Journal of Sustainability Science and Management 2007 Volume 2(1): 95-98

ELECTRICAL CHARACTERIZATION OF CHLOROPHYLL

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Abstract The localization of electron in the molecule structure of chlorophyll has been found to exhibit conducting characteristic as semiconductor materials. To obtain a complete picture of this behavior, the energy gap, dark electrical conductivity and current-voltage characterization of chlorophyll have been measured at room temperature. A simple diode has been fabricated using chlorophyll thin film by the spin coating technique. Indium tin oxide (ITO) and aluminum layers were used as their electrodes. The energy gap of chlorophyll was found to be 5.15 eV and the average electrical conductivity was 1.92 x 10^{-9} $\Omega^{-1}m^{-1}$. The forward current-voltage measurement indicated a bias voltage in the range of 0.540 V to 0.996 V. The backward current-voltage measurement showed a bias voltage in the range of -0.012 V to -1.032 V. Beyond the reading of 0.996 V and -1.032 V for the forward and the backward voltages the current increased slowly.

KEYWORDS: Chlorophyll, thin film, indium tin oxide, diode

Introduction

Chlorophyll is the molecule that traps this 'most elusive of all powers' - and is called a photoreceptor. It is a very effective photoreceptor because it contains a network of alternating single and double bonds, and the orbital can delocalize for stabilizing the structure. It is found in the chloroplasts of green plants, and it is the element that makes the plants green. The basic structure of a chlorophyll molecule is a porphyrin ring, co-ordinated to a central atom (Roberts, 1990) as shown in Fig. 1. There are actually 2 types of chlorophyll, namely *a* and *b*. They differ only slightly, in the composition of a side chain (in *a* it is -CH_3, in *b* it is CHO). Both of these two chlorophylls are very effective photoreceptors. These delocalized polyenes have very strong absorption bands in the visible regions of the spectrum, allowing the plant to absorb the energy from sunlight. The chlorophyll photosynthesis mechanism is based on a solar-electron-pump (El-Sayed, 1992).

Thin film is a very thin layer material of about 10^{-6}-10^{-9} m thick, deposited on solid substrate such as glass, ceramic or other materials. The properties of the films may differ from the original bulk materials. The combination of the thin film technology and chlorophyll had been studied previously by Patten (1998). His plan was to coat a surface with dyes that absorb various colors of light; the combination of dyes should trap almost all of the incoming solar energy. Numerous researchers have conducted studies on pure chlorophyll materials and extrinsic materials (Roberts, 1990; El-Sayed, 1992; Patten, 1998), however studies on the chlorophyll behavior in the electronic molecules are inadequate. In this respect, the present work focuses on the determination of energy gap and electrical conductivity of chlorophyll thin film. In addition, the chlorophyll has been fabricated as a diode structure in order to observe its current-voltage characteristics.

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Experimental Details

The chlorophyll called porphyrin was extracted from the herbs plant. This plant is largely used in traditional medicine. The chlorophyll solution was prepared at 996 mg/ml in chloroform. The chlorophyll solution was deposited on the ITO, quartz and glass substrate using spin coating method (Spin Coater KW-4A). The spin speed was set at 2000 rpm for 40 second. The average of the chlorophyll thin films thickness was (492 ± 1) Å. The electrical conductivity of chlorophyll thin film which deposited on glass substrate was measured using four point probe system. The absorption of chlorophyll thin film which deposited on the quartz substrate was determined by UV visible spectrometer model Shimadzu UV-160. The spectrum was viewed at wavelength from 200 nm to 1000 nm.

The chlorophyll thin film that deposited on ITO substrate was used to fabricate a pn junction diode. Before deposition, 3 mm of ITO was removed using mixture of 2 ml nitric acid and 6 ml hydrochloride acid. The removal of ITO is important for a *p-n* junction. The temperature of deposition process was 24°C. As shown in Fig. 2, Aluminum as electrode cathode was built on the edge of the ITO substrate using the Electron Gun (Balzer PLS 570) at a pressure of 2.5 x 10^{-5} mbar. The thickness of electrode was 0.15 μm. The ITO was used as an anode because it is a good donator for hole and low work function. Aluminum was chosen as a cathode because the work function was higher than that of the chlorophyll (Kim *et al.*, 1999). The chlorophyll thin film functions as hole and electron carriers. The forward and backward current voltages were measured on the diode chlorophyll using a set of multi meter (Keithley model 238) which was monitored by a controller (Trigger model 2361) and connected to a computer for observation. The result was presented in graph current versus voltage as shown in Fig. 4.

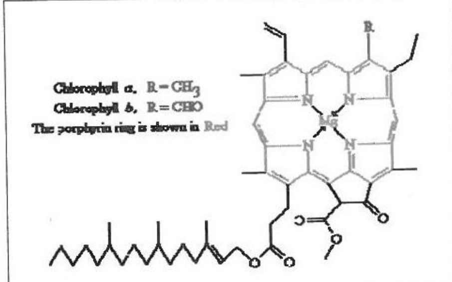

Figure 1. The basic structure of a chlorophyll molecule (After Roberts)

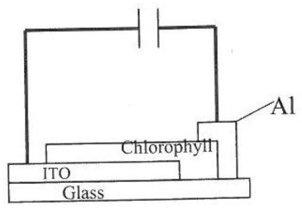

Figure 2. Arrangement of ITO, chlorophyll and aluminum for measure the current-voltage characteristics

Results and Discussion

The optical energy gap of chlorophyll thin film was determined by the combination of the absorption of UV-Visible spectrum. This relationship is explained by Eqns. 1 and 2, following Eckertova (1986a).

$$\alpha = (hv - E_f)^{1/2} \qquad (1)$$

$$E_f = hc / \lambda \qquad (2)$$

The energy gap can be determined from the extension of the tangent line at curve to the x axis. The point of intersection of tangent line with the x axis is the energy gap. The value is about 5.15 eV (Fig. 3). The determination of the dark electrical conductivity was calculated using Eqn. 4 using the values of current, *I* and voltage, *V* of chlorophyll thin film as tabulated in Table 1. The expressions used are:

$$\rho = \pi t / \ln 2 \times V / I \quad (3)$$

$$\sigma = 1 / \rho \quad (4)$$

where t is thin film thickness (492 ± 1) Å. The electrical conductivity σ of chlorophyll thin film is $(1.92 \pm 0.08) \times 10^{-9}\ \Omega^{-1}m^{-1}$.

Table 1. The current, voltage and dark electrical conductivity of the chlorophyll thin film

Voltage, V (mV) ± 0.01	Current, I (A) ± 0.01	Conductivity, σ ($\Omega^{-1}m^{-1}$)
1.04×10^{-02}	1.00×10^{-10}	2.12×10^{-09}
1.20×10^{-02}	1.00×10^{-10}	1.84×10^{-09}
1.16×10^{-02}	1.00×10^{-10}	1.90×10^{-09}
1.17×10^{-02}	1.00×10^{-10}	1.88×10^{-09}
1.19×10^{-02}	1.00×10^{-10}	1.85×10^{-09}

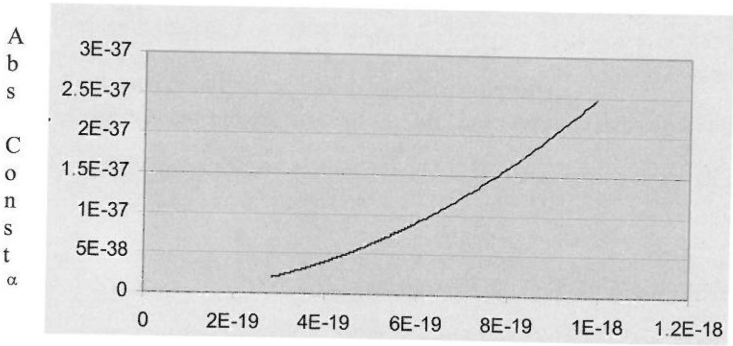

Figure 3. The graph of α^2 versus E_f

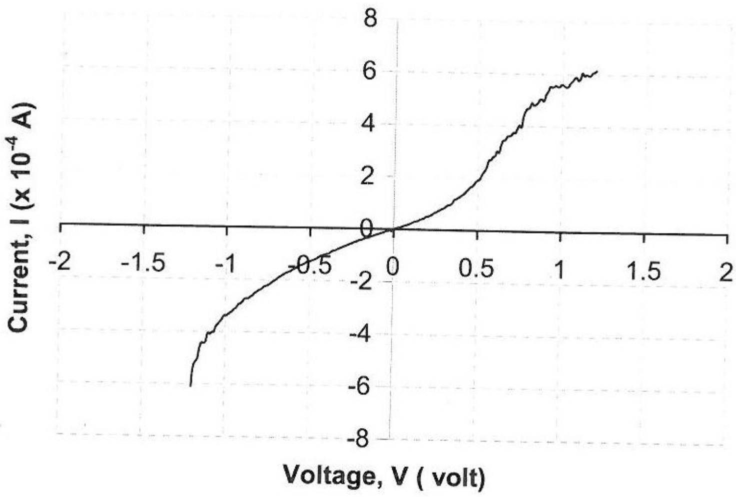

Figure 4. Current- voltage curve optimum at voltage range -1.2 V to 1.2 V

Figure 4 shows the current-voltage characteristics of the chlorophyll diode with the optimum value of the voltage applied into the circuit in the range of – 1.2 V to 1.2 V. In the forward region, the voltage at which the current starts to increase rapidly is called the knee voltage of the diode which is equals to the barrier potential (Malvino, 1999). In the chlorophyll diode the knee voltage is approximately about 0.02 V, very small indeed than that of the knee voltage of Si and Ge diodes of 0.7 V and 0.3 V respectively. This lower value of knee voltage is an advantage and it is very useful in producing devices with higher efficiencies.

Conclusion

The chlorophyll thin film and chlorophyll diode have been successful fabricated using the spin coating apparatus. The energy gap and the dark electrical conductivity of chlorophyll thin film were found to be 5.15 eV and $1.92 \times 10^{-9}\ \Omega^{-1}m^{-1}$ respectively. The results indicated that chlorophyll thin film is an insulator, however the current-voltage characteristics of the chlorophyll diode have shown that optimum values of the voltage are in the range of – 1.2 V to 1.2 V. The curve displayed is a pn junction diode characteristic. The encouraging results of this study provides opportunity for further research in the development of solar cells and sensors based on chlorophyll of an organic origin.

Acknowledgements

The authors would like to thank MOSTI and UMT as sponsors for this fundamental research grant no: 54140.

References

Eckertova, L. 1986a. Physics of thin Film. Plenum Press. New York.

El-Sayed, M.A. 1992. Molecular Mechanism(s) of Solar-to-Electric Energy Conversion by the Other Photosynthetic System in Nature, Bacteriorhodopsin. Acc. Chem. Res. 25: 279-286.

Kim H., A. Pique, J.S. Horwitz, H. Mattoussi, H. Murata, Z.H. Kafafi and D.B. Chrisey. 1999. Indium Light Emitting Tin Oxide Films For Organic Devices. Journal of Applied Physics 86(11): 6451-6461.

Malvino, A. P. 1999. Electronic Principles. Glencoe McGraw-Hill. Singapore.

Pankove, J. 1971. Optical Process in Semiconductor. Daver Publications Inc. New York.

Patten, G.V. 1998. Photoinduced Electron Transfer in Supramolecular Systems for Artificial Photosynthesis. Chemical Reviews 98: 435-461.

Roberts, G.(pnyt). 1990. Langmuir-Blodget films. Plenum Press, New York.

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