INVENTOPIA 2025

FBM-SEREMBAN INTERNATIONAL INNOVATION COMPETITION (FBM-SIIC)

# INNOVATION IN ACTION: TURNING IDEAS INTO REALITY

# Chapter 45

# Fabrication of Organic Field-Effect Transistor-Based Biosensor

Irfan Danial Ismadi[1], Muhammad Fakhrullah Mohamad Azmi[1], Muhammad Fadzlisyam Redzuan[1], Izzah Afifah Ibrahim[1], Mohd Ifwat Mohd Ghazali[1], Nizam Tamchek[2], Nurul Azmawati Mohamed[3] & Shahino Mah Abdullah[1*]

[1]SMART RG, Faculty of Science and Technology, Universiti Sains Islam Malaysia, Bandar Baru Nilai, Nilai 71800, Negeri Sembilan, Malaysia
[2]Faculty of Science, Universiti Putra Malaysia, 43400, UPM Serdang, Selangor Darul Ehsan, Malaysia
[3]Faculty of Medicine and Health Sciences, Universiti Sains Islam Malaysia, Bandar Baru Nilai 71800, Negeri Sembilan, Malaysia

*shahinomah@usim.edu.my*

**ABSTRACT**
In this project, triisopropylsilylethynyl-pentacene (TIPS-pentacene) will be utilized as a semiconducting polymer matrix for the preparation of biosensors based on organic field-effect transistor (OFET) structure. A thin layer of TIPS-pentacene can be easily formed on a silicon substrate through solution processable technique. Through polymer blend method which allows synergistic combinations of stacking configurations of multiple polymers energy levels which will enhance overall charge transport. Novel pentacene derivatives will also be proposed using machine learning method and computational study for synthesizing new narrow energy band gap polymer matrix. Analytical techniques, such as ultraviolet-visible (UV-Vis) spectroscopy will be used in the characterization of the materials properties. The proposed biosensor based on integration of biological compound into OFET will facilitate the government.

**Key Words:** Triisopropylsilylethynyl-pentacene; organic field-effect transistor; semiconducting polymer matrix; biosensor

## 1. INTRODUCTION

Previous research has demonstrated the potential of organic field-effect transistor (OFET) based biosensors for detecting the various disease by the presence and amount of biological compound. The non-volatile of OFET memory devices also have attracted the eyes of technologies due to their easily integrate switching structure and non-destructive readout. The OFET can help us in various of way it can be. It has prospective applications in a number of domains that may have an influence on day-to-day living, such as sensing technologies, healthcare, and flexible electronics.

## 2. LITERATURE REVIEW

In the previous research, they have demonstrated the potential of OFET-based biosensors for detecting the various disease by the presence and amount of biological compound. The OFET devices eventually has limitation to their performance and affect environments due to lack of charge mobility, stability and reproducibility(Ajayan et al., 2023). There are several method and strategies that can optimize the functionality of OFET device. This is one of the ways to increase the functionality of OFET devices called blend strategy which make detection infectious diseases more accurate and faster. The blending techniques can significantly increase the charge carrier transport that able to increase charge mobility.

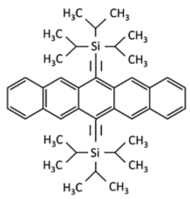

Figure 13: TIPS-pentacene molecular structure

In this project, 6,13-bis(triisopropylsilylethynyl)pentacene (TIPS-pentacene) will use as polymer matrix for the preparation of OFET-based biosensor. The TIPS-pentacene was selected as main polymer matric due to it has high solubility in many organic solvents which make it easier to be utilized in many solutions process methods for the large area and low cost for electronic devices. As shown at Figure 1, it also can be using the same solvent that be dissolved by other semiconductor materials. By mixing TIPS-pentacene, it can allow its electrical parameter such as energy band gap so it can be tuned. It is expected that by reducing the energy band gap, it can help to increase the mobility. Two different conjugated polymers with different band gap and tunable will produced a composite that could be adjusted by changing the blending ratio of the two polymers.

## 3. METHODOLOGY

### 3.1. Synthesis of narrow the energy band gap of pentacene derivatives

TIPS-pentacene, a conjugated polymer will be dissolved using two different solvents, chloroform and dimethylformamide (DMF). After mixing TIPS-pentacene with each solvent, they will be constantly stirring for 1 hour using magnetic stirring to obtain evenly solution. As result, there will be two sample for each solvent. The samples will be undergoing UV-Vis test. A new solution of co-polymer materials will be prepared for creating interpenetrating polymer-networks (IPN).

### 3.2 Fabrication of organic field effect transistor

The ITO glass substrate was purchased from Ossila which is uses for OFET and sensing. It has been designed to enable the fabrication and characterization of transistor and sensing devices without need for vacuum evaporations or probe station. This is for make a system more ideal to reducing materials screening experiments cost while allow devices to be produced and tested with a notably simpler approach.

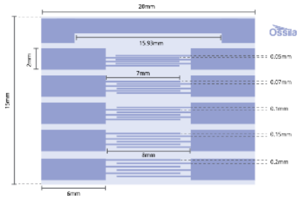


Figure 2: Ossila ITO OFET substrate variable schematic

The transistor can be fabricated by simply depositing an organic semiconductor, gate insulator and gate on the substrates. Synthetic metal such as PEDOT; PSS, deposited from solution for the gate, will make a fully functional OFET with solution processing alone and eliminating vacuum evaporation process. The substrates were designed to work on with wide different material system which allow transistor to be fabricated in the matter of times.

### 3.3 Optimization of biosensor

To achieve optimized interpenetrating polymer networks (IPN) by using the combination of other polymer materials. The TIPS-pentacene will be added into this co-polymer solution to tune its energy band gap. The same method of phase 2 are used to fabricate the same OFET sensor devices but with a different combination of co-polymer IPN. The process will be continuing by fabrication the same OFET biosensor devices on the ITO coated PET film with pre-patterned source drain channel.

### 3.4 Collecting data and analyse

The fabricated OFET biosensor will be connected to a microcontroller unit (MCU) and an Analog Devices M1K ADALM1000, which will be used to collect data based on changes in electrical signals when the sensor detects the presence of a target substance. The result will be analysed using Tauc plot method. This method will help us to determine the optical band gap energy. The optical band gap energy of semiconductor is a crucial parameter that will defines the minimum photon energy required to excite an electron from the valence band to the conduction band.

## 4. RESULTS AND DISCUSSION

The electrical properties of an organic semiconductor are studied to measure the current-voltage characteristics. The charge carrier transport in the polymer material across a gap between the source and drain terminal will be the main electrical characteristic in the OFET.

By using UV-Vis spectroscopy, the results are obtaining which can determine the material's light absorption in solution form

.

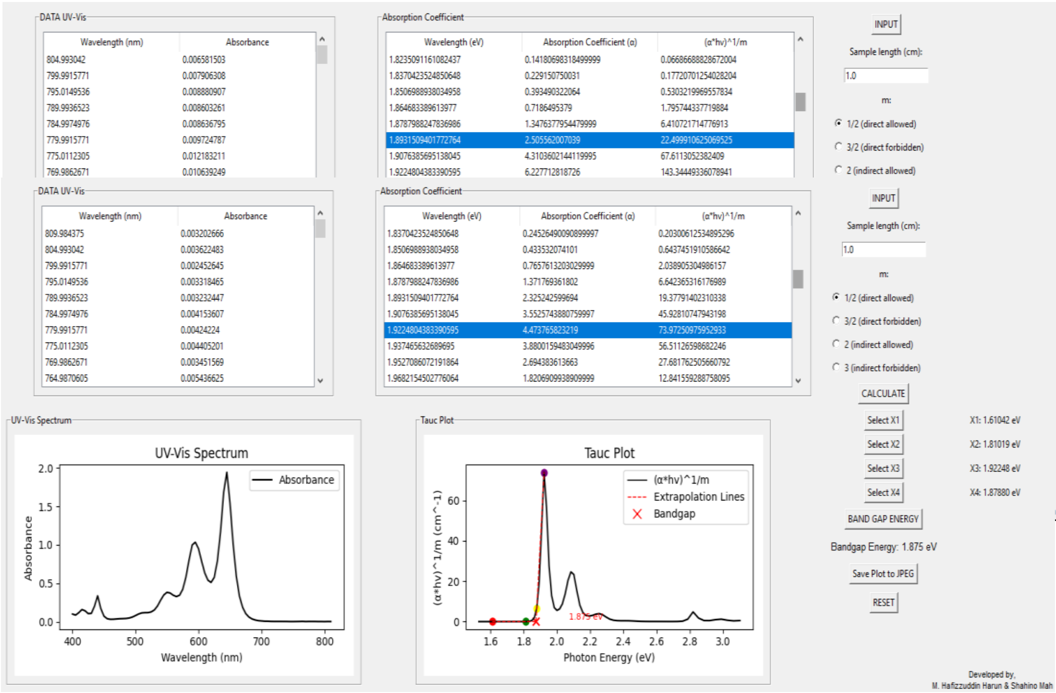


Figure 3: The plotted graph of TIPS-pentacene solvent with chloroform

Figure 4: The plotted graph of TIPS-pentacene solvent with dimethylformamide

As shown at Figure 3, the energy band gap was calculated by software when we enter the data. The Tauc Plot are used to determine the optical bandgap, either disordered or amorphous semiconductors. The optical band gap of TIPS-pentacene ranging from 1.6 eV to 1.87 eV. In this research, the value of optical bandgap was found to be 1.888 eV when dissolve in chloroform. While for the graph absorbance vs wavelength (nm), the curve shows the same curve of the blue colour wavelength which is peak between 600 nm to 700 nm. The value of energy band gap, 1.875 eV was obtained when dissolved in DMF as shown at Figure 4. The result of UV-Vis spectrum also similar to TIPS-pentacene dissolved in Chloroform.
The formula uses to calculate the Tauc plot is:

$$(ahv)^{1/n} = A\,(hv - Eg) \qquad - \quad (1)$$

where α is absorption coefficient being a function of wavelength α(λ), h is Planck constant, Eg is an optical band gap of a semiconductor, v is frequency, A is proportionality constant, and n is Tauc exponent. Tauc coefficient is typically chosen as one of four values depending on the type of dominating transition in a studied semiconductor and according to the commonly used rules, n = 1/2 for direct (allowed) transitions, n = 3/2 for direct (forbidden) transitions, n = 2 for indirect (allowed) transition, n = 3 for indirect (forbidden) transitions (Haryński et al., 2022).

## 5. CONCLUSION AND RECOMMENDATION

The solution of TIPS-Pentacene dissolved in both DMF and chloroform have been prepared to determine optical energy band gap. This measure will be very helpful for the fabrication of OFET- based biosensor. By comparing the result between two solvent, the DMF have slightly better in bandgap energy which is 1.875 eV while for solvent chloroform which is 1.888 eV. By combining both lower bandgap blended polymer matrix and increase in Gate applied voltage which make detection rate will significantly increase. It can be a potential candidate for biomedical sensor to rapidly detect infection diseases because of have better internal charge carrier.

## REFERENCES

Ajayan, J., Mohankumar, P., Mathew, R., Thoutam, L. R., Kaushik, B. K., & Nirmal, D. (2023). Organic Electrochemical Transistors (OECTs): Advancements and Exciting Prospects for Future Biosensing Applications. *IEEE Transactions on Electron Devices*, *70*(7), 3401–3412. https://doi.org/10.1109/TED.2023.3271960

Haryński, Ł., Olejnik, A., Grochowska, K., & Siuzdak, K. (2022). A facile method for Tauc exponent and corresponding electronic transitions determination in semiconductors directly from UV–Vis spectroscopy data. *Optical Materials*, *127*, 112205. https://doi.org/10.1016/J.OPTMAT.2022.112205