Scaling behaviors of transient noise current in organic field-effect transistors

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A B S T R A C T

Top-contact and bottom-gate organic field-effect transistors (OFETs) based on poly(3-hexylthiophene), P3HT polymer has been fabricated with thermal treatment condition. Transient noise currents of the OFETs are measured at various source–drain voltages ranging from 0 V to 60 V with respect to a fixed gate voltage of 60 V. The results from conventional power spectral density method are compared with the more robust Detrended Fluctuation Analysis. The latter has been proven to be reliable for fractal signals particularly in the presence of nonstationary effects. Interesting transitions between multiscaling and monoscaling behaviors are observed in the power spectral density as well as the Detrended Fluctuation Analysis plots for different applied source–drain voltage $V_{\text{ds}}$. Uncorrelated white noise characteristics are observed for noise current measured at low $V_{\text{ds}}$, meanwhile 1/f noise like scaling behaviors are observed at intermediate $V_{\text{ds}}$. At higher $V_{\text{ds}}$, the noise characteristics appeared to be close to Brownian-like power-law behavior. The scaling characteristics of the transient noise current can be related to the charge carrier dynamics. It is also found that large numbers of trap centers are induced when the device is stressed at high applied $V_{\text{ds}}$. The existence of these trap centers would disperse charge carriers, leading to 1/f type noise that could diminish the presence of Brownian noise in a very short time.

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1. Introduction

The discovery of conducting polymer [1] has triggered huge interest for the development of organic and polymer based electronic and optoelectronic devices such as the organic field-effect transistors (OFETs), organic light emitting diodes (OLEDs), polymer solar cells, etc. [2,3]. For instance, field-effect transistors (FETs) [4–7] based on polymer and organic materials had been demonstrated since the early 80s. Since then, studies and development of OFET have become important in the viewpoint of technological prospects as well as the fundamental understanding from scientific aspects. This is mainly because OFET plays a significant role as the main component in cheap and flexible analog and digital electronics circuits. Moreover, OFET also serves as an important tool to study the carrier transport and light emission properties of organic semiconductors.

A field-effect transistor (FET) basically consists of an organic or inorganic semiconducting layer that is separated from the gate electrode by a layer of dielectric; source and drain electrodes that are separated by a (channel) length $L$ and are in contact with the semiconducting layer. The source electrode is usually kept at zero bias and meant for charge carrier injection. When the gate voltage $V_g$ (potential difference between the source and gate electrodes) is biased at a more positive (negative) level than that of the source voltage $V_s$, electrons (holes) are injected into the semiconducting layer within the channel region. The amount of accumulated charges is proportional to the gate voltage $V_g$. This relationship is the foundation of the field-effect transistor.

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