

Preparation and a Study the Optical Properties of a Mixture of Magnesium Oxide and Ferrous Oxide by UV-Vis Technique

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Abstract: The physical and chemical properties of metal oxides give them a very significant role in various industries. Many of these oxides considered as the raw materials for many technological applications, from paints, mirrors, ceramics and steel. Most of these oxides fall within the range of semiconductors; they are thus used in the manufacture of electronic devices such as diodes, transistors, integrated circuits and solar cells. Some of oxides when they get mixed together they produce a material with enhanced optical properties. Thus, this research aims to form a mixture from Ferrous oxide and Magnesium oxide to produce a material with better optical properties that can be used in various applications. One sample of magnesium oxide MgO, One sample of ferrous oxide FeO and 4 samples of a mixture of magnesium oxide and ferrous oxide $\text{Fe}_x\text{Mg}_{(1-x)}\text{O}_2$ were prepared using the sol-gel method. Then these samples were tested in a UV-Vis spectrometer, and then the optical properties (Absorption - Reflection - Transmittance - Absorption coefficient - Extinction coefficient - Energy gap) were found as functions of wavelength. The results showed that there is an improvement in the absorption of the mixture samples to ultraviolet radiations compared to the absorption of the pure ferrous oxide, as it have a very high absorption (0.99au), a low transmittance (0.11%), and a negative value of reflection (-0.051%). The mixture samples are closer to the ideal semiconductor energy gap compared to the pure iron oxide energy gap. Therefore, the material $\text{Fe}_x\text{Mg}_{(1-x)}\text{O}_2$ can be used as a semiconductor material used in the electronics industry, rather, it can be used as a filter for ultraviolet rays due to its high absorption of it.

Keywords: Mixture, Magnesium Oxide, Ferrous Oxide, Optical Properties, UV-Vis Technique

1. Introduction

In the past few decades, metal-oxides have drawn considerable attention and have been applied in diverse fields of applications because of their full spectrum of various behaviors, such as dielectrics, Ferro electricity, magnetism, superconductivity, optical spectroscopy, and light emission [1] according to their physical, chemical, optical and magnetic properties. Yet, processing oxides into particular devices structure to suit specific applications is still a challenge. As a result, many techniques have emerged so we can widen the tenability of the properties such as doping and mixing oxides.

Mixed-metal oxide field is an interest mandated by advancements in all areas of industry and technology, many synthesis methods used for the fabrication of different multinary oxide such as co precipitation, hydrothermal processing, solvothermal methods and sol-gel chemistry [2]. The sol-gel method has demonstrated high potential to control the bulk and surface properties of the oxides as well as several advantages this method have, include its versatility and the possibility to obtain high purity materials, the provision of an easy way for the introduction of trace elements, allowance of the synthesis of special materials, and energy saving by using low processing temperature compared to other thermal methods [3].

Ferrous oxide (FeO) and magnesium oxide (MgO) were chosen to be the subject of this research due to many reasons; one of the reasons that they are one of the most common oxides used in different industries, not only because of their abundance in nature, but because of their properties that qualify them for that. Both oxides have high stability, highly magnetic, relatively low cost and easy to prepare. They are insoluble in water and alkalies while they dissolve in acids and they both used as a catalyst [4].

Since ferrous and magnesium oxides have separately played significant role in industries as a result to their significant properties, mixing them together could produce a material for much more applications furthermore, they could enhance each other in their limited area. One of the more important techniques to determine the optical properties of the materials is the UV-Vis spectroscopy, for that reason it is used to characterize the mixture of Mg and Fe oxides [5].

The absence of compounds from mixtures of metal oxides despite the high quality demonstrated by studies of this type of mixtures is one of the problems that calls for the existence of methods for studying and preparing this type of metallic mixtures and then studying their different properties to find out the possibility of their use in the fields of industry, especially electronics. Providing adequate information on mixtures of some metal oxides is of great importance due to the quality of the properties of this type of mixtures, in addition to finding different types of mixtures with specific and clear characteristics that can be used in the purposes of different industries is a great addition in the field of scientific research of materials [6].

2. Materials and Devices

The materials used in this experiments are Magnesium Nitrate dehydrate $\text{Mg}(\text{NO}_3)_2 \cdot 6(\text{H}_2\text{O})$ in a form of pure white powder, Ferrous Nitrate dehydrate $\text{Fe}(\text{NO}_3)_3 \cdot 9(\text{H}_2\text{O})$ in a form of pure red powder, de ionized water and Nitric Acid in order to produce the six samples of the formula $\text{Fe}_x\text{Mg}_{(1-x)}\text{O}_2$ where $x = 0, 1, 3, 7, 9$.

2.1. Devices

- 1) Sensitive balance
- 2) Magnetic stirrer
- 3) Beakers
- 4) Weight tube
- 5) Pipette

2.2. The Sol-Gel Method

The sol-gel system consists of several locally available tools through which polystyrene can be doped, these are:

1. Magnetic stirrer and hot plate
2. Holders
3. Thermometers
4. Beakers
5. Sensitive balance

3. Experimental

MgO: 6.54 g of Magnesium nitrate $\text{Mg}(\text{NO}_3)_2 \cdot 6(\text{H}_2\text{O})$ was dissolved in 75ml of water, then the mixture was put in the magnetic stirrer for 60 min, some nitric acid was added to adjust the PH and left for sixty minutes, then it cooled down to room temperature and so we obtain the liquid hydroxide of sample one.

FeO: 7.08g of Iron (III) nitrate or ferric nitrate $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ was dissolved in 49ml of water, then the mixture was put in the magnetic stirrer for 60 min, some nitric acid was added to adjust the PH and left for sixty minutes, then it cooled down to room temperature and so we obtain the liquid hydroxide of sample two.

In the preparation of $\text{Fe}_{0.9}\text{Mg}_{0.1}\text{O}_2$ 8,00 g of ferric nitrate dissolved on 55ml of water were added to 3.27g of magnesium nitrate dissolved on 37 ml of water, the mixture put in the magnetic stirrer for 60 min, some of the nitric acid was added at the beginning of the interaction to adjust the PH. Thus we obtain the liquid hydroxide of sample three.

To prepare sample four $\text{Fe}_{0.7}\text{Mg}_{0.3}\text{O}_2$: 5.55g of ferric nitrate dissolved on 39ml of water were added to 4.65g of magnesium nitrate dissolved on 53ml of water, the mixture put in the magnetic stirrer for 60 min, some of the nitric acid was added at the beginning of the interaction to adjust the PH. Thus we obtain the liquid hydroxide of sample four.

The synthesis of $\text{Fe}_{0.3}\text{Mg}_{0.7}\text{O}_2$ obtained when 2.60g of ferric nitrate dissolved on 18ml of water was added to 5.35g of magnesium nitrate dissolved on 61ml of water, the mixture put in the magnetic stirrer for 60 min. some of the nitric acid was added at the beginning of the interaction to adjust the PH.

In order to prepare $\text{Fe}_{0.1}\text{Mg}_{0.9}\text{O}_2$, then a 3.77g of ferric nitrate dissolved in 62 ml of water were added to 5.98g of magnesium nitrate dissolved on 68 ml of water, the mixture put in the magnetic stirrer for 60 min. some of the nitric acid was added at the beginning of the interaction to adjust the PH.

As the six samples were in the form of liquid hydroxide, putting them on oven at 300 C for 120 min was the choice to get the dry powder of $\text{Fe}_x\text{Mg}_{(1-x)}\text{O}_2$ ready for characterization.

4. Optical Properties

The changes that light undergoes upon interacting with a particular substance are known as the optical properties of that substance. These optical properties are influenced by the macroscopic and microscopic properties of the substance, such as the nature of its surface and its electronic structure. Since it is usually far easier to detect the way a substance modifies light than to investigate its macroscopic and microscopic properties directly, the optical properties of a substance are often used to probe other properties of the material. There are many optical properties, including the most well-known: reflection, refraction, transmission and absorption. Many of these optical properties are associated with important optical constants, such as the refractive index and the extinction coefficient. Various methods have been

developed for the determination of optical constants of solids. They differ with respect to sample geometry (bulks, thin films, multi layers, powders etc.) and optical properties (absorbing and non-absorbing) [7].

4.1. Transmittance

It is the fraction of incident electromagnetic power that is transmitted through and emerged from a sample. So it can define as the ratio of the transmitted power to the incident power [8].

$$T = \frac{I_t}{I_0} \quad (1)$$

T: Transmittance. I_t : the intensity of transmitted light I_0 : the intensity of incident light.

4.2. Absorbance

Absorbance is the quantity of light absorbed by a sample. It can define as the ratio of incident to transmitted radiant power through a material. Selective absorption is responsible for the coloration of many optical materials [9].

$$A = -\log_{10} \left(\frac{I}{I_0} \right) \quad (2)$$

A: Absorbance

4.3. Reflection

Reflection is the ratio of the reflected power to the power incident on the surface [10].

$$R + T + A = 1 \quad (3)$$

4.4. Absorption Coefficient

The absorption of light by an optical medium is quantified by its absorption coefficient α , which is the measure of the ability of a medium to absorb light. It also can be defined as the fraction of the power absorbed in a unit length of the medium [11].

$$\alpha = \frac{4\pi k}{\lambda} \quad (4)$$

α : Absorption coefficient, k : Extinction coefficient λ : Wave length

Extinction coefficient

It is a measure of that light lost due to scattering and absorption per unit volume [12].

$$K = \frac{\alpha \lambda}{4\pi} \quad (5)$$

4.5. Band Gap

The band gap is the minimum energy required to excite an

electron that is stuck in its bound state into a free state where it can participate in conduction.

The whole band in semiconductors consists of valence band (E_V) and conduction band (E_C). The valence band is the lower energy level where electrons are bounded while conduction band is the energy level at which electrons considered free. The gap in energy between (E_V) and (E_C) is what it called and gap (E_G) [13-15].

$$(\alpha h\nu)^2 = C(E_G - h\nu) \quad (6)$$

Where C is constant, E_G : the energy gap, h: Plank constant, ν : frequency.

5. Results and Discussion

In this part of the research, the main results that have been obtained from the experiments made of $\text{Fe}_x\text{Mg}_{(1-x)}\text{O}_2$ are presented. The data of UV-visible light range is used to evaluate some optical properties and optical band gap.

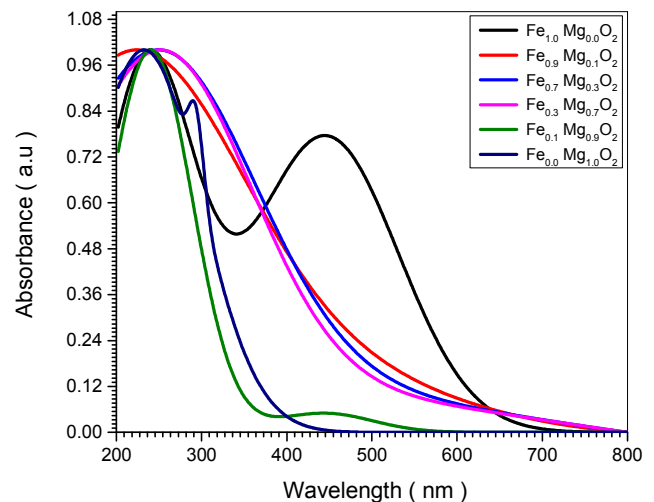


Figure 1. The relation between absorbance and wavelengths of $\text{Fe}_x\text{Mg}_{(1-x)}\text{O}_2$ samples.

The absorbance behavior of curves found is not the same for $\text{Fe}_x\text{Mg}_{(1-x)}\text{O}_2$ samples, when they characterized using UV-Vis 1240 spectrophotometer as shown Figure 1. It shows that for $\text{Fe}_x\text{Mg}_{(1-x)}\text{O}_2$ samples, the absorbance of $\text{Fe}_{1.0}\text{Mg}_{0.0}\text{O}_2$ sample at wavelengths of 240 nm is corresponding to the photon energy of 5.17 eV, and at wavelengths of 450 nm it is corresponding to the photon energy 2.76 eV. But for $\text{Fe}_{0.0}\text{Mg}_{1.0}\text{O}_2$ the absorbance at wavelengths 240 nm only which corresponding to the photon energy 5.17 eV. Different variation of $\text{Fe}_x\text{Mg}_{(1-x)}\text{O}_2$ gives different values as showing in Figure 1. It is conducted that the absorbance of FeO is almost 0.72 at the region of visible light, while MgO has great absorbance at UV region almost 0.99 au. The result of the mixture samples of ferrus oxide and magnesium oxide indicate that the absorbance of FeO improved very well when it mixed up with MgO.

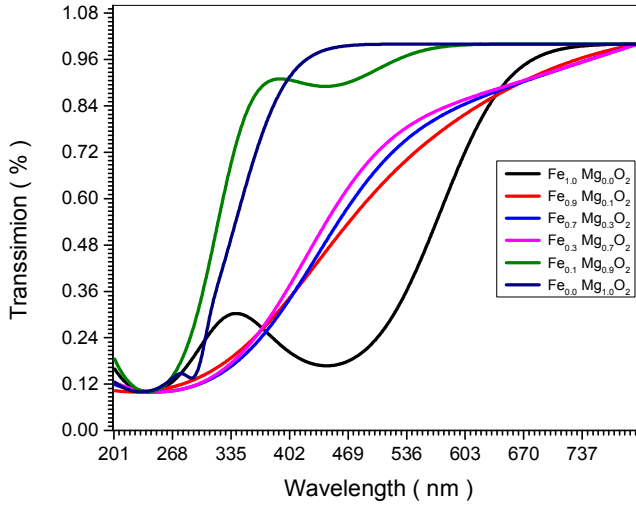


Figure 2. The relation between transmission and wavelengths of $Fe_xMg_{(1-x)}O_2$ samples.

The transmission behavior of curves found is not the same for $Fe_xMg_{(1-x)}O_2$ samples, when they characterized using UV-Vis 1240 spectrophotometer as shown Figure 2. It shows that for $Fe_xMg_{(1-x)}O_2$ samples the relation between transmission and wavelengths that the effect of mixing increases the transmission values when the rate of Fe x decreases. It conducted that the higher the concentrations of Magnesium oxide in the sample, the lower the UV transmittance.

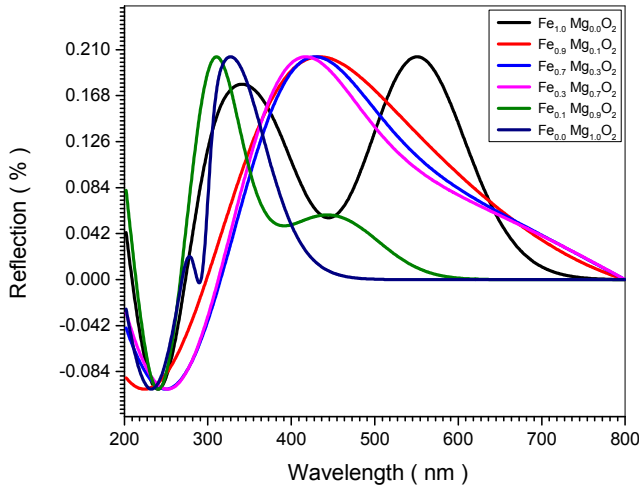


Figure 3. Relation between reflection and wavelengths of $Fe_xMg_{(1-x)}O_2$ samples.

The reflection behavior of curves found is not the same for $Fe_xMg_{(1-x)}O_2$ samples, when they characterized using UV-Vis 1240 spectrophotometer as shown Figure 3. It shows that for $Fe_xMg_{(1-x)}O_2$ samples, the maximum value of the reflection comes in three ranges of the wavelength, first one in ranged from (305 to 335) nm, the second is ranged from (400 to 470) nm, and the last one is ranged at wavelength from (525 to 575) nm, in this three ranges the samples become a mirror. It concluded that according to the graph in Figure 3, FeO has relatively high reflection compared to MgO, while the sample of the mixture of both oxides has shown better

reflection abilities which means ferrous oxide reflection has been enhanced when FeO is mixed with MgO.

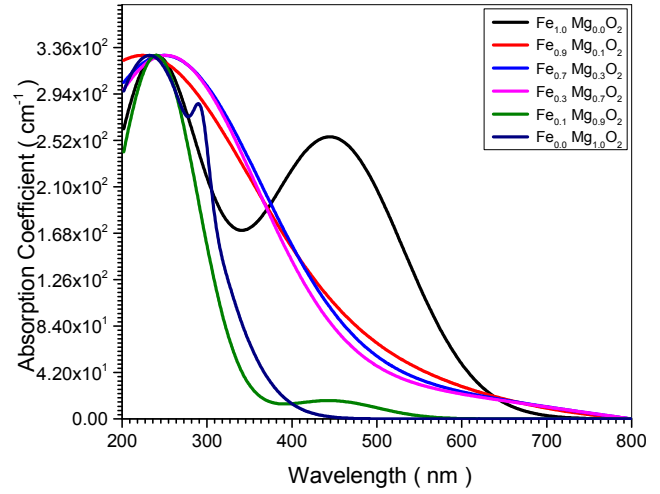


Figure 4. The relation between absorption coefficient and wavelengths of $Fe_xMg_{(1-x)}O_2$ samples.

The absorption coefficient (α) of the $Fe_xMg_{(1-x)}O_2$ samples was found from the following relation $\alpha = \frac{2.303 \times A}{t}$ where (A) is the absorbance and (t) is the optical length in the samples. Figure 4 shows the plot of (α) with wavelength (λ) of $Fe_xMg_{(1-x)}O_2$ samples, in which we obtained that the value of $\alpha = 0.241 \times 10^3 \text{ cm}^{-1}$ for all $Fe_xMg_{(1-x)}O_2$ samples in the UV region (240 nm), but it has different value on the other wavelength of the spectra, it means that at (240 nm) the absorption is corresponding to a direct electron transition, and the properties of this state are important since they are responsible for electrical conduction.

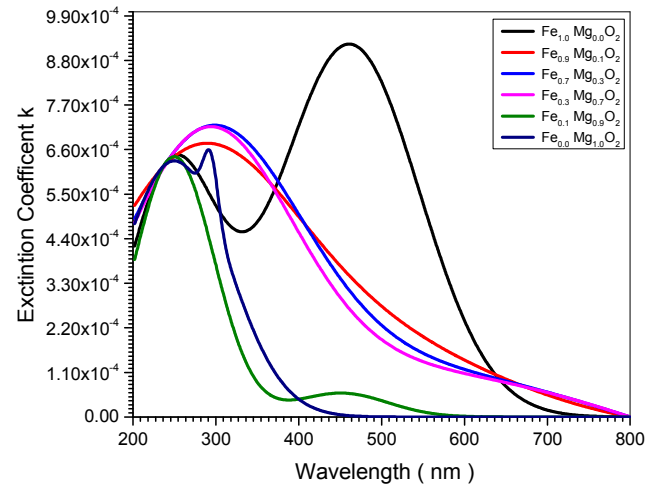


Figure 5. The relation between extinction coefficient and wavelengths of $Fe_xMg_{(1-x)}O_2$ samples.

Extinction coefficient (K) was calculated using the equation $k = \frac{\alpha \lambda}{4\pi}$. The variation at the (K) values as a function of (λ) are shown in Figure 5, $Fe_xMg_{(1-x)}O_2$ samples. It is observed that the spectra graph of (K) is the same as the graph of (α). The Extinction coefficient (K) obtained clarify that the value of (K) at the (240 nm) wavelength depends on

the samples treatment method, where the value of (K) at 240 nm for all $\text{Fe}_x\text{Mg}_{(1-x)}\text{O}_2$ samples equal 6.49×10^{-4} . Obviously FeO has a quite low value of K compared to other samples.

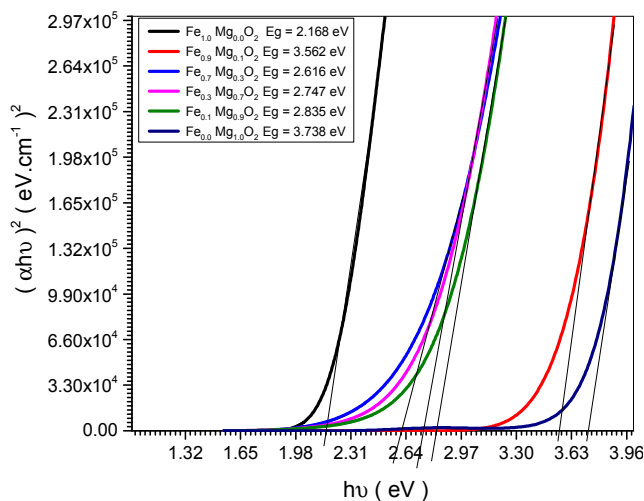


Figure 6. Optical energy band gap of $\text{Fe}_x\text{Mg}_{(1-x)}\text{O}_2$ samples.

The optical energy gap (Eg) has been calculated by the relation $(\alpha h\nu)^2 = C(h\nu - E_g)$ where (C) is constant. By plotting $(\alpha h\nu)^2$ vs photon energy (hν) as shown in Figure 6 for the $\text{Fe}_x\text{Mg}_{(1-x)}\text{O}_2$ samples. And by extrapolating the straight thin tangent of the curve to intercept the energy axis, the value of the energy gap has been calculated. In Figure 6 the value of (Eg) of $\text{Fe}_{1.0}\text{Mg}_{0.0}\text{O}_2$ sample obtained is equal to (2.168) eV while for $\text{Fe}_{0.0}\text{Mg}_{1.0}\text{O}_2$ sample obtained is equal to (3.562) eV. The value of (Eg) increased from (2.168) eV to (3.562) eV. The increasing of (Eg) related to increased of Mg_{1-x} . It was observed that the different Mg_{1-x} confirmed the reason for the band gap shifts. It is conducted that the energy gap of FeO (which ≈ 2.16 eV) makes FeO a better semiconductor than MgO (3.33 eV). So the combination of ferrous oxide and magnesium oxide enhances MgO semiconducting quality.

6. Conclusion

This paper focused on making a mixture of Ferrous oxide and Magnesium oxide with enhanced properties. Each of the two substances has its own distinct properties, but the goal of making the mixture is to study the changes in its optical properties, and to know the effect of each substance on the properties of the other. The obtained results shows that there is a clear improvement on the optical properties, and the characteristics of the mixture has covered a wide range of the visible and ultraviolet spectra. It also shows the high susceptibility of the mixture samples to absorb ultraviolet radiations, this trait can be use as protective shields for ultraviolet rays in medical fields, and research laboratories etc.

7. Recommendations

This research recommended that:

1. To be conducted with more specific study especially in the scale of nanoparticles.
2. To be conducted taking into account to make doping for the mixture using any of materials with highly optical properties.
3. Studies on this mixture should be extended to include all the physical properties in order to have thorough information about it to be use to the fullest.

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