Field-Controlled Ion-Locked Polymorphic Electronics for Hardware Security

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Hardware security comes at a high price in the U.S. at $200 billion annually. Polymorphic electronics provide a potential solution to hardware security threats by preventing unauthorized parties from accessing circuitry information through reverse engineering. The goal of this work is to obscure a device's function by taking advantage of electric double layer (EDL) gating to reconfigure NAND gates to/from NOR gates on-demand. The key innovation is a custom synthesized polymer electrolyte that reacts under an electric field created by the EDL (~V/nm), retaining charges in the channel by crosslinking the polymer electrolyte. Ion mobility is confirmed in a lateral, parallel-plate capacitor geometry, and graphene field effect transistors (GFETs) are used to test non-volatile doping. Preliminary evidence of non-volatile doping is observed by programming GFETs at positive gate voltages ($V_G > +2$ V), and then sensing the Dirac point shift and ON/OFF ratio change. Positive programming voltages less than +2 V showed no effect on the doping; however, the device becomes more n-type and ON/OFF increases as V_G increases from +2 to +5 V. Note that in the absence of non-volatile doping mechanism, grounding the gate would dissipate the EDL and reverse the doping effect; however, in the case of our custom synthesized electrolyte, the doping effect persists even after the gate bias is grounded, confirming non-volatile doping at the graphene channel. Applying a negative V_G demonstrates a semi-permanent - but reversible - doping effect. Specifically, as V_G increases from -1 to -5 V, the Dirac point shifts less n-type and ON/OFF decreases, implying that the doping effect is reversible, but non-volatile. We further explored a dual-gate configuration, where the side gate served for programming and the back gate for reading the Dirac point. Here, the device was programmed and then grounded at a temperature above the polymer's glass transition temperature (T_g). Subsequently, it was read at a temperature below T_g to restrict ion mobility and observe the Dirac point shift. Positive programming ($V_{SG} = +5V$) induced a similar n-type shift, while subsequent negative programming ($V_{SG} = -5V$) rendered the device less n-type. We will present further measurements with higher salt concentrations and investigate the effect of reversing the programming sequence (negative followed by positive). The work is supported by the National Science Foundation (NSF, U.S.) under Grant No. ECCS-EPMD-2132006.