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Analysis of Interface Trap Density of Organic-Organic Interface with Capacitance-Voltage Characteristics

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1. Introduction

The OTFTs are attracted much attention because of their potential applications to flexible devices such as flexible displays and organic RFIDs [1-2]. However, the interface charge properties of organic semiconductor to organic insulator, which are critical to performance, are not clearly identified yet.

In this paper, we applied the combined high-low frequency capacitance-voltage characteristics to analyze the interface trap density between pentacene and gate insulators such as SiO_2 and polyvinylphenol (PVP).

2. Experiments

We fabricated two types of capacitors consisting of metal-insulator-semiconductor-metal (MISM) structure. One capacitor used p^+-Si substrate for gate electrode and SiO_2 for insulator and pentacene for semiconductor and Au for top electrode. The other capacitor employed PVP insulator on Al electrode and pentacene for semiconductor and Au for top electrode.

We used by E4980A LCR meter of Agilent to measure the capacitance-voltage characteristics with the various frequency of small signal in dark environment to avoid degradation due to light [5]. The interface traps density was extracted by eq.1 [3].

$$D_{it} = \frac{C_{Ins}}{q}\left[\left(\frac{1}{\Delta C/C_{Ins} + C_{HF}/C_{Ins}} - 1\right)^{-1} - \left(\frac{1}{C_{HF}/C_{Ins}} - 1\right)^{-1}\right] \qquad (1)$$

where $\Delta C = C_{LF}-C_{HF}$, C_{Ins}, C_{LF} is the low frequency capacitance, and C_{HF} is the high frequency capacitance.

3. Result and discussion

The equivalent circuit of MISM with SiO_2 insulator is shown in Fig. 1. MISM/ SiO_2 has the parasitic capacitances caused by SiO_2 (C_{ox}) and p^+-Si (C_{Si}) substrate. Therefore, the measured C-V curves should be modified by eliminating the parasitic capacitance. In Fig.2 the C-V curves were measured with the various frequencies from 20 Hz to 1 MHz. The C-V curves were reduced to the minimum capacitance in the positive voltage where pentacene layer was totally depleted, and they were rose to the maximum capacitance of 90 nF/cm^2, which is similar to the theoretical value of 100 nF/cm^2. The threshold voltage was about 10V, indicating the negative fixed interface charge density of -9x10^{-7} Coul/cm^2. As the frequency increased, C-V curves were smeared out because the interface traps could not respond to high frequency. The relaxation frequency was about 1KHz as shown in Fig.3. The interface trap density was extracted from the low C-V at 20 Hz and the high C-V at 10 KHz, and depicted in Fig.7. The interface trap density was varied from 10^{13} cm^{-2} to 10^{10} cm^{-2} as the Fermi energy level moved along the bandgap.

MISM/PVP capacitor exhibited the simple equivalent circuit as shown in Fig.4 so that it did not need modification as done in MISM/SiO_2 capacitor. The C-V curves also exhibited the smeared-out phenomena as SiO_2 capacitor, representing the existence of interface trap. The threshold voltage was -10V, indicating the positive fixed interface charge of +9x10^{-7} Coul/cm^2, which was different from SiO_2 insulator. The relaxation frequency was about 1 KHz similar to that of SiO2, implying that the relaxation frequency is related to pentacene. The interface trap density was very similar to SiO_2 varied from 10^{13} cm^{-2} to 10^{10} cm^{-2}, indicating that the interface traps density was attributed to pentacene near interface, being independent from insulators.

4. Conclusions

We fabricated two types of MISM capacitors with the same pentacene and the different insulators such as SiO_2 and PVP insulator, respectively. The fixed interface trap charge was different depending on insulator; the positive charge for PVP and the negative for SiO_2. However, the interface trap density exhibited the same variation from 10^{13} cm^{-2} to 10^{10} cm^{-2} independent from insulator, indicating that the interface trap was attributed to pentacene near interface.

Acknowledgements

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References

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[5] Cipolloni S., et. al, Thin solid films **515** (2007) 7546 Degradation by light

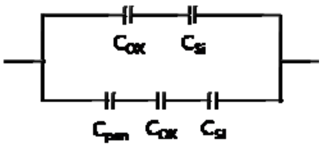

Fig. 1 The equivalent circuit of MISM/SiO_2 capacitor.

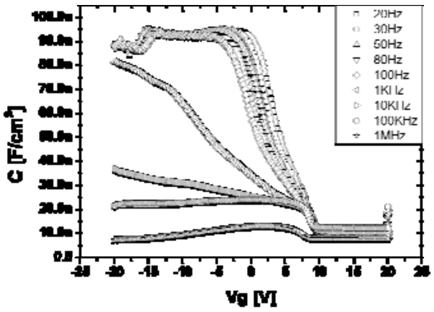

Fig. 2 The C-V curves with the various frequencies of MISM/SiO_2.

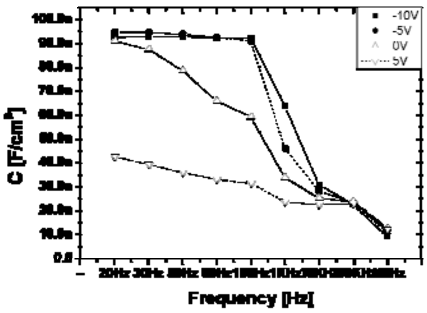

Fig. 3 The frequency dependence of MISM/SiO_2 capacitor.

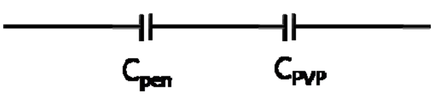

Fig. 4 The equivalent circuit of MISM/PVP capacitor.

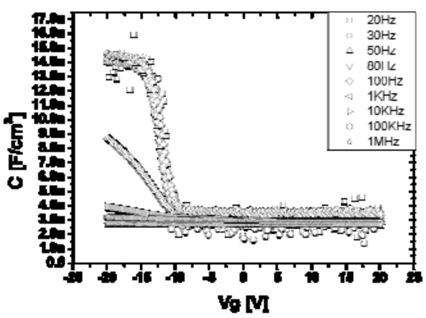

Fig. 5 The C-V curves with the various frequencies of MISM/PVP.

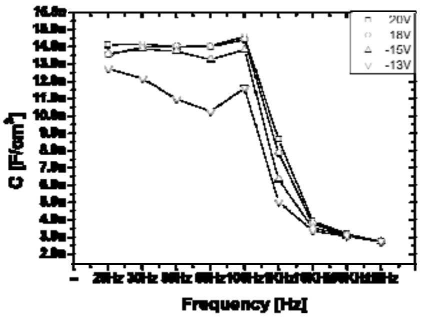

Fig. 6 The frequency dependence of MISM/PVP capacitor.

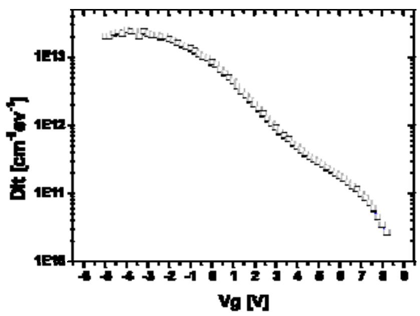

Fig. 7 The interface trap density of MISM/SiO_2 capacitor.

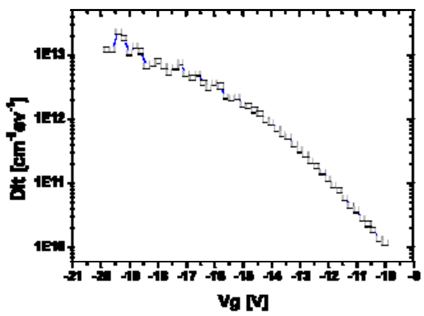

Fig. 8 The interface trap density of MISM/PVP capacitor.