

Hysteresis in Carbon Nanotube Field-Effect Transistors

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Carbon nanotube field effect transistors (CNTFETs) have many possible applications in future nano-electronics due to their excellent properties. However, one of the major challenges regarding their performance is the noticeable gate hysteresis which is often displayed in their transfer characteristics. The hysteresis phenomenon is often attributed to water-mediated charge transfer between the CNT and the dielectric layer or the CNT and the water layer itself. In this study, we have attempted to improve our understanding of the hysteresis in CNTFETs, and to use the CNTs to learn more about the processes which are responsible for this phenomenon.

Since the hysteresis involves mobility of charge, we have first developed a quantitative method to measure lateral and temporal charge density on dielectric layers using electrostatic force microscopy (EFM) [1]. Using this approach, we find that upon applying gate voltage compliance in the vicinity of grounded electrodes, a water-assisted surface charge redistribution is induced and results in screening of the electric field originates from the gate electrode. Following a thorough study, we provide experimental evidence that the hysteresis in suspended CNTFETs, as well as in on-surface CNTFETs operating at low gate voltages, is based on the described above phenomenon of charge redistribution, and is not related to charge injection from the CNT itself as previously believed [2]. These findings are of fundamental importance not only to CNT devices, but also to nano-scale devices in general, as they may help in controlling or completely eliminating the hysteresis effect seen in those devices.

Finally, we report of gate-induced modification of water adsorption on dielectrics. Using both EFM and CNTFETs-based measurements to probe charge redistribution on the dielectric surface, we have been able to extract the surface humidity, and to modify it with the applied external gate biases. Furthermore, we find that upon the adsorption of

2-3 layers of water the surface conductivity saturates [3]. This information is very relevant to CNTFETs as well as to other nano-scale devices which operation is very sensitive to the actual surface humidity. In addition, one can think of several interesting applications for the ability to electrically control the amount of surface water using the gate electrode, such as the realization of electrical switches to water-dependent chemical reactions.

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