IOSR Journal Of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 13, Issue 2 Ser. II (Mar. – Apr. 2021), PP 39-48
www.Iosrjournals.Org

Synthesis , optical, and electrical Properties Study of YBCO at Room Temperature

SarahEzzedineHamza[1], Mahmoud Hamid Mahmoud Hilo[2]
[1]*Graduate student (PhD), Physics Department,Faculty of Science ,Sudan University of Science and Technology Khartoum, Sudan*
[2]*Physics Department, Faculty of Science, Sudan University of Science and Technology*
Corresponding Author: Sarah Ezzedine Hamza Mudawi

Abstract:
*YBCO is a family of crystalline chemical compounds famous for displaying hight-temperature superconductivity And synthesized YBCO superconductor by using solid åstate reaction in order to study structural, optical and electrical properties of pure Yttrium Barium Copper Oxide (YBCO) and when dopping with Aluminium oxide AL_2O_3. The optical properties for pure$YBa_2Cu_3O_7$ and $YBa_2Cu_3O_7$ whichdopped with $AL_2O_3$was studied by using ultraviolet-visibleSpectrophotometry (UV/VIS),the transmittance and absorbance spectra were recorded include the wavelength range of (200-800)nm, the results showed thatTransmittance decreases with the increasing in the wavelength between (200- 300) nm, and then remains constant with increasing the wavelength, and absorbance increased with the increasing wavelength between (200- 300) nm, and then remains constant with increasing the wavelength, and the Absorption Coefficient, refractive index and extinctioncoefficient were also calculated. The optical energy gap decrease when we increase the dopping with $YBa_2Cu_3O_7$ whichdopped with AL_2O_3, and also The optical conductivity increase with elevated of absorbance.Theelectrical properties studied by using I-V measurements, We also subjected our sample for I-V characterization at different sample through four probe method and able to measure the critical current density (J) and found a decrement of critical current density with increment of dopping, where electrical conductivity was calculated, the **results** also showed that The electrical conductivity for pure$YBa_2Cu_3O_7$ and $YBa_2Cu_3O_7$ dopped with AL_2O_3 its increase when increased the dipping concentration.*

Keywords: *YBCO, Conductivity, Optical energy Gap.*

Date of Submission: 09-03-2021 Date of Acceptance: 23-03-2021

I. Introduction:

The phenomenon of superconductivity was discovered by Kamerlingh Onnes in 1911, in metallic mercury below 4 K (−269.15 °C).[1] Ever since, researchers have attempted to observe superconductivity at increasing temperatures with the goal of finding room-temperature superconductor.[2]By the late 1970s, superconductivity was observed in several metallic compounds (in particular Nb- based, such as NbTi, Nb_3Sn, and Nb_3Ge) at temperatures that were much higher than those for elemental metals and which could even exceed 20 K (−253.2 °C). In 1986,[11] J. Georg Bednorz and K. Alex Müller, working at the IBM research lab near Zurich, Switzerland were exploring a new class of ceramics for superconductivity.[7] Bednorz encountered a barium-doped compound of lanthanum and copper oxide whose resistance dropped to zero at a temperature around 35 K (−238.2 °C).[3]High-temperature superconducting electronic devices have attracted extensive attentions due to their notable advantages, such as small size, low loss, low noise, high sensitivity, and easy integration with other microwave solid-state circuits. During the first half of the century after the discovery of superconductivity,[9] the problem of fluctuation smearing of the superconducting transition was not even considered. In bulk samples of traditional superconductors the critical temperature Tc sharply divides the superconducting and the normal phases.[9] The electrical conduction is highly anisotropic, with a much higher conductivity parallel to the CuO2 plane than in the perpendicular direction. Generally, critical temperatures depend on the chemical compositions, cations substitutions and oxygen content. They can be classified as superstripes; i.e., particular realizations of superlattices at atomic limit made of superconducting atomic layers, wires, dots separated by spacer layers, that gives multiband and multigap superconductivity.[12]

II. Materials And Methods:

Sample Preparation:

The samples YBCO were prepared by a solid state reaction by two methods [sintering samples in air, then mixing them with polymer],using appropriate weights of highly pure materials Y_2O_3, BaO, and CuO powders. In proportion to their molecular weights, the total weight of the compounds was calculated as follow

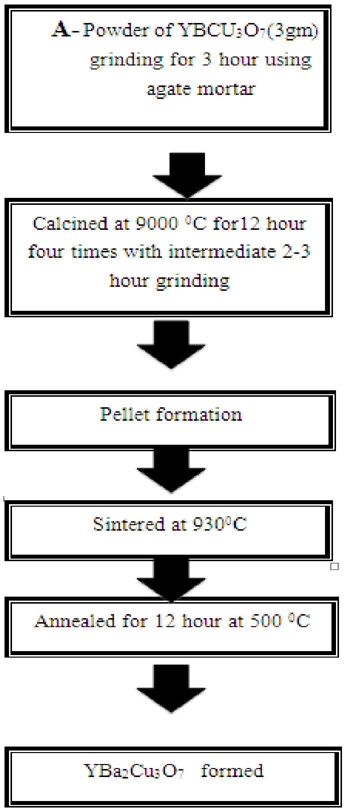
Powder name	Ratio Atomic Weight
3O2Y	0.4538985 gm
Ba_3Co	1.5866853 gm
CuO	0.9594162 gm
AL_2O_3	0.09 gm

A. **First step:**

Measuring the weight of each reactant by using a sensitive balance with4-digit type (KERN).

B. Second step:

Synthesis of YBCO superconductor:



Stochiometric amount of Yttrium Oxide, Barium Carbonate and Copper Oxide was taken as precursers to obtain the desire material YBCO.

$$Y_2O_3 + 2BaCO_3 + 3CuO \quad 2YBa_2Cu_3O_7$$

The ingredients were grounded together in an agate mortar for 2-3 hrs to obtain a homogeneous mixture. After grinding, the powder was calcined at 900 0C in a muffle furnace for 12 hour and then the calcined powder was again heated for 4-5 times with intermediate grinding at the same temp.. After repeated heating, the resultant powder obtained, is pressed into pellets of 1mm thickness and finally sintered at 930 0C for 12 hrs and followed by oxygen annealing for 12 hrs for Oxygen uptake and thus obtained the resultant YBCO.

C. Third step :

Sample	$YBa_2Cu_3O_7$ (gm)	$_3O_2AL$(gm)	The percentage of doped
S_1	0.500	0	%100
S_2	0.485	0.015	%3
S_3	0.470	0.030	%6
S_4	0.455	0.045	%9

Table (1) volumetric of powder used forsample preparation

III. Experimental Method:

Several methods can be applied to characterize the optical properties and obtain the absorbance, transmittance and reflactance spectrum. UV-vis-spectroscopy,light passed through asample at a specific wavelength in the uv or visblie spectrum.if sample absorbs some of the light, not all of light will be pass through, or be trancmitted or be reflected.The reflectivity(R) can be calculated according to the law of energy conservation and by knowing the value of each transmittance(T) and Absorbance (A).

$$\boldsymbol{R + A + T = 1}$$

The UV-vis-spectroscopy is one of the mothed for determinig the band gap of YBCO. It is used for evaluating the optical absorption characteristic of YBCO. Tauc's formula is used for determining the band gap, which is given by

$$(\alpha h\nu)^n = c\,(h\nu - Eg)^n$$

where Eg is the absorption band gap, α the absorption coefficient, hν the photoenergy, c constant relative to the material, and n=2 to direct transition and ½ for an indirect transition.

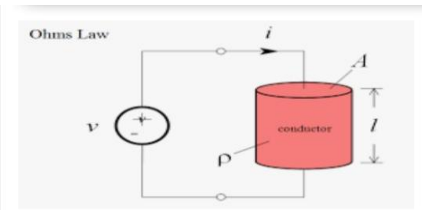
The optical response of a material is mainly studied in terms of the optical conductivity (σ)which is given by the relation

$$\sigma = \frac{\alpha\, n\, c}{\pi 4}$$

where c is the velocity of light,α is the absorption coefficient and n is the refractive index. It can be seen clearly that the optical conductivity directly depends on the absorption coefficient and the refractive index of the material.

The synthesized sample was analysed with V-I measurements, The experimental set up for performing I-V measurement was same as in the case of R-T measurement; but the purpose of measurement of this quiet different. Here we measure current against the voltage at fixed temperature to calculate a most valuable parameter Jc, which is the critical current density. The intercept of the I-V curve will give me critical current I_0 and the by using the formula current per unit area we can calculate Jc at different sample from the constant temperature(room temperature) in the superconducting state.

The electrical resistance of a wire would be expected to be greater for a longer wire, less for a wire of larger cross sectional area, and would be expected to depend upon the material out of which the wire is made. Experimentally, the dependence upon these properties is a straightforward one for a wide range of conditions, and the resistance of a wire can be expressed as



$$\boldsymbol{R = \frac{\rho\, L}{A}}$$

where is ρresistivity, L length, A cross sectional area.The factor in the resistance which takes into account the nature of the material is the resistivity. Although it is temperature dependent, it can be used at a given temperature to calculate the resistance of a wire of given geometry. It should be noted that it is being presumed that the current is uniform across the cross-section of the wire, which is true only for Direct Current. For Alternating Current there is the phenomenon of "skin effect" in which the current density is maximum at the maximum radius of the wire and drops for smaller radii within the wire. At radio frequencies, this becomes a major factor in design because the outer part of a wire or cable carries most of the current. The inverse of resistivity is called conductivity(σ). There are contexts where the use of conductivity is more convenient.

$$\sigma = \frac{1}{\rho}$$

IV. Results And Discussion:

a. The results of The UV-vis -spectrometry (UV/VIS): for analysis samples:

❖ **Optical Absorbance:**

The Absorbance spectrum was measured as a function of wavelength of pure$YBa_2Cu_3O_7$shown in figure [(4.1)] which represents Absorbance before doping it decreases and increases in range wavelength (200-300)nm and then remains constant,as we can see from the figure below. The highest peak is intended for the highest absorption and the lowest for the lowest absorption. The table below shows the highest peak recorded and the lowest peak.

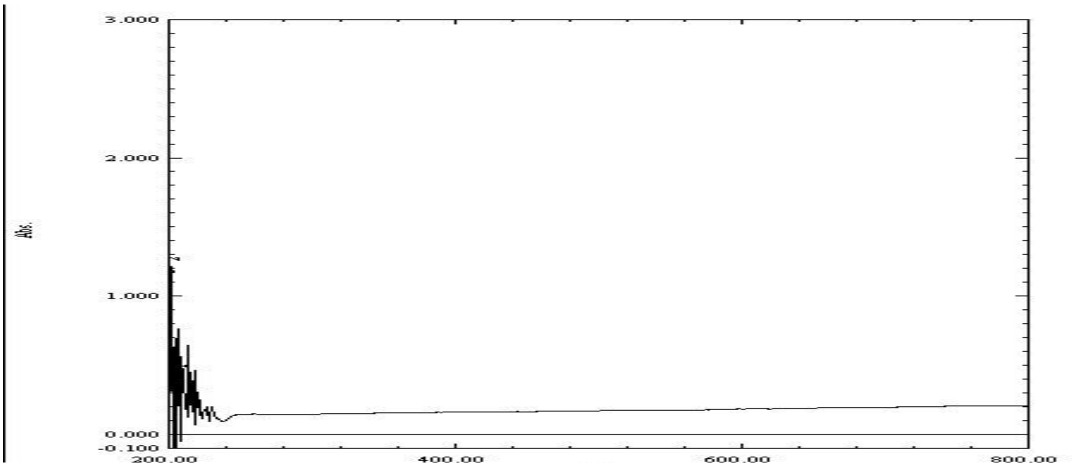


Fig (1) **UV-vis –spectrometry spectrum of pure YBCO sample (s_1)**

N0	pV/	Wavelength (nm)	Abs. (a.u)	α (cm^{-1})	N	σ (s^{-1})
1	▲	206.00	0.372	0.8567	0.17882	36.5668×10^8
2	▲	202.00	1.144	2.634	0.5416	81.9615×10^8
3	▼	238.00	0.100	0.2303	0.1251	6.87690×10^8
4	▼	203.00	0.125	0.2878	0.1294	8.88928×10^8

Table (2) UV-vis –spectrometry Spectrum description for pure YBCO sample (s_1)

The Absorbance spectrum was measured as a function of wavelength of $YBa_2Cu_3O_7$ doped with AL_2O_3 by volume ratio (0.015,0.03,0.045) shown in figure [(4.1)] which represents Absorbance after doping it decreases and increases in range wavelength (200- 300)nm and then remains constant,as we can see from the figure below. It turns otut that the absorption increases with increasing doped. from the figure we able to calculated absorption coefficient, refractive index and optical conductivity, we observed increment of an optical conduvtivity increases in absorbance.

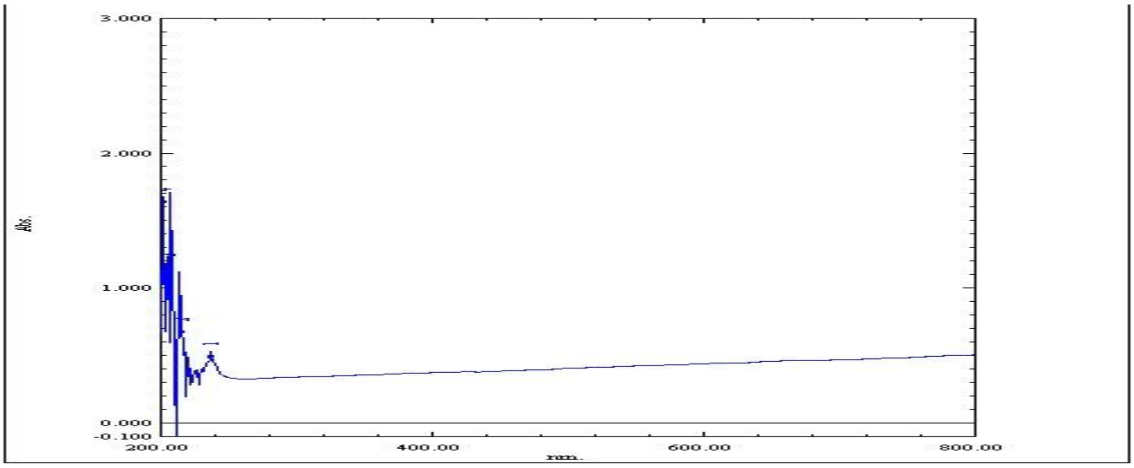


Fig (2) **UV-vis –spectrometry spectrum of YBCO which dopped with AL_2O_3sample (s_2)**

No	Pv/	Wavelength (nm)	Abs.(a.u.)	α (cm^{-1})	N	σ (s^{-1})
1	↑	237	0.463	1.066	0.199	5.0500×10^{8}
2	↑	215	0.643	1.480	0.255	8.9842×10^{8}
3	↑	205	1.129	2.600	0.527	32.618×10^{8}
4	↑	201	1.611	3.710	1.238	109.33×10^{8}
5	↓	261	0.328	0.755	0.169	3.0374×10^{8}
6	↓	222	0.338	0.778	0.170	3.1485×10^{8}
7	↓	212	0.522	1.202	0.217	6.2093×10^{8}
8	↓	203	0.675	1.554	0.268	9.9144×10^{8}

Table (3) UV-vis –spectrometry Spectrum description for YBCO which dopped with AL_2O_3sample (s_2)

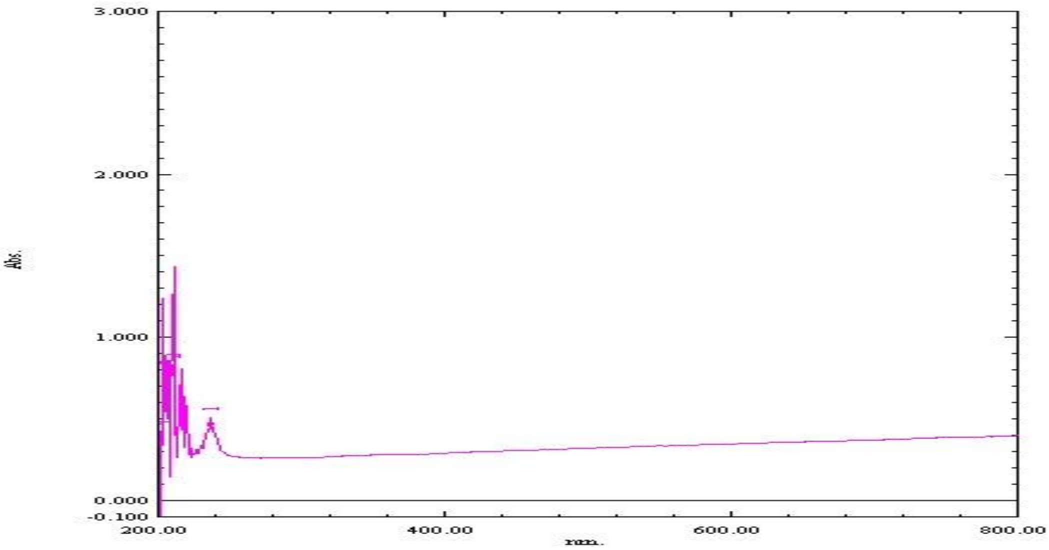


Fig (3) **UV-vis –spectrometry spectrum of YBCO which dopped with AL_2O_3sample (s_3)**

No	Pv/	Wavelength (nm)	Abs.(a.u.)	α (cm^{-1})	N	σ (s^{-1})
1	↑	237	0.437	1.006	0.194	4.646×10^{8}
2	↑	210	0.764	1.759	0.304	12.729×10^{8}
3	↑	207	0.728	1.676	0.289	11.530×10^{8}
4	↑	201	0.357	0.822	0.173	3.3853×10^{8}
5	↓	225	0.294	0.677	0.160	2.5786×10^{8}
6	↓	202	0.324	0.746	0.165	2.9302×10^{8}

Table (4) UV-vis –spectrometry Spectrum description for YBCO which dopped with AL_2O_3sample(s_3)

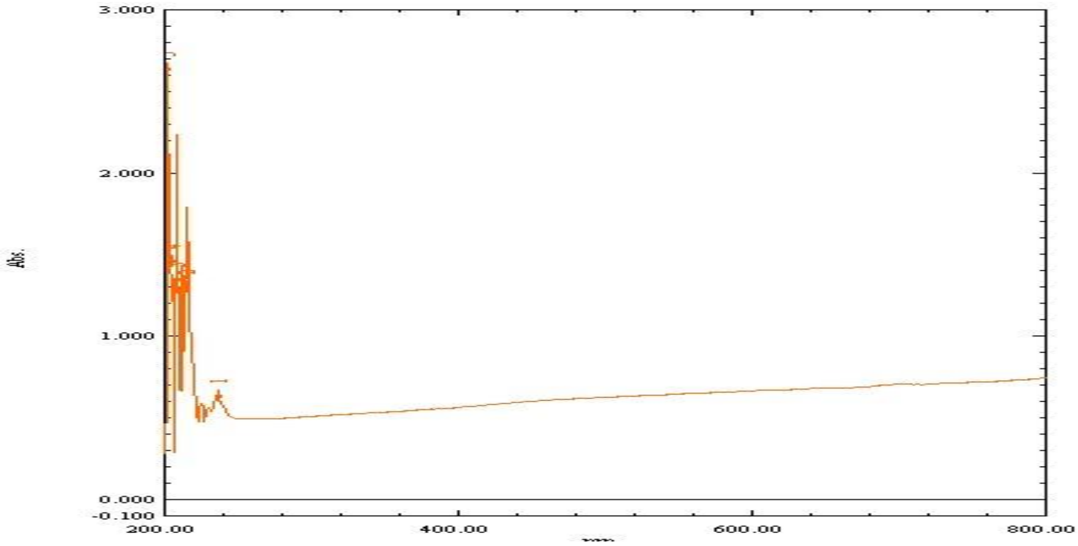


Fig (4) UV-vis –spectrometry spectrum of YBCO which dopped with AL_2O_3sample (s_4)

No	Pv/	Wavelength (nm)	Abs.(a.u.)	α (cm^{-1})	N	σ (s^{-1})
1	↑	236	0.601	1.384	0.241	7.940 ×10^8
2	↑	215	1.274	2.934	0.667	46.587×10^8
3	↑	208	1.314	3.026	0.714	51.433×10^8
4	↑	205	1.426	3.284	0.868	67.858×10^8
5	↑	202	2.608	6.006	6.069	867.72×10^8
6	↓	255	0.492	1.133	0.542	14.618×10^8
7	↓	227	0.538	1.239	1.157	34.126×10^8
8	↓	211	1.196	2.754	0.588	38.549×10^8
9	↓	207	1.276	2.938	0.669	46.790×10^8
10	↓	204	1.415	3.258	0.744	57.703×10^8

Table (5) UV-vis –spectrometry Spectrum description for YBCO which dopped with AL_2O_3sample (s_4)

❖ **Optical Transmittance :**

The Transmittance patterns of the pure $YBa_2Cu_3O_7$ samples is shown in figure [(4.1)], The figure shows the the transmittance as a function of the wavelength of pure $YBa_2Cu_3O_7$, where we notice an increase and decrease in the transmittance with an increase in the wavelength in the range (200 – 300),and from there it gradually decreases.

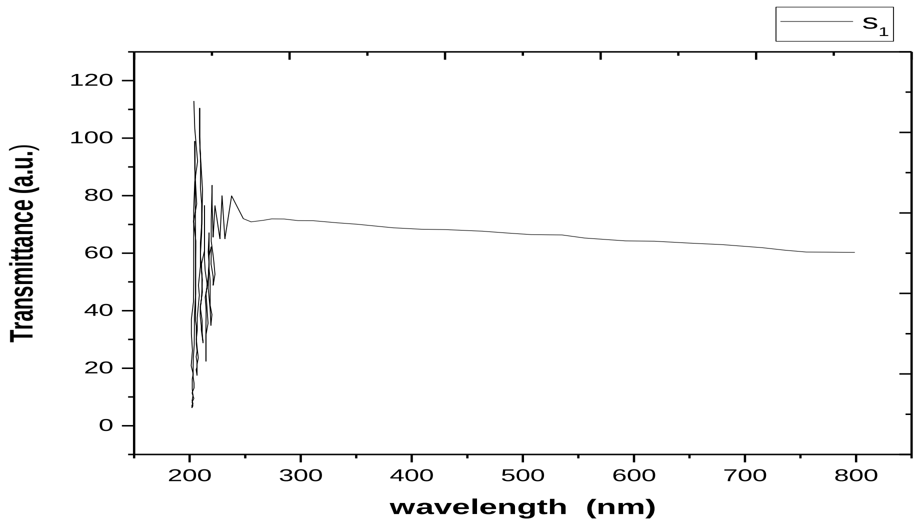


Fig (5) Transmittance spectrum of YBCO which dopped with AL_2O_3

The Transmittance patterns of the $YBa_2Cu_3O_7$doped with AL_2O_3samples is shown in figure [(4.1)], The figure shows the the transmittance as a function of the wavelength of YBa2Cu3O7 doped with AL2O3,where we notice an increase and decrease in the transmittance with an increase in the wavelength in the range (200 – 300),and from there it gradually decreases. We also note that the transmittance in the thrd sample (s_3) is higher than in the second and fourth and the highest value shown in the second sample (s_2).

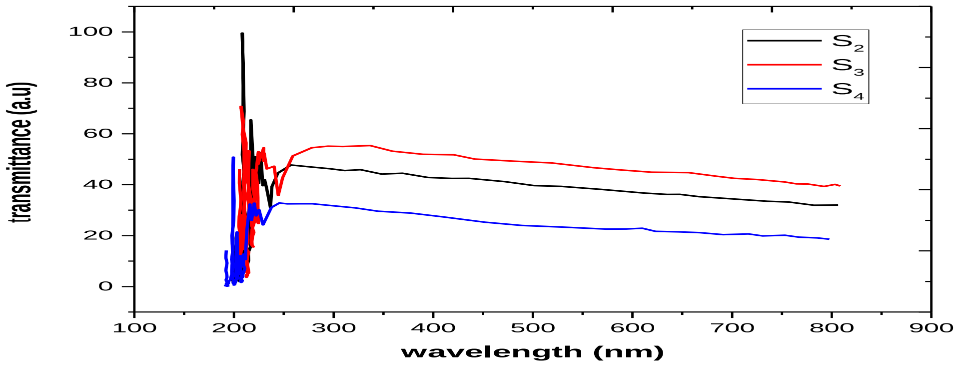


Fig (6) Transmittance spectrum of YBCO which dopped with AL_2O_3

❖ **Optical Reflectance:**

The reflectance was calculated by using the transmittance and absorbance spectra based on the energy retention law, The figure shows the reflectance as a function of the wavelength of the pure $YBa_2Cu_3O_7$, where we obsrve an increase and decrease in the reflectance with an increase in the wavelength in the range (200 – 300),and from there it gradually increases.

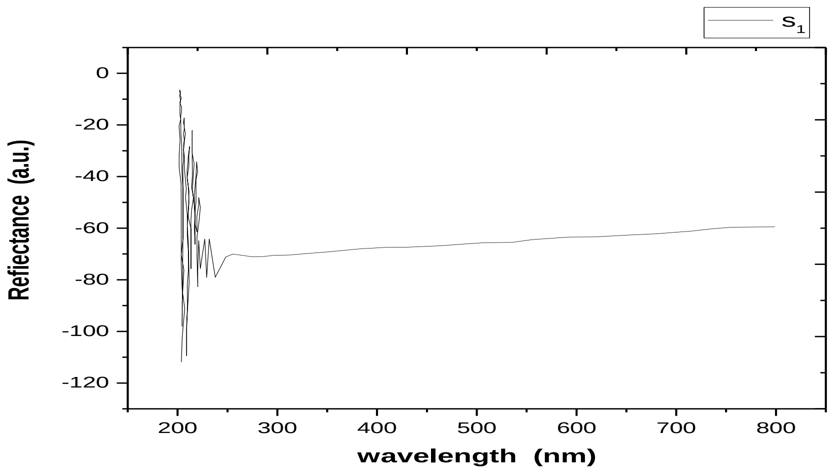


Fig (7) Reflectance spectrum of pure YBCO

The reflectance was calculated by using the transmittance and absorbance spectra based on the energy retention law, The figure shows the reflectance as a function of the wavelength of the $YBa_2Cu_3O_7$doped with AL_2O_3samples is shown in figure [(4.1)], where we obsrve an increase and decrease in the reflectance with an increase in the wavelength in the range (200 – 300),and from there it gradually increases, from there it gradually decreases. We also note that the transmittance in the thrd sample (s_3) is higher than in the second and fourth and the highest value shown in the second sample (s_2).

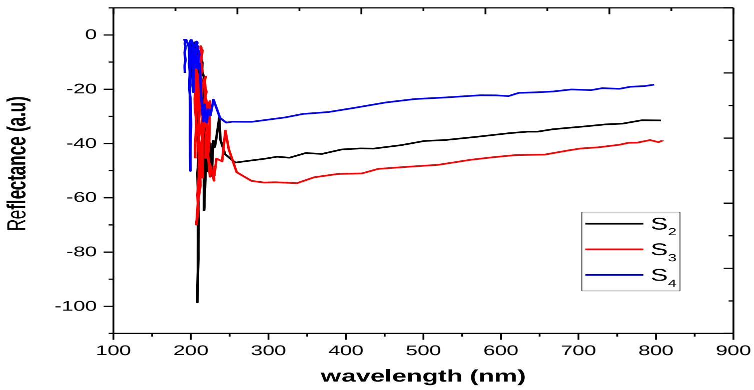


Fig (8)Reflectance spectrum of YBCO which dopped with AL_2O_3

❖ **optical energy gap:**

The optical energy gap value was calculated for $YBa_2Cu_3O_7$doped with AL_2O_3 samples is shown in figure [(4.1)], this is done through a graph between the energy value of the incident photon (hv)and $(\alpha hv)^2$ and by drawing the outer tangent of high absorption region of the curve to cross the energy axis of the photon at (y=0) where the point of intersction at x-axis is the value of the optical energy gap, through th figures (),and the results are shown in the table ()The optical energy gap less up doped, this is because the doped formed objective levels within the energy gap that led to the absorpation of low-energy photons, thus reducing the energy gap.

sample	Eg(pure)(ev)	Eg(doped)(ev)
S_1	5.02	--
S_2	--	4.88
S_3	--	4.02
S_4	--	3.91

Table (6) Energy gap values for the allowable electronic transition of pure YBCO and **YBCO which dopped with AL_2O_3**

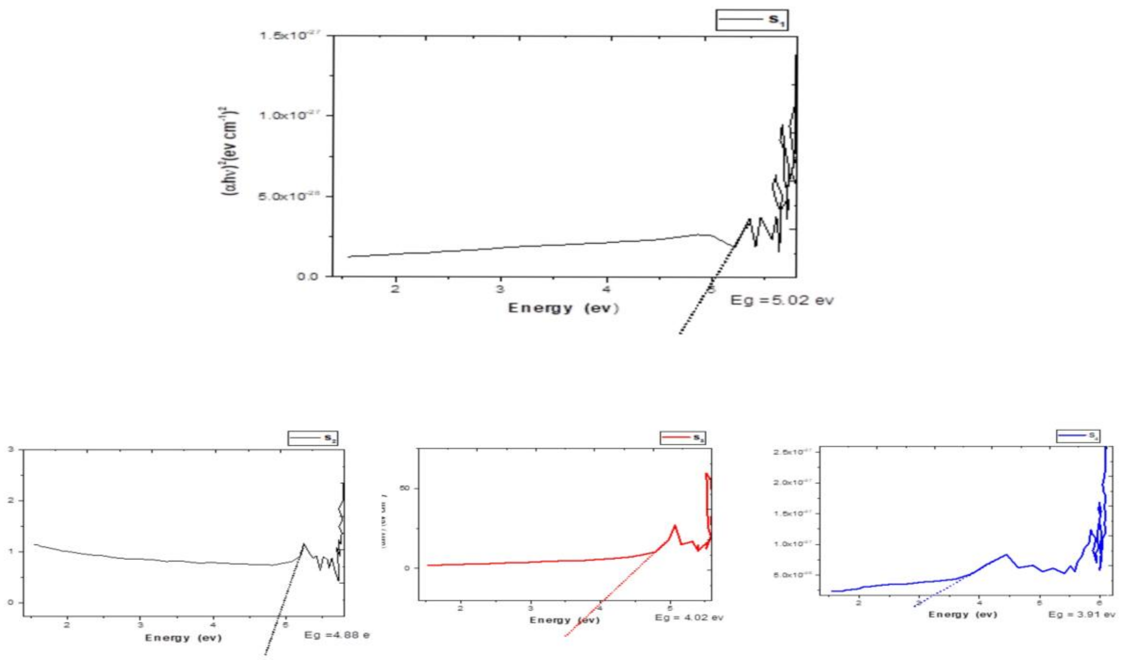


Fig (9)Energy gap values for the allowable electronic transition of pure YBCO and YBCO which dopped with AL_2O_3

b. The results of I-V analysis for analysis samples:

In this measurement we applied current across two probes and voltage was measured at constant temperatures with the help of close cycle referigerator. for pure $YBa_2Cu_3O_7$ The current was varying with the current source and calculated their corresponds voltage.From the figures at a ccertain temperature (30k) the critical current Ic is calculated. From the figures 10-14 the graph between current and voltage. From the figure, we observed an increment of critical current density which is clearly shown in figure-15.

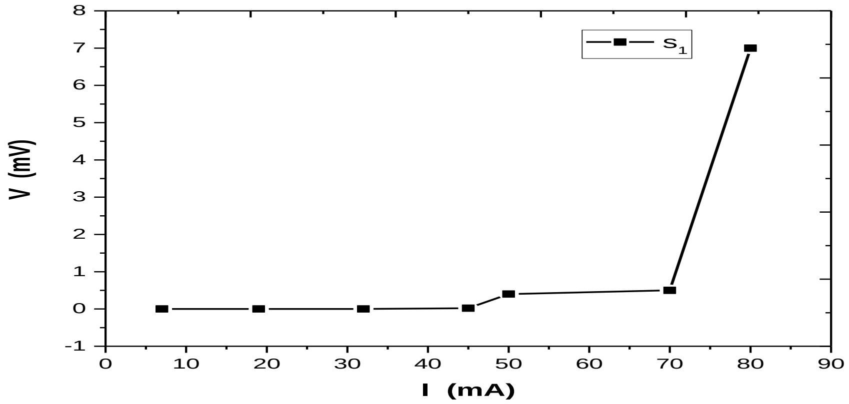


Fig (10) Graph between Current vs Voltage for samples (s_1)at room tempertuer

Ic= CriticaL Current(mA)	Jc=CURRENT DENSITY (A/m2)	ρ=Resistivity (Ωm)	σ= Conductivity
7	0.2147687×10^3	--	--
19	0.5829436×10^3	--	--
32	0.9817998×10^3	--	--
45	1.3806560×10^3	$0.10212536 \times 10^{-3}$	9.791887×10^3
50	1.5340623×10^3	0.0369851×10^{-3}	27.03915×10^3
70	2.1476872×10^3	0.0330284×10^{-3}	30.28624×10^3
80	2.4544997×10^3	0.0346736×10^{-3}	28.84038×10^3

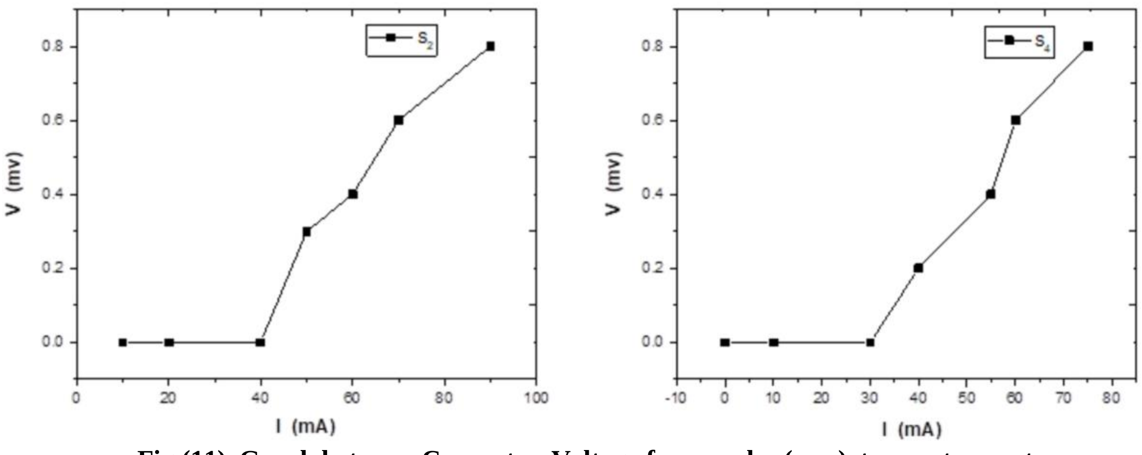


Fig (11) Graph between Current vs Voltage for samples (s_2,s_4)at room tempertuer

Ic= CriticaL Current(mA)	Jc=CURRENT DENSITY (A/m2)	ρ=Resistivity (Ωm)	σ= Conductivity
10	0.30681×10^3	--	--
20	0.61362×10^3	--	--
40	1.22724×10^3	--	--
50	1.53406×10^3	0.027738×10^3	36.051625×10^3
55	1.68746×10^3	0.033622×10^3	29.742430×10^3
60	1.84087×10^3	0.046231×10^3	21.630507×10^3
70	2.14768×10^3	0.056086×10^3	17.829761×10^3
75	2.30109×10^3	0.049174×10^3	20.335949×10^3
90	2.76131×10^3	0.041094×10^3	24.334452×10^3

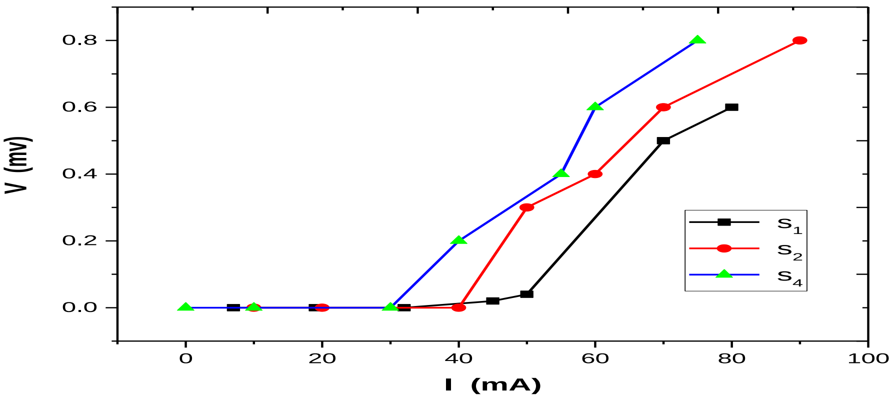


Fig (12) Comparision of graph between Current vs Voltage for all samples at room temperture

V. Conclusion:

through this study, The YBCO superconductor is prepared successfully via solid state reaction method. The UV-vis spectroscopyspectrum showed that the transmittance decreases with the increasing wavelength in the range (200- 300) nm, and then remains constant with increasing the wavelength, and absorbance increases with the increasing wavelength in the range (200- 300) nm, and then remains constant with increasing the wavelength. We found the optical energy gap decrease when we increase the dopping with $YBa_2Cu_3O_7$ whichdopped with AL_2O_3, and we found that the value of the energy gap is located between (5.02-3.91)ev. The decrease in optical energy gap lead to rise the value of the conductivity which can be useful in the developing of the soler cells. The optical conductivity increase with elevated of absorbance and when we use pure $YBa_2Cu_3O_7$ the absorbance elvated to hight point at λ=202 nm with small grading in values and we doped $YBa_2Cu_3O_7$ with AL_2O_3 also the absorbance elevated with large grading in values and meet with pure $YBa_2Cu_3O_7$ in hight value of absorbance at λ=202 nm which mean that the $YBa_2Cu_3O_7$ work perfectly at ultra violet area in the electromagnetic spectrum. We also subjected our sample for IV characterization at different sample at room temperature via four probe method and able to find the critical current density at the subsequent temperatures and found a decrement of critical current density with increment of temperature.

Reference:

[1]. Roland Hott, Reinhold Kleiner, Thomas Wolf& Gertrud Zwicknagl, (2004), SUPERCONDUCTING MATERIALS – A TOPICAL OVERVIEW, A. Narlikar (Ed.),"Frontiers in Superconducting Materials",Verlag Berlin.

[2]. AdirMoysesLuiz, (2010), Superconductor, JanezaTrdine, 51000 Rijeka, Croatia, ISBN 978-953-307-107-7 (chap3).

[3]. Hiroshi Kamimura, Hideki Ushio, ShunichiMatsuno, Tsuyoshi Hamada,(2005),Theory of Copper Oxide Superconductors, Berlin Heidelberg New York, 10 3-540-25189-8.

[4]. NikolayPlakida,(2005),Theory of copper oxide superconductors,Verlag Berlin Heidelberg Germany, 978-3-642-12632-1.

[5]. P.J. (Peter John), (2004), The rise of the superconductors, Springer Printed in the United States of America, 0-7484-0772-315.

[6]. Lawrence Dresner,(2002), Stability of Superconductors, ©2002 Kluwer Academic Publishers New York, Boston, Dordrecht, London, Moscow, 0-306- 45030-5.

[7]. Harshman, D. R., Fiory, A. T., & Dow, J. D. (2011). Theory of high- TC superconductivity: transition temperature.Journal of Physics: Condensed Matter, 23(29), 295701.

[8]. Peczkowski, P., Szterner, P., Jaegermann, Z., Kowalik, M., Zalecki, R., & Woch, W. M. (2018), Effects of Forming Pressure on Physicochemical Properties of YBCO Ceramics, Journal of Superconductivity and Novel Magnetism, 31(9), 2719-2732.

[9]. Szterner, P., Pęczkowski, P., & Jaegermann, Z. (2017). Ceramiczne nadprzewodniki wysokotemperaturowe–otrzymywanie YBa2Cu3O7-x metodami prażenia. Prace Instytutu Ceramiki i Materiałów Budowlanych, 10.

[10]. Howe, B. A. (2014), Crystal structure and superconductivity of YBa2Cu3O7- x.

[11]. Dalla Piazza, B.; Mourigal, M.; Christensen, N. B.; Nilsen, G. J.; Tregenna Piggott, P.; Perring, T. G.; Enderle, M.; McMorrow, D. F.; Ivanov, D. A.; Rønnow, H. M. (2015). "Fractional excitations in the square-lattice quantum antiferromagnet" .

[12]. Fédérale de Lausanne, 23 December 2014. Retrieved 23 December 2014,"How electrons split: New evidence of exotic behaviors" . Nanowerk. École Polytechnique. 23 December 2014. Archived from the orig

Sarah Ezzedine Hamza Mudawi, et. al. "Synthesis , optical, and electrical Properties Study of YBCO at Room Temperature." *IOSR Journal of Applied Physics (IOSR-JAP)*, 13(2), 2021, pp. 39-48.