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Dependence of electrical property on the applied magnetic fields in spin coated Fe(III)-Phorphyrin films

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Abstract. We report here on the experimental results of the effect of external magnetic field on the current flow in plane surface of Fe(III)-porphyrin thin layer. The deposition of the Fe(III)-porphyrin thin layer was done by spin coating method. The I-V characteristics of film were measured by means of two point probes. The sample of layer number N = 4 was used to evaluate the magnetic effect on the electrical currents. The ohmic characteristics of the I-V film measurement were obtained. The current decreases when magnetic field is applied to the system and saturated current is obtained at a given magnetic field. Here, the decrease in the current can be attributed to the recombination of carrier charge under the magnetic field. In addition, the magnitude of the saturated current is found to increase with the increase in the voltage used.

I. Introduction

In recent decades, the study of organic materials as electronic devices has grown very rapidly. One of the organic materials that is very attractive for advanced development is porphyrin or metalloporphyrin. Porphyrin is a specific macro cyclic compound with four ring-pyrrole attached to the bridge of methane [1]. A diversity of biochemical functions can be modified by a slight variation of atoms that bind to these macrocyclic compounds. Recently, it has been found that porphyrin layers also show a magnetic field response. Hence, porphyrin- or metalloporphyrin-based layers have a great opportunity to be developed as one of electronic device materials.

For examples, studies on the coupling between porphyrin and a thin layer of ferromagnetic cobalt and nickel substrates have been carried out by Bernien et al, [2], following by the success of the experiment by

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Wende et al [3] in preparing the iron molecules octaethylporphyrin (FeEOP) monolayer on a thin layer of nickel and cobalt. This finding suggests that the material is able to act as a new type of molecule magnet. The reported study has indicated that porphyrin coupling with the substrate can create opportunities to accomplish magnetization reversal which is induced by the substrate. This modification, in turn, will be able to alter the electronic transport properties [4]. Other achievements have also confirmed that a large external magnetic field applied to the system is able to reverse spin orientation of the parallel state into perpendicular field of molecular orientation observed as a single molecular switching state [5]. Interestingly, Hu et al. [6] has also reported experimentally that the organic semiconductor of nonmagnetic materials can exhibit a significant response to an applied magnetic field with a low level in the event of electroluminescence, photocurrent and injection-electric current.

So far, only a few numbers of articles have reported the influence of magnetic field on the Fe(III)-porphyrin thin layers. In this experiment, we have systematically studied the effect of external magnetic field on the I-V types of the Fe (III)-porphyrin layers on a Cu-substrate. It should be noted that the I-V types of in-plane surface films used in this study and the magnetic field orientation perform/set to parallel-antiparallel of the current direction.

2. Experimental Methods

Material used in this experiment was Fe(III)–Porphyrin powders (100 mg) purchased from Frontier Scientific- USA (FeM658). Solvent of chloroform was purchased from Merck. Cu-Substrates and ITO-coated glass substrates (Aldrich-578 274) were used separately to deposit Fe(III)-porphyrin layer. Film depositions of Fe(III)-porphyrin layer were performed by using spin coater (Chemat Technology KW-4A) and the electrical property of the obtained films were evaluated by using I-V meter.

The detailed procedure of experiments was conducted in the following steps.
First, Fe((III)–porphyrin powder (100 mg, Frontier Scientific-FeM658) was dissolved in chloroform (10 mL, Merck) and stirred with a magnetic stirrer for 60 min at a rotational speed of 200 rpm. Then, the solution was used to deposit Fe(III)-porphyrin layer by using spin coating method. Second, Fe(III)-porphyrin layers were deposited with rotating speed of 500 rpm for 20 s followed by post-heating at 40 °C for 60 s. This procedure was repeated to obtain four types of layers. Third, the characterization of the layers including electrical property was done by using I-V measurement without and under external magnetic field B.

3. Results and Discussion

Figure 1 shows the I-V graph of voltage versus current for the Fe(III)-porphyrin thin layer with the number of layers N = 4 evaluated without and under magnetic field B = 10 mT. It can clearly be seen that for both samples (with and without magnetic field), the current I increases with the increase in the voltage V. The electric current (I) is observed to decrease for the whole variation of voltage when the magnetic field in plane of the films is applied. This result is consistent with that reported by Hu et al. [6], which states that external magnetic field affects the charge carrier recombination events in the material, resulting in neutral atoms due to combination of charge carriers, therefore some of charge carriers in the material are no longer available. This causes the number of charge carriers in the material reduces significantly, leading to the lower measurable current compared to that of material without the application of magnetic field.

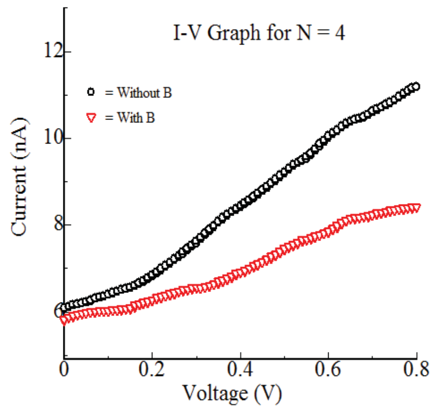

Figure 1. Electrical Characteristic of spin coated Fe(III)-phorpyrin films with four layers, without and with under magnetic field (B).

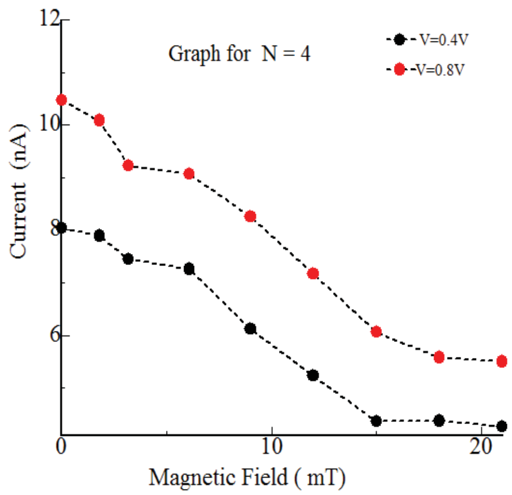

Figure 2. The current profiles of the thin films as a function of the magnetic field in the spin coated Fe(III)-porphyrin layers with the layer number of N = 4 evaluated at a voltage V = 0.4 and 0.8 volts.

Figure 2 shows the current profiles of the thin films as a function of the magnetic field in the spin coated Fe(III)-porphyrin layers with the layer number N = 4 evaluated at a voltage V = 0.4 and 0.8 volts. For two different voltages, the current I decreases with increasing magnetic field and reaches
saturated value at a certain magnetic field. For V = 0.4 volts, current reaches saturation value at I = 4.3 nA when the field of 15 mT is applied. And, when V = 0.8 volts, saturated current of 5.7 nA is achieved when a magnetic field of 18 mT is used. The result may be explained as follows. When the magnetic field is applied, the charge carriers in the material undergo recombination to yield neutral species so that the

number of charge carriers in the system is reduced. With the increase in magnetic field, no recombination occurs because the recombination depends on the applied voltage as a source of carrier charge generation.

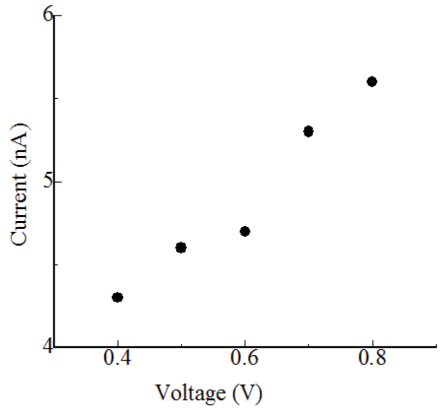

Figure 3. Relationship between saturated current and applied voltage.

Figure 3 shows the saturated current as a function of voltage. As can be seen from the figure, the saturated current increases with the increase of voltage. If the voltage can act as a carrier-charge source, it is easily understood that the increase in the voltage enhances the number of carrier charge. At low value *V*, i.e. 0.4 volts, the saturated current is 4.3 nA. In contrast, the saturated current of 5.6 nA is obtained for the voltage of 0.8 volts. This indicates that the magnetic field affects the distribution of the whole available carrier charge number.

4. Conclusions
We have reported the experimental results about the effect of external magnetic field on the current flow in plane surface morphology of the Fe(III)-porphyrin thin layer. The deposition of the Fe(III)-porphyrin thin layer was successfully done by spin coating method. The I-V characteristics of the film have been systematically measured by means of two point probe. The sample with layer number N = 4 is used to evaluate the magnetic effect on the electric currents. The ohmic characteristic profiles of the I-V measurement are obtained. The current has been found to decrease when magnetic field is applied and the saturated current is obtained at a given magnetic field. Here, the decrease in the current may be attributed to the recombination process of carrier charge generated by the magnetic field. In addition, it has also been found that the magnitude of saturated current increases with the increase of applied voltage. This indicates that the recombination of carrier charge is a function of used voltage.

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