SEARCH FOR SUPERCONDUCTIVITY WITH NANODEVICES

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Carrier density is one of the most important parameters in changing the electronic properties of materials. The most useful and conventional way to control the carrier density is chemical syntheses. On the other hand, physicists and electronic engineers have developed a field effect transistor (FET) device for changing the carrier density by electric fields. Furthermore, by introducing a liquid gating technique, electric field induced carrier density can reach the level to induce insulator-metal transition and even superconductivity. The liquid gated device is providing us with new opportunities to create new states of matter, which are not accessible through conventional chemistry. Here, we chose an organic polymer, polythiophene, and fabricated a gated and liquid gated FET device by a drop-casting method. Polythiophenes have a variety of derivatives whose crystallinity is much better than other organic polymers. This is highly beneficial to promote the carrier transport as compared to other polymer systems, and thus, polythiophene could be a promising candidate to observe an electric field induced metallic state. We made a direct comparison between solid gated and liquid gated FETs and discuss the possibility of insulator-metal transition.

Search for Superconductivity with Nanodevices

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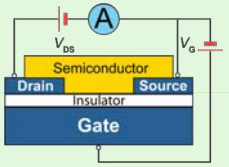
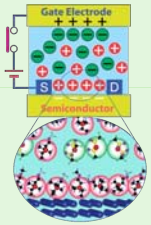
Introduction

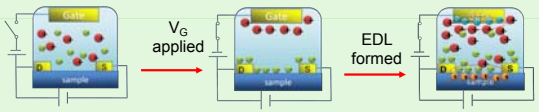
Background:

Conventional FET



Electric Double Layer Transistor

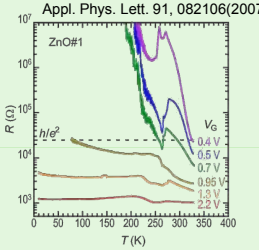




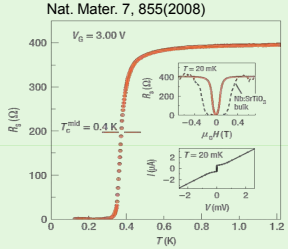
Notable Research:

Gate Induced insulator-to-metal Transition and Superconductivity

H. Shimotani et al., Appl. Phys. Lett. 91, 082106(2007)



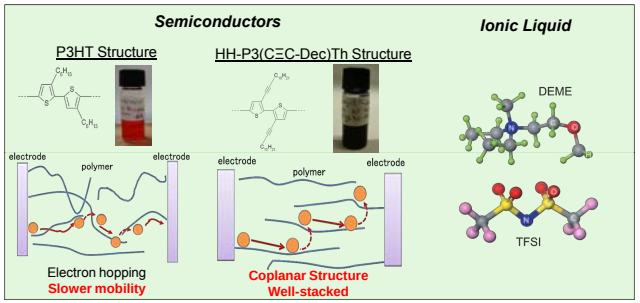
K. Ueno et al., Nat. Mater. 7, 855(2008)



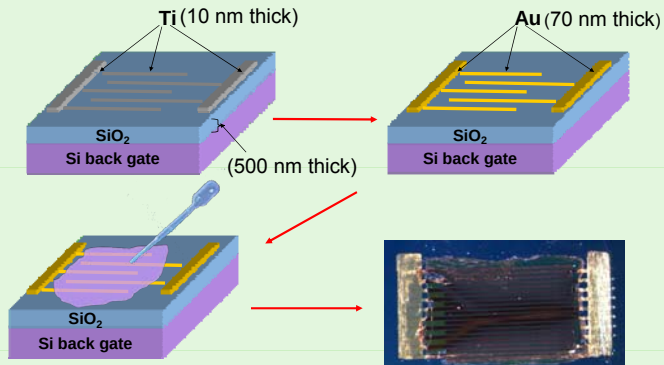
Aim: To realize superconductivity in materials that have not been reached by conventional chemistry

Methods

Materials and Device Fabrication



Methods cont'd

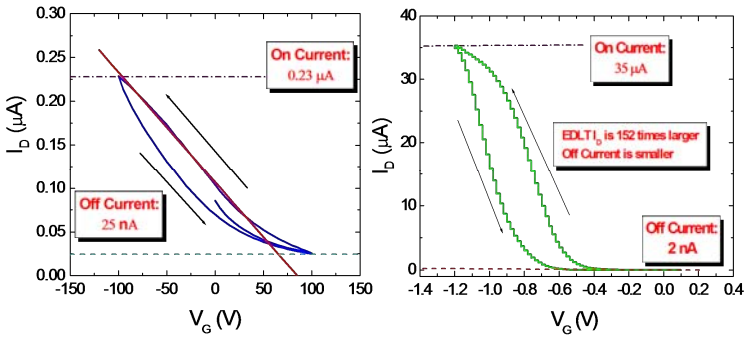


Measurement Apparatus:

Probe Station

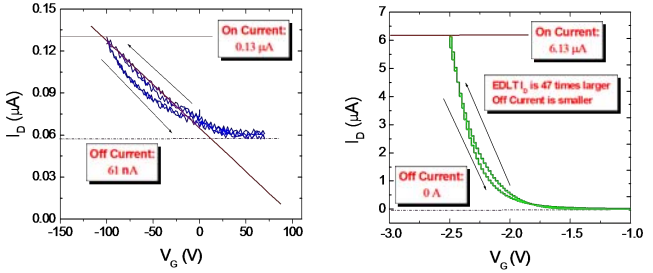
Results

1. Comparison of P3HT FET & EDLT Transfer Characteristic Curves

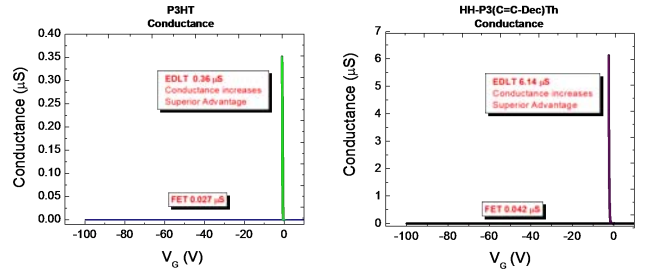


Results cont'd

2. Comparison of HH-P3(CΞC-Dec)Th FET & EDLT Transfer Characteristic Curves



3. Comparison of P3HT & HH-P3(CΞC-Dec)Th Conductance



4. FET Carrier Motilities of P3HT & HH-P3(CΞC-Dec)Th

Polymer Material	V_{DS} (V)	Capacitance (nF/cm^{-2})	Slope	FET Carrier Mobility (μ) (cm^{2}V^{-1}s^{-1})
P3HT	-5	6.73 x 10^{-9}	1.28 x 10^{-9}	2.28 x 10^{-5}
HH-P3(CΞC-Dec)Th	-30	6.73 x 10^{-9}	6.91 x 10^{-9}	2.82 x 10^{-4} ← one order larger

$$\mu = \frac{L}{WCV_{DS}} \frac{dI_D}{dV_G}$$

Conclusion and Future Work

- Demonstrated the first field-effect transistor (FET) operation of HH-P3(CΞC-Dec)Th. The modulation of conductance in the electric double layer transistor (EDLT) was increased compared to the conventional FET in both polymers, however with poor mobility yield.

Future work will focus on optimizing fabrication techniques such as:

- Drop cast conditions
- Annealing temperature
- Introduce spin coating

This should improve the crystallinity of the polythiphene films, which may enhance the mobility, and thus the conductivity. This should aid in the metallization of the materials

Acknowledgement

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