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Synthesis and a Study the Optical Properties of Yttrium Barium Copper Oxide (YBCO) Using UV-Vis Techniques

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Abstract: Yttrium barium copper oxide (YBCO) is a family of ctaline chemical compounds, famous of displaying high temperature super conductivity. It includes the first material lever discovered to become superconducting above the boiling point of liquid nitrogen (77K) at about 92K. The physical and chemical properties of metal oxides give them a very significant role in various industries. The aim of this study is to prepare three samples of (YBCO) in laboratory, and then to characterize them to determine their optical properties, its importance brake out as it acts in scope of a super conductor, and then to study the characteristics of (YBCO) using the UV-Vis device. Three samples of the composite by different percentage (100, 90, and 80)% of Yttrium oxide with chemical extenuation method were prepared. The optical properties of the samples (the absorbance, absorption coefficient, transmittance, reflectance and energy gap) had been studied with UV-Vis spectrometer. Results found show that all the optical properties of the compound act in the range of UV only, and the absorbance decreases with the decreasing of the YO percentage, transmittance, and reflectance increase with the decreasing of YO percentage in the sample. The energy gap showed very good results that undergoes with the opinion of superconductivity in which a superconducting materials must have a very small energy gap which found to be in the range of 0.0035 eV to 0.0045 eV.

Keywords: Yttrium Oxide, YBCO, Chemical Extenuation Method, Optical Properties, UV-Vis Technique

1. Introduction

From 1908 H. Kamerlingh Onnes, having successfully liquefied helium, was able to measure the electrical resistance of metals at very low temperatures [1]. The startling discovery made in 1911 was that as the temperature of a sample of Hg was reduced, the resistance did not fall continuously as expected, but instead at around 4.2 K dropped suddenly to zero over a range of a few hundredths of a degree. This phenomenon was termed superconductivity and was found to occur for other elements such as Pb, Sn and Al at critical temperatures between 4-10 K. The fact that this is a real disappearance of the resistivity, rather than just a decrease below that measurable using a standard voltmeter was confirmed by studying the persistence of circulating currents in a superconducting loop another important property of

superconductors was discovered in 1933 by Meissner & Ochsenfeld [2]. One would expect, due to the perfect conductivity, that magnetic flux should be excluded from entering a superconductor, but also it was found that flux was expelled from the material as it was cooled through its transition temperature. This phenomenon is termed the 'Meissner effect'. The expulsion of the magnetic field requires the flow of circulating 'screening currents' and hence the existence of the Meissner effect necessitates that the resistance must be zero. This 'perfect diamagnetism' demonstrates that superconductivity is a true thermodynamic state and that in moving from the normal to the superconducting state, a material undergoes a thermodynamic phase transition. [3]

It has long been a dream of scientists working in the field

of superconductivity to find a material that becomes a superconductor at room temperature [4]. A discovery of this type will revolutionize every aspect of modern day technology such as power transmission and storage, communication, transport and even the type of computers we make. All of these advances will be faster, cheaper and more energy efficient. This has not been achieved to date. However, in 1986 a class of materials was discovered mostly use on bench-tops is Yttrium – Barium – Copper Oxide, or $YBa_2Cu_3O_7$, otherwise known as the 1-2-3 superconductor, and are classified as high temperature [5]. Until 1986, the record transition temperature for a superconductor was 23 K In that year, Bednorz and Muller synthesized the compound La_2Cuo_4 which remains superconducting up to 30 K, and soon afterwards other superconducting cuprites materials were discovered with even higher transition temperatures. $YBa_2Cu_3O_7$-δ (YBCO) has a Tc of 92 K, which is significant because it is greater than the boiling point of liquid nitrogen at atmospheric pressure it has been found that. Bi-Sr-Ca-Cu-O, Tl- Ba-Ca-Cu-O and Hg- Ba-Ca-Cu-O compounds have higher critical temperatures. [6]

The discovery of a room temperature super conductor has been a long standing dream of many scientists; the existence of resistivity in electrical devices and wires makes many problems, such as increasing of heat so the discovery of a super conductor material can gives a wide range of possibilities to solve the resistance problem [7].

The Yttrium barium Cupper Oxide (YBCO) compound seems to be very importance since its discovery of it, but the main and great goal to be achieved is to find a super conductor at or near the room temperature as mentioned above, the type of superconductors that named ceramic superconductors which were discovered the first time in the middle of the past century, and the YBCO is found to be one of them, so the researchers paid it their attention, and because of this reason my research takes the same way to share my opinions and experience in this field [8].

2. Materials

The - Yttrium oxide (Y_2O_3) – Wight powder -
1. Barium Carbonate ($BaCO_3$) -;
2. Copper oxide (CuO) – black powder;
3. Diluted sulfuric acid;
4. Distilled water.

2.1. Devices

Sensitive balance;
Magnetic stirrer;
Beakers;
Weight tube;
Pipette;
Marble Mortar;
500 ml crucible;
1500°C Carbolated oven.

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 $Mg(NO_3)_2 \cdot 6(H_2O)$ 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 PHand left for sixty minutes, then it cooled down to room temperature and so we obtain the liquid hydroxide of sample one.

To obtain the desired superconducting compound, each of Y_2O_3 (0.151gm), $BaCO_3$ (0.529 gm), CuO (0.320 gm) were considered as initial weights equivalent to 1 gm for the whole sample. There were three samples prepared in order investigate the present of Yttrium in the compound. To increase the quantity of the sample, each of the starting materials were multiplied by 3, and as the results the new calculated weights will be according to the following.

The blow weights in gram were obtained using the below equation

$$\frac{1}{2}Y_2O_3 + 2BaCO_3 + 3CuO \rightarrow YBa_2Cu_3O_7 + 2CO_2 \uparrow$$
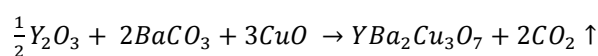
Sample (1)

Y_2O_3 (0.151gm)*3 = 0.453gm

$BaCO_3$ (0.529 gm)*3 =1.587gm

CuO (0.320 gm)*3= 0.96gm

Sample (2)

Y_2O_3 (0.151gm)*3 = 0.4077gm

$BaCO_3$ (0.529 gm)*3 =1.587gm

CuO (0.320 gm)*3 = 0.96gm

Sample (3)

Y_2O (0.151gm)*3 = 0.3624gm

$BaCO_3$ (0.529 gm)*3 =1.587gm

CuO (0.320 gm)*3 = 0.96gm

In the way of preparing the sample, the above weights were achieved using a sensitive balance with atmosphere insulating glass. In the beginning, the Mortar was washed using the distilled water, and diluted sulfuric acid by 40%. The washing process has been done in sequence, as the tool were washed first using tap water, followed by immersing into the diluted sulfuric acid, then kept to dry and washed for

second time by using the distilled water. Tools were eventually washed by acetone to guaranty the removal of any unwanted contaminations.

Beginning with the first sample (100% present of Y_2O_3), the dry mix is ground with clockwise gentle movement for 30 mints, until a gray mixed powder is obtained. The powder is carefully transferred to high temperature resistance crucible, and placed into Carbolite oven for 1 hour at 850 0C. After the oven is cooled down, the black mixture is removed into the Mortar and ground with addition of acetone, for 30 minutes. Again, the mixed gray powder is placed into the oven for 5 hours at 8500C. As final step, oven is cooled down to the room temperature, and the hard burned powder is ground for 30 minutes and taken to the analysis afterward.

Following the same above way, sample 2 and 3 were prepared with 90%, 80% in Sequence.

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) [9].

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 [10].

$$T = \frac{I_t}{I_0} \tag{1}$$

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 [11].

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

A: Absorbance.

4.3. Reflection

Reflection is the ratio of the reflected power to the power incident on the surface [12].

$$R + T + A = 1 \tag{3}$$

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 [13].

$$\alpha = \frac{4\pi k}{\lambda} \tag{4}$$

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

4.5. Extinction Coefficient

It is a measure of that light lost due to scattering and absorption per unit volume [14].

$$K = \frac{\alpha \lambda}{4\pi} \tag{5}$$

4.6. 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 gab in energy between (E_V) and (E_C) is what it called and gab (E_G) [15].

$$(\alpha h\nu)^2 = C(Eg - h\nu) \tag{6}$$

Where C is constant, Eg: 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 $Fe_xMg_{(1-x)}O_2$ are presented. The data of UV-visible light range is used to evaluate some optical properties and optical band gap.
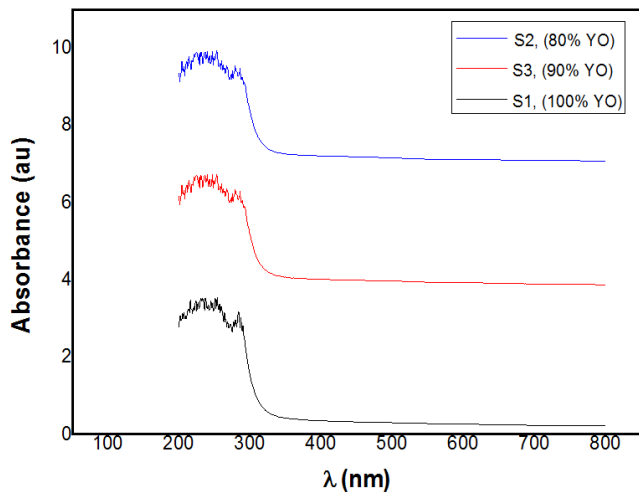
5.1. Absorbance

Figure 1. *The absorbance as a function of the wavelength for the three sample of different YO percentage.*

Absorption spectrum was measured as a function of wavelength in the range (200-800) nm for all YBCO samples with concentrations (100, 90, and 80)% of yttrium oxide in the compound. We note that the absorbance was in the UV range in the range of 200-300 nm and there is no absorption outside the UV range.

Absorption increases by decreasing wavelength, reaching a maximum value of (3.71) au at 238 nm. It was found that the absorbability of the origin sample of Yttrium barium copper oxide which contain Yttrium oxide of 100% gives the highest absorbance which equal to 3.71 (au), and then when the Yttrium oxide percentage decreased to 90%in the composite, the absorbance decreased to 3.56 (au), and when the Yttrium oxide percentage decreased to 80% in the composite, the absorbance decreased to 3.54 (au), the decreasing in the Yttrium oxide percentage in the compound showed the deceases of the absorbability of (YBCO).
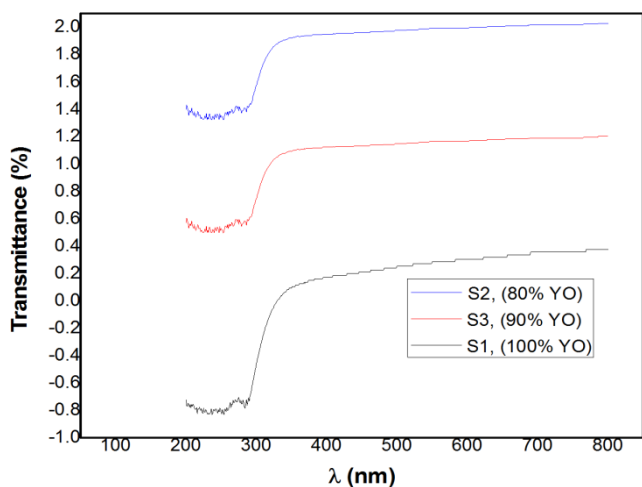
5.2. Transmittance

Figure 2. *The transmittance as a function of the wavelength for the three sample of different YO percentage.*

The transmittance spectrum was measured as a function of the wavelength in the range (200-800) nm for all YBCO samples with concentrations (100, 90 and 80%) of yttrium oxide in the compound. Note that the transmittance was in the UV range in the range of 200-300 nm and there is no penetration outside the UV range. The transmittance increases with increasing wavelength, reaching a maximum value of (-0.83211)% at 254 nm wavelength.

It was reached that the transmittance increase by the decrease of yttrium oxide, the first sample which contain yttrium oxide of 100% give less transmittance which is about (-0.85249)% at wavelength (238)(nm), and then the Transmittance increased by the decrease of yttrium oxide percentage gradually to become (-0.83456)% at wave length (253) nm, when the percentage of yttrium oxide decrease to 90%, and it become (-0.832113595)% at wave length (254) nm at 80% of yttrium oxide percentage.

5.3. Reflectance

The reflectivity spectrum was measured as a function of wavelength in the range (200-800) nm for all YBCO samples with concentrations (100, 90 and 80)% of the yttrium oxide in the compound. Note that the reflectivity was in the ultraviolet range in the range of (200-300) nm and there is no penetration beyond the ultraviolet range.

Reflectivity is increased by increasing wavelength, reaching a maximum value of (-1.699) at 283 nm. The reflectance of (yttrium barium copper oxide) increased with decrease the ratio of yttrium oxide. The first sample of (YBCO) which contain yttrium oxide 100% have less reflectance which (-1.8575) wave length (238) nm, then increase to (-1.72544) to wave length (253) nm at 90% of yttrium oxide and became (-1.6991126) to wave lengths (283) nm for 80% of yttrium oxide.
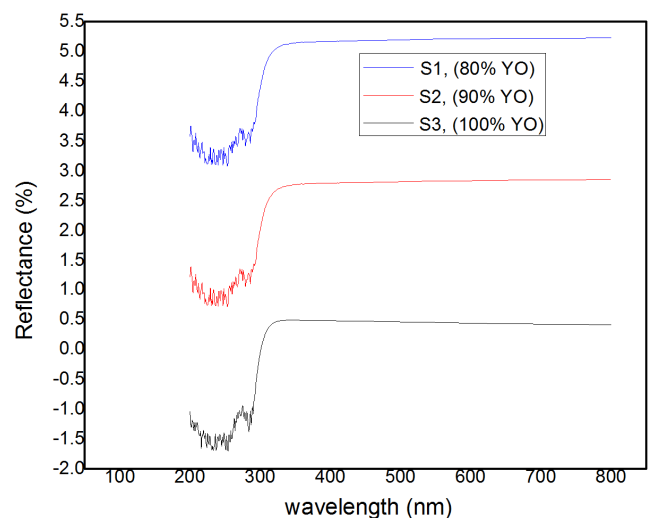

Figure 3. *The reflectance as a function of the wavelength for the three sample of different YO percentage.*

5.4. Energy Gap

The energy gap showed very good results that undergoes

with the opinion of superconductivity in which a superconducting materials must have a very small energy gap which found to be in the range of 0.0035 eV to 0.0045 eV. The energy gag showed increasing with the decreasing of the YO percentage in the samples which meant that the best sample is the sample of the 100% Yttrium oxide (YO) which is also means that the change of the percentage does not make good sense for the (YBCO) and the structure build in the literature review is the best one, on the other hand this helps in searching about other parameters that can make real development in the compound future to act as a room temperature superconductor.
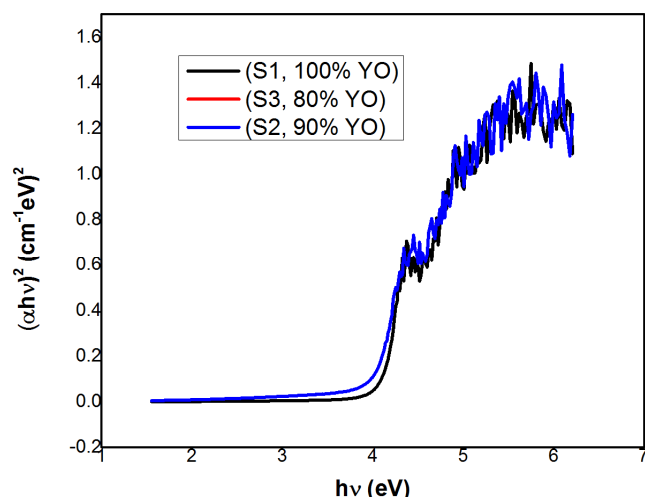

Figure 4. The energy gap for the three sample of different YO percentage.

6. Conclusion

This paper focused on preparing samples of YBCO using Sol-Gel method and treated the samples via UV-Vis spectroscopy. The obtained result shows that there is a clear improvement on the optical properties, and concluded that the optical properties of this compound are excellent and enable it to be used in many fields. The study also recommends studying the compound after doping with some metal oxides.

At the conclusion of this research, it can be said that the results are good in the possibility of preparing the compound of yttrium barium copper oxide in the laboratory and then studying its optical properties which gave good results, but the process of changing the rate of yttrium oxide in the compound did not lead to an improvement in the characteristics, especially the energy gap.

References

[1]   Carbotte, J. P.; Schachinger, E. & Basov, D. N. (1999). Coupling strength of charge carriers to spin fluctuations in high-temperature superconductors. Nature, 401, 6751, pp. 354-356.

[2]   Cava, R. J.; Batlogg, B.; Krajewski, J. J.; Farrow, R.; Rupp Jr, L. W.; White, A. E.; Peck, W. E. & Kometani, T. (1988). Superconductivity near 30 K without copper: the Ba 0.6 K 0.4 BiO 3 system. Nature, 332, pp. 814-816.

[3]   Cava, R. J. (2000). Oxide superconductors. Journal American Ceramic Society; 83, 1, pp. 5-28 Chakraverty, B. K.; Ranninger, J. & Feinberg, D. (1998). Experimental and Theoretical Constraints of Bipolaronic Superconductivity in High T c Materials: An Impossibility. Phys. Rev. Letters, 81, pp. 433-436.

[4]   Dalfovo, F.; Giorgini, S.; Pitaevskii, L. P. & Stringari. (1999). Theory of Bose-Einstein condensation in trapped gases. Reviews of Modern Physics, 71, 3, pp. 463-512.

[5]   J. G. Bednorz & K. A. Müller (1986). "Possible high T_c superconductivity in the Ba−La−Cu−O system". Z. Phys. B. 64 (1): 189–1^ Gibney, Elizabeth (5 March 2018). "Surprise graphene discovery could unlock secrets of superconductivity". News. Nature. 555 (7695): 151–152.

[6]   Bibcode: 2018Natur. 555 151G. doi: 10.1038/d41586 -018-02773 w. PMID 29517044. Superconductors come broadly in two types: conventional, in which the activity can be explained by the mainstream theory of superconductivity, and unconventional, where it can't. 93. Bibcode: 1986ZPhyB..64..189B. doi: 10.1007/BF01303701.

[7]   Grant, Paul Michael (2011). "The great quantum conundrum". Nature. Nature Publishing Group, a division of Macmillan Publishers Limited. All Rights Reserved. 476: 37–39.

[8]   Van Camp, Michel; Francis, Olivier; Lecocq, Thomas (2017). "Recording Belgium's Gravitational History". Eos. 98. doi: 10.1029/2017eo089743.

[9]   Van Camp, Michel; de Viron, Olivier; Watlet, Arnaud; Meurers, Bruno; Francis, Olivier; Caudron, Corentin (2017). "Geophysics From Terrestrial Time-Variable Gravity Measurements". Reviews of Geophysics. 55 (4): 2017RG000566. Bibcode: 2017RvGeo..55..938V. doi: 10.1002/2017rg000566. ISSN 1944-9208.

[10] Drozdov, A; Eremets, M; Troyan, I; Ksenofontov, V (17 August 2015). "Conventional superconductivity at 203 kelvin at high pressures in the sulfur hydride system". Nature. 525 (2–3): 73–76. arXiv: 1506.08190. Bibcode: 2015Natur.525...73D. doi: 10.1038/nature14964. PMID 11369082.

[11] R. L. Dolecek (1954). "Adiabatic Magnetization of a Superconducting Sphere". Physical Review. 96 (1): 25–28. Bibcode: 1954PhRv...96...25D. doi: 10.1103/PhysRev.96.25.

[12] H. Kleinert (1982). "Disorder Version of the Abelian Higgs Model and the Order of the Superconductive Phase Transition" (PDF). Lettere al Nuovo Cimento. 35 (13): 405–412. doi: 10.1007/BF02754760.

[13] J. Hove; S. Mo; A. Sudbo (2002). "Vortex interactions and thermally induced crossover from type-I to type-II superconductivity" (PDF). Physical Review B. 66 (6): 064524. arXiv: cond-mat/0202215. Bibcode: 2002PhRvB..66f4524H. doi: 10.1103/PhysRevB.66.064524.

[14] Lev D. Landau; Evgeny M. Lifschitz (1984). Electrodynamics of Continuous Media. Course of Theoretical Physics. 8. Oxford: Butterworth-Heinemann. ISBN 978-0-7506-2634-7.

[15] David J. E. Callaway (1990). "On the remarkable structure of the superconducting intermediate state". Nuclear Physics B. 344 (3): 627–645. Bibcode: 1990NuPhB.344..627C. doi: 10.1016/0550-3213(90)90672-Z.