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A Field Effect Transistor based on an n-type dibenzothiophene derivative

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1. Abstract

Thin films of 3,7-bis(dibenzothophene-4-yl)-dibenzothiophene-S,S-dioxide (IR-35F) have been prepared using the thermal evaporation technique. The films were investigated with optical absorption spectroscopy, atomic force microscopy, and DC electrical measurements. In addition, thin film FET structures were made and field effect characteristics measured, giving a maximum mobility of 1.75×10^{-6} cm^{2}V^{-1}s^{-1}.

2. Introduction

Organic transistors are the subject of a large amount of international research, and have potential commercial applications in, for example, flexible displays. Compared to traditional silicon devices, they have low production costs, and much of the processing can be done at or near room temperature, and the techniques involved tend to be simpler than on silicon.

However, although excellent progress continues to be made on the development of field effect transistors (FETs, see Figure 1) and electronic circuits based on p-type organic semiconductors [1], devices based on n-type organic materials are not so well advanced [2, 3]. The dibenzothiophene moiety has already been exploited in the design of p-type FETs, providing high hole mobilities of 0.15 cm^{2}V^{-1}s^{-1} and device ON-OFF ratios $> 10^6$ [4]. Incorporation of an electron deficient dibenzothiophene-S,S-dioxide group into a material will increase its electron affinity [5] thus offering a strategy for the design of n-channel devices. This report is a study into the electrical and FET characteristics of 3,7-bis(dibenzothiophene-4-yl)-dibenzothiophene-S,S-dioxide (IR-35F, Figure 2).

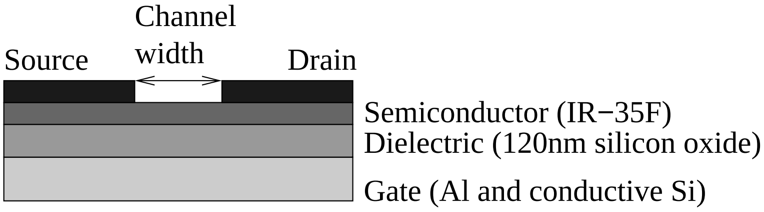

Figure 1. Schematic structure of a thin film transistor

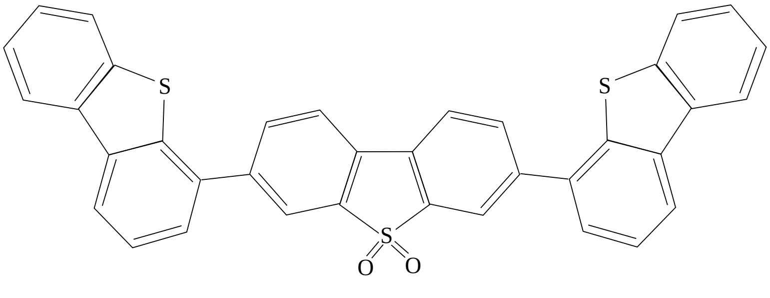

Figure 2. The IR-35F molecule

3. Experimental methods

Thin films of IR-35F were prepared on glass slides and silicon wafers using a vacuum sublimation process at a pressure of approximately 10^{-5} mbar. A purpose-built evaporator for organic materials was used for this. For in-plane electrical measurements, 100 nm of gold was first evaporated through a shadow mask to establish contacts 1.1 mm wide along the length of a glass slide. Field effect transistors were fabricated using a 'top-contact' configuration, using highly doped silicon (resistivity $10^{-3}\Omega$ cm) as the gate electrode and silicon dioxide (thickness approximately 120 nm) as the gate insulator. Following deposition of the IR-35F, gold source and drain contacts were evaporated through a contact mask to provide a channel length of 50 μm and a width of 1.1 mm.

4. Results

Figure 3 shows an AFM image of an evaporated IR-35F film, 30nm thick, on glass. The film appears polycrystalline, with an average grain size of about 300nm, slightly greater than that observed for pentacene evaporated under similar conditions, which showed a grain size of around 100-200nm (Figure 4). The absorption spectrum for the evaporated film is similar to that measured for a dichloromethane solution (Figure 5), suggesting that the material had not dissociated on vacuum sublimation.

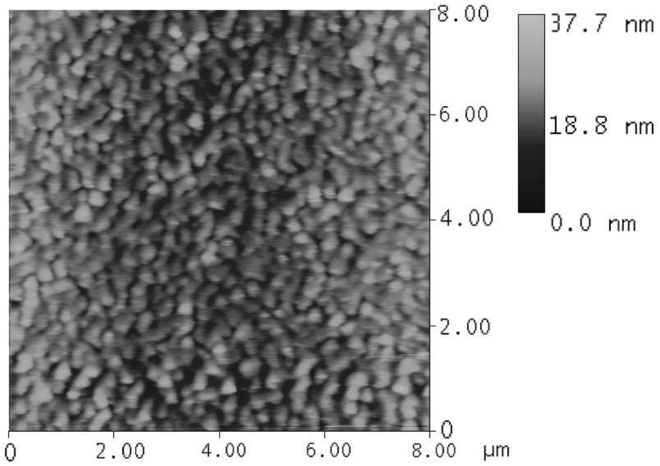

Figure 3. AFM image of a thermally evaporated film of IR-35F on glass

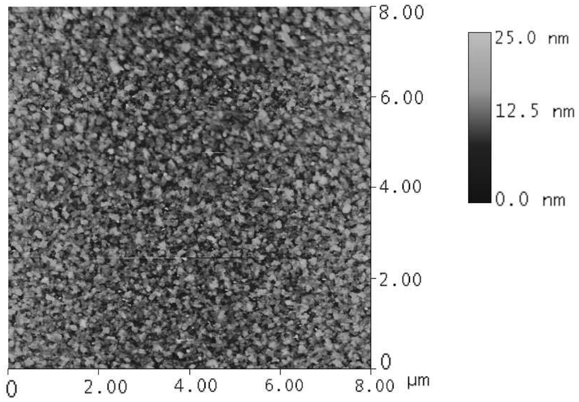

Figure 4. AFM image of a thermally evaporated film of pentacene on glass

The in-plane DC conductivity of the IR-35F film was found to be comparable to the underlying glass substrate. However, in the FET experiment, it was found that the film conductivity could be influenced by the field effect. The transistor characteristics measured in air, and shown below in

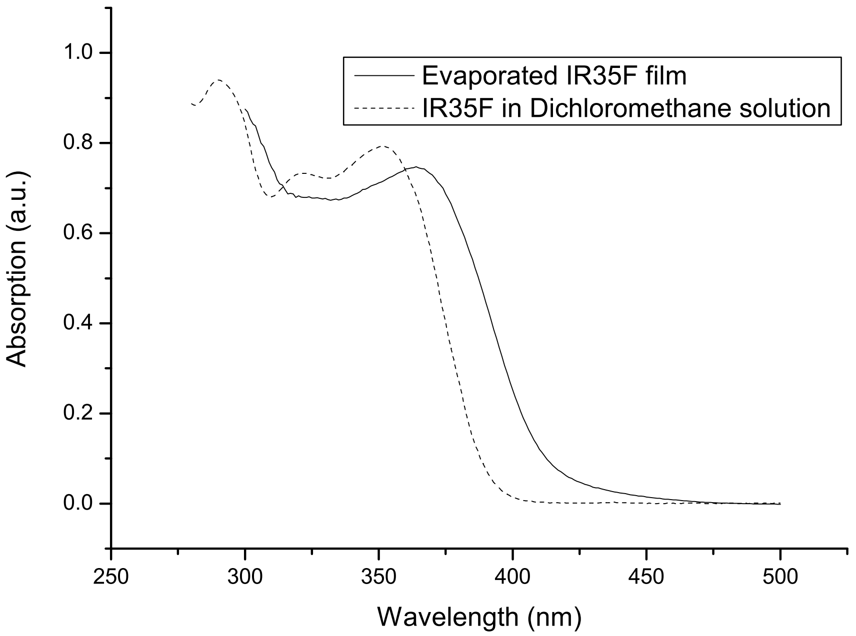

Figure 5. Absorption spectra for IR-35F in a dichloromethane solution and as an evaporated film

Figure 6, confirmed that the IR-35F was an n-type semiconductor. The shape of the source-drain current versus source-drain voltage plot before saturation is a little unusual and could be attributed to the nature of the contacts between the source and drain electrodes and the organic film; this is currently the subject of further study.

A plot of the square root of the source-drain current in the saturation region versus the gate voltage (Figure 7) provided a carrier mobility value of 1.75×10^{-6} cm^2 V^{-1} s^{-1}.

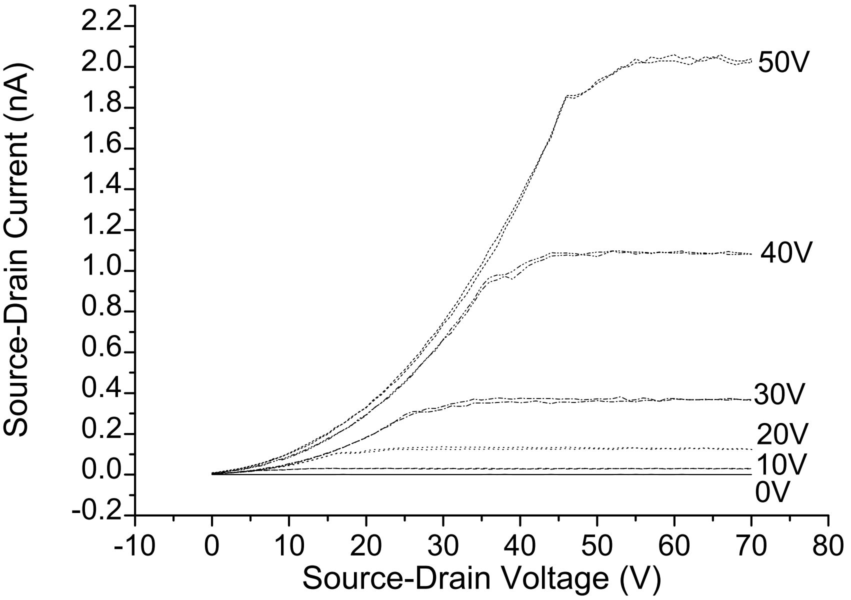

Figure 6. Source-drain current versus source-drain voltage characteristics as a function of gate voltage

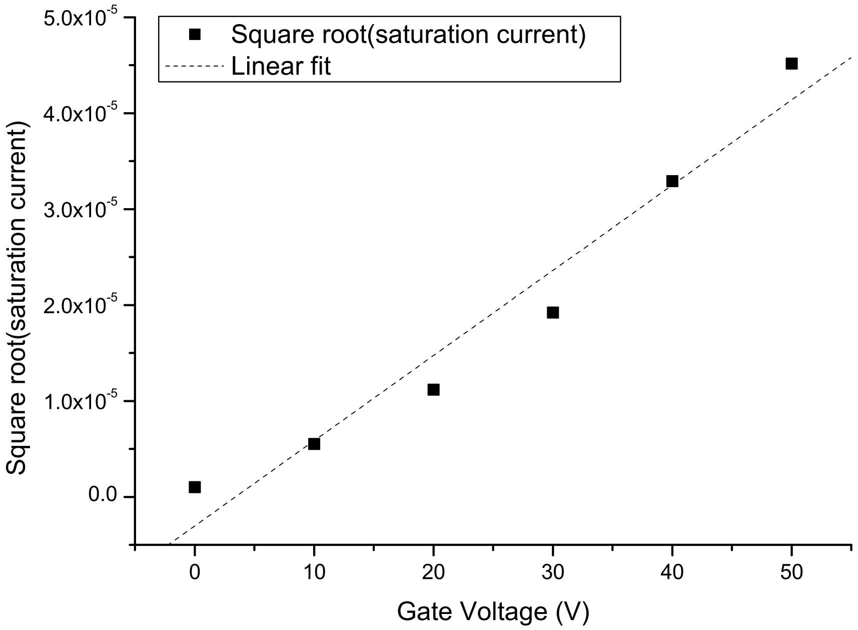

Figure 7. Square root of saturation current versus gate voltage

5. Remarks

Morphological and electrical behaviour of evaporated IR-35F films were measured, with promising results. Work is currently ongoing into investigating the influence of the electron affinity of alternative functional groups on the compound to see if the transistor mobilities can be improved.

References

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