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Investigating the Electric Conductivity, Magnetic Inductivity, and Optical Properties of Gum Arabic Crystals

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ABSTRACT

Samples of Gum crystals of different thicknesses were prepared by drying Gum solution. A special Capacitor was designed, to be used, for this study. Investigations were carried out with special emphasis on the effects of temperature, crystal thickness, light intensity, upon the desired properties. The maximum value of electric permittivity was 2.8×10^{-4} C/Nm^2.Themaximum value of electric conductivity was 9.88×10^{-7} ohm^{-1} cm^{-1}.The results indicated that; Gum Arabic crystals could be considered as weak semiconductors. The light intensity has slight effect on the conductivity, permittivity, and the current passing through the crystals. The results from this study also encourage more researches in this field.
Keywords: Gum Arabic, Investigation, Electric Conductivity, permittivity, light intensity Semiconductor.

1. INTRODUCTION

Gum Arabic is produced from many species of Acacia, of African origin. Gum Arabic is a natural polymer, that plays an important role in our daily live. Due to the high viscosity, Gum Arabic has many uses in food stuffs and, as an adhesive material, to make stable suspension mixtures, for medical syrapies, lithography, textiles, paint, inks, and cosmetics [1,2]. Gum Arabic is the most important commercial poly-saccharides, and it is probably the oldest food hydro-colloid in current use. Gum Arabic is high molecular weight polymeric compounds, composed mainly of carbon core mixed in heterogeneous manner, including some metals in ionic forms, for example {Ca^{+2} , Mg^{+2} , K^{+} }, as salts of macromolecules [3].

Chemically, Acacia Senegal gum is an Arabian galactoy protein composed of arabinose {17-34%}, galactose {32- 50%}, rhamnose {n- 16%}, glu carbonic acid {3- 50%} and protein 1,8- 16%} with an optical rotation of {28° to 32°}, and the refractive index, found to be 1.32 – 1.38 [4-6].

Lot of studies has been done on Gum Arabic, but all are about the normal uses of Gum Arabic. Recently, few works have been reported on synthetic polymers, and polymer based Nano composites [7-16]. However this study has taken a different domain, in concern to find new applications for Gum Arabic, such as: manufacture of electronic circuits, semiconductors, optical sensors, solar cells, capacitors, resistors or, as lenses or filters.

The objectives of this study:
1.1determination of the voltage (V) needed to derive the current (I), through the Gum Arabic crystals.
1.2 Study of the relation between the light properties, and the conductivity
1.3determinations of the optimum conditions needed for these properties.

2. LITERATURE REVIEW

The elements and their compounds, which aggregate into the solid cobles, are classified as; amorphous, poly crystalline, and single crystalline materials depends on arrangement of atoms in the materials. When the atoms in the materials are arranged in regular manner with a three – dimensional periodicity that extends throughout a given volume the solid, the material is considered to be as crystal. In polycrystalline materials the periodic arrange of atom is interrupted randomly along two dimensional sections that can interest dividing a given volume of solid into a number of smaller single crystalline regions. If however, there is no periodicity in the arrangement of atom the material is classified as amorphous.

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Although semi conducting properties are observed in all three classes of solids, semi conducting materials in single crystalline, when consider that the spacing between nearest neighbor atoms in a solid is typically several angstroms{10^{-8} cm} and atoms are arranged randomly there. It would be very difficult to construct a useful physical theory of semiconductor behavior [17-21].

In single crystals however, the theoretical problems are reduced to manageable size, and we find that many of the important properties of solids, are actually determined by the periodicity of the atoms. Practically the use of single crystal could greatly simplify the number of the processing steps, in the high device fields that are characteristic of modern integrated circuit technology. Also charge carriers in device operations, most useful semiconductor devices are fabricated with single crystalline material [22-26]. Semiconductor materials have basically the same structure as insulators, as the filled valence bands are separated from any empty conduction band by a band gap containing no allowed energy states. The difference ties into size of band gap ^{E}g, which is smaller in semiconductors than in insulators. The relative small band gaps of semiconductors allow for excitations of electrons from the lower valence band to the upper conduction band by reasonable amount of thermal or optical energy at the room temperature semiconductors with ^{E}g equals 1.0 eV, will have a significant number of electrons excited thermally across the energy gap into the conduction band, where as an insulator with ^{E}g about 10.0 eV, will have an eligible number of such excitations. Thus an important difference between semiconductors and insulators is that the number of electrons available for conduction can be increased greatly in semiconductors by thermal or optical energy. The distinction between insulators and semiconductors is a degree of order, rather than kind. Insulators have larger band gaps, perhaps 3 eV or more, while semiconductors have band gaps ranging from 2.5 eV, down to 0.1eV.

In metals, the energy bands, either overlap or, the one only partially filled with electrons and, the empty energy states are intermixed within the bands so that electrons can move freely under the influence of an electric field (24,27,28).

2.1 Simple Lattices:

Although no semiconductors crystallize into simple lattice they form the basis for understanding the more complicated semiconductors structure. We will use them to illustrate some of the more important concepts involved in forming a mathematical description of the crystal lattice.

A concept most useful in specifying the underlying geometry of crystal structure is the Brava's Lattice. A Brava's lattice is the infinite matrix of points which, together with the atoms or molecules situated at the points, form the crystal structure it has the property that arrangement of Lattice sites around any given lattice site is the same as that around any other site mathematically, A Brava's Lattice consist of all points generated by the vectors.

$R = \sum n_i, a_i, \quad i = 1, 2, 3 \ldots\ldots etc.$ **(2-1)**

Where, a_i is noncoplanow vectors, and n_i take on all integral values. The a_i which generates the Brava's Lattice is known as primitive vector.

In the simple cubic structure, which has an atom at each corner of a cube of dimension the Brava's Lattice can be determined by three mutually orthogonal vectors.

$a_1 = ax, a_2 = ay, a_3 = az$ **(2-2)**

Where x, y, and z are Cartesian unit vectors. This set of vectors demonstrates the basic symmetry of the structure and it is easy to see that the entire Brava's Lattice can be constructed with these vectors this set of primitive vectors is not unique, however, in defining the simple cubic Brava's can also be used to construct the Lattice as well as an infinite number of other sets.

The body-centered cubic structure has an atom at each corner of cubic dimension and one at the point determined by the intersection of the cubic body diagonals, another Lattice of interest in semiconductor crystal structure is the hexagonal close packed Lattice. Although not a Brava's Lattice, because the Lattice sites are not equivalent it consist of two interpenetrating simple hexagonal Lattices which are Brava's Lattice. The simple hexagonal Lattice consist of Lattice site at each corner of an equilateral triangle of side a, with an additional set of points on the triangle at a distance above the first.[28,29].

3. MATERIALS and METHODS

3.1 Gum samples which are natural exudates nodules of acacia Senegal trees, were collected, dried at room temperature and kept in plastic containers for analysis.

3.2 Most of the instrumental methods, used for analysis, are sensitive, such as micro digit 924 made in Russia, spectral lamp housing No. 284050 made in DK, He-Ne laser wavelength 632-3 nm, model 134, made in Germany, melting point apparatus No. SMP2, made in Britain, Tesla meter model 51662, made in Germany, the others are non-sensitive like Analog output model 177, made in USA, in addition to voltmeter 220-240 volt, power supply 10 KV, made in Germany. A capacitor, which was made especially for this study, consists of two parallel plates connected with a meter on series and, a voltmeter on parallel, in an electric circuit, connected to a Power supply producing 10 kV, alternating current AC.

4. Experimental Work:

An accurate weight of Gum Arabic powder, was taken and dissolved in 100 ml of de-ionized water, plastic plates, were plated with the viscous liquor, by developing layers of different thicknesses, and then dried at room temperature. The plated layers of gum were used to study the following parameters.

4.1 Study of the relation between the conducted current and the potential difference:

The relation between the current mA, , and the potential difference kV, was studied, for all samples of different thickness, by placing the Gum plates between the two parallel plates of the capacitor, to conduct electricity, and then the amounts of passed current were measured, by using micro-digit ammeter. See Fig (4.1).

4.2 Determination of permittivity:

The permittivity of the 19 samples was calculated, from the relation between the current and potential voltages, from step **4.1** above, by using the famous following relation (30):

$$\frac{v}{i} = \frac{1}{2\pi fc} = \frac{1}{wc} = X_c \qquad \textbf{(4.2-1)}$$

$$\varepsilon = c\, d / A \qquad \textbf{(4.2-2)}$$

v= potential voltage kV

1= current m A

f = the frequency (Hz) = 60 Hz

c = capacitance (farad)

d = distance {thickness} cm

A = area of plate cm^2 = 34.56 cm^2

ε= permittivity

π = 3.14

X_c= capacitive reactance (ohm)

4.3 Determination of the effect of thickness of transmission, at different wavelengths, on the conducted current: [17,18, 31,32].

The relation between the current and the different thicknesses was studied, by using a digit-micrometer, at different wavelengths:

Mercuric lamp, λ = 450 nm, at 0.06 ml wt. /cm^2,

He-Ne laser or sodium lamp, λ = 597 nm at 0.035 ml wt. /cm^2,

Halogen lamp, λ =550 nm, at 0.0134 ml wt. /cm^2.

Using the following relation;

$$I_o = I_r + I_{ab} + I \qquad \textbf{(4.3-1)}$$

$$I = I_r / I_o + I_{ab} / I_o + I_t / I_o \qquad \textbf{(4.3-2)}$$

$$\mathbf{T = I_t / I_o} \qquad \textbf{(4.3-3)}$$

$$T\,\% = I_t / I_o * 100 \qquad \textbf{(4.3-4)}$$

Where,

T% = transmission %

I_t = sample intensity

I_o= sources intensity

4.4 Determination of the effect of thickness of transmission, at different temperatures, on the conducted current:

The relation between the current mA, and potential difference kV, was studied, for all samples of different thickness, at different temperatures:

102, 112, 122, 132 and 142°C,

Using hot air, the Analog output model 177 and, the voltmeter 220- 240V,

Then the energy gap was calculated at different temperatures, from the relation between the current, potential different, and the temperatures:

30° C, 187° C, 192 ° C, 197 ° C and 202 ° C

Using the following formula [3].

$$I = Io\,(e^{\varepsilon (v-vg) / (KT-1))} \qquad \textbf{(4.4-1)}$$

$$V-V_o = ka/e \qquad \textbf{(4.4-2)}$$

$$E_g = eV_o \qquad \textbf{(4.4-3)}$$

$$E_g = eV - ka \qquad \textbf{(4.4-4)}$$

Where,

E_g= Energy gap

e = Electron change 1.60219×10^{-19} joule
V = potential difference
a = slop
k = Boltzmann's constant = 1.3807×10^{-34} $J.K^{-1}$

4.5The relation between the permittivity and the conductivity was studied

The relation between the current mA and, potential different was measured, for the 19 samples, at different light intensities:

3, 8 μ wt./cm^2,

3, 77 μ wt./ cm^2,

3.57 μ wt. /cm^2,

3-13 μ wt. /cm^2,

The permittivity was calculated using Analog output model 177, volt meter 220-240 volt, and He-Ne laser, model 134, at λ = 632.3 nm

$$\frac{v}{i} = \frac{1}{2\pi fc} = \frac{1}{wc} = X\,c \quad \textbf{(4.2-1)}$$

ε = c d /A……………………………………………… (4.2-2)

Then the conductivity was found for 19 samples from equation

E = $(1 / E_o)\ \sigma = (1 / E_o)\ q/A$…………………………… **(4.5-3)**

σ = conductivity ohm^{-1}
A = area of plate cm^2
d = thickness (distance cm)

σ = n ε /μ c………………………………………………. **(4.5-4)**

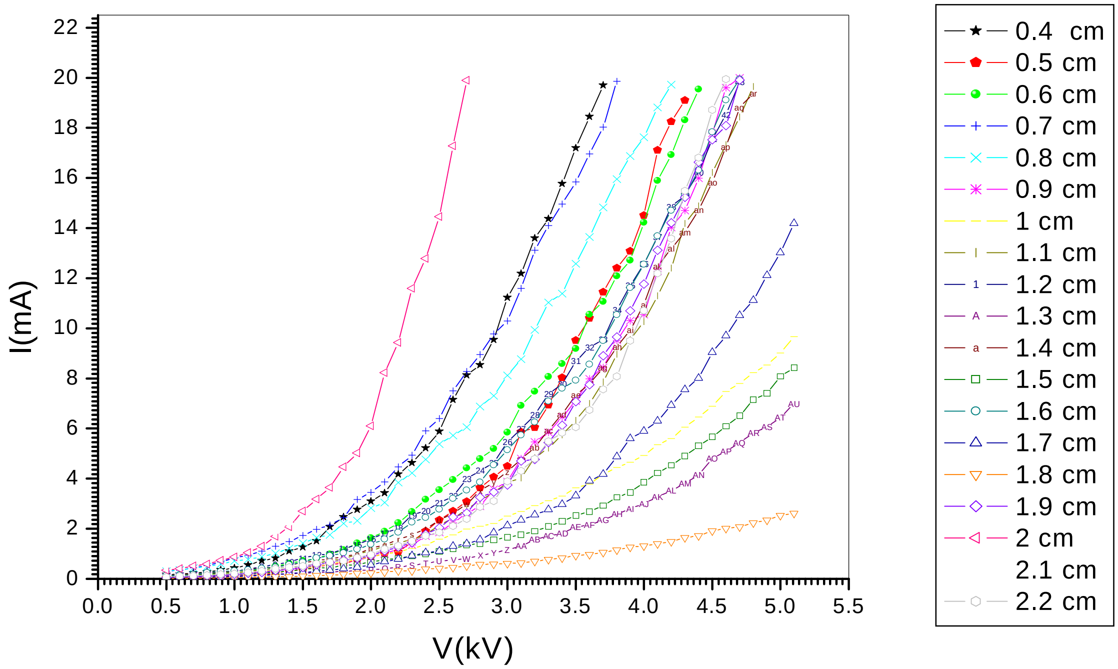
Where
ε= permittivity C/Nm^2
μ = permeability N/m^2
n = refractive index
c = speed of light 3×10^8 m/s.
The maximum value of electric permittivity is 2.8×10^{-4} C/Nm^2.
Maximum value of electric conductivity is 9.88×10^{-7} ohm^{-1} cm^{-1}.

5. RESULTS AND DISCUSSIONS

Fig (1), shows linear relationships between the applied voltage (V), (in the range 0.5 to 5.2 kV), and the current (I) passing through the crystals,(Gum slabs), of variable thicknesses, from 0.4 to 2.2 cm.

The results show that, the increase in electric current passing through is directly proportional to the increase in potential difference applied, and the passing electric current reaches its maximum value at 19.99 mA. The passing current, also decreases as the thickness increases.

Fig. (1): shows the relation between the potential difference (V),and the current (I), obeys the semiconductor behavior. Each curve corresponds to a certain thickness.



The current for certain voltages, seems, in general, to increase while the thickness decreases, this is due to the fact that when the thickness decreases, the resistance decreases, that means the current should increase. But the increase of current with the decreasing thickness is not in a regular way, and this is attributed to the fact that the resistance R, which is given by equation (4.5-5) below:

$R = dV/dI = 1/e\beta(I - I_o)$ ………………………………….**...(4.5-5)**

Which is not a direct inverse function of the current (I). Moreover the resistance of the Gum crystal is found, by using the following relation:

$I = dQ \backslash dt = CdV \backslash dt \sim \omega c V$ **…………………………………. (4.5-6)**

Where the capacitance (C) is related to the Capacitor plate area (A), and the distance between the capacitor plate (d),

And, electric permittivity could be calculated via the relation:

$c = \varepsilon A/d$**……………………………………………….…..(4.5-7)**

Thus the resistance (R) is given by

$R = V/i = 1/\omega c = d/\omega A \varepsilon, I = (\varepsilon A \omega /d) V$**…………….……….. (4.5-8)**

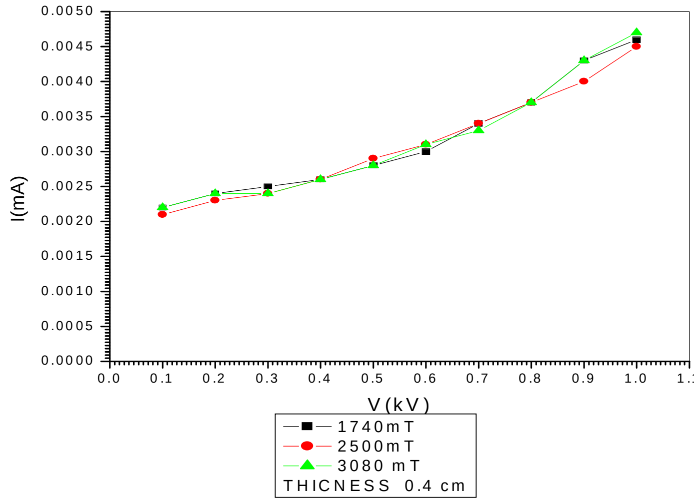
Fig (2- 10), for various thicknesses, are almost similar.

And need not to depict all of them. All Figs. show linear relationships between the applied voltage(V), (in the range 0.0 to 1.1 kV), and the current(I) passing through Gum Arabic crystals (Gum Arabic slabs) of different thicknesses, from 0.4 to 2.0 cm,

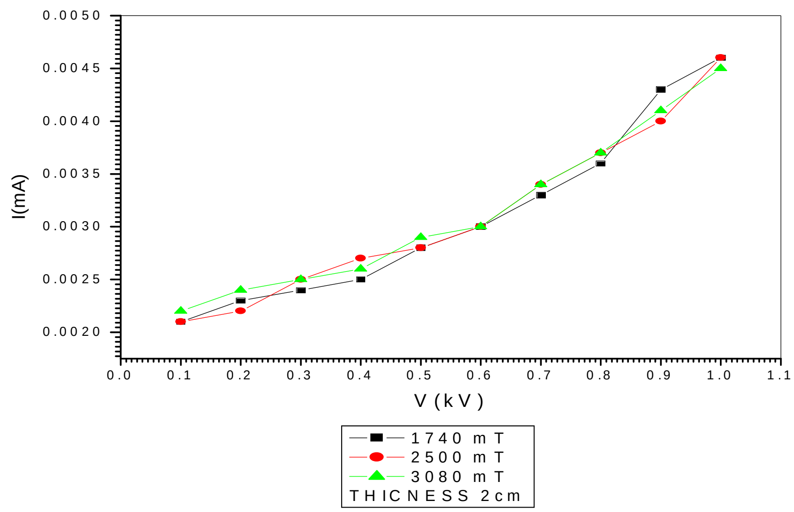
Fig (2 & 3): Variation of current (mA) with the potential different (kV) for different magnetic inductions (using the thickness 0.4 cm) at the room temperature.

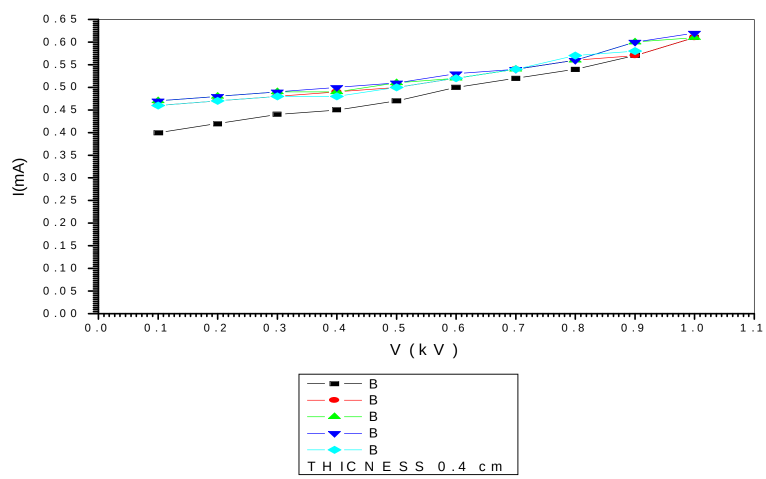
Also the readings at three different magnetic induction values, at room temperature, are almost the same. Which means that, using different magnetic induction values, would have no significant effects.

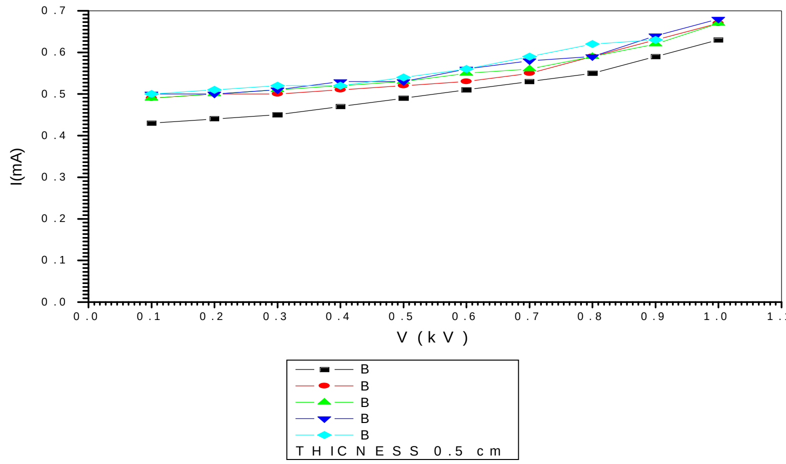
Fig (2 &3): Variation of current (mA) with the potential different (kV) for different magnetic inductions (… mT), using the thickness (0.4 - 2 cm), at the room temperature.

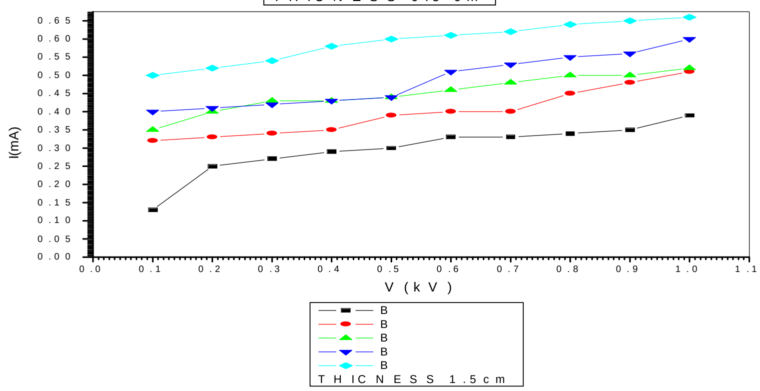


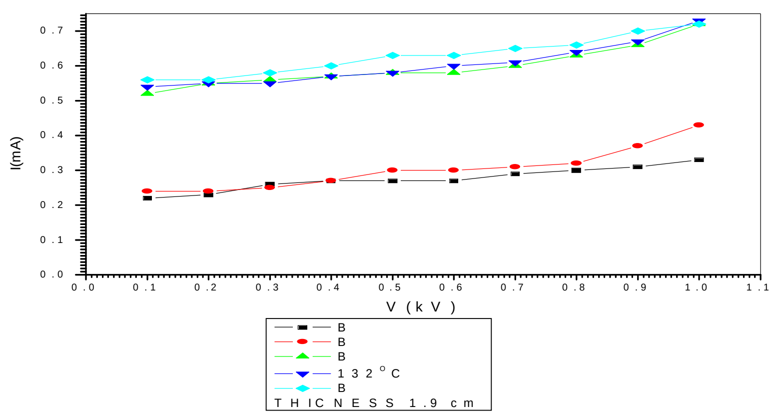
The results from all 19 samples show that the relation between (V) and (I), obeys the semiconductor relationship.

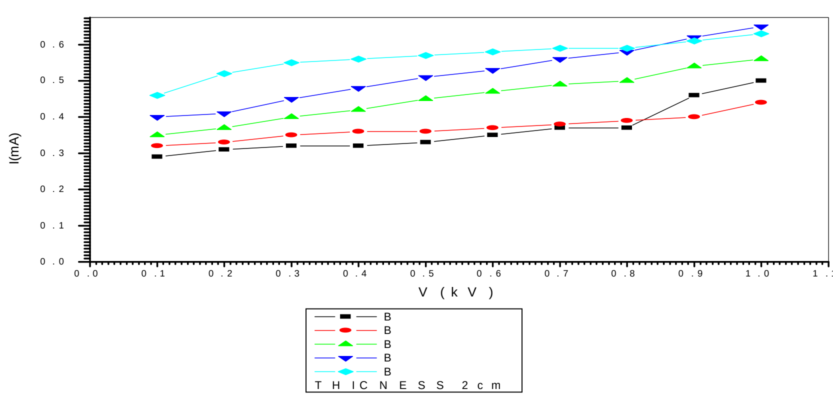





I(mA)
V (kV)
B
B
B
B
B
THICNESS 0.5 cm


I(mA)
V (kV)
B
B
B
B
B
THICNESS 1.5 cm


I(mA)
V (kV)
B
B
B
132 °C
B
THICNESS 1.9 cm


I(mA)
V (kV)
B
B
B
B
B
THICNESS 2 cm

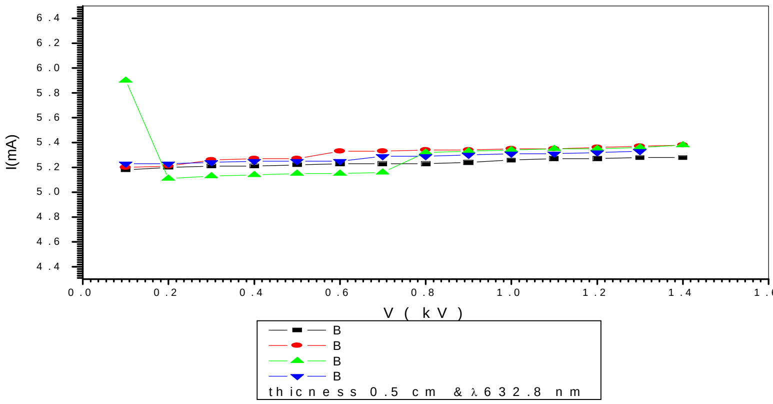
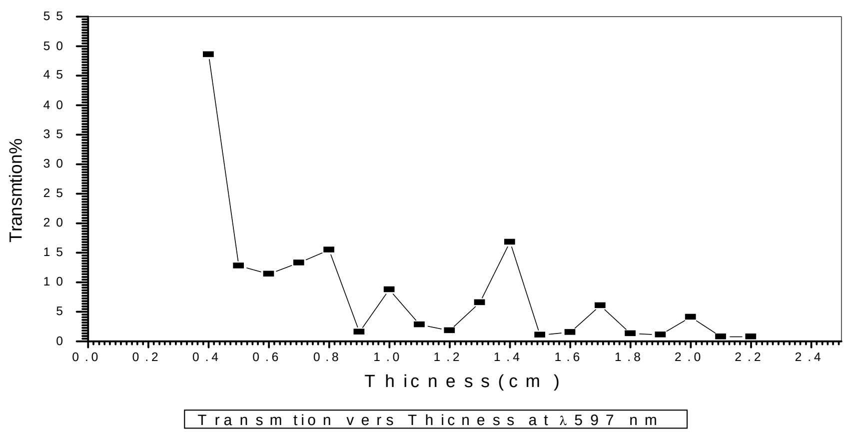
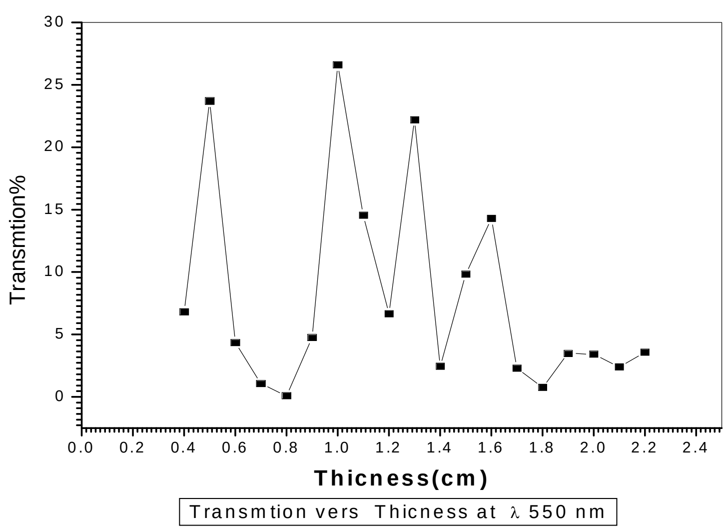


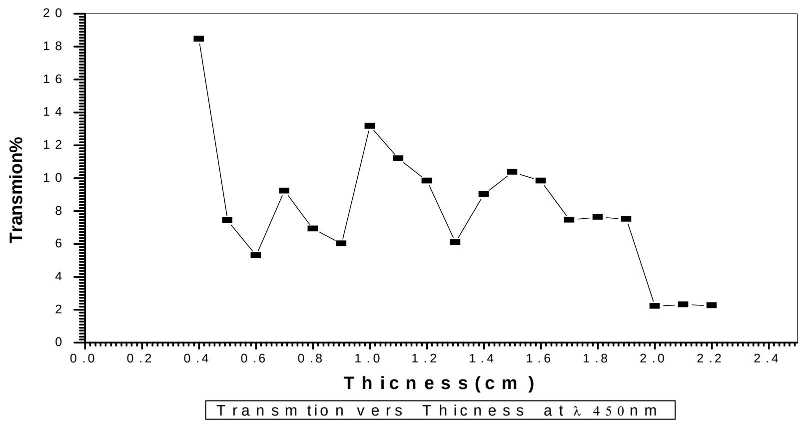
Fig (4 to 9 above): Variation of transmission % with the thickness (0.2 – 2.4 cm). at different temperatures: B = 102, 112, 122, 132 and 142°C,

Variation of transmission % with the thickness (0.2 – 2.4 cm) and λ .

Fig (10, 11, 12 below) Using a constant beams at, λ =597 nm, λ =550 nm, and λ =450 nm, at the room temperature,







The results from determinations of light transmission, show that: Gum Arabic absorbs light. And the light transition through the crystals, decreases as the thickness increases but, the light transmission increases as the light wavelength increases; The transition at: $\lambda_{=}$597nmis 48.58%, $\lambda_{=}$550 nm is 23.71%, $\lambda_{=}$ 450nm is 18.16% , and $\lambda_{=}$ 450 nm is 0.24mA.

Fig (13 to 17): Variation of energy gap (eV) with temperatures, at various wavelengths, at defined thicknesses (cm), and B lines show the temp. Values: 30o C, 187o C, 192 o C, 197 o C and 202 o C., respectively.

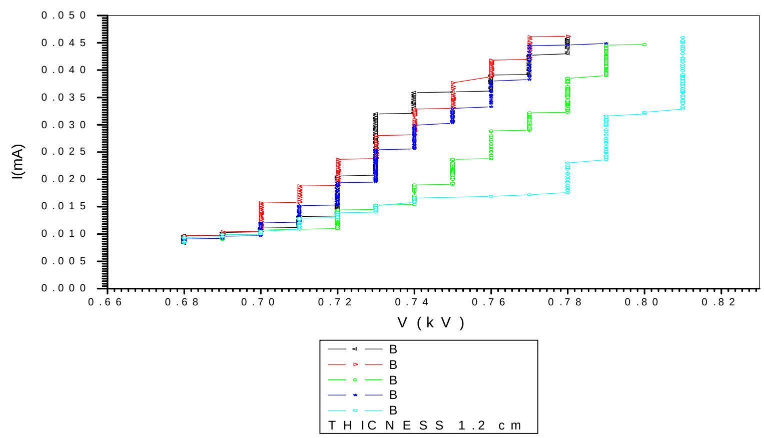


Fig. 13

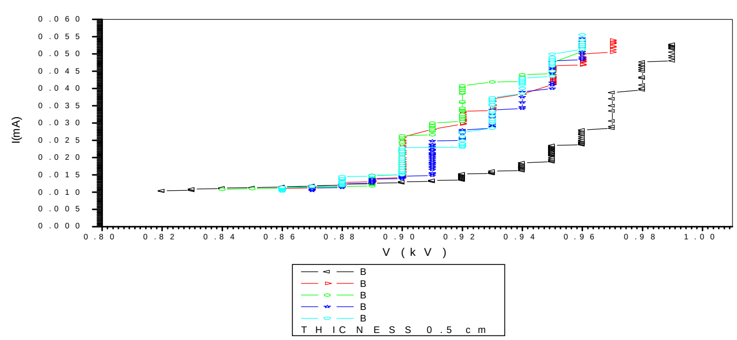


Fig. 14

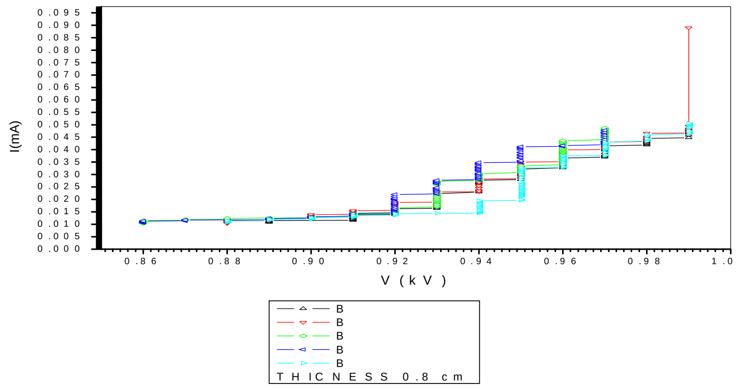


Fig. 15

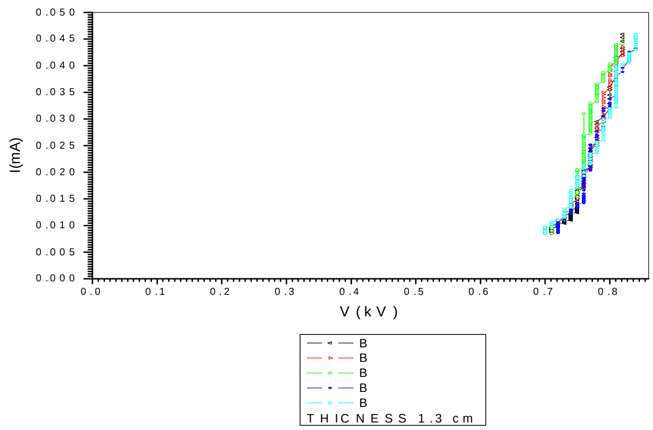


Fig. 16

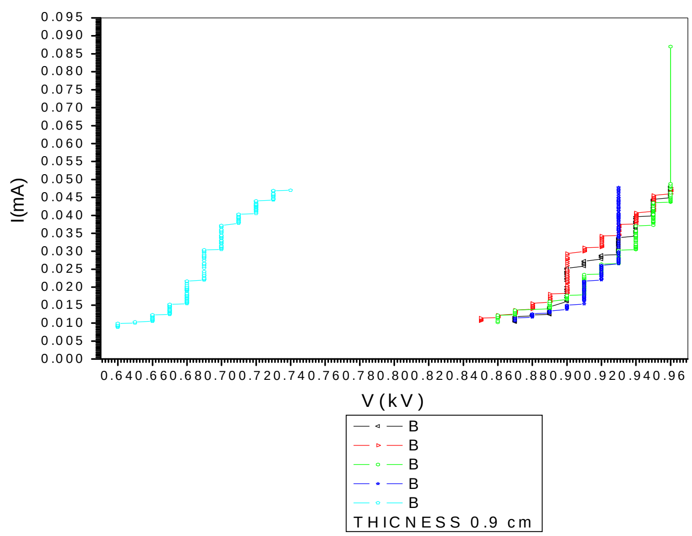


Fig. 17

Fig (18 to 24 below): depict the variation of current (m A) with the potential difference (kV), at various thicknesses (cm), for different light intensities, and λ =632.8 nm, at the room temperature.

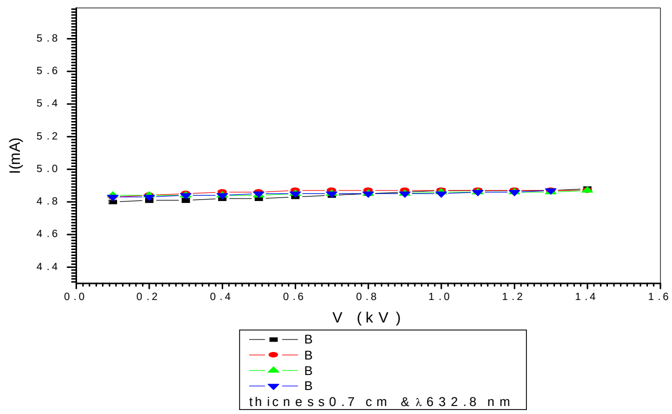


Fig. 18

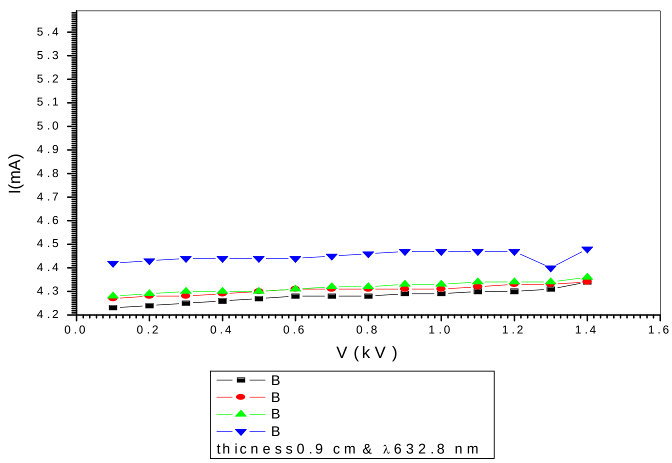


Fig. 19

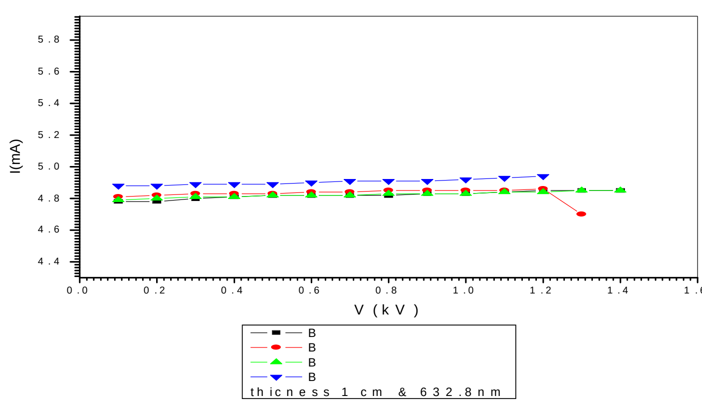


Fig. 20

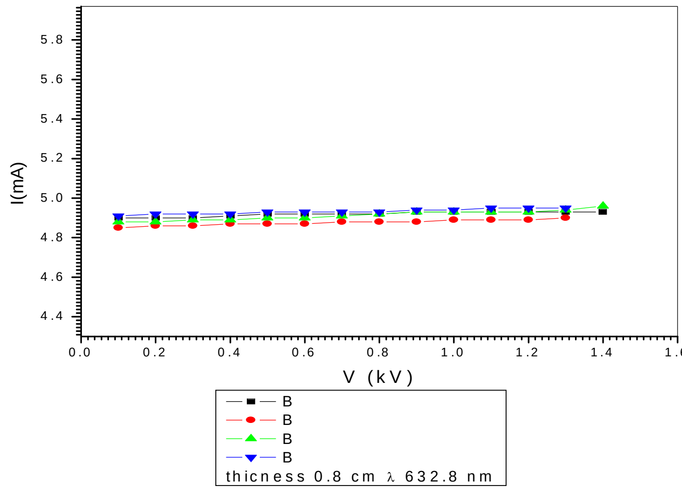


Fig. 21

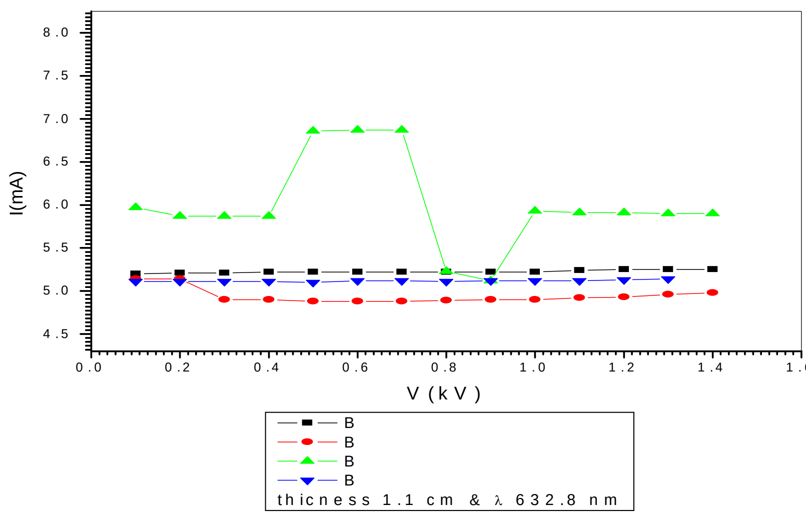


Fig. 22

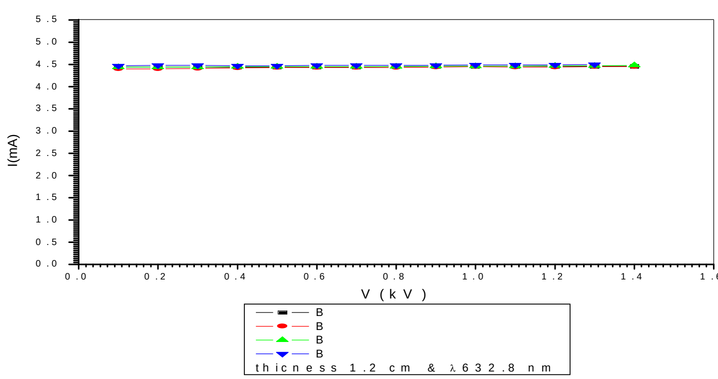


Fig. 23

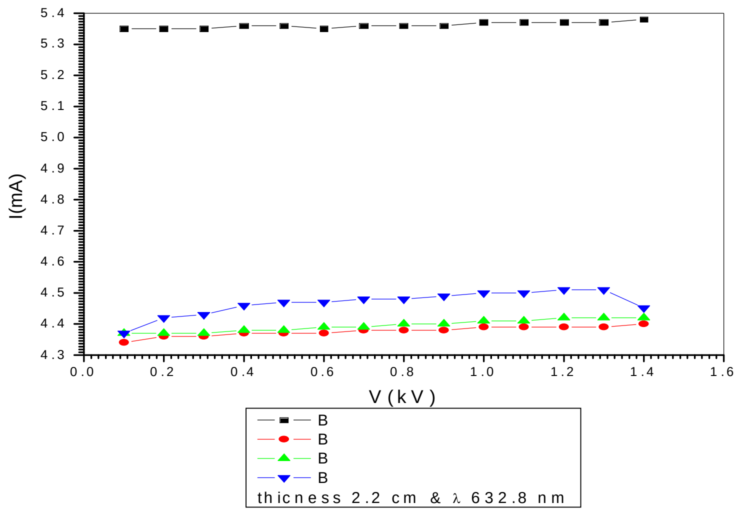


Fig. 24

A very interesting relationship is exhibited in figures (18)to (22) between the applied voltage (V) and the passing current (I), this is shown by five samples, studied at different temperatures.

The current values show an abrupt jump at certain voltages. This again indicates the existence of energy bands within the Gum Arabic crystals,

which indicates that: the resistance here is affected by the permittivity which is highly dependent on the chemical composition of the impurities of Gum Arabic. Since the chemical composition for each sample is different, thus one expects the relation between current(I) and, the thickness (d) to be non-regular as far as (I) is affected by permittivity, which is affected by the impurities which are different for different samples.

The relations between (V) and (I) as investigated in Fig (2 to 11), for each thickness at different magnetic flux densities .This relation is linear in the range of (V) from 0.1 to 1.1 kV, in all Figs., which is in conformity with the fact that in figure (1). The range of (V) from 0.4 to 1.5 kV, describes a linear relation between (V) and (I). This linear relation can be obtained from equation (5-1) for small (V), by using Tayler expansion for the exponential term where,

$e^{\chi} = \sim 1+\chi$ for small χ

Thus equation (5-1) for small (V) reads

$$I = I_o \; [1+e\beta(V-V_g)-1] = e\,\beta\, I_o V - e\,\beta\, I_o V_g \quad \textbf{(5-9)}$$

Hence equation (5-9) shows that, for small (V) , the relation between (V) and (I) is linear .Thus it explains why the curves (V) vs (I) in Fig (2 to 11) are straight lines.

The relation between (V) and(I) for Gum Arabic samples in figures (2 to 11) is taken for a coil surrounding each sample. The magnetic susceptibility is obtained with the aid of equations (3.6) substituting (l), (d), (N), (A), to get χ and the magnetic permeability is obtained from equation (3.4). The minus sign indicates that the Gum Arabic is a diamagnetic material.

The refractive index is found from the values of permittivity and magnetic permeability by using equation (3.5). The values obtained are in the range 1.32 to 1.38 .This ranges is comparable to that obtained by (Ghada, 2003). Figures (12) to (14) show that the transmission T decreases as sample thickness increases, for different wavelengths. The relationship is nearly exponential, which is in agreement with the relation cited in equations (4.4), where

$$T = I / I_o = e^{-\mu\chi} \quad \textbf{(5-10)}$$

The odd points results from the variation in impurities for different samples, which affect the attenuation coefficient, which depends strongly on the impurities and chemical composition (Barrow, 1981). (Uemura; 1982).

The variation of photocurrent generated when exposing samples to laser beams of different wave lengths is shown in Fig (15 to17). The current decreases as the thickness increases, which can be explained by equation (5-10).

A very interesting relationship is exhibited in Fig (18 to 22) between (V) and (I), for five samples at different temperatures. The currents show an abrupt jump at certain voltages. This again indicates the existence of energy bands. This is because when the voltage difference equal to the value

$\Delta v = E_g / e$……………………………….………………...**(5-11)**

A stream of electrons leaves the upper valence band to the conduction band, upon increasing the voltage further again. A certain voltage difference

$\Delta v = \tilde{E}_g / e$…………………………………… …… ……….. **(5-12)**

Again causes electrons to move from a lower valence band to the conduction band. According to table (4.19) the energy gaps range from 80 to 220eV. This indicates that Gum Arabic behaves like a semi-conductor with large energy gap, or like an insulator. This result is in conformity with that of equation (5-4).

The relation between (V) and (I) in Fig (18 to 24 above) for each sample, shows a linearity that is not appreciable (Meislich and Sharefkin, 1994).

These linear relations are in conformity with equation (5-5).

Fig (42 to 60), show the relation between (V) and (I) for each sample at different light intensities. These relations are again linear and can be easily explained by equation (5-5). Previous results show that, Gum Arabic samples contain some inorganic chemicals such as K, Ca, Ti, V, Mn, Fe, Ni, Cu, Zn, Ga, As, Br, Rb, Sr, Y, W, Tl, Pl, Bi, Al_2O_3, SiO_2, P_2O_5, Nb, Mo, Ag, Sn, Sb, Cs, Ba, Pt, .Which indicate that, Gum Arabic is weakly semi conductive substance.

Conclusions and Recommendations:

The electrical properties of gum Arabic indicate that; its behavior resembles that of a semiconductor with a large band gap. A new technique based or taking more than 100 readings for (V) and (I) is recommended to be used, to find the values of the energy gap.

The magnetic properties of Gum Arabic shows that it is a diamagnetic material..

The refractive index is found to be in the range comparable with that of some previous studies [33].

Finally more researches in this field are recommended to prove that, Gum Arabic is an industrial material that could find applications with the recent technologies. It is also important to promote experimental techniques necessary to be utilized in such researches, and by using other types of Gums from different places.

REFERENCES

1.Mokhtar , L . M. M (2006): M.Sc. Thesis University of Khartoum.

2.Karamalla, K. A. (1995): Gum Arabic Chemistry.

3.Fadel Elshiekh, M. E. (2008): Ph.D. Thesis, University of Sudan for Sciences and Technology.

4.Ibrahim,A.T.(2010), M.Sc. Thesis, University of Sudan for Sciences and Technology.

5.Eassam, H. A. (2002), M.Sc. Thesis, University of Sudan for Sciences and Technology.

6.FAO. (1990): Food and Nutrition Paper No-49 Rome.

7. Fernandes, D. M., A. A. Winkler Hechenleitner S. M. Lima, L. H. C. Andrade, A. R. L.Caires, E. A. Gomez Penida, Mater. Chem. Phys. **128,** 371, (2011).

8.Kumar, R. V., R. Elgamiel, Y. Diamant, and A.Gedaken.

9.Parveen, M. F., S. Umapathy, V. Dhanalakshmi and R. Ambarasan, J. Appl. Poly. Sci. **118**, 1728 (2010)

10. Lou, Y, M. Liu, X., Miao, L. Zhang, and X. Wang, Poly. Comp. **31**, 1184 (2010).

11. Lamastra, F. R., A. Bianco, A. Merriggi, G. Montesperelli, F. Nanni, and G. Gusmano, Chem. Eng. J. **145,** 169, (2008).

12. Bouropoulos, N., G. C. Psarras, N. Moustakas, A. Chrissanthopoulos, and S. Baskoutas, Phys. Stat. Sol. (a) **205**, 2033 (2008).

13. Mahmoud, W. E. and A. A. Al-Ghamdi, Polym. Int. **59**, 1282(2010).

14. Augustine, M. S., P. P. Jeeju, V. G. Sreevalsa, and S. Jayalek shimi, J. Phys. Chem. Solids, **73**, 396(2012).

15. Bhadra, D., J. Sannigrahi, B. K. Chaudhuri and H. Sakata, Polym. Comp. **33**, 436 (2012).

16. Chamal, C. V, J. P. Jog, Express Polym. Lett. **2**, 294(2008).

17. Barrow, G. M (1981): Physical Chemistry for the Life Sciences Second Edition Tokyo Japan.

18. Barrow,G. M. (1983): Physics Chemistry.

19. Bodenstein, M. Z (1931): Physics Chemistry New York.

20. Cromer .A. H (1974) : Physics for the Life Sciences . New York.

21.Gnutzmann, U, and Clauseker, K (1974): Applied Physics .Chang, L. L, Gobeli, G. W., and Allen, F. G (1966): Semiconductors and Semimetals Ne

22.Burstein, E. A, and Buchner, S (1968): Physics of Semiconductors, Institute of Physics Conference Series London (1979).

23.Islam,S. S.: Semiconductor Physics and Devices .New Delhi.

24.Roth, L.M., Zwerdling, S. (1959): Theory of Optical Magneto –Absorption Effects in Semiconductors .

25.Schiff, L.I (1968): Quantum Mechanics Third Edition Singapore.

Singapore

26.Goldman, I.I (1961): Problem in Quantum Mechanics.

27.Burns, G (1985): Solid State Physics.

28.Brown,G.H (1971): Photochromic USA.

29.Nasar, S.A (1992): Electro Magnetics USA.

30.Buerger, M. J (1970): Contemporary Crystallography New York.

31.Tanford,C. (1961):Physical Chemistry of Macromolecules New York.

32.Lewis, B. A., and Smith, F. (1957): J.Amer.Chem. Soc.

33.Meislich, E.K., and Sharefkin, J. (1994): Organic Chemistry USA

34.Moore,J.W., and Pearson, R.G(1981):Kinetics and Mechanism USA.

35.Niclause, M. J., and Letort, M (1966): Advanced Photochemistry

36.Nour , N.M (1996) : M.Sc. Thesis University of Khartoum.

37.Ouellette, R. J. (1998): Organic Chemistry ABrief Introduction.

38.Plooster, M.N., and Garvin, D (1956): America Chemistry Society New York.

39.Ramachandran, G.N., Sasiseknaran, V (1968): Conformations of Poly Peptides and Proteins New York.

40.Sears, F.W. (1972): Electricity and Magnetism.

41.Sedra ,A . , Smith, K. C (-------): Microelectronic Circuits.

42.Segmuller, A., and Tsu, R (1974): International Conference on the Physics of Semiconductors Germany.

43.Sheng, S. L. (1993) : Semiconductor Physical Electronics New York and London.

44. Siddig, N.E. (1996), M.Sc. Thesis University of Khartoum.

45.Szwarc, M (1968): Electron Transfer Processes New York.

46.Thomas, G., Rice, T .M (1981): Optical Study of Interacting Donors in Semiconductors.

47.Uemura, Y. (1982):Recent Topics in Semiconductor Physics Tokyo Japan.

48.Wolfe, C. M., Holon yak ,N. J., Stallman, G. E (1989):Physical Properties of Semiconductors New Jersey.

49.Abd Elhadi, A . O (2010) : M.Sc. Thesis University of Khartoum.

50.Abdeilrhman, E.A . O (2004) Ph.D. Thesis, University of Sudan for Sciences and Technology.

51.Abdeilrahman,M.A.(2008): PhD Thesis University of Khartoum.

52. Ali, G .F .M (2003): M.Sc. Thesis, University of Khartoum.

53.Ashcroft, N.W (1976): Solid State Physics USA.

54. **http**://www.springerlink.com /Content /t515720 r 70654gx8l

55. http://dynodon.com/Printing-Process-Explained/Lithography-Files/Fountion –Solution.html

56. **http**://Onlinelibrary.Wiley.Com/Doi/10.1002/pi.709/Abstract .

57. **http**://www.tootoo.com/buy-usedeltchingpress .

http://SitereSources.Worldbank.Org/INTAFRMDTF/Resources/GumArabic PolicyNot.pdf

http://www.Snpes.Com/Rumors/Arabic.htm .

http://www.Pacifier.Com/~kthayer/htm/Gumarabic.html .

http://American Printer.Com/ Mag / Printing-Understanding Conductivity

http://www.Mxrnol.Com/Applications/Fountain Solutiona-pp.htm .