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كلية العلوم – قسم الفيزياء

Optical Characterisation Of (Channelrhodopsin 2) Conjugated Polymer.

A graduation project submitted to the Department of Physics in partial fulfilment of the requirements for the degree of Bachelor of Science in Applied Physics.

By

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Abstract

This project aims to understand and explore the potential application of conjugated polymers in optoelectronic devices. In this project, the spectra properties of conjugated polymer Channelrhodopsin 2 (ChR2) have been demonstrated. Room temperature measurements of the absorption and transmission spectra of ChR2 dissolved in solvents such as acetone were highlighted. Investigation of absorption spectra indicated two distinct peaks occur nearly at 342 nm and 465 nm. The calculation of the energy band gap of conjugated polymer calculated using the first derivative method shows a good agreement with the result obtained from the spectra.

الملخص

الهدف من هذا المشروع هو فهم واستكشاف التطبيق المحتمل للبوليمر المترافق في الأجهزة الإلكترونية البصرية. في هذا المشروع تم توضيح الخواص الطيفية للبوليمر المترافق (Chr2) Channelrhodopsin 2 ثم قياس طيف الامتصاص والانتقال على درجة حرارة الغرفة للبوليمر المترافق المذاب في المذيبات مثل الأسيتون. اشارت دراسة أطياف إلى وجود ذروتين متميزين عند 342 نانومتر و 465نانومتر تقريبا. حساب فجوة الطاقة للبوليمر المترافق المحسوب باستخدام طريقة المشتقة الأولى يظهر توافقا جيدا مع النتيجة التي تم الحصول عليها من الأطياف.

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Chapter 1 Introduction

Conjugated polymers having π-conjugated backbones with alternating single and double (or triple) covalent bonds for charge transport have had impressive consideration since the discovery of conductive polyacetylene in the 1970s [1]. Conjugated polymers offer several advantages such as lightweight, tuneable optoelectronic properties, and mechanical compliance. In addition, the application of conjugated polymer thin films in large-area stretchable electronics, such as solar cells, stretchable organic field-effect transistors (OFETs), and bendable or stretchable organic light-emitting diodes. These stretchable electronics are very promising for the Internet of Things, healthcare, and consumer electronics. Unlike conventional rigid electronics, stretchable electronics must possess efficient charge transport, and good mechanical deformability, for example: sustaining the initial good performance under large strain. The stretchable polymer films can be realised by blending rigid conjugated polymers with deformable elastomers such as styrene−ethylene−butylene−styrene (SEBS), and polydimethylsiloxane (PDMS), This approach has seriously accelerated forward the application of conjugated polymers in stretchable electronics[1].

Conjugated polymers (CB) afford connected charge carrier transport channels in the condensed states because of the effective p-electron overlap between neighbouring chains [2]. Recently, donor-acceptor (D–A) conjugated polymers have shown brilliant charge carrier transport properties due to their relatively small band gap and effective mass. Thus, the charge carrier transport ability of D – A polymer is mostly limited by the microstructures in thin films) For instance, the respectable mobilities of 1.32 and 0.55 cm^2 /(v.s) in stacked or fully stretchable. More importantly, this stretchable organic filed effective transistor OFET shows little degradation in electrical performance after 1000 cycles at 25% strain. In such blend films, the conjugated polymers guarantee efficient charge transport, and the elastomers contribute to the mechanical deformability, the fundamentally stretchable conjugated polymers are more attractive for the application in stretchable electronics because they not only offer the potential for precisely controllable electrical and mechanical properties but also possess the ability for simple fabrication of large-area uniform films for high-density integrated device arrays. Nevertheless, the inherent competition between mechanical compliance and charge transport has long existed and has become a chokepoint [3].

Chapter 2 Theory

Absorption

Absorption is the process in which optical energy is converted to internal energy of electrons, atoms, or molecules. When a photon is absorbed, the energy may cause an electron in an atom to go from a lower to a higher energy level, thus changing the internal momentum of the electron and the electron's internal quantum numbers. Energy in a solar cell or photodetector is then converted to electricity because the excited charge carriers can travel more freely through the material. The electrons absorbing the energy may be part of atoms which make up solids, liquids, gases, or plasmas. They may be around isolated neutral atoms, ionic compounds, or complicated organic molecules.

Besides, the electrons absorbing the energy may be part of conductive, insulating, or semiconducting materials. Various materials exhibit distinct absorption characteristics and their capacity to absorb a particular wavelength of light is influenced by their molecular or atomic composition. For example the energy levels of neon atoms are separated by an energy gap of Eg=1.96 eV which corresponds with energy of red photons of wavelength 632.8 nm [5]. If a photon of this energy impinges upon neon gas, the photon may be absorbed, and an electron of a neon atom would be excited to the higher energy level depending on the allowed energy states. Therefore, useful information about the materials's characteristics can be extracted from absorption spectra.

Transmission

Testing the way light travels through numerous types of materials is indispensable to the success of various industries. Therefore, Transmission refers to the amount of light that can successfully pass through the material without being absorbed. The extent of the transmission of light depends on the type of material the light strikes. Transparent and translucent materials transmit light, but opaque materials do not. If light is not transmitted, it may have been reflected or absorbed. There are two principal forms of light transmission:

Internal Transmission

Internal light transmission is a test to measure a glass's ability to filter light through it, affording a clear idea of the glass's numerous properties. This also helps those testing, as they can see if there might be any potential issues with their materials so they can work out a viable solution.

External Transmission

This type of light transmission can be recognised by the intensity of light entering the glass rather than its intensity after exiting it. Calculating these factors can help provide an accurate figure for the actual amount of light allowed to pass through a material, rather than just the percentage provided by internal light transmission testing.

Chapter 3 Experimental setup

Channelrhodopsin 2 (Chr2) polymer, provided by Prof Khalid Ibn Ouf , has a molecular weight (Mw) of 60,000 g/mol. Sample preparation is carried out in the physics department at Imamu University. Three samples of Chr 2 dissolved in acetone solvent and the concentration varied according to the following (0.5 mg/ml, 0.25 mg/ml, 0.12 mg/ml). Figure 3.1 shows one of the prepared samples.

Figure 3.1 Image of 2mg of Chr2 dissolved in 4ml of acetone

Next, Absorption and transmission spectra were recorded using a Shimadzu spectrophotometer from Kyoto, Japan as indicated in Figure 3.2

Figure 3.2 Image of the SHIMADZU-1900I UV-vis NIR Spectrophotometer

Before taking the measurement, the spectrometer was calibrated and several tests were conducted by testing a sample of acetone to see if there is a result from the spectrophotometer to ensure everything worked as it should.

Chapter 4 Result and Discussion

The absorption spectra of the conjugated polymer dissolved in acetone is shown in figure 3.3 at various concentrations ranging from 0.5 mg/ml to 12 mg/ml. There are two unique characteristics in the spectrum. The primary peak at nearly 342 nm is correlated with the second feature, which is a peak seen at about 464 nm. These two peaks originate from electron transition from higher to lower energy levels. All three samples show a drop in the Intensity by nearly 4% indicating the influence of the concentration in the spectra. The optical density gently drops as the concentration changes, however, thegeneral shape of the absorption spectral remains constant. The full width at half maximum (FWHM) it is nearly 1.5 a.u by manual measurement of the spectra of all samples is reduced as the polymer concentration decreases. This suggests a relationship between concentration and spectral linewidth since it shows the peak shrinking as the concentration drops (decreases form peak I to peak II) figure 3.3.

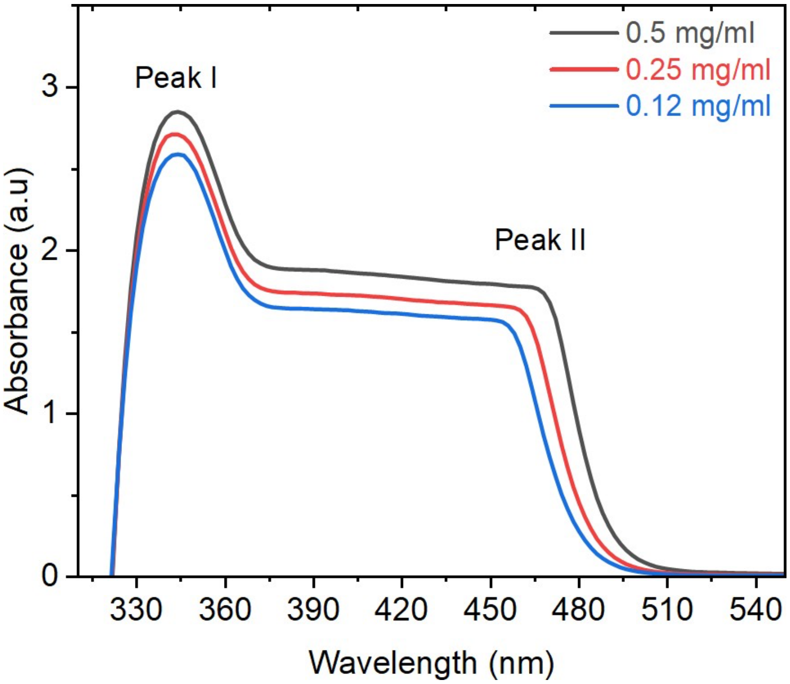

Figure 3.3 Room temperature measurements of absorption spectra as a function of wavelength.

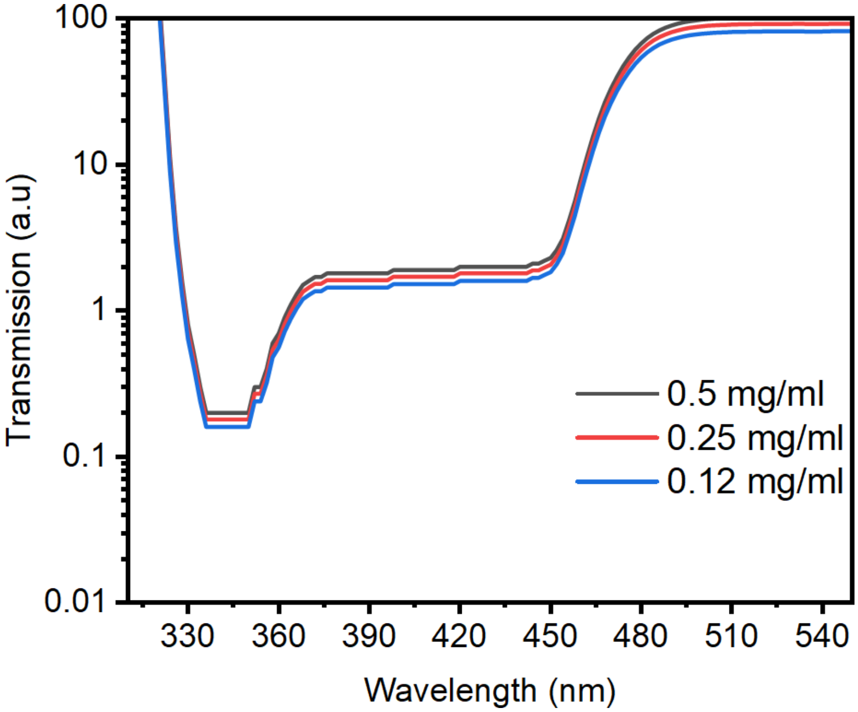

Figure 3.4 The transmission spectra versus wavelength are measured at 300 K.

Figure 3.4 plots the transmission spectra as a function of wavelength for Chr 2 polymer dissolved in different concentrations. Interestingly, two peaks at 345 nm and a slightly longer wavelength of 450nm of the transmission match those on the absorption spectra (both absorption and transmission shows same intensity) presented in Figure 3.3 and Figure 3.4.

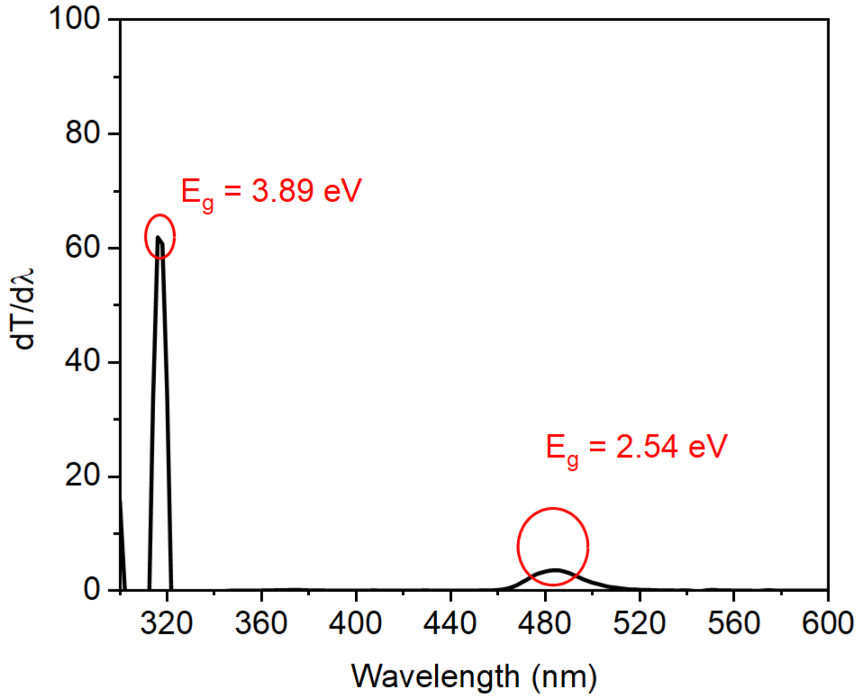

Figure 3.5 First derivative of transmission as a function of wavelength where the energy band gap values are indicated in red circles.

The energy bandgap E_g is a term used to describe the electron transition from a higher energy level (conduction band) to a lower energy level (valence band). Therefore, the energy bandgap of the conjugated polymer can be determined by taking the first derivative of the transmission spectra over the photon wavelength (dT/dλ). According to this method, peaks at energies correspond to band gap energies using the relation:

$$E_g = \frac{hc}{λ}$$

Where h is Planck's constant, c is the speed of light, and λ is the wavelength. Figure 3.5 shows an energy bandgap of 3.89 and 2.54 eV for Peak I and Peak II respectively.

Chapter 5 Conclusion

In this experiment, we investigate the optical properties of conjugate polymer dissolved in acetone at various concentrations going from 0.5mg/ml to 0.12mg/ml. The absorption spectra exhibited two distinct peaksthat originated from the transition of electrons for conduction to the valence band. The peak position shows blue shift characteristic behaviour as concentration changes. The determination of the energy band gap using the first derivative of transition spectra over the wavelength shows two energyband gaps of 3.89 eV and 2.54 eV peaking at 342 nm and 464 nm respectively.

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