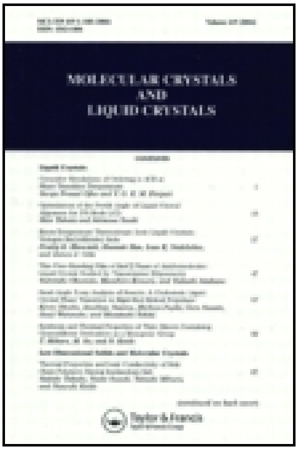

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An Organic Field-Effect-Transistor Based on Langmuir-Blodgett Films of a New Asymmetrically Substituted Phthalocyanine, 1,8-Naphthaimide-Tri-Tert-Butylphthalocyanine

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An Organic Field-Effect-Transistor Based on Langmuir-Blodgett Films of a New Asymmetrically Substituted Phthalocyanine, 1,8-Naphthaimide-Tri-Tert-Butylphthalocyanine

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The Langmuir-Blodgett films of 1,8-naphthaimide-tri-tert-butylphthalocyanine were prepared, which can be used as the semiconductor thin layers of organic field-effect transistor (FET), functioned as a p-channel accumulation device with carriers mobility about $2.05\times 10^{-5} cm^2V^{-1}s^{-1}$.

Keywords: Phthalocyanine; Langmuir-Blodgett films; Field-effect transistor

INTRODUCTION

Recently, there has been increased interest in organic and polymeric thin film field-effect transistors (FETs) due to their potential application in low-cost memory cards and smart price tags and labels[1]. Phthalocyanines (Pcs) and metallophthalocyanines (MPcs) have been attracted particular attention in this field because of their thermal and chemical stability[2]. Former works mainly concern about symmetrical phthalocyanines, little about asymmetrical phthalocyanines because of the difficulties in synthesis[3]. In this paper, we will report the fabrication of Langmuir-Blodgett (LB) films of a new asymmetrical phthalocyanine, 1,8-naphthaimide-tri-tert-butylphthalocyanine (NaBuPc), and its application of in FETs.

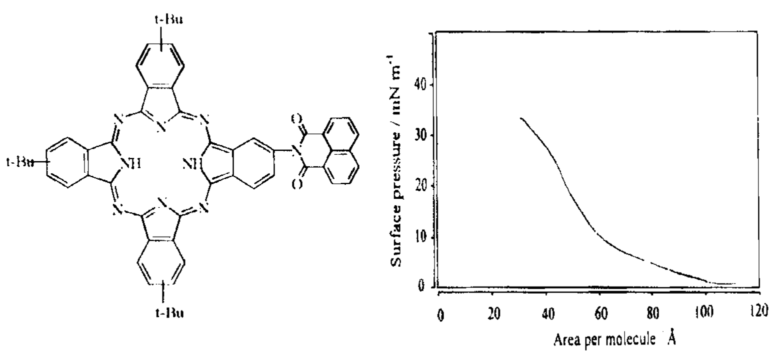
EXPERIMENTS

The chemical structure of NaBuPc is shown in Figure1(a), the synthesis of it was reported before[4]. The LB films of NaBuPc were fabricated on KSV-5000 instrument (Finland). A chloroform solution of NaBuPc (V=150 μl, $C=10^{-4}$ M) was spread onto pure water at 20±0.5 °C. At a constant surface pressure (22 mN m^{-1}), the monolayers on the subphase were transferred onto the interdigital electrodes of FET at a speed of 20 mm min^{-1}.

The organic FET of NaBuPc was fabricated on a glass substrate. A gold stripe (8×12 mm^2) was deposited onto glass substrate as the gate electrode. The insulating layer, polymethylmethacrylate (PMMA), was cast by spin coating from its CH_3CN solution, the thickness was about 200 nm determined by a Dektak 3030 surface profilmeter. Two gold interdigital electrodes were evaporated upon PMMA to form the source (S) and drain (D). Finally, 5-layer NaBuPc LB films were covered onto the interdigital electrodes. The conduction channel of this FET is about 0.75 mm long, 95.9 mm wide. All electrical measurements in this study were performed at room temperature and in air. A HP-4140B picoammeter/dc voltage source was used to determine the current-voltage characteristics of NaBuPc FETs.

RESULTS AND DISCUSSIONS

Figure 1(b) shows the surface pressure-area isotherm of NaBuPc. The steeply inclining part corresponding to the formation of the solid monolayer and the high surface pressure of the collapse point of the monolayer indicating the good film-forming behavior of this Pc compound. From the surface pressure-area isotherm



(a) (b)

FIGURE 1 (a) The Chemical structure of NaBuPc; (b) π-A isotherm of NaBuPc the limiting area per molecule is estimated to be 70A^2. This value is useful for estimating the configuration of phthalocyanine molecules at the air-water interface.

The current-voltage characteristics of the FET of NaBuPc LB films are shown in Figure 2. As is evident in Figure 2, I_{DS} does not saturate even at high V_{DS} but tends to increase in proportional to V_{DS}. Although the saturated area does not observe, the field effect is still obvious, the conductivity of NaBuPc increases with increasing negative gate bias. This maybe due to the existence of parallel conductance which can not be controllable in the present primitive FET[5]. As well known, FETs based on phthalocyanines, their conduction channels are formed by the injection of majority carriers in an accumulation layer. NaBuPc is a p-type semiconductor thus the forming transistor is a p-type transistor and is working in an accumulation mode under applied negative bias V_{GS}. Increasing the gate voltages(V_{GS}) results in the injection of majority carriers into the semiconductor NaBuPc layer.

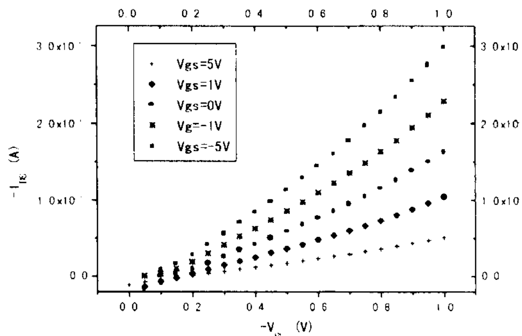


FIGURE 2 The current-voltage characteristics of 5-layer NaBuPc LB films FET

Field-effect mobility (μ_{FET}) of NaBuPc can be calculated from its I-V characteristics when the drain and gate are connected[6]. The determination of the μ_{FET} of the NaBuPc LB films is depicted in Figure 3, where the square root of the drain current (corrected for the ohmic current) at $V_{DS}=V_{GS}$ is plotted versus the gate voltage for the same FET. The slope of the line gives the mobility of $2.05\times10^{-5}cm^2V^{-1}s^{-1}$, and its extrapolation to the V_G axis gives the threshold voltage V_T about $-0.38V$.

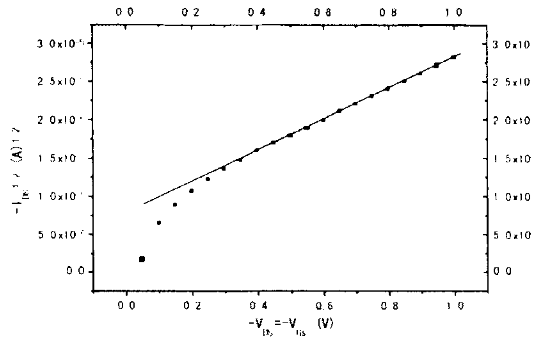


FIGURE 3 The relationship of $I_{DS}^{1/2}$ versus V_{DS} at voltage $V_{DS} = V_{GS}$.

which implies that the FET is a normally-off type transistor[7]. The mobility of the studied LB films of NaBuPc is still not large enough because of the limit of the material itself properties, it is our next aim to develop new molecular materials and devices with high carrier mobility.

In summary, NaBuPc possesses not only good solubility in common organic solvents but also ideal LB films characteristics at room temperature. Its thin LB films can be used as the semiconductor thin layers of organic field-effect transistors and exhibit obviously field effect.

Acknowledgements

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