



**Sudan University of Science and Technology**  
**College of Graduate Studies**



## **Synthesis of Yttrium Barium Copper Oxide and Optimizing for Superconductivity Application using UV-Vis Spectroscopy**

**تخليق أكسيد اليوتيريوم باريوم نحاس (YBCO) وتوليفة لتطبيقات الموصلية الفائقة باستخدام التحليل الطيفي للأشعة فوق البنفسجية**

**A dissertation submitted as a partial fulfillment of the requirement for a master Degree (M.Sc.) in physics**

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## الآية

قال تعالى:

" أَمَّنْ هُوَ قَانِتٌ آنَاءَ اللَّيْلِ سَاجِدًا وَقَائِمًا يَحْذَرُ الْآخِرَةَ وَيَرْجُو رَحْمَةَ رَبِّهِ قُلْ هَلْ يَسْتَوِي الَّذِينَ يَكْفُرُونَ وَالَّذِينَ  
لَا يَعْلَمُونَ إِنَّمَا يَتَذَكَّرُ أُولُوا الْأَلْبَابِ "

صدق الله العظيم

سورة الزمر الايه (9)

## Dedication

*I would like to dedicate this research to the pure spirits of my mother and father, to my angle and my friend and my source of strength after God my husband Sir Alkhatim, to the beautiful features of pure self pious heart manor words daughter of my precious niece Rayan, to the flame of intelligence and light my son Shams Eldeen, to which I see optimism and innocence in her eyes my daughter Alaa, to the face full of love, honesty and tolerance my son Muhammad, to the two little ones who enjoy life by being by my side my daughters Israa and Aaya, to the three precious to myself Lola, Hanem, and Soma, to my brothers and sisters, to my ants, to all my Family and friends*

# **Acknowledgements**

**I would like to express my sincere gratitude to my supervisor**

**Dr. Mahmoud Hamid Mahmoud Hilo**

For his respect full super vision to undertake this thesis with his knowledge of physics and gave me much encouragement and support to enable completion of this study.

My thanks must be extended to Ustaz. Mohammed Kamal, and Ustaz Elhady from El Nielin University; and Dr. Ali Suliman from Omdurman Islamic University, for their help and support.

## Abstract

In this thesis three samples of Yttrium Barium Copper Oxide (YBCO) were prepared and characterized via UV-Vis spectroscopy to determine their optical properties. It's importance brake out as it acts in the scope of superconductor, then its characteristics was studied using UV-Vis device, the samples were composited by different percentage (100, 90, and 80) % of Yttrium oxide which prepared with the chemical extenuation method.

The optical properties of each sample (the absorbance, absorption coefficient, transmittance, reflectance and energy gap) had been studied .results obtained showed that all the optical properties of the synthesized compound acts in the range of UV only, and reflectance increased with decreasing of yttrium oxide percentage, while transmittance and reflectance increased with the deceasing of yttrium oxide percentage in the sample

The energy gap (0.0035 eV to 0.0045 eV) obtained to match with the specification of superconductor's energy gap, which is probably a very good results, that is for superconducting material, must have a very small energy gap.

## المستخلص

في هذا البحث تم تحضير ثلاث عينات من أكسيد اليوتيريوم باريوم نحاس (YBCO) ودرست بواسطة التحليل الطيفي للأشعة فوق البنفسجية لتحديد خصائصها البصرية والتي تعتبر أمر مهم للغاية في مجال او نطاق الموصل الفائق ، ثم تمت دراسة خصائصه باستخدام جهاز UV-Vis ، وتم تكوين العينات بنسبة مئوية مختلفة (100 ، 90 ، و 80)٪ من أكسيد الإيتريوم الذي تم إعداده باستخدام طريقة التخفيف الكيميائي .

تمت دراسة الخواص البصرية لكل عينة (الامتصاص ، معامل الامتصاص ، النفاذية ، الانعكاس ، فجوة الطاقة) .النتائج التي تم الحصول عليها أظهرت أن جميع الخصائص البصرية للمركب تظهر وتعمل في نطاق الأشعة فوق البنفسجية فقط، ووجد ان الانعكاسية تزداد مع تناقص نسبة أكسيد الإيتريوم، وكذلك زادت النفاذية مع انخفاض نسبة أكسيد الإيتريوم في العينة.

فجوة الطاقة التي تم الحصول عليها كانت في المدى (0.0035 فولت إلى 0.0045 فولت) والتي تعتبر مناسبة جدا مع مواصفات فجوة الطاقة في الموصلات الفائقة، والتي ربما تكون نتائج جيدة للغاية، والتي تتعلق بالمواد فائقة التوصيل، ذات فجوة الطاقة الصغيرة جدًا.

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# CHAPTER ONE

## Introduction

### 1.1 Preface

From 1908 H. Kamerlingh Onnes, having successfully liquefied helium, was able to measure the electrical resistance of metals at very low temperatures. 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 4-10K. 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. 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. [1]

## **1.2 High – T<sub>c</sub> superconductors**

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. 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 used on bench-tops is Yttrium – Barium – Copper Oxide, or  $\text{YBa}_2\text{Cu}_3\text{O}_7$ , otherwise known as the 1-2-3 superconductor, and are classified as high temperature

Until 1986, the record transition temperature for a superconductor was 23 K. In that year, Bednorz and Muller synthesized the compound  $\text{La}_2\text{CuO}_4$  which remains superconducting up to 30 K, and soon afterwards other superconducting cuprites materials were discovered with even higher transition temperatures.  $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$

(YBCO) has a  $T_c$  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.[2]

### **1.3 Research problem**

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 give a wide range of possibilities to solve the resistance problem.

The Yttrium barium Copper Oxide(YBCO) compound seems to be very importance since its discovery, but the main and great goal to be achieved is to find a superconductor 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 raised their concern on YBCO, that is why this research discussion is prepared as to contribute on researches of YBCO on applications of superconductivity .the same way to share my opinion and experience

### **1.3.1 Aims**

This research aimed to the following:

### **1.3.2 General Objective**

To Synthesize YBCO and optimize it for application on superconductivity.

### **1.3.3 Specific Objectives**

- To synthesize the Yttrium barium Copper Oxide (YBCO) superconductor.
- To characterize optical properties of the YBCO in order to optimize it for applications of superconductivity
- To compare the results of this research with theoretical and experimental results on the literature review

### **1.4 Methodology**

The method used here in this research is to carry out experiment on which the sample of (YBCO) is prepared. Then the practical test for its properties using the UV-Vis device spectrometry is carried out too.

## **1.5 Lay out**

The research of the discussion is prepared into four chapters

Chapter one is prepared for the introduction.

Chapter two is for the theoretical background and the literature review

Chapter three is for the experimental part where results are shown

And finally chapter four is denoted to the discussion and conclusion.

## CHAPTER TWO

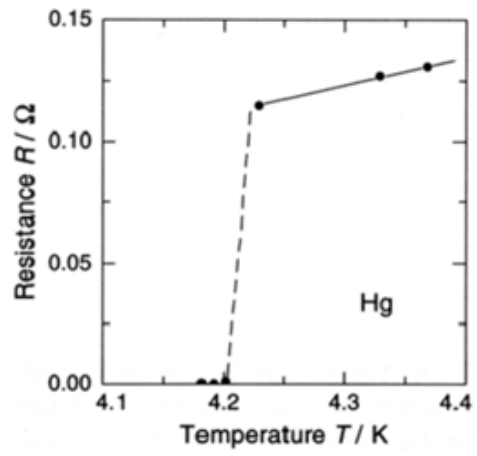
### Theoretical Background

#### 2.1 The discovery of superconductors

The phenomenon of superconductivity, in which the electrical resistance of certain materials completely vanishes at low temperatures, is one of the most interesting and sophisticated in condensed matter physics. It was first discovered by the Dutch physicist Heike Kamerlingh Onnes, who was the first to liquefy helium (which boils at 4.2 Kelvin at standard pressure). In 1911 Kamerlingh Onnes and one of his assistants discovered the phenomenon of superconductivity while studying the resistance of metals at low temperatures. They studied mercury because very pure samples could easily be prepared by distillation.

As in many other metals, the electrical resistance of mercury decreased steadily upon cooling, but dropped suddenly at 4.2 K, and became undetectably small. Soon after this discovery, many other elemental metals were found to exhibit zero resistance when their temperatures were lowered below a certain characteristic temperature of the material, called the critical temperature ( $T_c$ ) refer to figure (2.1)





**Fig (2.1)** The resistance of mercury measured by Onnes.

Table (2.1) The critical temperature of some superconductors,

Element	$T_c$ (K)	Element	$T_c$ (K)	Element	$T_c$ (K)
Al	1.19	Nb	9.2	Tc	7.8
Be	0.026	Np	0.075	Th	1.37
Cd	0.55	Os	0.65	Ti	0.39
Ga	1.09	Pa	1.3	Tl	2.39
Hf	0.13	Pb	7.2	U	0.2
Hg	4.15	Re	1.7	V	5.3
In	3.40	Rh	0.0003	W	0.012
Ir	0.14	Ru	0.5	Zn	0.9
La	4.8	Sn	3.75	Zr	0.55
Mo	0.92	Ta	4.39		

Compound	$T_c$ (K)	Compound	$T_c$ (K)	Compound	$T_c$ (K)
Nb <sub>3</sub> Sn	18.1	MgB <sub>2</sub>	39	UPt <sub>3</sub>	0.5
Nb <sub>3</sub> Ge	23.2	PbMo <sub>6</sub> S <sub>8</sub>	15	UPd <sub>2</sub> Al <sub>3</sub>	2
Cs <sub>3</sub> C <sub>60</sub>	19	YPd <sub>2</sub> B <sub>2</sub> C	23	(TMTSF) <sub>2</sub> ClO <sub>4</sub>	1.2
Cs <sub>3</sub> C <sub>60</sub>	40	HoNi <sub>2</sub> B <sub>2</sub> C	7.5	(ET) <sub>2</sub> Cu[Ni(CN) <sub>2</sub> ]Br	11.5

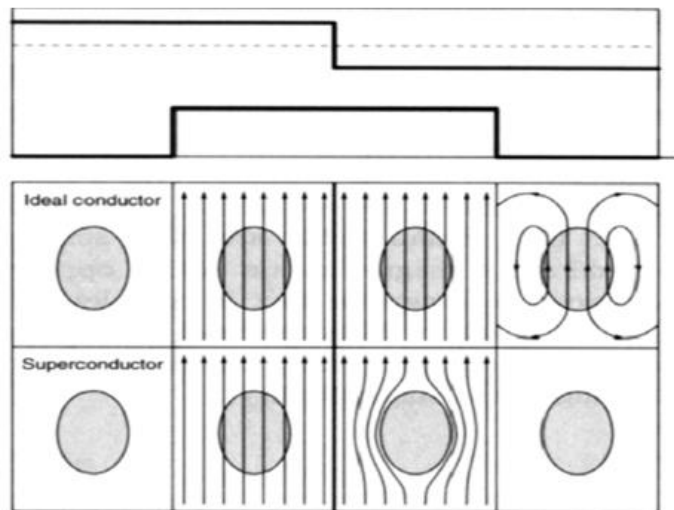
High- $T_c$ superconductor	$T_c$ (K)	High- $T_c$ superconductor	$T_c$ (K)
La <sub>1.83</sub> Sr <sub>0.17</sub> CuO <sub>4</sub>	38	Tl <sub>2</sub> Ba <sub>2</sub> Ca <sub>2</sub> Cu <sub>3</sub> O <sub>10+x</sub>	125
YBa <sub>2</sub> Cu <sub>3</sub> O <sub>6+x</sub>	93	HgBa <sub>2</sub> Ca <sub>2</sub> Cu <sub>3</sub> O <sub>8+x</sub>	135
Bi <sub>2</sub> Sr <sub>2</sub> Ca <sub>2</sub> Cu <sub>3</sub> O <sub>10+x</sub>	107	Hg <sub>0.8</sub> Tl <sub>0.2</sub> Ba <sub>2</sub> Ca <sub>2</sub> Cu <sub>3</sub> O <sub>8.33</sub>	134

## 2.2 Type I and II superconductors

In 1933, Walter Meissner and Robert Ochsenfeld discovered a magnetic phenomenon that showed that superconductors are not just perfect conductors.

Illustrates thought experiment that highlights this difference. Imagine that both the ideal conductor and superconductor are above their critical temperature,  $T_c$ . That is, they both are in a normal conducting state and have electrical resistance. A

magnetic field,  $B_a$ , is then applied. This results in the field penetrating both materials. Both samples are then cooled so that the ideal conductor now has zero resistance. It is found that the superconductor expels the magnetic field from inside it, while the ideal conductor maintains its interior field. Note that energy is needed by the superconductor to expel the magnetic field. This energy comes from the exothermic superconducting transition.



**Fig ( 2 .2) The Meissner effect,**

### **2.2.1 Type I**

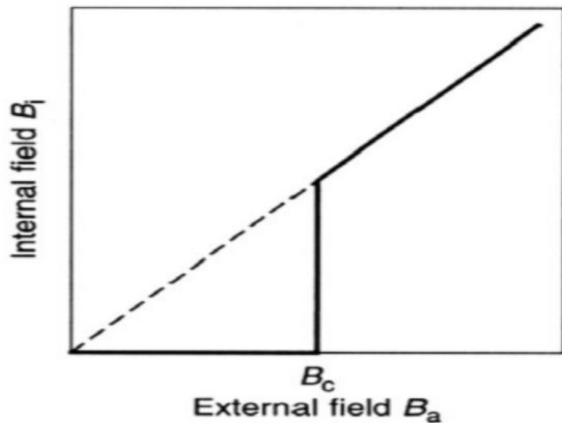
High magnetic fields destroy superconductivity and restore the normal conducting state. Depending on the character of this transition, we may distinguish between type I and II superconductors. The graph shown in Figure (2.3) illustrates the internal magnetic field strength,  $B_i$ , with increasing applied magnetic field. It is

found that the internal field is zero (as expected from the Meissner effect) until a critical magnetic field,  $B_c$ , is reached where a sudden transition to the normal state occurs. This results in the penetration of the applied field into the interior. Superconductors that undergo this abrupt transition to the normal state above a critical magnetic field are known as type I superconductors. Most of the pure elements in table (2.1) tend to be type I superconductors. Type II superconductors; on the other hand, respond differently to an applied magnetic field, as shown in Figure (2.4). An increasing field from zero results in two critical fields,  $B_{c1}$  and  $B_{c2}$ . At  $B_{c1}$  the applied field begins to partially penetrate the interior of the superconductor. However, the superconductivity is maintained at this point. The superconductivity vanishes above the second, much higher, critical field,  $B_{c2}$ . For applied fields between  $B_{c1}$  and  $B_{c2}$ , the applied field is able to partially penetrate the superconductor, so the Meissner effect is incomplete, allowing the superconductor to tolerate very high magnetic fields. [3]

### **2.2.2 Type II**

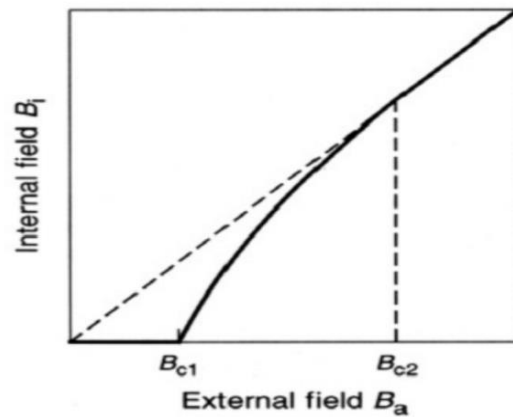
Type II superconductors are the most technologically useful because the second critical field can be quite high, enabling high field electromagnets to be made out of superconducting wire. Most compounds shown in table (2.1) are type-II superconductors. Wires made from say niobium-tin ( $Nb_3Sn$ ) have a  $B_{c2}$  as high as 24.5 Tesla – in practice it is lower. This makes them useful for applications

requiring high magnetic fields, such as Magnetic Resonance Imaging (MRI) machines. The advantage of using superconducting electromagnets is that the current only has to be applied once to the wires, which are then formed into a closed loop and allow the current (and field) to persist indefinitely – as long as the superconductor stays below the critical temperature. That is, the external power supply can be switched off. As a comparison, the strongest permanent magnets today may be able to produce a field close to 1 Tesla. However, it is possible to obtain up to 24.5 Tesla from a niobium–tin superconductor. There is a misconception amongst some non-specialists that the term "Type II" refers to the copper oxide based high temperature superconductors discovered in the late 1980s. While these are type II superconductors, so are many superconductors discovered before that time.



**Fig (2.3) Type- I superconductor**

**Behavior**

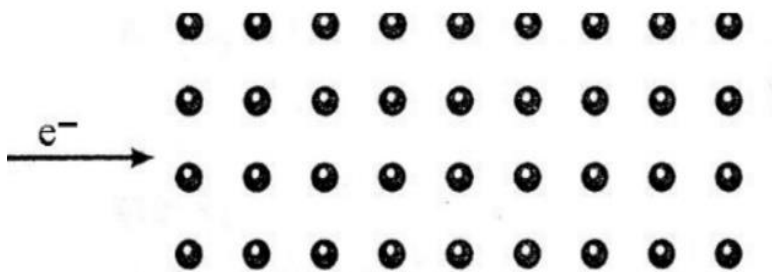


**Fig (2.4) Type-II superconductor**

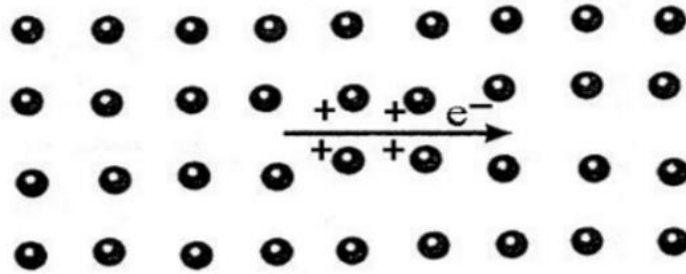
**Behavior**

### 2.3 BCS theory and Cooper pairs

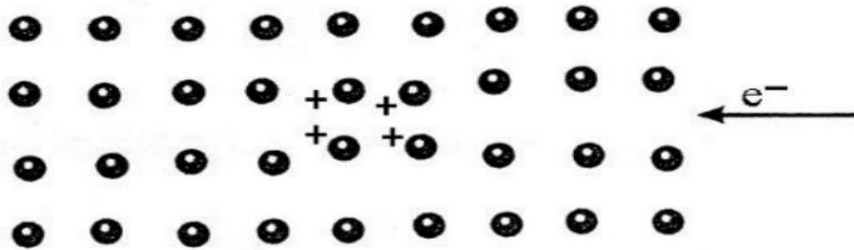
According to classical physics, part of the resistance of a metal is due to collisions between free electrons and the crystal lattice's vibrations, known as phonons. In addition, part of the resistance is due to scattering of electrons from impurities or defects in the conductor. As a result, the question arose as to why this does not happen in superconductors? A microscopic theory of superconductivity was developed in 1957 by John Bardeen, Leon Cooper and J .Robert Schrieffer, which is known as the BCS theory. The central feature of the BCS theory is that two electrons in the superconductor are able to form a bound pair called a Cooper pair if they somehow experience an attractive interaction between them. This notion at first sight seems counterintuitive since electrons normally repel one another because of their like charges. This may be thought of in the following way and is illustrated in Figure (2.7).



**Fig (2.5) First electron approach a section of the crystal lattice.**



**Fig (2.6) First electron deforms part of the lattice electro-statically.**



**Fig (2.7) Second electron is attracted to the net positive charge of the deformation.**

From the BCS theory, the total linear momentum of a Cooper pair must be zero. This means that they travel in opposite directions as shown in Figure (2.7). In addition, the nominal separation between the Cooper pair (called the coherence length) ranges from hundreds to thousands of ions separating them! This is quite a large distance and has been represented incorrectly in many textbooks on this subject. If electrons in a Cooper pair were too close, such as a couple of atomic spacing apart; the electrostatic (coulomb) repulsion will be much larger than the attraction from the lattice deformation and so they will repel each other. Thus there

will be no superconductivity. A current flowing in the superconductor just shifts the total momentum slightly from zero so that, on average, one electron in a Cooper pair has a slightly larger momentum magnitude than its pair. They do, however, still travel in opposite directions.

The interaction between a Cooper pair is transient. Each electron in the pair goes on to form a Cooper pair with other electrons, and this process continues with the newly formed Cooper pair so that each electron goes on to form a Cooper pair with other electrons. The end result is that each electron in the solid is attracted to every other electron forming a large network of interactions. Causing just one of these electrons to collide and scatter from atoms in the lattice means the whole network of electrons must be made to collide into the lattice, which is energetically too costly. The collective behavior of all the electrons in the solid prevents any further collisions with the lattice. Nature prefers situations that spend a minimum of energy. In this case, the minimum energy situation is to have no collisions with the lattice. A small amount of energy is needed to destroy the superconducting state and make it normal. This energy is called the energy gap. [4]

## **2.4 High – T<sub>c</sub> superconductors**

It has long been a dream of scientists working in the field of superconductivity to find a material that becomes a super conductor at room temperature. 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 by Bednorz and Müller that led to superconductors that we use today on a bench-top with liquid nitrogen to cool them. Not surprisingly, Bednorz and Müller received the Nobel Prize in 1987 (the fastest-ever recognition by the Nobel committee). The materials mostly used on bench-tops is Yttrium – Barium – Copper Oxide, or  $\text{YBa}_2\text{Cu}_3\text{O}_7$ , otherwise known as the 1-2-3 superconductor, and are classified as high temperature superconductors (HTC)

## **2.5 Classification**

There are many criteria by which superconductors are classified. The most common are

### **2.5.1 Response to a magnetic field**

A superconductor can be Type I, meaning it has a single critical field, above which all superconductivity is lost and below which the magnetic field is completely expelled from the superconductor; or Type II, meaning it has two critical fields, between which it allows partial penetration of the magnetic field through isolated

points. These points are called vortices. Furthermore, in multi component superconductors it is possible to have a combination of the two behaviors. In that case the superconductor is of Type-1 [5]

### **2.5.2 Theory of operation**

It is conventional if it can be explained by the BCS theory or its derivatives, unconventional, otherwise.[6]

### **2.5.3 Critical Temperature**

A superconductor is generally considered high-temperature if it reaches a superconducting state above a temperature of 30 K[7]; as in the initial discovery by Georg Bednorz and K. Alex Müller [5]. It may also reference materials that transition to superconductivity when cooled using liquid nitrogen – that is, at only  $T_c > 77$  K, although this is generally used only to emphasize that liquid nitrogen coolant is sufficient. Low temperature superconductors refer to materials with a critical temperature below 30 K. One exception to this rule is the iron pnictide group of superconductors which display behavior and properties typical of high temperature superconductors, yet some of the group have critical temperatures below 30K

### **2.5.4 Material**

superconducting pnictides (like fluorine-doped LaOFeAs) or organic superconductors (fullerenes and carbon nanotubes; though perhaps these examples should be included). Superconductor material classes include chemical elements (e.g. mercury or lead), alloys (such as niobium-titanium, germanium-niobium, and niobium nitride), ceramics (YBCO and magnesium diboride) and the chemical elements, as they are composed entirely of carbon).

### **2.6 Elementary properties of superconductors**

Heat capacity Most of the physical properties of superconductors vary from material to material, such as the critical temperature, critical field, and critical current density at which superconductivity is destroyed. On the other hand, there is a class of properties that are independent of the underlying material. For instance, all superconductors have exactly zero resistivity to low applied currents when there is no magnetic field present or if the applied field does not exceed a critical value. The existence of these "universal" properties implies that superconductivity is a thermodynamic phase, and thus possesses certain distinguishing properties which are largely independent of microscopic details.

## 2.7 Zero electrical DC resistance

The simplest method to measure the electrical resistance of a sample of some material is to place it in an electrical circuit in series with a current source  $I$  and measure the resulting voltage  $V$  across the sample. The resistance of the sample is given by Ohm's law as  $R = V / I$ . If the voltage is zero, this means that the resistance is zero.

Superconductors are also able to maintain a current with no applied voltage whatsoever, a property exploited in superconducting electromagnets such as those found in MRI machines. Experiments have demonstrated that currents in superconducting coils can persist for years without any measurable degradation. Experimental evidence points to a current lifetime of at least 100,000 years. Theoretical estimates for the lifetime of a persistent current can exceed the estimated lifetime of the universe, depending on the wire geometry and the temperature. In practice, currents injected in superconducting coils have persisted for more than 23 years in superconducting gravimeters.[8][9] In such instruments, the measurement principle is based on the monitoring of the levitation of a superconducting niobium sphere with a mass of 4 grams. In a normal conductor, an electric current may be visualized as a fluid of electrons moving across a heavy ionic lattice. The electrons are constantly colliding with the ions in the lattice, and during each collision some of the energy carried by the current is

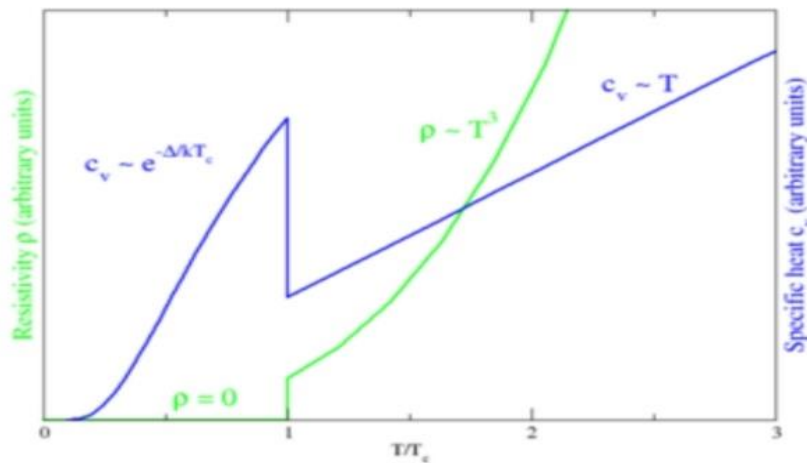
absorbed by the lattice and converted into heat, which is essentially the vibrational kinetic energy of the lattice ions. As a result, the energy carried by the current is constantly being dissipated. This is the phenomenon of electrical resistance and Joule heating.

The situation is different in a superconductor. In a conventional superconductor, the electronic fluid cannot be resolved into individual electrons. Instead, it consists of bound pairs of electrons known as Cooper pairs. This pairing is caused by an attractive force between electrons from the exchange of phonons. Due to quantum mechanics, the energy spectrum of this Cooper pair fluid possesses an energy gap, meaning there is a minimum amount of energy  $\Delta E$  that must be supplied in order to excite the fluid. Therefore, if  $\Delta E$  is larger than the thermal energy of the lattice, given by  $k_B T$

Where  $k_B$  is Boltzmann's constant and  $T$  is the temperature, the fluid will not be scattered by the lattice. The Cooper pair fluid is thus a superfluid, meaning it can flow without energy dissipation.

In a class of superconductors known as type II superconductors, including all known high-temperature superconductors, an extremely low but nonzero resistivity appears at temperatures not too far below the nominal superconducting transition when an electric current is applied in conjunction with a strong magnetic field, which may be caused by the electric current. This is due to the motion of magnetic

vortices in the electronic super fluid, which dissipates some of the energy carried by the current. If the current is sufficiently small, the vortices are stationary, and the resistivity vanishes. The resistance due to this effect is tiny compared with that of non-superconducting materials, but must be taken into account in sensitive experiments. However, as the temperature decreases far enough below the nominal superconducting transition, these vortices can become frozen into a disordered but stationary phase known as a "vortex glass". Below this vortex glass transition temperature, the resistance of the material becomes truly zero.



**Fig (2.8) Behavior of heat capacity ( $C_v$ , blue) and resistivity ( $\rho$ , green) at the superconducting phase transition.**

In superconducting materials, the characteristics of superconductivity appear when the temperature  $T$  is lowered below a critical temperature  $T_c$ . The value of this critical temperature varies from material to material. Conventional

superconductors usually have critical temperatures ranging from around 20 K to less than 1 K. Solid mercury, for example, has a critical temperature of 4.2 K. As of 2015, the highest critical temperature found for a conventional superconductor is 203K for H<sub>2</sub>S, although high pressures of approximately 90 Giga Pascal were required [10]. Cuprate superconductors can have much higher critical temperatures: YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7</sub>, one of the first cuprate superconductors to be discovered, has a critical temperature above 90 K, and mercury-based cuprates have been found with critical temperatures in excess of 130 K. The explanation for these high critical temperatures remains unknown. Electron pairing due to phonon exchanges explains superconductivity in conventional superconductors, but it does not explain superconductivity in the newer superconductors that have a very high critical temperature.

Similarly, at a fixed temperature below the critical temperature superconducting materials cease to act as superconductor when an external magnetic field is applied which is greater than the critical magnetic field. This is because the Gibbs free energy of the superconducting phase increases quadratically with the magnetic field while the free energy of the normal phase is roughly independent of the magnetic field. If the material superconducts in the absence of a field, then the superconducting phase free energy is lower than that of the normal phase and so for some finite value of the magnetic field (proportional to the square root of the

difference of the free energies at zero magnetic field) the two free energies will be equal and a phase transition to the normal phase will occur. More generally, a higher temperature and a stronger magnetic field lead to a smaller fraction of electrons that are superconducting and consequently to a longer London penetration depth of external magnetic fields and currents. The penetration depth becomes infinite at the phase transition.

The onset of superconductivity is accompanied by abrupt changes in various physical properties, which is the hallmark of a phase transition. For example, the electronic heat capacity is proportional to the temperature in the normal (non-superconducting) regime. At the superconducting transition, it suffers a discontinuous jump and thereafter ceases to be linear. At low temperatures, it varies instead as  $e^{-\alpha/T}$  for some constant,  $\alpha$ . This exponential behavior is one of the pieces of evidence for the existence of the energy gap.

The order of the superconducting phase transition was long a matter of debate. Experiments indicate that the transition is second-order, meaning there is no latent heat. However, in the presence of an external magnetic field there is latent heat, because the superconducting phase has lower entropy below the critical temperature than the normal phase. It has been experimentally demonstrated[11] that, as a consequence, when the magnetic field is increased beyond the critical field, the resulting phase transition leads to a decrease in the



temperature of the superconducting material due to the effect of long-range fluctuations in the electromagnetic field. In the 1980s it was shown theoretically with the help of a disorder field theory, in which the vortex lines of the superconductor play a major role, that the transition is of second order within the type II regime and of first order (i.e., latent heat) within the type I regime, and that the two regions are separated by a critical point.[12] The results were strongly supported by Monte Carlo computer simulations.[13]

## **2.8 Meissner effect**

When a superconductor is placed in a weak external magnetic field  $H$ , and cooled below its transition temperature, the magnetic field is ejected. The Meissner effect does not cause the field to be completely ejected but instead the field penetrates the superconductor but only to a very small distance, characterized by a parameter  $\lambda$ , called the London penetration depth, decaying exponentially to zero within the bulk of the material. The Meissner effect is a defining characteristic of superconductivity. For most superconductors, the London penetration depth is on the order of 100 nm.

The Meissner effect is sometimes confused with the kind of diamagnetism one would expect in a perfect electrical conductor: according to Lenz's law, when a changing magnetic field is applied to a conductor, it will induce an electric current in the conductor that creates an opposing magnetic field. In a perfect

conductor, an arbitrarily large current can be induced, and the resulting magnetic field exactly cancels the applied field.

The Meissner effect is distinct from this it is the spontaneous expulsion which occurs during transition to superconductivity. Suppose we have a material in its normal state, containing a constant internal magnetic field. When the material is cooled below the critical temperature, we would observe the abrupt expulsion of the internal magnetic field, which we would not expect based on Lenz's law.

The Meissner effect was given a phenomenological explanation by the brothers Fritz and Heinz London, who showed that the electromagnetic free energy in a superconductor is minimized provided

Where  $H$  is the magnetic field and  $\lambda$  is the London penetration depth.

This equation, which is known as the London equation, predicts that the magnetic field in a superconductor decays exponentially from whatever value .A superconductor with little or no magnetic field within it is said to be in the Meissner state. The Meissner state breaks down when the applied magnetic field is too large. Superconductors can be divided into two classes according to how this breakdown occurs. In Type I superconductors, superconductivity is abruptly destroyed when the strength of the applied field rises above a critical value  $H_c$ . Depending on the geometry of the sample, one may obtain an intermediate

state[14] consisting of a baroque pattern[15] of regions of normal material carrying a magnetic field mixed with regions of superconducting material containing no field. In Type II superconductors, raising the applied field past a critical value  $H_{c1}$  leads to a mixed state (also known as the vortex state) in which an increasing amount of magnetic flux penetrates the material, but there remains no resistance to the flow of electric current as long as the current is not too large. At second critical field strength  $H_{c2}$ , superconductivity is destroyed. The mixed state is actually caused by vortices in the electronic super fluid, sometimes called fluxions because the flux carried by these vortices is quantized. Most pure elemental superconductors, except niobium and carbon nano tubes, are Type I, while almost all impure and compound superconductors are Type II.

## **2.9 London moment**

Conversely, a spinning superconductor generates a magnetic field, precisely aligned with the spin axis. The effect, the London moment, was put to good use in Gravity Probe B. This experiment measured the magnetic fields of four superconducting gyroscopes to determine their spin axes. This was critical to the experiment since it is one of the few ways to accurately determine the spin axis of an otherwise featureless sphere.

## 2.10 High-temperature superconductivity

Until 1986, physicists had believed that BCS theory forbade superconductivity at temperatures above about 30 K. In that year, Bednorz and Müller discovered superconductivity in a lanthanum-based cuprate Perovskite material, which had a transition temperature of 35 K (Nobel Prize in Physics, 1987). It was soon found that replacing the lanthanum with yttrium (i.e., making YBCO) raised the critical temperature above 90 K.[16]

This temperature jump is particularly significant, since it allows liquid nitrogen as a refrigerant, replacing liquid helium.[16] This can be important commercially because liquid nitrogen can be produced relatively cheaply, even on-site. Also, the higher temperatures help avoid some of the problems that arise at liquid helium temperatures, such as the formation of plugs of frozen air that can block cryogenic lines and cause unanticipated and potentially hazardous pressure buildup.

Many other cuprate superconductors have since been discovered, and the theory of superconductivity in these materials is one of the major outstanding challenges of theoretical condensed matter physics.[17] There are currently two main hypotheses: the resonating-valence-bond theory, and spin fluctuation which has the most support in the research community. The second hypothesis proposed that electron pairing in high-temperature superconductors is mediated by short-range spin waves known as paramagnets.[dubious – discuss]

In 2008, holographic superconductivity, which uses holographic duality or AdS/CFT correspondence theory, was proposed by Gubser, Parnoll, Herzog, and Horowitz, as a possible explanation of high-temperature superconductivity in certain materials.[18]

Since about 1993, the highest-temperature superconductor has been a ceramic material consisting of mercury, barium, calcium, copper and oxygen ( $\text{HgBa}_2\text{Ca}_2\text{Cu}_3\text{O}_{8+\delta}$ ) with  $T_c = 133\text{--}138$  K. The latter experiment (138 K) still awaits experimental confirmation, however in February 2008, an iron-based family of high-temperature superconductors was discovered. Hideo Hosono, of the Tokyo Institute of Technology, and colleagues found lanthanum oxygen fluorine iron arsenide ( $\text{LaO}_{1-x}\text{F}_x\text{FeAs}$ ), an oxy pnictide that superconducts below 26 K. Replacing the lanthanum in  $\text{LaO}_{1-x}\text{F}_x\text{FeAs}$  with samarium leads to superconductors that work at 55 K.[19]

In May 2014, hydrogen sulfide ( $\text{H}_2\text{S}$ ) was predicted to be a high-temperature superconductor with a transition temperature of 80 K at 160 Giga Pascal of pressure. In 2015,  $\text{H}_2\text{S}$  has been observed to exhibit superconductivity at below 203 K but at extremely high pressures — around 150 Giga Pascal [20]

In 2018, a research team from the Department of Physics, Massachusetts Institute of Technology, discovered superconductivity in layer graphene with one layer twisted at an angle of approximately 1.1 degrees with cooling and applying a

small electric charge. Even if the experiments were not carried out in a high-temperature environment, the results are correlated less to classical but high temperature superconductors, given that no foreign atoms need to be introduced.

## **2.11 Applications**

Superconducting magnets are some of the most powerful electromagnets known. They are used in MRI/NMR machines, mass spectrometers, the beam-steering magnets used in particle accelerators and plasma confining magnets in some tokamaks. They can also be used for magnetic separation, where weakly magnetic particles are extracted from a background of less or non-magnetic particles, as in the pigment industries.

In the 1950s and 1960s, superconductors were used to build experimental digital computers using cryotron switches. More recently, superconductors have been used to make digital circuits based on rapid single flux quantum technology and RF and microwave filters for mobile phone base stations.

Superconductors are used to build Josephson junctions which are the building blocks of SQUIDs (superconducting quantum interference devices), the most sensitive magnetometers known. SQUIDs are used in scanning SQUID microscopes and magneto encephalography. Series of Josephson devices are used to realize the SI volt. Depending on the particular mode of operation,

a superconductor-insulator-superconductor Josephson junction can be used as a photon detector or as a mixer. The large resistance change at the transition from the normal- to the superconducting state is used to build thermometers in cryogenic micro-calorimeter photon detectors. The same effect is used in ultrasensitive bolometers made from superconducting materials.

Other early markets are arising where the relative efficiency, size and weight advantages of devices based on high-temperature superconductivity outweigh the additional costs involved. For example, in wind turbines the lower weight and volume of superconducting generators could lead to savings in construction and tower costs, offsetting the higher costs for the generator and lowering the total LCOE.[21]

Promising future applications include high-performance smart grid, electric power transmission, transformers, power storage devices, electric motors (e.g. for vehicle propulsion, as in vactrains or maglev trains), magnetic levitation devices, fault current limiters, enhancing spintronic devices with superconducting materials, and superconducting magnetic refrigeration. However, superconductivity is sensitive to moving magnetic fields so applications that use alternating current (e.g. transformers) will be more difficult to develop than those that rely upon direct current. Compared to traditional power lines superconducting transmission lines are more efficient and require only a fraction of the space, which would not only

lead to a better environmental performance but could also improve public acceptance for expansion of the electric grid.[22]

## **2.12 Optical properties**

In physics, refraction is the change in direction of a wave passing from one medium to another or from a gradual change in the medium.[23] Refraction of light is the most commonly observed phenomenon, but other waves such as sound waves and water waves also experience refraction. How much a wave is refracted is determined by the change in wave speed and the initial direction of wave propagation relative to the direction of change in speed. For light, refraction follows Snell's law, which states that, for a given pair of media, the ratio of the sines of the angle of incidence  $\theta_1$  and angle of refraction  $\theta_2$  is equal to the ratio of phase velocities ( $v_1 / v_2$ ) in the two media, or equivalently, to the indices of refraction ( $n_2 / n_1$ ) of the two media.

Refraction of light at the interface between two media of different refractive indices, with  $n_2 > n_1$  since the phase velocity is lower in the second medium ( $v_2 < v_1$ ), the angle of refraction  $\theta_2$  is less than the angle of incidence  $\theta_1$ ; that is, the ray in the higher-index medium is closer to the normal.

Optical prisms and lenses use refraction to redirect light, as does the human eye. The refractive index of materials varies with the wavelength of light, and thus the



angle of the refraction also varies correspondingly. This is called dispersion and causes prisms and rainbows to divide white light into its constituent spectral colors[24]. When a wave moves into a slower medium the wave fronts get compressed. For the wave fronts to stay connected at the boundary the wave must change direction.

Consider a wave going from one material to another where its speed is slower. If it reaches the interface between the materials at an angle one side of the wave will reach the second material first, and therefore slow down earlier. With one side of the wave going slower the whole wave will pivot towards that side. This is why a wave will bend away from the surface or toward the normal when going into a slower material. In the opposite case of a wave reaching a material where the speed is higher, one side of the wave will speed up and the wave will pivot away from that side.

Another way of understanding the same thing is to consider the change in wavelength at the interface. When the wave goes from one material to another where the wave has a different speed  $v$ , the frequency  $f$  of the wave will stay the same, but the distance between wave fronts or wavelength  $\lambda = v/f$  will change. If the speed is decreased, such as in the figure to the right, the wavelength will also decrease. With an angle between the wave fronts and the interface and change in distance between the wave fronts the angle must change over the interface to keep

the wave fronts intact. From these considerations the relationship between the angle of incidence  $\theta_1$ , angle of transmission  $\theta_2$  and the wave speeds  $v_1$  and  $v_2$  in the two materials can be derived. This is the law of refraction or Snell's law and can be written as [25]

In physics, refraction is the change in direction of a wave passing from one medium to another or from a gradual change in the medium. Refraction of light is the most commonly observed phenomenon, but other waves such as sound waves and water waves also experience refraction. How much a wave is refracted is determined by the change in wave speed and the initial direction of wave propagation relative to the direction of change in speed.

Polarization is a property applying to transverse waves that specifies the geometrical orientation of the oscillations. In a transverse wave, the direction of the oscillation is perpendicular to the direction of motion of the wave. A simple example of a polarized transverse wave is vibrations traveling along a taut string (see image); for example, in a musical instrument like a guitar string. Depending on how the string is plucked, the vibrations can be in a vertical direction, horizontal direction, or at any angle perpendicular to the string. In contrast, in longitudinal waves, such as sound waves in a liquid or gas, the displacement of the particles in the oscillation is always in the direction of propagation, so these waves do not exhibit polarization. Transverse waves that

exhibit polarization include electromagnetic waves such as light and radio waves, gravitational waves, and transverse sound waves in solids.

Reflection is the change in direction of a wave front at an interface between two different media so that the wave front returns into the medium from which it originated. Common examples include the reflection of light, sound and water waves. The law of reflection says that for specular reflection the angle at which the wave is incident on the surface equals the angle at which it is reflected. Mirrors exhibit specular reflection.

In physics, absorption of electromagnetic radiation is how matter takes up a photon's energy and so transforms electromagnetic energy into internal energy of the absorber. A notable effect (attenuation) is to gradually reduce the intensity of light waves as they propagate through a medium. Although the absorption of waves does not usually depend on their intensity, in certain conditions (optics) the medium's transparency changes by a factor that varies as a function of wave intensity, and storable absorption occurs.

Transmittance of the surface of a material is its effectiveness in transmitting radiant energy. It is the fraction of incident electromagnetic power that is transmitted through a sample, in contrast to the transmission coefficient, which is the ratio of the transmitted to incident electric field.

Diffraction refers to various phenomena that occur when a wave encounters an obstacle or a slit. It is defined as the bending of waves around the corners of an obstacle or through an aperture into the region of geometrical shadow of the obstacle/aperture. The diffracting object or aperture effectively becomes a secondary source of the propagating wave. Italian scientist Francesco Maria Grimaldi coined the word "diffraction" and was the first to record accurate observations of the phenomenon in 1660. In optics, dispersion is the phenomenon in which the phase velocity of a wave depends on its frequency. In optics, a diachronic material is either one which causes visible light to be split up into distinct beams of different wavelengths (colors), or one in which light rays having different polarizations are absorbed by different amounts.

Birefringence is the optical property of a material having a refractive index that depends on the polarization and propagation direction of light. These optically anisotropic materials are said to be birefringent. The birefringence is often quantified as the maximum difference between refractive indices exhibited by the material. Crystals with non-cubic crystal structures are often birefringent, as are plastics under mechanical stress.

## **2.13 Devices**

Ultraviolet–visible spectroscopy or ultraviolet–visible spectrophotometer (UV–Vis or UV/Vis) refers to absorption spectroscopy or reflectance spectroscopy in part of

the ultraviolet and the full, adjacent visible spectral regions. This means it uses light in the visible and adjacent ranges. The absorption or reflectance in the visible range directly affects the perceived color of the chemicals involved. In this region of the electromagnetic spectrum, atoms and molecules undergo electronic transitions. Absorption spectroscopy is complementary to fluorescence spectroscopy, in that fluorescence deals with transitions from the excited state to the ground state, while absorption measures transitions from the ground state to the excited state distance between the flux lines becomes smaller [26].

## 2.14 Principle of ultraviolet–visible absorption

Molecules containing bonding and non-bonding electrons (n-electrons) can absorb energy in the form of ultraviolet or visible light to excite these electrons to higher anti-bonding molecular orbitals. The more easily excited the electrons (i.e. lower energy gap between the HOMO and the LUMO), the longer the wavelength of light it can absorb. There are four possible types of transitions ( $\pi\text{-}\pi^*$ ,  $n\text{-}\pi^*$ ,  $\sigma\text{-}\sigma^*$ , and  $n\text{-}\sigma^*$ ), and they can be ordered as follows:  $\sigma\text{-}\sigma^* > n\text{-}\sigma^* > \pi\text{-}\pi^* > n\text{-}\pi^*$ .

## 2.15 Applications

UV/Vis spectroscopy is routinely used in analytical chemistry for the quantitative determination of different analyses, such as transition metal ions, highly conjugated organic compounds, and biological macromolecules.

Spectroscopic analysis is commonly carried out in solutions but solids and gases may also be studied.

Solutions of transition metal ions can be colored (i.e., absorb visible light) because d electrons within the metal atoms can be excited from one electronic state to another. The color of metal ion solutions is strongly affected by the presence of other species, such as certain anions or ligands. For instance, the color of a dilute solution of copper sulfate is a very light blue; adding ammonia intensifies the color and changes the wavelength of maximum absorption ( $\lambda_{\text{max}}$ ).

Organic compounds, especially those with a high degree of conjugation, also absorb light in the UV or visible regions of the electromagnetic spectrum. The solvents for these determinations are often water for water-soluble compounds, or ethanol for organic-soluble compounds. (Organic solvents may have significant UV absorption; not all solvents are suitable for use in UV spectroscopy. Ethanol absorbs very weakly at most wavelengths.) Solvent polarity and pH can affect the absorption spectrum of an organic compound. Tyrosine, for example, increases in absorption maxima and molar extinction coefficient when pH increases from 6 to 13 or when solvent polarity decreases. While charge transfer complexes also give rise to colors, the colors are often too intense to be used for quantitative measurement.

## 2.16 The Beer-Lambert law

It states that the absorbance of a solution is directly proportional to the concentration of the absorbing species in the solution and the path length.<sup>[3]</sup> Thus, for a fixed path length, UV/Vis spectroscopy can be used to determine the concentration of the absorber in a solution. It is necessary to know how quickly the absorbance changes with concentration. This can be taken from references (tables of molar extinction coefficients), or more accurately, determined from a calibration curve

A UV/Vis spectrophotometer may be used as a detector for HPLC. The presence of an analytic gives a response assumed to be proportional to the concentration. For accurate results, the instrument's response to the analytic in the unknown should be compared with the response to a standard; this is very similar to the use of calibration curves. The response (e.g., peak height) for a particular concentration is known as the response factor.

The wavelengths of absorption peaks can be correlated with the types of bonds in a given molecule and are valuable in determining the functional groups within a molecule. The Woodward–Fieser rules, for instance, are a set of empirical observations used to predict  $\lambda_{\text{max}}$ , the wavelength of the most intense UV/Vis absorption, for conjugated organic compounds such as dienes and ketones. The

spectrum alone is not, however, a specific test for any given sample. The nature of the solvent, the pH of the solution, temperature, high electrolyte concentrations, and the presence of interfering substances can influence the absorption spectrum. Experimental variations such as the slit width (effective bandwidth) of the spectrophotometer will also alter the spectrum. To apply UV/Vis spectroscopy to analysis, these variables must be controlled or accounted for in order to identify the substances present. The method is most often used in a quantitative way to determine concentrations of an absorbing species in solution, using the Beer-Lambert law

Where  $A$  is the measured absorbance (in Absorbance Units (AU)),  $I_0$  is the intensity of the incident light at a given wavelength,  $I$  is the transmitted intensity,  $L$  the path length through the sample, and  $c$  the concentration of the absorbing species. For each species and wavelength,  $\epsilon$  is a constant known as the molar absorptive or extinction coefficient. This constant is a fundamental molecular property in a given solvent, at a particular temperature and pressure, and has units of  $1/M \cdot cm$

The absorbance and extinction  $\epsilon$  are sometimes defined in terms of the natural logarithm instead of the base-10 logarithm. The Beer-Lambert Law is useful for characterizing many compounds but does not hold as a universal relationship for the concentration and absorption of all substances. A 2nd order polynomial



relationship between absorption and concentration is sometimes encountered for very large, complex molecules such as organic dyes (Xylenol Orange or Neutral Red, for example).

UV–Vis spectroscopy is also used in the semiconductor industry to measure the thickness and optical properties of thin films on a wafer. UV–Vis spectrometers are used to measure the reflectance of light, and can be analyzed via the Forouhi-Bloomer dispersion equations to determine the Index of Refraction ( $n$ ) and the Extinction Coefficient ( $k$ ) of a given film across the measured spectral range.

## CHAPTER THREE

### Experimental Set up

#### 3.1 Materials

- Yttrium oxide ( $Y_2O_3$ ) – Wight powder -
- Barium Carbonate ( $BaCO_3$ ) -
- Copper oxide ( $CuO$ ) – black powder
- Diluted sulfuric acid
- Distilled water

#### 3.2 Devices (apparatus)

Marble Mortar



500 ml crucible



1500 C<sup>0</sup> Carbolated oven



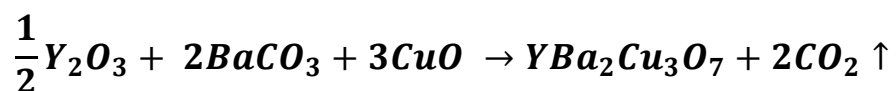
## Sensitive balance



### 3.3 Method

To obtain the desired superconducting compound, each of  $Y_2O_3$ (0.151 gm),  $BaCO_3$  (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



Sample (1)

$$\text{Y}_2\text{O}_3(0.151\text{ gm}) * 3 = 0.453\text{ gm} \quad (3.1)$$

$$\text{BaCO}_3(0.529\text{ gm}) * 3 = 1.587\text{ gm}$$

$$\text{CuO}(0.320\text{ gm}) * 3 = 0.96\text{ gm}$$

Sample (2)

$$\text{Y}_2\text{O}_3 (0.1359\text{ gm}) * 3 = 0.4077\text{ gm} \quad (3.2)$$

$$\text{BaCO}_3 (0.529\text{ gm}) * 3 = 1.587\text{ gm}$$

$$\text{CuO} (0.320\text{ gm}) * 3 = 0.96\text{ gm}$$

Sample (3)

$$\text{Y}_2\text{O} (0.1208\text{ gm}) * 3 = 0.3624\text{ gm} \quad (3.3)$$

$$\text{BaCO}_3 (0.529\text{ gm}) * 3 = 1.587\text{ gm}$$

$$\text{CuO} (0.320\text{ gm}) * 3 = 0.96\text{ gm}$$

In preparing each sample, the above weights were obtained using a sensitive balance with atmosphere insulating glass. In the beginning, the Mortar was washed using distilled water and diluted sulfuric acid 40%. The washing process has been done in sequence, as the tool were washed firstly using tap water, followed by immersing it 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  $850\text{ }^{\circ}\text{C}$ . 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  $850^{\circ}\text{C}$ . 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 steps for, sample 2 and 3 were prepared with 90%, 80% respectively.

### **3.4 UV / Vis spectroscopy**

(UV / Vis) is a type of spectroscopy that is classified under absorption spectroscopy, which occurs in the field of UV spectrum and in the visible spectrum. This means that spectroscopy uses light in both the visible and the near fields of the UV spectrum, and even parts of the near-infrared (NIR) spectrum. Absorption or reflection in the visible field affects the perceived color sensation on

chemicals, where electronic transitions occur as a result of the effect of electromagnetic radiation.

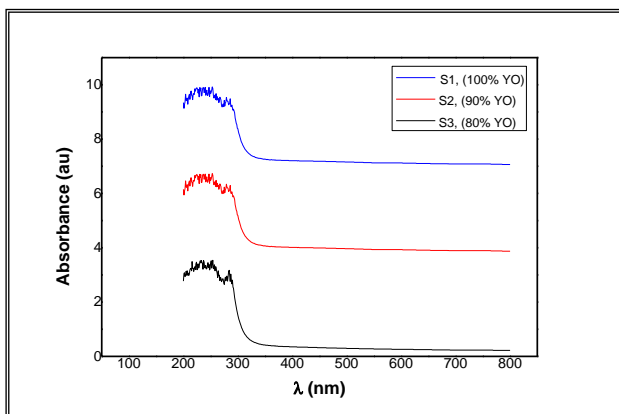
**Photos of the samples during preparations**



## Chapter Four

### Results and Discussion

#### 4.1 Absorbance

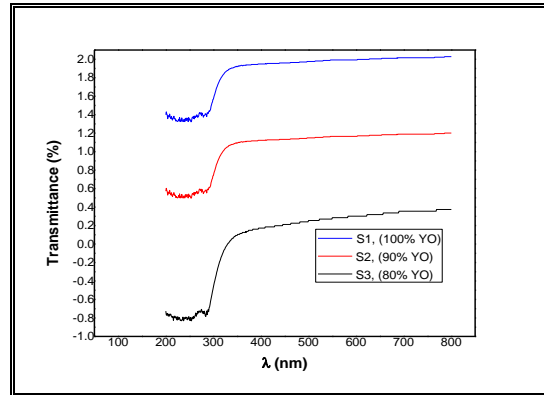


**Fig (4.1) the absorbance as a function of the wavelength for the three sample of different YO percentage**

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 decreases of the absorbability of (YBCO).

## 4.2 Transmittance



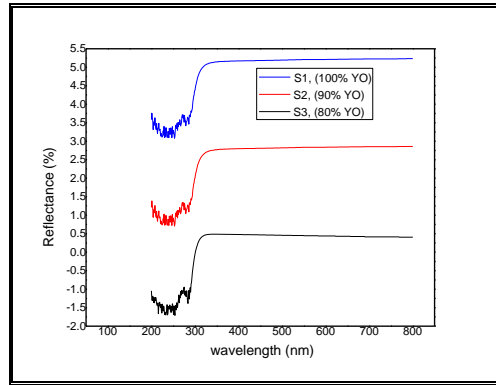
**Fig (4.2) the transmittance as a function of the wavelength for the three sample of different YO percentage**

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.



### 4.3 Reflectance

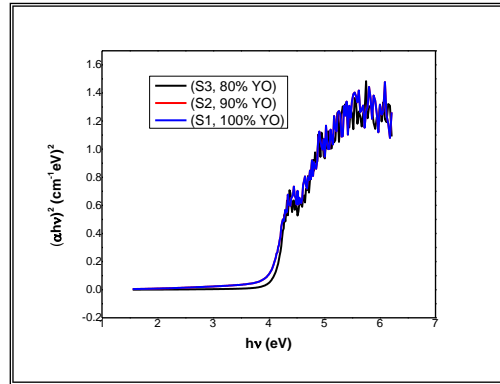


**Fig (4.3) the reflectance as a function of the wavelength for the three sample of different YO percentage**

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.

## 4.4 Energy gap



**Fig (4.4) the energy gap for the three sample of different YO percentage**

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 gap 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.

## 4.5 Conclusion

At the conclusion of this research, it can be said that the results were 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.

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