The influence of channel length to the characteristics of CuPc based OFET thin films

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Abstract. The main focus of this research is to characterize organic field effect transistor (OFET) thin films based on CuPc with a *bottom-contact* structure and varied *channel length*. OFET was prepared by Si substrate cleaning in the ultrasonic cleaner first, then deposition of the *source* and *drain* electrodes on the substrate with vacuum evaporation at room temperature, and finally CuPc thin film deposition among the *source*, *drain*, and *gate* electrodes. The distance between *source* and*drain* electrodes is the *channel length* of the CuPc thin film. In this research, the *channel length* was varied; 100 μm, 200 μm and 300 μm, with the same active areas of 2.9-3.42 V and different current, $I_{DS.}$ The result showed that the shorter *channel length* causes, the bigger I_{DS} flowing on the OFET

1. Introduction

Phthalocyanine as semiconductor materials and its derivatives have potential commercial aspects and offer better applications than that of silicon [1]. This material also exhibits high sensitivity to the gas acceptor (like electrons) and high absorption on the crystal surface of thin films followed by the charge transfer reaction affecting the electrical carrier concentration which increases the conductivity. Based on research in 1995, phthalocyanine is a complex compound suitable for gas sensor equipment and detecting NO_2 gas [2]. The organic field effect transistor (OFET) principles are: applied *gate* voltage generating the electric field by the accumulation of charge carriers at the interface between the dielectric gate and the organic materials, as channel materials [3]. The charge carriers (hole/electron) is different in the applied *gate* voltage. The number of the free charge carriers at the *channel* depends on the *gate* voltage, and it can be varied. Therefore, the number of charge carriers between the semiconductor and the *gate* will increase when the *gate* voltage is higher. When the voltage is applied to the *drain* electrode, the current will flow through the channel, from *the source*- to the *drain* electrodes. Thus, the current can be controlled by the applied *gate* voltage, while the *drain* voltage is required to manage the charge carriers from the *source* to the drain [4].As a new developing sensing platform, organic field-effect transistor (OFET) based sensors have attracted intriguing attention owing to their advantages of plenty organic material resources, mechanical flexibility, and microarray compatibility [5].

This research is due to OFET's advantages compared to silicon-based transistor, an inorganic field effect transistor. OFET is an environmentally friendly material, easy and inexpensive electronics device in fabrication, and simple in its usage, opening an opportunity to be the basis of future microelectronics technologies. The structure of CuPc molecule can be seen in Figure 1. Nowadays, OFET performance has been improved towards the mass a manufacturing. With cheap and great potential as future electronic component (for example as a smart card component), thus, this organic material can replace the expensive Si technology [6].

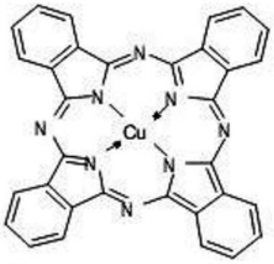

Figure 1. The structure of CuPc molecule [7].

In general, a field effect transistor consists of several basic components; conductor, insulator, and semiconductor materials. OFET is a type of transistor with semiconductor material made from an organic material or a polymer. However, when compared with inorganic transistors, OFET charge carrier mobility, in general, is still very low, $1.2\ 10^{-5}\mathrm{cm}^2.\mathrm{V}^{-1}.\mathrm{s}^{-1}$ [8]. Phthalocyanine is stable at room temperature and can be deposited as thin films by thermal evaporation [7,9-10]. This material can also be applied for photoconductive and photovoltaic, which its current response has been reviewed [3,11-12].

CuPc material is a fascinating topic to be studied further because it has high sensitivity to existing gas. In this research, the CuPc thin film was grown on the substrate Si/SiO$_2$ by vacuum evaporation at room temperature. The growth of CuPc thin films was used as the basis for OFET formation.

2. Methods

2.1. *OFET preparation*

OFET thin films were prepared by forming *bottom-contact* structure, Figure 2. First, Si substrate was cleaned, with ethanol in the ultrasonic cleaner,then*source*- and *drain*-film were deposited on the substrate by pure gold. This deposition was done by lithography techniques and vacuum evaporation at room temperature. Each method differs in complexity, the number of sensors used the cost and effectiveness [13]. Finally, CuPc thin film was deposited between and on *source* and *drain*, Figure 2.

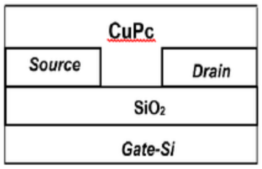

Figure 2. OFET with *bottom-contact* structure.

2.2. *OFET characterization*

OFET characterization is performed to determine the resistance, conductivity, and mobility of the carrier. I-V characterization was done by connecting the source to the grounded, while the *gate*- and drain electrodes were connected, reverse bias. To measure the mobility, the current flowing from the *source* to the *drain* which the current (I_{DS}) was measured by varying the drain voltage (V_D) for each value of the gate voltage (V_G).Therefore it can be said that the observation of the situation is due to the saturation of I_{DS} pinch-off of channel [3].

3. Result and Discussion

OFET characterization can be seen in Figure 3. The *gate* potential is varied; -3, -1.5, 0, 1.5, and 3 V, while the applied voltage between source and *drain* is 3 V.

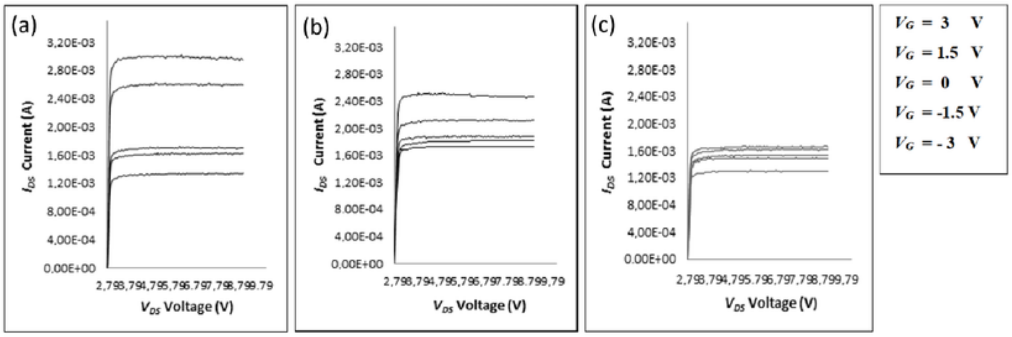

Figure 3. I-V characteristic of the semiconductor with (a) 300 µm, (b) 200 µm, and 100 µm *channel length*

The results in Figure 3 shows that the V_{DS} increasing causes I_{DS} increasing until the saturation point of the transistor, as described in Ohm's law. If V_{DS} increased, depletion area continues to rise, so that eventually occurs in conditions of a *cut-off* voltage (V_P). While the value of the voltage V_{DS} that causes *cut off* and called the cut-off failure despite an increase in the value of V_{DS} increases. Drain current I_{DS} OFET at that time is the maximum drain current (I_{DS}) and is achieved when $V_G = 0$ V and $V_{DS} > |V_P|$. For the analysis of the active area OFET, just to the *gate* voltage $V_G = 0$ volts, as shown in Figure 3.

I-V characteristics of OFET with a channel length 100 µm isain the active area V_D of 2.79 V to 3.42 V and current I_D 1.95×10^{-4} A to 16.9×10^{-4} A. As for the saturation area OFET at a voltage V_D of 3.43-9 V, and this is a *cut-off* area.I-V characteristics of OFET with a channel length 200 µm a shows an active area, V_{DS}, in 2.79-3.42 V and current I_{DS} 1.49 10^{-4} A to 1.49 10^{-3} A. While the saturation area OFET at a voltage V_{DS} of 3.43 V to 9 V and this is a *cut-off* area. I-V characteristics of OFET with a channel length 300 µmshows the active area, V_D, 2.79-3.43 V and strong current I_{DS} 5.77×10^{-6} A to 1.3×10^{-3}A. As for the OFET saturation area at a voltage, V_{DS} of 3.43 V to 9 V and this is a *cut-off* area.

4. Conclusion

OFET CuPc based thin films have successfully been prepared with a channel lengtha 100µm, 200 µm, and 300 µm. They have the same active area of 2.79 V to 3.4 V. The size of CuPc OFET is small 6.15 mm^2 that make it easy to *mobile*. The length of a channel on OFET causes the smaller OFET current on the a*gate* voltage of 0 V.

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