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Electrical Current Noise in Langmuir-Blodgett Thin Films

Hingar Arus Elektrik dalam Filem Nipis Langmuir-Blodgett

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Abstract

The electrical current noise of a metal-insulator-semiconductor (MIS) diode-like device fabricated by Langmuir-Blodgett (LB) technique has been studied at low to moderate dc bias current at room temperature. The result shows that the current noise spectral density $S_I(f)$ is *1/f* like and the noise power was highly dependent on the bias current. The *1/f* noise was not observed at zero bias. It is believed that at low bias current, the origin of noise was due to the bulk phenomena - silicon substrate and contacts whilst at higher bias current, the origin of noise in the device was solely from the LB films – surface influence.

Keywords LB films, low-frequency noise measurement, 1/f noise, current noise spectral density

Abstrak

Kajian mengenai hingar arus elektrik bagi peranti menyerupai sebuah diod yang dibina dengan mengunakan teknik Langmuir-Blodgett (LB) telah dijalankan pada arus rendah sehingga sederhana pada suhu bilik. Hasilnya menunjukkan ketumpatan spektra hingar arus $S_I(f)$, adalah berbentuk *1/f* dan kuasa hingar adalah sangat bergantung kepada arus pincang. Hingar *1/f* tidak dikesan pada pincang sifar. Adalah dipercayai bahawa pada arus pincang rendah, hingar adalah disebabkan oleh fenomena pukal – perumah silicon dan sambungan-sambungan manakala pada arus pincang yang lebih tinggi, asalan hingar didalam peranti adalah dari filem-filem LB sendiri – pengaruh permukaan.

Kata Kunci Filem LB, pengukuran hingar berfrekuensi rendah, hingar 1/f, ketumpatan spektra arus hingar

Introduction

The Langmuir-Blodgett (LB) technique is one of the most promising methods for preparing organic thin films. This method can be used to fabricate highly ordered ultra thin films of various organic materials based on amphiphilic molecules. It has some advantages such as precise control of the monolayer thickness, homogeneous deposition of the monolayer over large areas and the possibility to make multilayer structures with varying layer composition (Petty, 2002). An additional advantage of the LB technique is that monolayer can be deposited on almost any kind of solid substrate. Nowadays molecular coating on solid surfaces is important in material science, chemistry, physics, and electronics with potential application in optoelectronic devices.

Electrical noise is the random fluctuation of an electrical quantity, unpredictably changes over time that are superimposed to its average value. They are influenced by the presence of localized defects and irregularities in the microstructures of the electron devices (Ciofi & Neri, 2000). Depending on the types of noise, the noise power spectral distribution can vary with frequency, and its power density can be measured in watts per hertz (W/Hz). Since the power in a resistive element is directly proportional to the square of the current across it, the noise current power spectral density can be described by taking the square of the noise current per unit bandwidth (A^2/Hz). There are many types of electrical noise exist in the electronic devices, such as thermal noise, shot noise, G-R noise and flicker noise. Flicker noise, also known as *1/f* noise, is a signal with a power spectral density that falls off inversely proportional to the frequency with a pink spectrum.

Low frequency electrical noise analysis is an effective diagnostic tool for device and material characterization, such as, for quality and degradation assessment in solid-state devices (Jones, 2002; Vandamme, Li, & Rigaud, 1994), and in organic devices (Ferrari et al., 2002). In this paper, we report the finding of the low frequency noise measurements performed in the frequency range of 1 to 1000Hz on a diode-like device prepared by Langmuir-Blodgett (LB) technique.

Experimental Detail

The device is a metal-insulator-semiconductor (MIS) sandwich structure fabricated on n-type silicon wafer (100), as the substrate. Bottom and top contacts were thermally evaporated aluminium (Al) metal. The LB films were 40 layers of cadmium stearate with the thickness of approximately 100 nm. The detailed description of the fabrication technique is given in Malik et al., 2003. The low frequency noise measurement set up consists of a low noise biasing circuit, a device under test (DUT), a transimpedance amplifier (EG&G 5182), and a dynamic signal analyser (HP 35665A) as shown in Figure 1.

Great care has been taken to make sure that the system noise is not influenced by noise other than that from the device-under-test (DUT). Metal boxes were used to protect the set up from the surrounding electromagnetic interference. Double shielded low noise BNC cables were used to connect between the DUT, transimpedance amplifier and the dynamic signal analyser. The transimpedance amplifier used was an ultra low noise current amplifier

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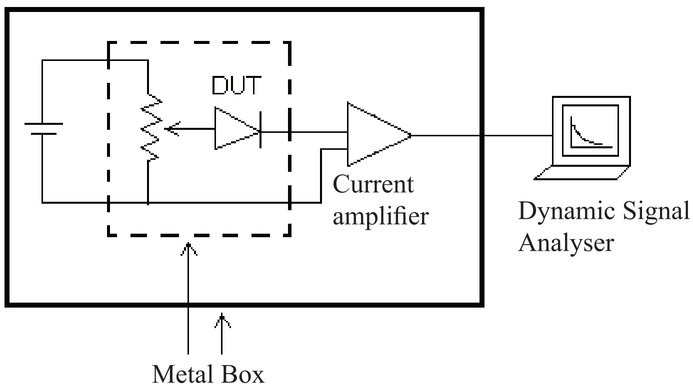

Figure 1 A schematic diagram of a low frequency noise measurement setup

with a maximum background noise power spectral density of 2.2×10^{-28} A^2/Hz in the range of 1 Hz to 4 kHz, at its highest gain (10^{-8} A/V). A custom-made program based on LabView software was developed for acquiring the noise data. The low-frequency electrical noise of the device were measured at low to moderate bias current at room temperature.

Result and Discussion

A set of data were obtained from the low-frequency noise measurement. The analysis of data has been done based on a generally accepted model explaining the 1/*f* noise in ohmic systems, which can be presented for the semiconductor diodes as (Hooge, Kleinpenning, & Vandamme, 1981),

$$S_I(f) = C\frac{I^{\beta}}{f^{\gamma}} \ \mathrm{A^2/Hz} \qquad ...(1)$$

where *C*, *β*, and *γ* are the *1/f* constants. *C* is a low frequency noise magnitude, which can be considered as a quality indicator of the device. *β* is a diode-specific parameter which determine the origin of the *1/f* noise in the DUT (Chen, Deen, & Peng, 2000). *I* is the dc bias current, and *f* is frequency.

Figure 2 shows the current noise power spectral density (PSD) as a function of frequency at different dc bias current. From this figure, we can see that for all bias current, PSD varies inversely with the frequency. By linear curve fitting the slope, which represent *γ*, was found to be in the range of 1.06 to 1.13 which lies within the range of accepted values to be considered as *1/f* noise (Chew, Yeo, & Chu, 2004). The system noise has been measured at no bias current and it comprises noise solely from DUT and transimpedance amplifier. This value is comparable to the conductivity measurement by LCR meter at thermodynamic equilibrium.

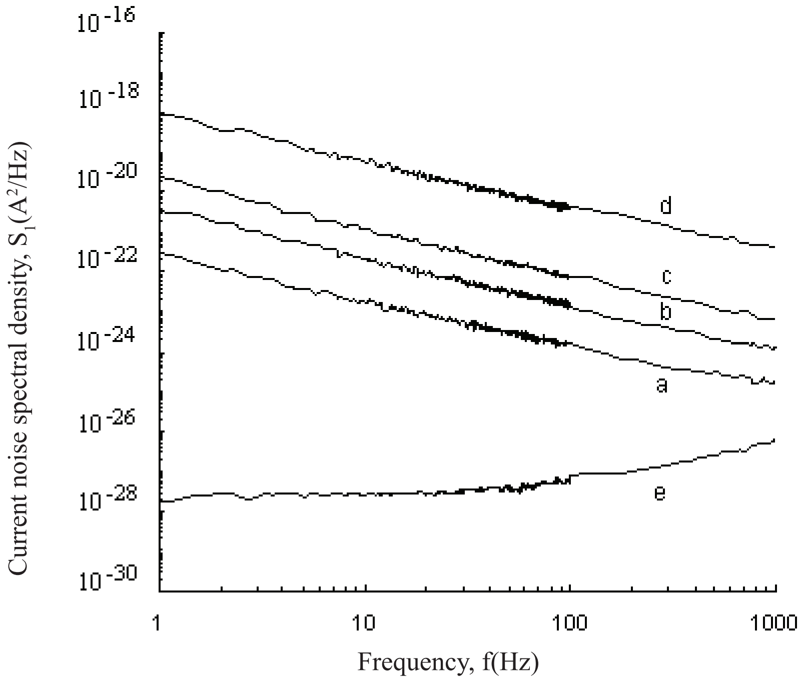

Figure 2 Current noise power spectral density, S_I (A^2/Hz), as a function of frequency at room temperature for 4 different bias currents, 20, 50, 100 and 400 nA (curve a,b,c, and d respectively). System noise was measured at thermodynamic equilibrium (curve e).

Further analysis has been done to find the β value. Figure 3 shows the noise power spectral density as a function of the bias current. The current noise is found to vary proportionally with the bias current. The same result has been reported in organic thin-film transistors (Martin et al., 2000). The values of β were extracted from the slope of the graph and two values of β were obtained. For current below 400nA (range A), β = 2.7 while for bias current above 400nA (range B), β = 1.1. The *1/f* noise observed is believed to be dominated by the series resistance of the silicon substrate and contacts. As the bias current exceeds 400nA, $S_I(f)$ scale with *I*, given indication that the noise is solely dominated by the mobility fluctuation of the carriers in the LB films and are less influenced neither by silicon series resistance nor contact.

The noise magnitude, *C*, has been extracted from the linear curve fitting of the normalised current noise spectral density ($f^{\gamma}S_I(f)/I^{\beta}$) vs. *I* at 3Hz and was found to be 1.8×10^{-1} and 1.8×10^{-11} for range A and B respectively. This result has shown that the magnitude of the noise power decreased with the bias current.

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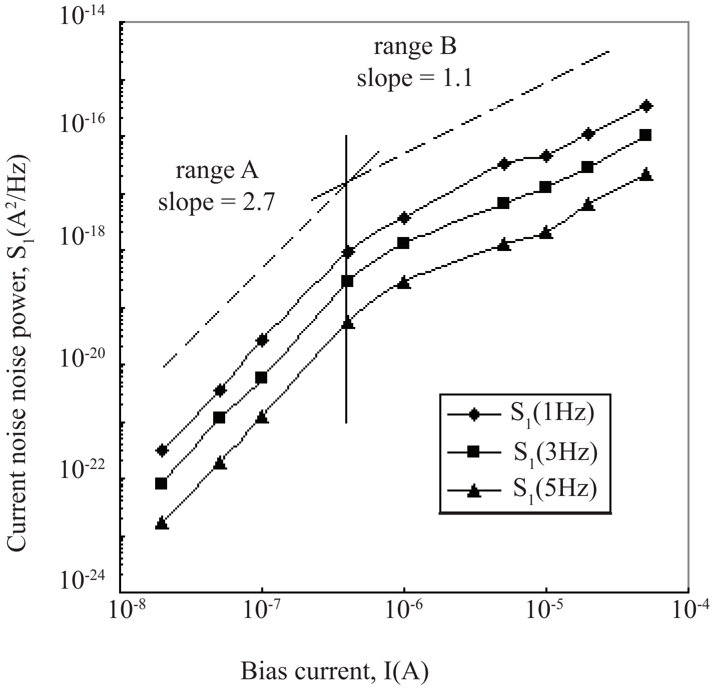

Figure 3 Extracted values of current noise power spectral density, S_I *(A^2/Hz)*, as a function of bias current at room temperature for frequency of analysis *f* = 1, 3, and 10 Hz.

Conclusion

In this work, a diode-like device in metal-insulator-semiconductor (MIS) structure was fabricated. The insulator was a 100nm Langmuir-Blodgett (LB) films of cadmium stearate. The device has been characterized by measuring the electrical current noise properties at low to moderate bias current at room temperature. The *1/f* noise was found to be dominant in the low frequency range with γ close to unity. From the measurement and data analysis, the noise parameters have been extracted. The origin of the noise was found to depend strongly on the bias current range.

References

Chen, X.Y., Deen, M.J. and Peng, C.X. (2000). Low-frequency electrical noise of high-speed, high-performance 1.3 μm strained multiquantum well gain-coupled distributed feedback lasers, *J. Appl. Phys*., 88 (11): 6746 - 6751.

Chew, K.W., Yeo, K.S., and Chu, S.F. (2004). Impact of technology scaling on the *1/f* noise of thin and thick gate oxide deep submicron NMOS transistors, *IEE Proc.-Circuit Devices Syst*., 151 (5): 415 - 421.

Ciofi C., and Neri B., 2000, Low frequency noise measurements as a characterization tool for degradation phenomena in solid-state devices, *J. Phys. D: Appl. Phys*., 33(21): R199 - R216.

Ferrari, G., Natali, G., Sampietro, M., Wenzl, F.P., Scherf, U., Schmitt, C., Güntner, R and Leising, G. (2002). Current noise spectroscopy on mLPPP based organic light emitting diodes, *Organic Electronics*, 31(1): 33-42.

Jones, B.K. (2002). Electrical noise as a reliability indicator in electronic devices and components, *IEE Proc.-Circuits Devices Syst*., 149(1):13-22.

Hooge, F.N., Kleinpenning, T.G.M., and Vandamme, L.K.J. (1981). Experimental studies on 1/f noise, *Rep. Prog. Phys*., 44(5): 479-532.

Malik, S., Ray, A.K., Hassan, A.K., and Nabok, A.V. (2003). Nanocomposite organic films on silicon, *IEEE Trans. Nanotechnology*, 2(3):149-153.

Martin, S., Dodabalapur, A., Bao, Z., Crone, B., Katz, H.E., Li, W., Passner, A., and Rogers, J.A. (2000). Flicker noise properties of organic thin-film transistors, *J. Appl. Phys*. 87(7): 3381- 3386.

Petty, M.C. (2002). *Application of organised molecular films to electronic and opto-electronic devices in studies in Interface Science, Organized Monolayers and Assemblies: Structure, Process and Function*, edited by D. Mobius and R.Miller, Elsevier Science.

Vandamme, L.K.J., Li, X., and Rigaud, D. (1994). 1/f noise in MOS devices, mobility or number fluctuations? *IEEE Trans. Electron Devices*, 41(11):2176-2187.