International Journal of Renewable Energy Technology Research
Vol. 3, No. 10, December 2014, pp. 1 - 8, ISSN: 2325 - 3924 (Online)
Available online at http://ijretr.org

Research article

Determination of energy gap copper oxide by four probe methods

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Abstract

In this study, on a four-probe, I put a sample of copper oxide, size $(10x15x3mm^3)$. Was used Then, electric current is passed at magnitude 8mA at different temperatures in the range $(29^0 - 150^0)$. And by taking 13 reading for the effort in this range, and using the energy equation, electrical resistivity has been found for copper oxide and it has been utilized in determining the energy gap according to the general energy equation.

The value of the energy gap of copper oxide using this method (1.6 eV) was also found very close to the experimental values. The difference in values is due to the presence of a small percentage of impurities in the sample and this method is effective in the calculation of the energy gap for some semiconductors. **Copyright © IJRETR, all rights reserved.**

Key words: copper, cupric oxide Cu_2O , CuO , energy gap E_g ,

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1. Introduction

Determination of the band gap energy of semiconductors and specially semiconductor nanostructures is of great interest since it is directly related to the nanometer sized particles. Therefore, many efforts have been focused on the evaluation of the band gap energy to investigate the optical properties. Semiconductor nanoparticles produced by various methods constituting different sizes, thereby particles size distribution introduces many consequences on the optical properties due to the corresponding band gap.

Therefore studying the particle size and their size distribution could be considered a crucial point.

Cuprous oxides Cu_2O and CuO are the main semiconductor phases of copper oxides. Cu_2O Form a cubic structure with lattice parameter of 4.27Å [1] . And direct band gap of 2.2 eV , while CuO has monoclinic crystal structure and indirect band gap of 1.4 eV [2]. A met stable copper oxide paramelacouite Cu_4O_3 , which is an intermediate compound between the Cu_2O and CuO also, had been reported [3]. Due to copper oxides potential applications, such as, in solar cells [4]. Catalysis [5]. And magnetic devices much attention has been attracted. Recently, extraordinary efforts have been made to investigate the optical properties of Cu_2O [6].

The structure of Cu/Cu_2O multilayer preparation using nonlinear electrochemical deposition with high precision in control thicknesses and number of layers. Their results lead to significant changes in the linear and nonlinear optical properties of Cu_2O and CuO multilayer structure [7]. The structural and optical properties of films electrodeposited on different substrates. Their results illustrate that, the kind of substrate strongly affect film morphology, crystal structure and optical properties [8].

The near infrared optical and photoelectric properties of Cu_2O under oxygen atmosphere. The absorption near the fundamental edge was characterized by several absorption bands with peak position at 0.65 um, 0.75 um, 0.88 um, 1.1 um with strongest one at 1.28 um [9]. The aim of this work is to find an appropriate theoretical consideration to obtain the value of the optical energy gap and compare results with experimental values.

Thus the electrical behavior of conductors, insulators and semi- conductors can be explained by the band energy theory of materials Determination of band gap energy is one of the fundamental experiments in physics. The commonly used methods of energy gap determination are:

(a) Wheatstone bridge method,

(b) Reverse saturation current method,

(c) The Four Probe method [10].

This study describes the energy gap determination using the Four Probe method.

2. Crystal structure cupric oxide

Copper (II) oxide belongs to the monoclinic crystal system, with a crystallographic point group of $2/m$ or C2h. The space group of its unit cell is C2/c, and its lattice parameters are a = 4.6837(5), b = 3.4226(5), c= 5.1288(6), α = 90°, β = 99.54(1)°, γ = 90°[11,12]. The copper atom is coordinated by 4 oxygen atoms in an approximately square planar configuration [13].

3. Uses Cupric oxide

Cupric oxide is used as a pigment in ceramics to produce blue, red, and green (and sometimes gray, pink, or black) glazes. It is also used to produce cup ammonium hydroxide solutions, used to make rayon. It is also occasionally used as a dietary supplement in animals, against copper deficiency [11]. Copper (II) oxide has application as a p-type semiconductor, because it has a narrow band gap of 1.2 eV . It is an abrasive used to polish optical equipment. Cupric oxide can be used to produce dry cell batteries. It has also been used in wet cell batteries as the cathode, with lithium as an anode, and dioxalane mixed with lithium per chlorate as the electrolyte. Copper (II) oxide can be used to produce other copper salts. It is also used when welding with copper alloys [13].

Another use for cupric oxide is as a substitute for iron oxide in termite. This can turn the termite from an incendiary to a low explosive.

4. Measurement of the energy gap by the Four Probe methods

This method is employed when the sample is in the form of a thin wafer, such as a thin semiconductor material deposited on a substrate. Figure-1 shows the semiconductor sample. It is about 10x15 mm^2 in size and is approximately 3mm thick.

5. Apparatus used

Figure-3 shows the complete experimental set-up used for determining the energy gap. It consists of four probes arranged linearly in a straight line at equal distance from each other. A constant current is passed through the two outer probes and the potential drop across the middle two probes is measured. An oven is provided with a heater to heat the sample so that behavior of the sample is studied with increase in temperature. Figure-4(a) shows the arrangement of the four probes that measure voltage and supply current to the surface of the crystal. The probes are about 2mm die metal rods fitted to the base using a spring. This arrangement provides a smooth touch on the crystal surface as shown in Figure-3(b). The four probes are lowered to touch the surface by loosening the screw that holds the four probes.

The energy gap of the semiconductor is given by the equation:

$$\mathrm{Eg} = \frac{2\mathrm{K}\ln\rho}{\frac{1}{\mathrm{T}}} eV \qquad (1)$$

Where:

K is the Boltzmann constant ($\mathrm{K} = 8.6\mathrm{x}10^{-5}\mathrm{eV/deg}$)

T is the temperature, in Kelvin,

ρ is the resistivity of the semiconductor crystal, given by:

$$\rho = \frac{V}{I} \times 2\pi S \qquad \text{Ohm-cm} \qquad (2)$$

Where:

S is the distance between the probes, in mm.

V is the voltage across the inner probes.

I is the current through the crystal.

6. Experimental procedure

1. The experiment consists of two parts. In the first part, the resistivity of the semiconductor material is determined.
2. The four probes are placed on the sample as shown in Figure-4(b). Care is taken to see that all the four probes touch the sample surface and make contact with the sample. A constant current was passed through the outer probes connecting it to the constant current source of the set-up. The current is set to 8mA. The voltage developed across the middle two probes was measured using a digital mille-voltmeter. A thermometer is inserted into the position to read the temperature of the semiconductor sample as shown in Figure-3. $\mathrm{V} = 0.423$ Volt
3. The room temperature was noted $\mathrm{T} = 29\ \mathrm{C}^\circ$.
4. The trial was repeated by placing the four probe arrangement inside the oven. The oven was connected to the heater supply of the set-up. For different temperatures, up to $150\ \mathrm{C}^\circ$, the voltage developed was noted and tabulated in Table-1.

The values of $\frac{1}{T} \times 10^{-3}$ and the corresponding values of $\log_{10}\rho$ are plotted corresponding

Values of $\log_{10}\rho$ are plotted on the graph and are found to line on the curve as shown in Figure-6.

The slope of the curve $\dfrac{\Delta \log_{10}\rho}{\Delta \frac{1}{T} \times 10^{-3}}$ was calculated curve as shown in Figure-6.

The slope of the curve $\frac{\Delta \log_{10} \rho}{\Delta \frac{1}{T} \times 10^{-3}}$ was calculated from the graph. Substituting the values of slope in Equation, energy gap E_g had obtained. Substituting the values of slope in the formula, had energy gap E_g is obtained.

$$E_g = 2K \frac{\Delta \log_{10} \rho}{\Delta \frac{1}{T} \times 10^{-3}} \qquad (3)$$

$$E_g = 2 \times 2.303 \times K \frac{\Delta \log_{10} \rho}{\Delta \frac{1}{T} \times 10^{-3}} \qquad (4)$$

7. Results and discussion

From the figure -6 slope values $= 0.6052$, let this value in equation (4)

Where: $\mathrm{k} = 8.6 \times 10\text{-}5\,\mathrm{eV}$ to obtain a solution for E_g

$$E_g = 2 \times 2.303 \times 8.6 \times 10^{-5} \times 0.6052 = 1.6eV \qquad (5)$$

This relation conformity to the general energy gap. And it’s a real able result.

8. Conclusion

From previous results one can conclude that the four probe method that has been used to perform the experimental measurements required for this investigation was found to work fairly successfully. As well, E_g value predicted using "mean-value theorem" give good value and fit the experimental results much better and quick than others.

9. Figures:

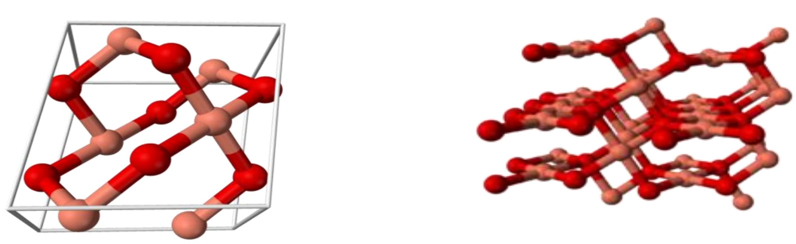

Figure (1): The unit cell of copper (II) oxide part of the crystal structure of CuO

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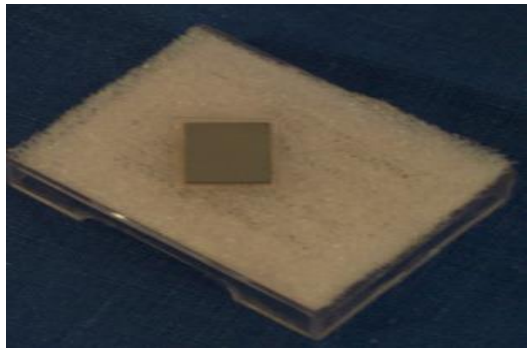

Figure (2): Sample of copper oxide wafer

Figure (3): The Four Probes Experimental Set-up

(a) **(b)**

Figure (4): (a) Four probes arranged linearly in a straight line (b) Crystal placed under the four probes.

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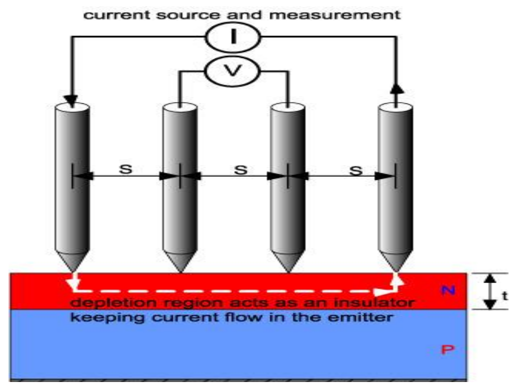

Figure (5): The dimensions of the four probes and the crystal thickness

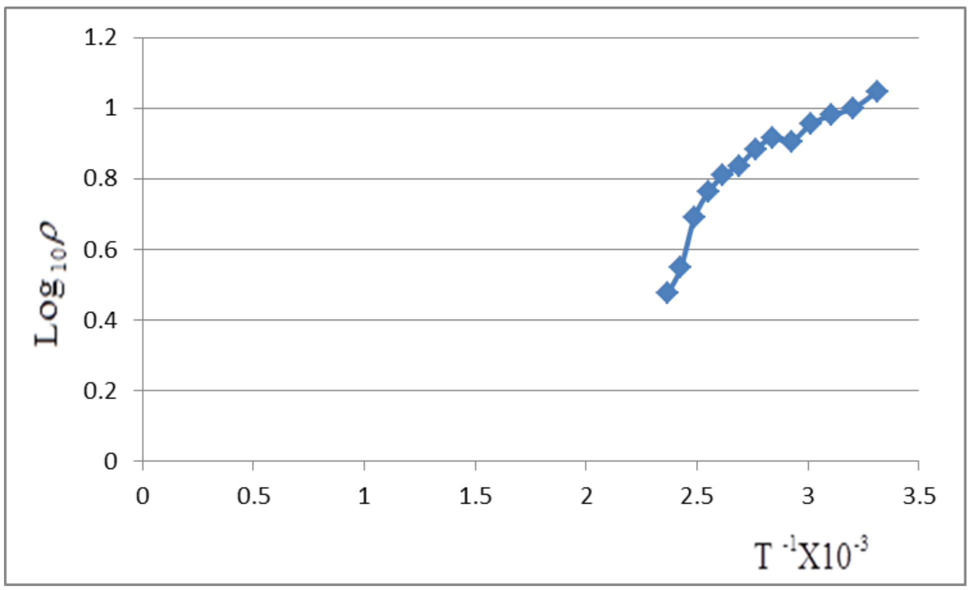

Figure (6): Variation of ρ with temperature T

Table (1): Variation of voltage with temperature

Temperature (T)		**Voltage** (V)	**Resistivity** ρ □□□□.cm)	$T^{-1}X10^{-3}$	$Log_{10}\rho$
C°	K°				
29	302	0.423	10.3451	3.31126	1.047346
39	312	0.401	10.0032	3.20513	1.000138
49	322	0.387	9.5643	3.10559	0.980653
59	332	0.365	9.0021	3.01205	0.954343

69	342	0.354	8.0345	2.92398	0.904958
79	352	0.343	8.2213	2.84091	0.914940
89	362	0.311	7.6544	2.76243	0.883911
99	372	0.277	6.8716	2.68817	0.837057
109	382	0.252	6.4564	2.61780	0.809990
119	392	0.219	5.7831	2.55102	0.762160
129	402	0.189	4.8946	2.48756	0.689717
139	412	0.167	3.5423	2.42718	0.549285
149	422	0.147	3.0022	2.36967	0.477439

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