1/f Noise in Langmuir-Blodgett Films Embedded with CdS Nanoparticles

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Introduction

The Low-frequency noise technique is regarded as being a sensitive tool, capable of probing down to localized microscopic phenomena of the devices [1]. It is often used as a diagnostic tool for determining the reliability of electron devices In this paper we report the low frequency noise measurement on Langmuir-Blodgett (LB) films of stearic acid embedded with CdS nanoparticles at low to moderate forward bias current at room temperature.

Experimental

Low frequency noise measurements were performed on a metal-insulator-semiconductor (MIS) diode-like device prepared by Langmuir-Blodgett (LB) technique. The insulator was 40 layers of LB films of cadmium stearate embedded with CdS nanoparticles. The thickness of the films was estimated to be approximately 100 nm. The detailed description of the fabrication technique is available in our earlier publication [2]. The low frequency noise measurement set up consisted of a low noise biasing circuit, a device under test (DUT), a current amplifier (EG&G 5182), and a dynamic signal analyser (HP 35665A) as shown in figure 1 [3].

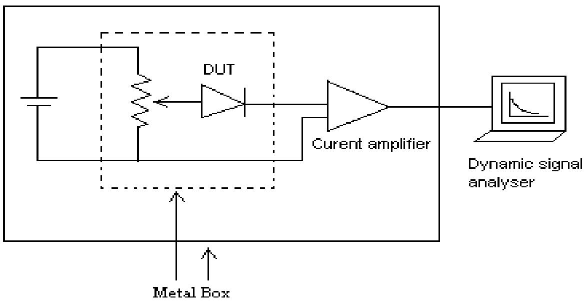

Fig. 1. A schematic diagram of a low frequency noise measurement set-up.

Batteries were used for powering the DUT and a transimpedance amplifier to avoid flicker noise, which might be introduced by the commercial dc power supply. Two metal boxes were used to protect the set-up from 50 Hz power line noise and from the surrounding electromagnetic interference. A wire-wound potentiometer was used since the inherent 1/f noise was smallest [4]. Double shielded low noise BNC cables were used to connect between the device under test, current amplifier and the dynamic signal analyser. The current amplifier used was an ultra low noise current amplifier with a maximum background noise power spectral density of $2.2x10^{-28} A^2 / Hz$ in the range of 1 Hz to 4 kHz, at its highest gain (10^{-8} A/V LN). A LabView program was developed for acquiring the data.

Results and Discussions

A modification of Hooge empirical model explaining the 1/f noise in ohmic systems can be presented for the semiconductor diodes as [5]

$$S_I(f) = C_{1/f} \frac{I^{\beta}}{f^{\gamma}} \qquad (1)$$

where $C_{1/f}$, β and γ are the 1/f constants. $C_{1/f}$ is a low frequency noise magnitude, which can be considered as a quality indicator of the device. β is a diode-specific parameter and also depends on the bias current range, is a measure of the mixing of various noise sources in the device, will determine the origin of the 1/f noise in the DUT [6]. γ is a measure of the distribution of traps responsible for the carrier number fluctuations. I and f are the dc bias current, and frequency respectively. Figure 2 shows the current noise power spectral density (PSD) as a function of frequency at different dc bias current. It can be seen that irrespective of bias current, the current noise power spectral density (PSD) varied inversely with the frequency. By linear curve fitting, the slope γ was found to be in the range of 1.15 to 1.35. The system noise was measured at no bias current and it comprises noise solely from DUT and current amplifier. This value was comparable to the conductivity vs. frequency characteristics measured by impedance meter at no dc bias current.

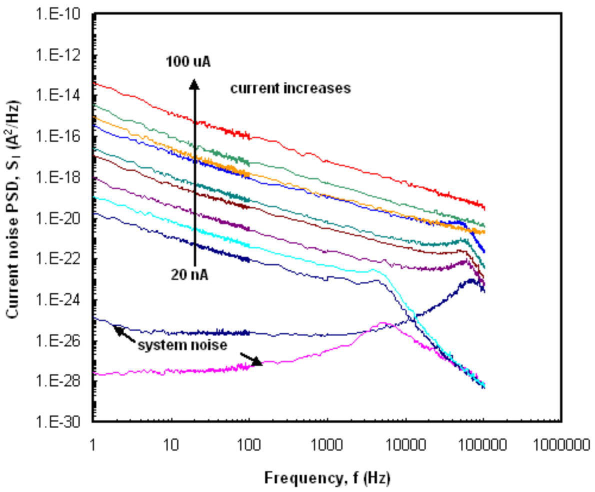

Fig. 2 Current noise power spectral density, S_I vs frequency at room temperature at several different bias currents from 20 nA to 100 uA. System noise has been measured at thermodynamic equilibrium.

Using the data in figure 2, the relationship between PSD and bias current at several frequencies were obtained and the results were plotted as in Figure 3. From linear curve fitting, two regimes were identified. A quadratic law was observed in regime A,. The 1/f noise observed was believed to be dominated by the series resistance of the silicon substrate and contacts.

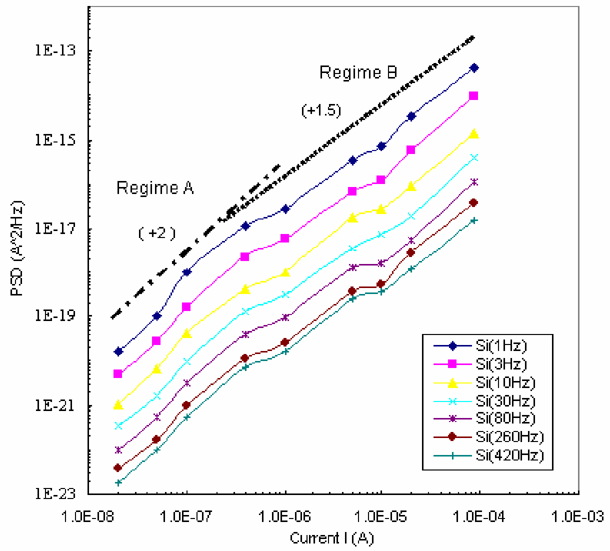

Fig. 3 Extracted values of current noise spectral density, S_I (A^2/Hz), as a function of the bias current at room temperature for frequency of analysis f = 1 to 420 Hz.

As the bias current exceeds 0.2uA, S_I (f) scaled with $I^{1.5}$ and the noise was dominated by the mobility fluctuation of the carriers in the films but was not significantly influenced either by silicon series resistance or contacts.

The noise magnitude ($C_{1/f}$) was extracted from the linear curve fitting of the normalised current noise spectral density ($f^{\gamma}S_I(f)/I^{2(\beta)}$) vs. I at 3Hz. (graph not shown) and was found to be 6.5 x 10^{-5} and 2.9 x 10^{-8} for range A and B respectively, implying that the noise magnitude decreased as the bias current exceeded certain value.

Conclusions

The low-frequency noise of a MIS diode-like device was investigated. The current noise power spectral density (PSD) at several fixed bias currents was found to be dependent on the bias current. From the measurement data the noise parameters were extracted. The 1/f noise was found to be dominant in the low frequency range with γ in between 1.15-1.35. The origin of the noise was found to depend on the bias current range. It is believed that by embedding the CdS nanoparticles into the stearic acid matrix, electron-trapping centres have been created which result in different current conduction behaviour from the untreated LB films of cadmium stearate.

References

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