11th International Conference on Advanced Materials
Rio de Janeiro Brazil
September 20 - 25
ICAM2009

Negative Capacitance Effect on Metal/Pentacene/Metal Structures

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Abstract – Capacitance spectroscopy measurements have been carried out on metal/pentacene/etal structures, with calcium, indium tin oxide or gold as electrodes. A negative capacitance (NC) effect has been observed at low frequencies for all devices. It has also been noticed that the NC effect is enhanced when a DC bias is applied.

In this work we have carried out impedance/admittance measurements in the frequency domain on devices comprising metal/pentacene/metal structures, with special focus on the dielectric response function associated to the equivalent parallel capacitance. Our main goal is to investigate the charge transport mechanism in pentacene, specially the influence of electronic traps. We have used the impedance spectroscopy technique as a tool to understand the influence of traps at the metal/organic semiconductor interface as well as in the bulk. The organic semiconductor pentacene is a small conjugated molecule which is a promising candidate as active material in organic field effect transistors (OFETs) and organic complementary metal/oxide/semiconductor (CMOS) inverters, due to its high charge carrier mobility [1-3]. All devices were prepared in a sandwich configuration, with the pentacene layer (150 nm of thickness) evaporated under vacuum (~ 10^{-7} mbar) between the electrodes. We have used calcium, ITO (indium tin oxide) and gold as electrodes. All the electrical measurements were done in a glove box (oxygen content around 1 ppm). A Semiconductor Parameter Analyzer HP 4155 A was used to measured the current-voltage (I-V) characteristics of the devices. The impedance spectroscopy measurements were done in the parallel circuit configuration, with an impedance analyzer/ gain phase Solartron SI 1260, for frequencies between 2 Hz and 10 MHz. We have first measured the capacitance spectrum at ambient temperature, zero DC bias and 200 mV AC amplitude for Ca/Pentacene/Ca/Al samples. At low frequencies the equivalent parallel capacitance drops abruptly, assuming negative values for frequencies lower than 50 Hz (Fig. 1). We have also observed negative capacitance (NC) for ITO/Pentacene/Au samples (Fig. 2). For the ITO/Pentacene/Ca samples (Fig. 3), the NC effect is not observed until DC bias higher than 750 mV is superimposed to the AC voltage. Although the NC effect has been previously observed in several electronic devices [4-6], we have not found reports on negative capacitance on pentacene-based devices until now. A theoretical approach to explain such behavior is still in progress.

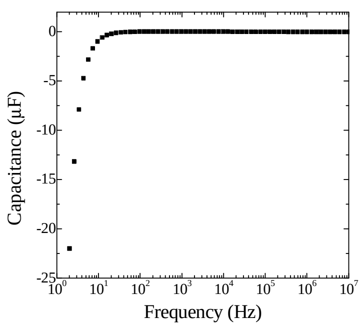

Figure 1: Capacitance as a function of frequency for Ca/Pentacene/Ca/Al.

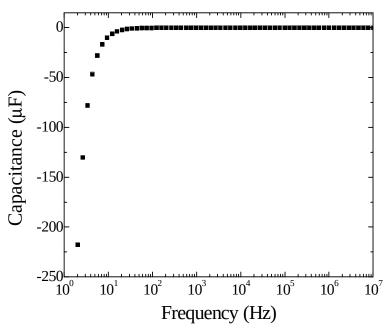

Figure 2: Capacitance as a function of frequency for ITO/Pentacene/Au.

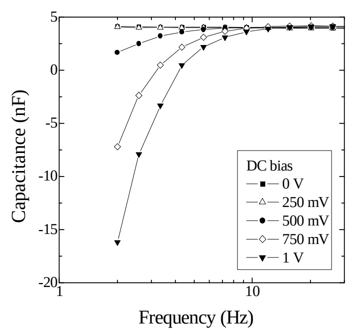

Figure 3: Capacitance as a function of frequency for ITO/Pentacene/Ca/Al.

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