Conductive Polymer Field-Effect Transistors (CPFETs)

Nicole R. Honesty Literature Seminar November 20, 2008

Conductive polymers are promising candidates for use in electronic devices including vapor sensors, electronic and photonic transistors, solar cells, and nanoscale lasers.[1,2] They have various advantages over their conventional counterparts some of which include: reasonable price, facile large-scale synthesis, solution processablility, and tunable properties.[3] Development of nanowires of conductive polymers is a step towards device miniaturization and continues to aid in the refinement of the charge transport theories of quasi 1-D systems.[4,5]

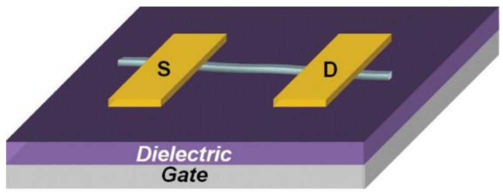
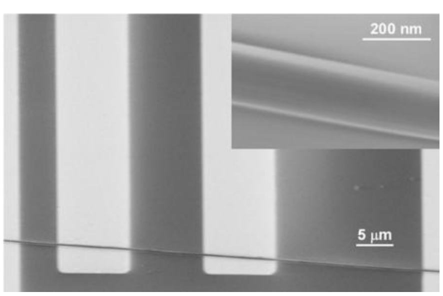


Figure 1. Field-Effect transistor (FET) schematic[1]

Fabrication of conductive polymer field-effect transistors (CPFETs) is a way to investigate charge transport and functionality of organic wires as gas sensors.[1,4,5] CPFET's have five parts: a semiconducting wire, a grounded source (S) electrode at which charges are created, a drain (D) electrode toward which charges flow when potential is applied, an insulating dielectric, and a gate electrode which modulates the channel shape and thus maximum current flow across the wire. Important variables that describe device performance are field-effect mobility (μ) how well the device transports charge carriers and on/off current ratios (I_{ON}/I_{OFF}) the difference in current between accumulation and depletion modes. The current benchmark devices in which holes are majority carriers is the Si nanowire FET[6] with μ_h of 1350 cm^2/Vs and current on/off ratios up to 10^6.

a) 

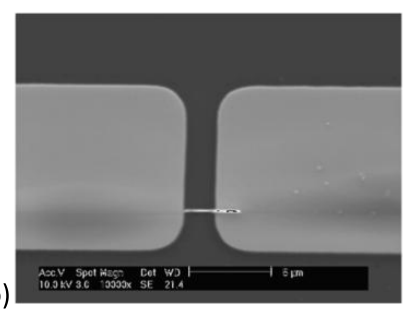
b) 

Figure 2. SEMs of a) Electrospun CPFET[7], b) Electolytically polymerized CPFET[8]

There are a variety of methods available to synthesize 1-D materials,[9] many of which require physical selection and alignment steps.[10] Polymer nanowires have also been formed using the above schemes.[1,10] Electrospinning and electrolytic polymerization of wires between the source and drain electrodes, however, do not require complicated alignment or functionalization. Electrospinning involves slowly pumping a polymer solution through a syringe with high potential (4-10 kV) aimed at a grounded electrode.[11] The diameter and field-effect characteristics can be varied by adjusting the tip shape as in the scanned tip method[12,13], the tip voltage, the distance from tip and anode, polymer concentration, and blending in other polymers[14,15]; however, producing nanowires with this technique is still nontrivial. Hole mobilities up to 0.03 cm^2/Vs and I_{ON}/I_{OFF} up to 106 for submicron (100 to 500 nm) diameter wires have been measured in CPFETs with wires produced this way.[7]

Directly polymerizing a wire between the source and drain electrodes is another CPFET fabrication method.[16] Arrays of CPFETs can easily be constructed by polymerizing wires across a predefined gap from source to the drain electrode. Devices created this way can have I_{ON}/I_{OFF} ratios of 10^3.[8] Single nanowire CPFETs can be electropolymerized by etching a channel into a dielectric layer between the electrodes controlling the dimension.[17] Kemp and coworkers have demonstrated a third method in which the shape and size of the source and drain electrodes are modified such that only one wire can grow from each and joining these across the gap between the electrodes.[18]

Of the various ways to make micro or nanofibers, electrospinning and electro-polymerization of polymer fibers between electrodes have been shown to allow for diameter and length control while remaining cost effective. Further optimization of the setup may yield electronics with moderate field effect mobilities and on/off ratios.

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