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Optical and Electrical Conductivity of Fe_3O_4 and Ni_2O_3 Thin Films through Optical Method

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Abstract: *In this work, the spin coating method was used to prepare thin films of samples of Nickel Oxide (Ni_2O_3) and Iron Oxide (Fe_3O_4) deposited on an ITO glass substrate with varying thicknesses (55.25, 78.7, 90.9, 144.9, and 263.15) for each. The optical method was used to determine the electrical and optical conductivity. The maximum values of optical conductivity equal $1.07x10^{15}$ sec^{-1}) for Ni_2O_3 and $1.05x10^{15}$ sec^{-1}) for Fe_3O_4 while the maximum values of electrical conductivity and optical conductivity is 37 Ω^{-1} for Ni_2O_3 and 35 Ω^{-1} for Fe_3O_4, for both samples thickness 263.1 nm has maximum value of optical and electrical conductivity.*

Keyword: thin film, Nickel Oxide, Iron Oxide, Optical Conductivity and Electrical Conductivity.

Introduction

In comparison to bulk solid materials, nanoparticles exhibit novel properties. The various effects, such as the small size effect, surface effect, quantum size effect, macroscopic quantum tunnel effect, and so forth, account for this variation in properties. Due to their numerous potential uses, nanocrystalline transition metal oxides have garnered a lot of attention in recent years. Nickel oxide (NiO) is an attractive material due to its chemical stability [1,2]. Nickel oxide (NiO) is an attractive material due to its chemical stability [3]. NiO with cubic lattice structure has a wide intrinsic band gap of ~3.6 eV. It shows interesting optical, electrical and magnetic properties. It is a promising candidate for wide range of applications such as smart windows, gas sensors, catalysts, anode material in Li ion batteries and nanoscale optoelectronic devices like electrochromic display [4,5]. Moreover, nanocrystalline NiO powder shows super parmagnetism effect which can be used for drug delivery and MRI (magnetic resonance imaging) agent [6]. Iron oxide (Fe2O3) nanomaterials have attracted special attention from the research fields due to the highly applicable and versatile in the supercapacitors, catalysis and drug delivery [7]. Iron oxides occur in many forms in nature, with magnetite (Fe_3O_4), maghemite (γ- Fe_3O_4), and hematite (α- Fe_3O_4) being probably the most common. Hematite (α- Fe_3O_4) is the one most important type of the iron oxides and widespread in rocks and soils. Hematite (α- Fe_3O_4) has a hexagonal unit cell in which two-thirds of the octahedral sites are occupied by Fe2+ ions (corundum structure) and has an energy gap (Eg = 2.1eV) [8]. A thin film is a layer formed by atom to atom or molecule to molecule condensation process and their thickness ranging from fraction of nanometer to several micrometres in thickness [9]. 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 [10,11]. The aim of this work is to study the influence of thickness on optical and electrical properties of NiO and Fe2O3 thin film using the optical method.

Theoretical Background

The relationship between the attenuation of light through a substance and the properties of the substance can be describe using Beer-Lambert law which relates the concentration of a sample to amount of light that absorbed when passes through the sample, the equation for this law is generally written as:

$$A = \varepsilon L c \qquad (1)$$

Where A is the absorbance of a sample, ε is molar extinction coefficient, L is a path length and c is concentration of the sample [12].

The absorption coefficient determines how far into a material light of a particular wavelength can be penetrate before it absorbed, it depends on the material and also on the wavelength of light which is being absorbed, absorption coefficient (α) can be calculated from relation:

$$\alpha = \frac{2.303 \times A}{x} \qquad (2)$$

Where A is the absorbance and x is optical path length of light through sample, in a material wit a low absorption coefficient, light is only poorly absorbed, and if the material is thin enough, it will appear transparent [13].

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The refractive index (n) is the relative between speed of light in vacuum to its speed in material which does not absorb this light. The value of n was calculated from the equation [14]:

$$n = \left[\left(\frac{(1+R)}{(1-R)}\right)^2 - (1 + k^2) \right]^{\frac{1}{2}} + \frac{(1+R)}{(1-R)} \qquad (3)$$

where (R) is the reflectivity and (k) is exciction cofficent.

The optical conductivity is a measure of frequency response of material when irradiated with light which is determined using the following relation:

$$\delta_{opt} = \frac{\alpha n c}{4\pi} \qquad (4)$$

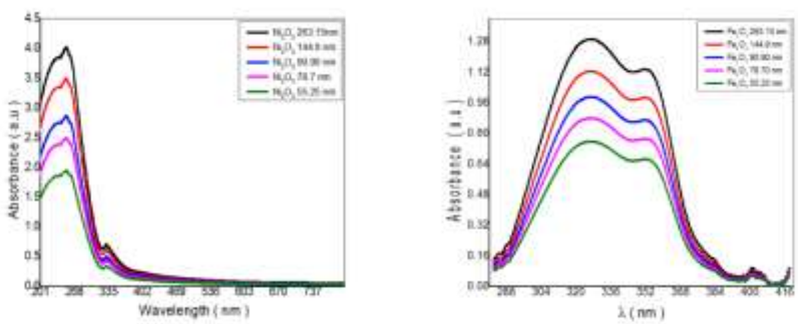
Where (c) is the light velocity. The electrical conductivity can be estimated using the following relation [15,16]:

$$\delta_{elec} = \frac{2\lambda\delta_{opt}}{\alpha} \qquad (5)$$

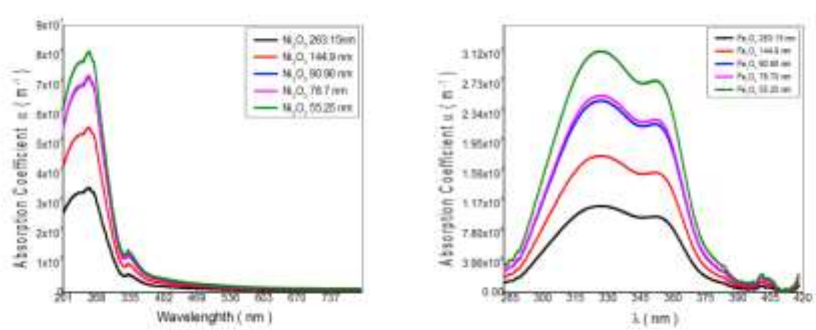
Material and Method

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 ($Fe(NO_3)_3.9H2O$)(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 optical and electrical conductivity were through optical method by measuring the absorbance of each sample using UV-VIS spectrometer (UV-1650PC Shimadzu software 1700, 1650, UV-visible recording spectrophotometer).

Results and Discussion



Fig(1) relation between absorbance and wavelengths Ni_2O_3 and Fe_3O_4 samples in different thicknesses



Fig(2) the relation between absorption cofficient and wavelengths of Ni_2O_3 and Fe_3O_4 samples

in different thicknesses

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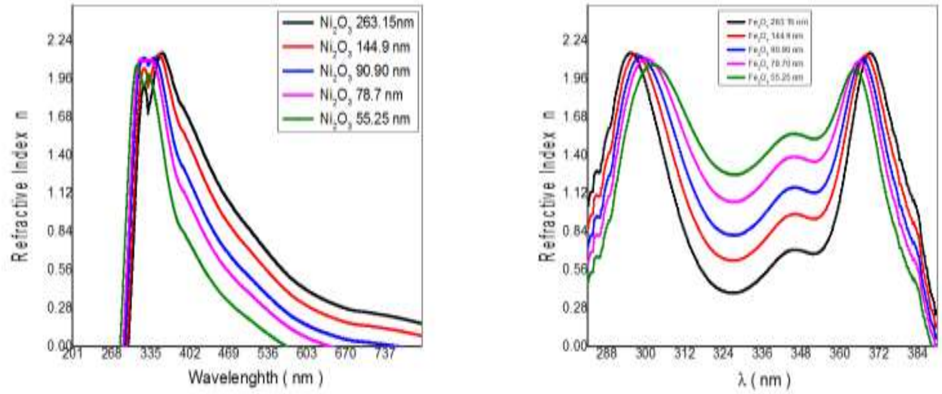
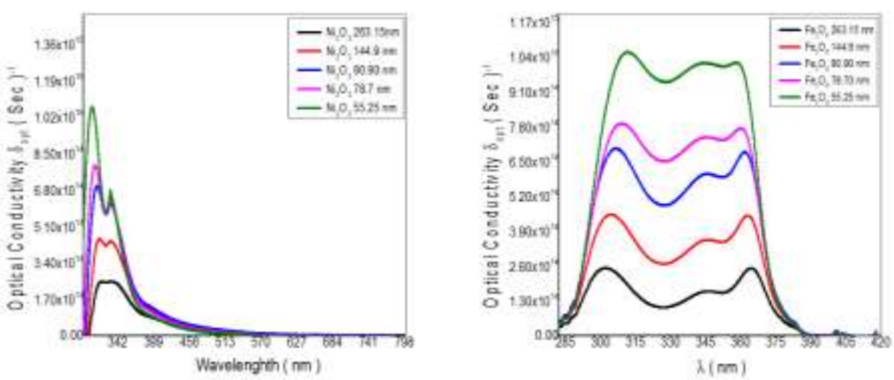
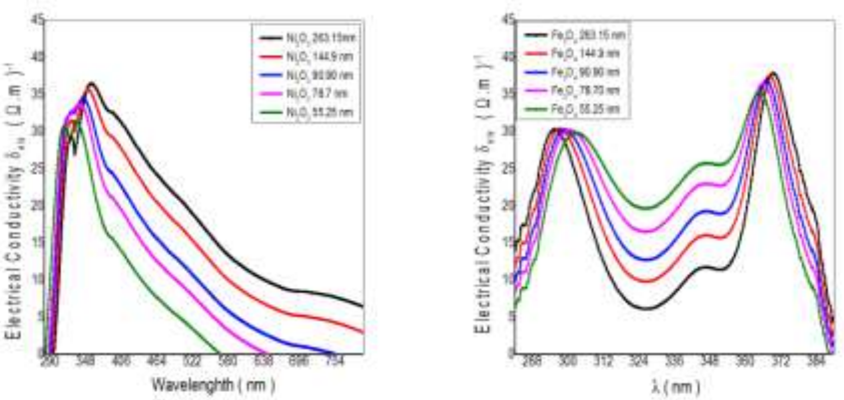


Fig(3) the relation between refractive index and wavelengths of Ni_2O_3 and Fe_3O_4 samples in different thicknesses



Fig(4) the relation between optical conductivity and wavelengths of Ni_2O_3 and Fe_3O_4 samples in different thickness



Fig(5) the relation between electrical conductivity and wavelengths Ni_2O_3 and Fe_3O_4 samples in different thickness

In fig. (1) , the relation between absorbance and wavelengths of Ni_2O_3 and Fe_3O_4 with different thicknesses was shown, the informly increase of the a absorption at wavelengths 252nm and 326 nm for Ni_2O_3 and Fe_3O_4 respectively. For both samples, the value of absorbance increase according to sample thickness increase. The absorption coefficient (α) of Ni_2O_3 and Fe_3O_4 with different thicknesses was displayed in fig (2), the maximum value of α at 263.15nm for both samples , the maximum value of α equal 8.16×10^7 cm^{-1} for Ni_2O_3 at wavelength 251 nm while for Fe_3O_4 the maximum 3.17×10^7 cm^{-1} at wavelength 325 nm in the U.V region, this means that the transition must corresponding to a direct electronic transition which responsible for electrical conduction. Fig (3) show the refractive index (n) of Ni_2O_3 and Fe_3O_4 with different thicknesses, the maximum value of (n) is (2.16) for all samples of Ni_2O_3 and Fe_3O_4 at the differances wavelength which is agreement with (blue sheft when the Ni_2O_3 thickness dccreased for all samples of Ni_2O_3 in different thickness and red sheft when the Fe_3O_4 thickness dccreased for all samples of Fe_3O_4 in different thickness . The high magnitude of optical conductivity equal (1.07×10^{15} sec^{-1}) for Ni_2O_3 and ($1.05x10^{15}$ sec^{-1}) for Fe_3O_4 samples as shown in fig (4) and this values confirm with the presence of very high photo-response of both samples which is refer to the high absorbance and then electron excitation by photon energy. Fig(5) show the relation between electrical conductivity and wavelengths of Ni_2O_3 and Fe_3O_4 with different thicknesses , the maximum value of electrical conductivity equal 37 $(\Omega.m)^{-1}$ at 400 nm for Ni_2O_3 with thickness 263.1 nm sample , but for Fe_3O_4 electrical condutivity equal 35 $(\Omega.m)^{-1}$ at 377 nm for Fe_3O_4 with thickness 263.1 nm sample. According to above results, these materials can be used in optoelctronics applications.

Conclusion

Thin films of Nickel Oxide Ni_2O_3 and Iron Oxide Fe_3O_4 were successfully fabricated with different thicknesses, the change in thickness effected on optical and electrical properties of samples, the fabricated thin films gave high optical conductivity which means highr current carriers generation increase with the thickness of sample increase, this unique properties of these materials make them sutable for optoelectronic applications.

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