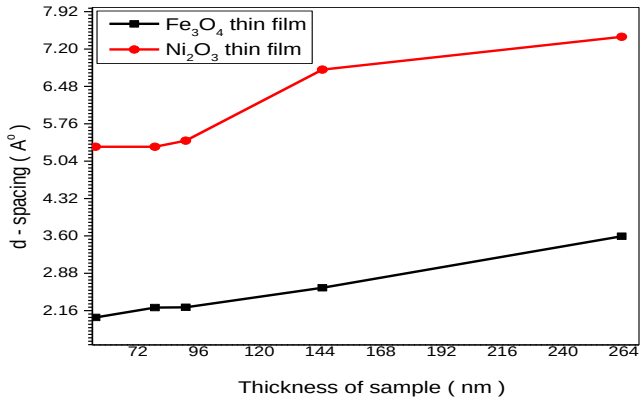

Fig (5) relationship between thicknesses and d- space of Fe_3O_4 and Ni_2O_3 samples

Table (1) and table (2) shows the XRD parameters of all (Iron and Nickel) Oxide samples at various crystalline orientations. Fig (2) describes the relation between thickness of (Iron and Niekcel) Oxide and density of all samples, it was observed that density of Iron Oxide samples increases when thickness of the thin film increases by rat (0.00405 mg. cm^{-3}/nm) but for Nickel Oxide increase by rate (0.001129 mg. cm^{-3}/nm). The dislocation density (δ) of (Iron or Nickel) Oxide samples nanoparticles were calculated and listed in table (1) and (2) respectively, from fig (4) the dislocation density of Iron oxide decreased by rate 0.00184 nm^{-2}/nm but for Nickel oxide decreased by rate 0.00449 nm^{-2}/nm. Fig (3) shows the relation between the (Iron and Niekcel)thin films theckness and crystallite size. The crystals size of Iron and Niekcel oxide rated of with thickness increases by rated 0.04757 samples and 0.01577 for Iron Oxide and Nickel Oxide samples respectively. Finally, fig (5) describes the relation between the thickness of (Iron and Niekcel) Oxide and d- spesing of all samples, for Iron oxide the d- spacing increased by rate 0.000494 of and or Niekcel Oxide increased by rate 0.002786.

Conclusion

Nickel Oxide Ni_2O_3 and Iron Oxide Fe_3O_4 Thin films were fabricated with different thicknesses, the crystal form of fabricated thin films confirm with the previous studies (cubic system for Fe_3O_4 and hexagonal for Ni_2O_3), all structure properties studied (density, particles size and d-space) increase with thickness increase expect dislocation density which decrease with thickness increase.

References

[1] Taghizadeh, F, (2016), the Study of Structural and Magnetic Properties of NiO Nanoparticles. Optics and Photonics Journal, Volume (6), pages (164-169). http://dx.doi.org/10.4236/opj.2016.68B027

[2] Attarad Ali, HiraZafar, Muhammad Zia, IhsanulHaq, Abdul RehmanPhull, JohamSarfraz Ali, AltafHussain,(2016), Synthesis characterization, applications, and challenges of iron oxide nanoparticles, Nanotechnology, Science and Applications , Volume (9), pages (49–67).

[3] Ababay Ketema Worku and et al, Structural and thermal properties of pure and chromium doped zinc oxide nanoparticles, Springer Natural Journal, SN Applied Sciences, 13 June 2021.

[4] Suvardhan Kanchi and Shakeel Ahmed, Green Metal Nanoparticles-Synthesis, Characterization and their Applications, first published by John Wiley & Sons, Inc ,2018.

[5] Malkiat S. Johal and Lewis E. Johnson, Understanding Nanomaterials, Second Edition, CRC Press, Taylor & Francis Group, 2018.

[6] Taghizadeh, F., the Study of Structural and Magnetic Properties of NiO Nanoparticles. Optics and Photonics Journal, Volume (6), 2016, pages (164-169) ..

[7] Aliakbar Dehno Khalaji, Nickel Oxide (NiO) nanoparticles prepared by solid-state thermal decomposition of Nickel (II) schiff base precursor, Journal of Ultrafine Grained and Nanostructured Materials, Vol.48, No.1, June 2015, pp.1-4.

[8] M. Naseem Siddique and et al, Investigation of optical properties of nickel oxide nanostructures using photoluminescence and diffuse reflectance spectroscopy, 2nd International Conference on Condensed Matter and Applied Physics (ICC 2017), puplished by American Institute of Physics, 2018.

[9] Israa Muzahem Rashid and et al, Green Synthesis of Nickle Oxide Nanoparticles for Adsorption of Dyes, Sains Malaysiana 51(2): 533-546, 2022.

[10]Attarad Ali, HiraZafar, Muhammad Zia, IhsanulHaq, Abdul RehmanPhull, JohamSarfraz Ali, AltafHussain, Synthesis, characterization, applications, and challenges of iron oxide nanoparticles, Nanotechnology, Science and Applications , Volume (9), (2016), pages (49–67).

[11] Maryna V. Ved and et al, Nanostructured Functional Coatings of Iron Family Metals with Refractory Elements, Nanochemistry, Biotechnology, Nanomaterials, and Their Applications, Selected Proceedings of the 5th International Conference Nanotechnology and Nanomaterials (NANO2017), August 23–26, 2017, Chernivtsi, Ukraine, springer, 2018.

[12] M. P. Deshpande Kiran N. Patel, Vivek P. Gujarati, Kamakshi Patel and S. H. Chaki, Structural, Thermal and Optical Properties of Nickel Oxide (NiO) Nanoparticles Synthesized by Chemical Precipitation Method, Advanced Materials Research, Vol. 1141, pp 65-71, 2016.