Photoresponsive Nanoscale Columnar Transistors

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- Molecular scaled transport junctions – electrical characteristics of small number of molecules – molecular electronics.
- Challenges – construction, measurement, understanding I – V characteristics of systems with molecules as conducting elements.
- SWNTs – Ballistic 1D conductors, molecule scale width, length suitable for nanofabrication, optoelectronic properties – fundamental building blocks of nanoelectronics. – point contact electrodes.

Background for the current work

Basic Concepts behind the device fabrication

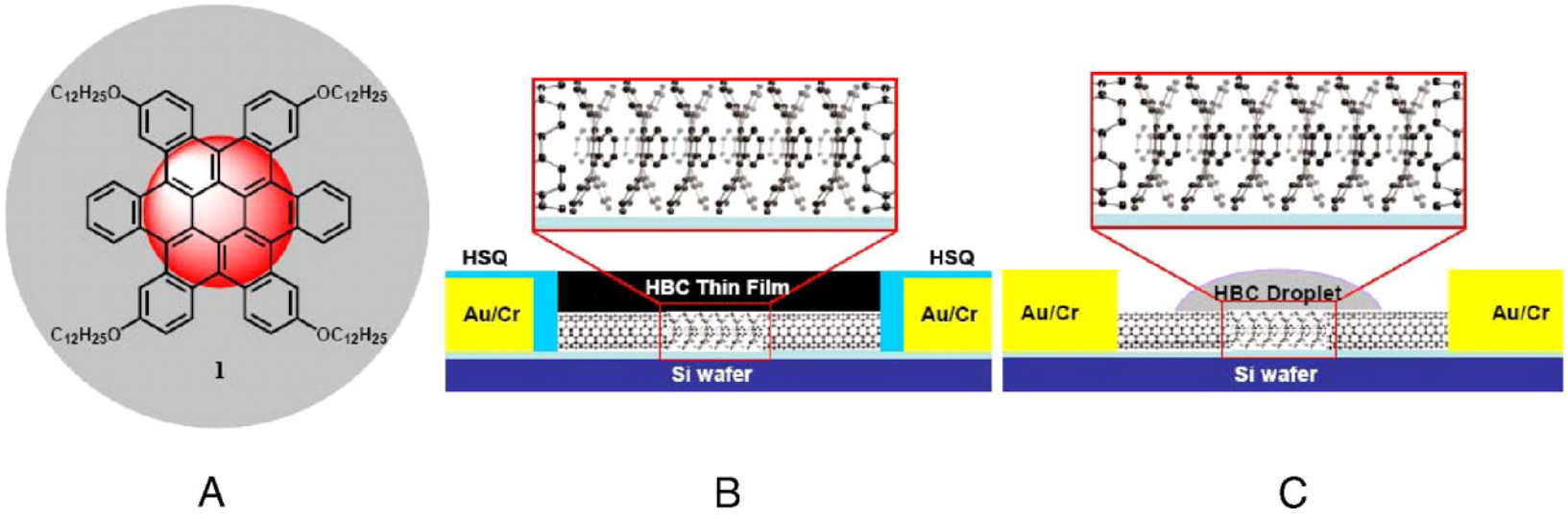
- Methods for forming nanogaps for electrical attachment of single molecules on to the ends of SWNTs. (SWNTs - electrodes)
- Carboxylic acid functionalised nanogaps from SWNTs (ultra fine electron beam lithography & precise oxygen plasma etching)
- Allows molecules to be wired through amide linkages (avoiding the problems related to thiol molecule - gold electrode interaction)
- Amide linkages – helps in withstand external stimuli and chemical treatment

Devices made using the above philosophy

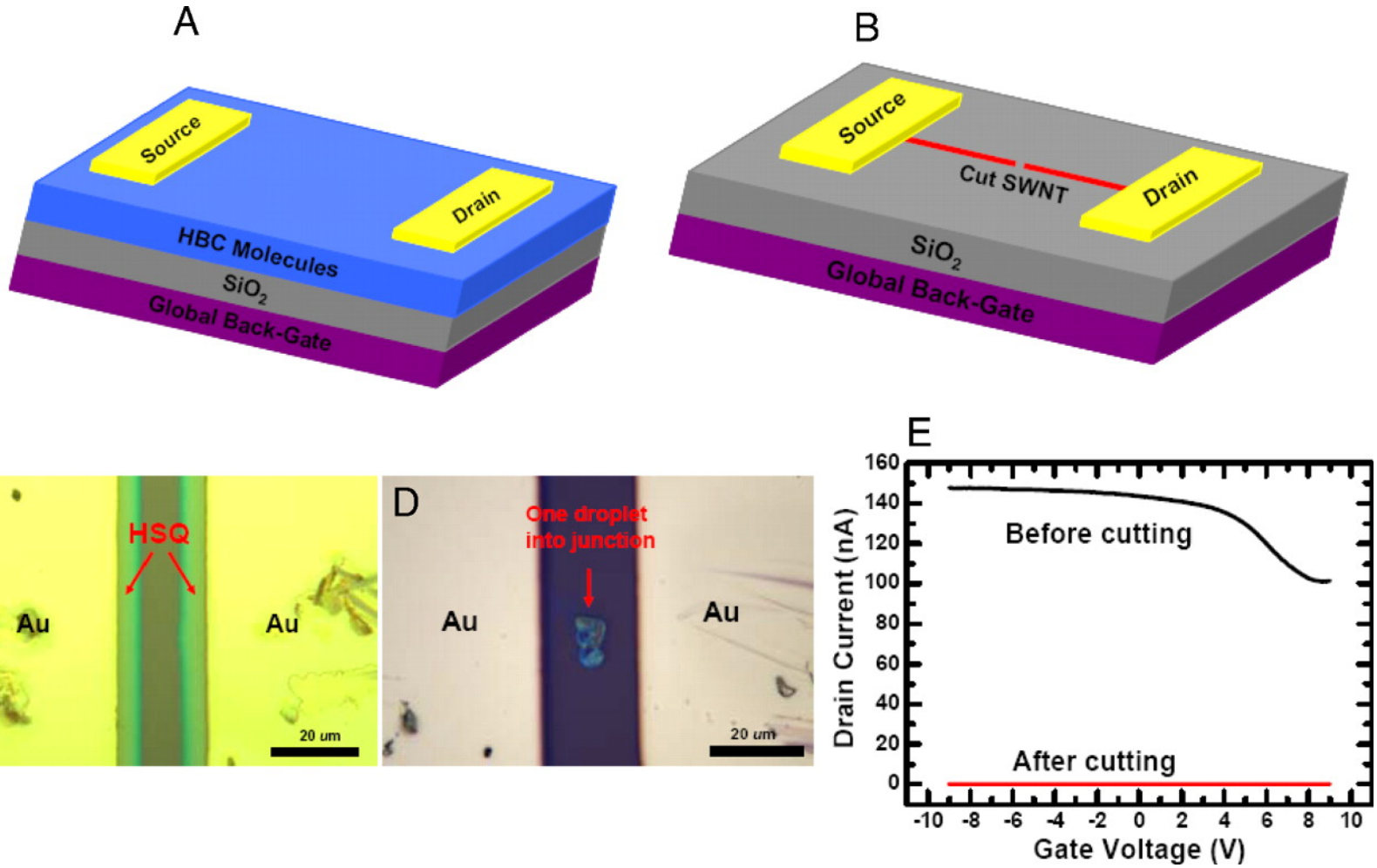
- Molecular electronic devices that are able to switch the conductance as a function of pH
- Detection of binding between protein and substrate
- Photoswitch the conductance between conjugated and non conjugated states
- measure the conductance between complementary and mismatched DNA strands
- Sense the existence of electron-deficient molecules.

- Development of a class of polycyclic aromatic hydrocarbons – self assembles - columnar liquid crystalline phases
- Reported synthesis of contorted tetra(dodecyloxy) hexabenzocoronene HBC – fusion of 3 pentacene subunits.
- Rlatively high carrier mobility's (0.02 cm^2/Vs) and current modulation with on-off ratio of 10^6:1
- Coexistence of the inner π - system as a conductive core and outer π - system as an insulative sheath

A schematic of how HBCs can be assembled to form nanoscale columnar transistors and measured by SWNT point contacts

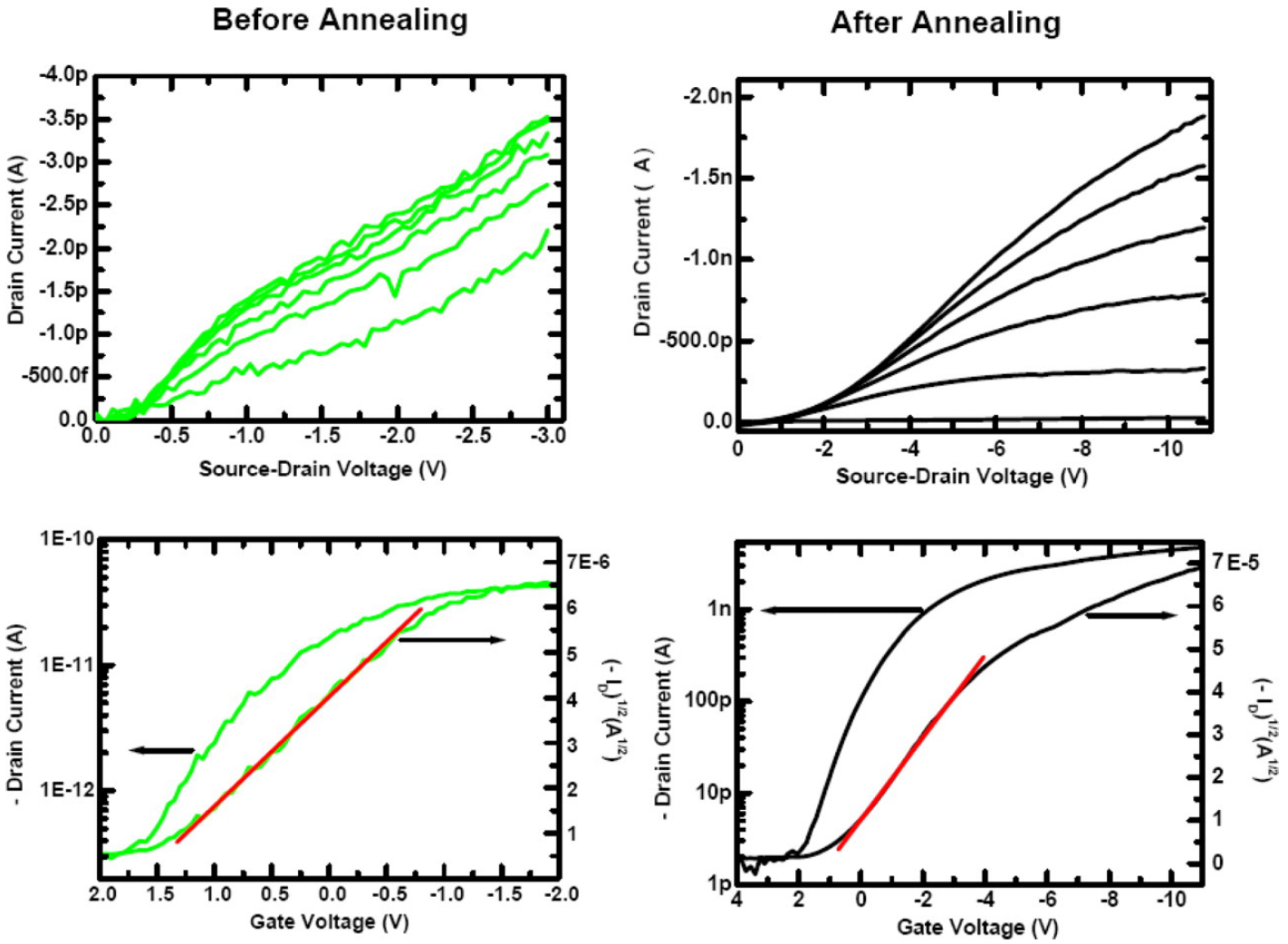


Device structure formed by cutting an individual metallic SWNT

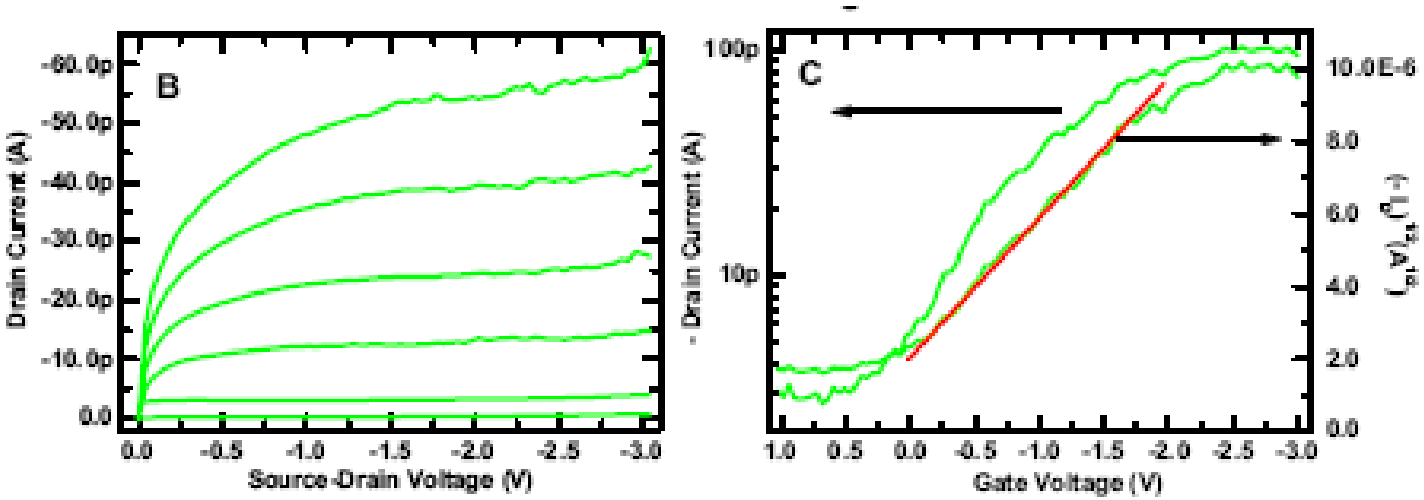


Hydrogensilsesquioxane resin (c)
SWNT – molecule – SWNT nanojunctions

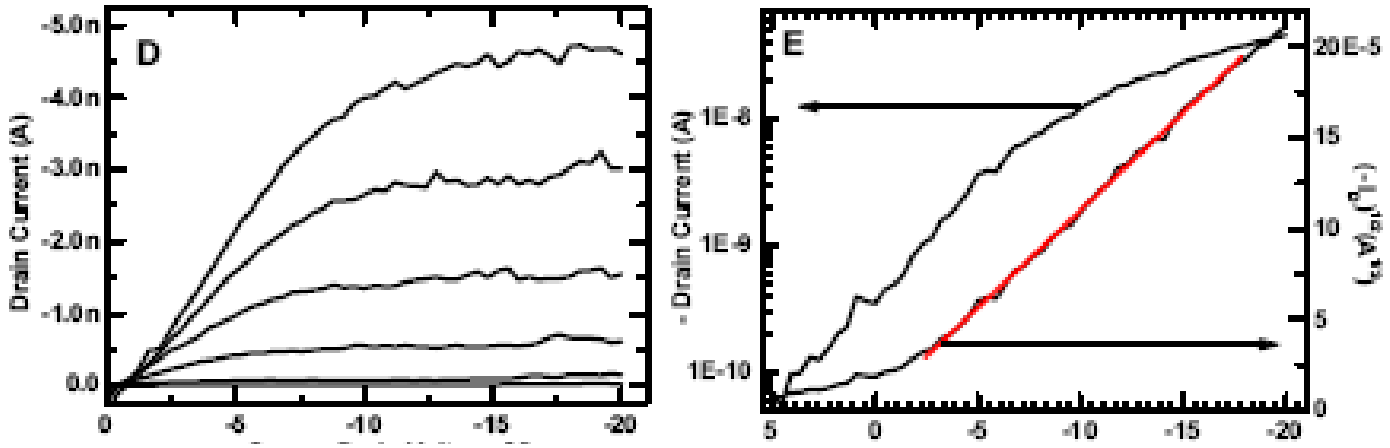
Device characteristics of the spin coated device before and after annealing



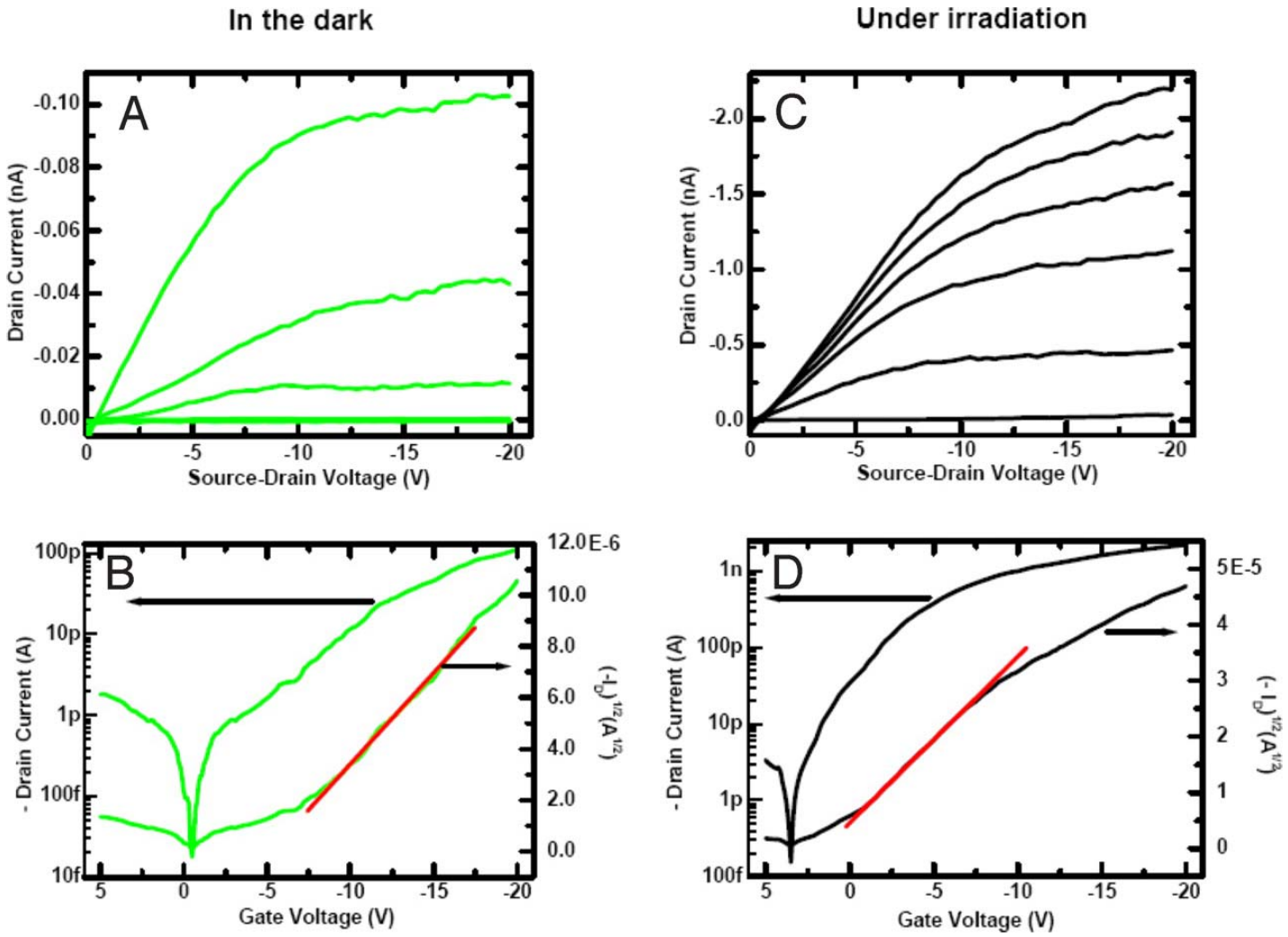
Device characteristics of the drop cast device before and after annealing



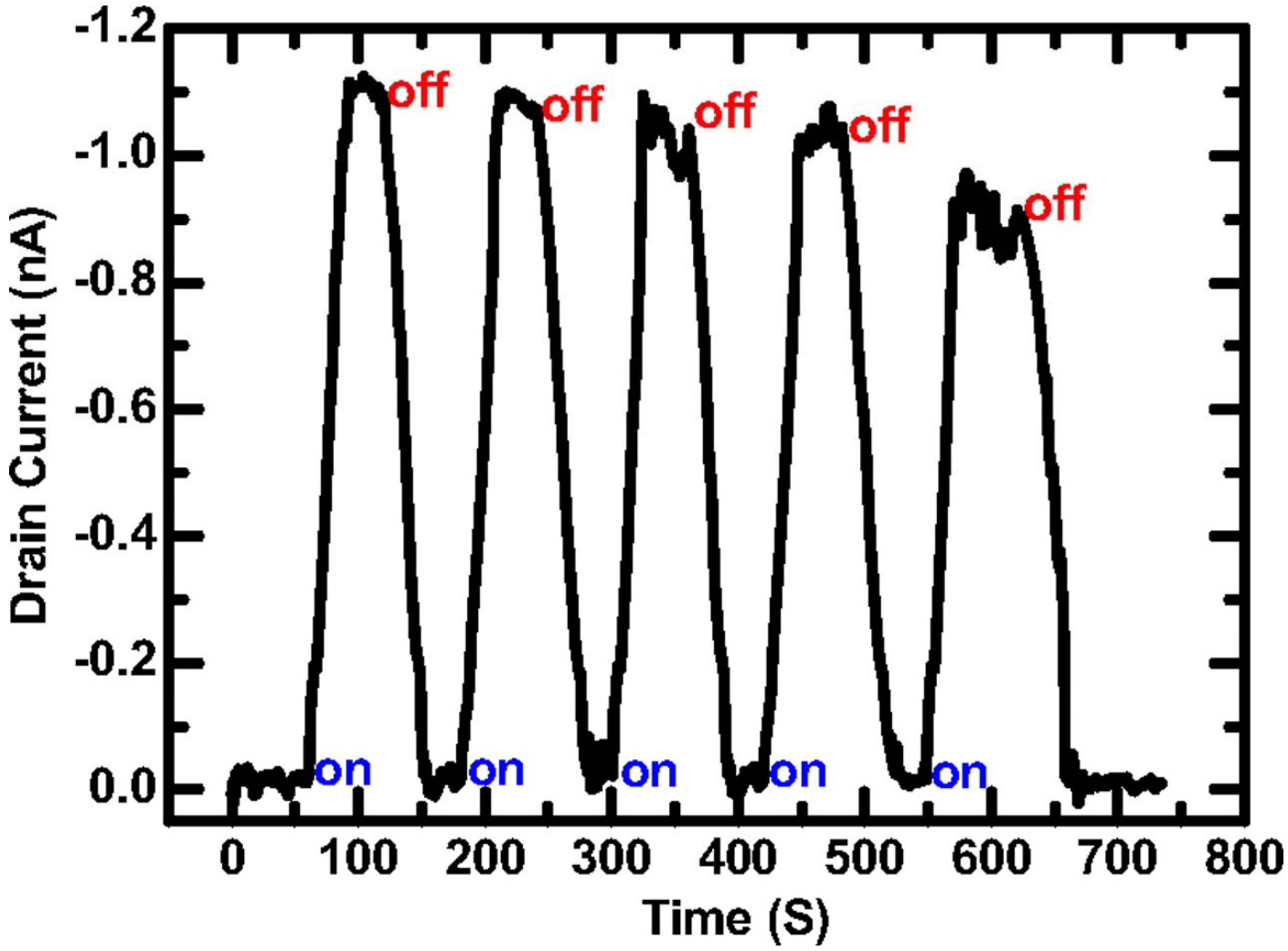
After annealing



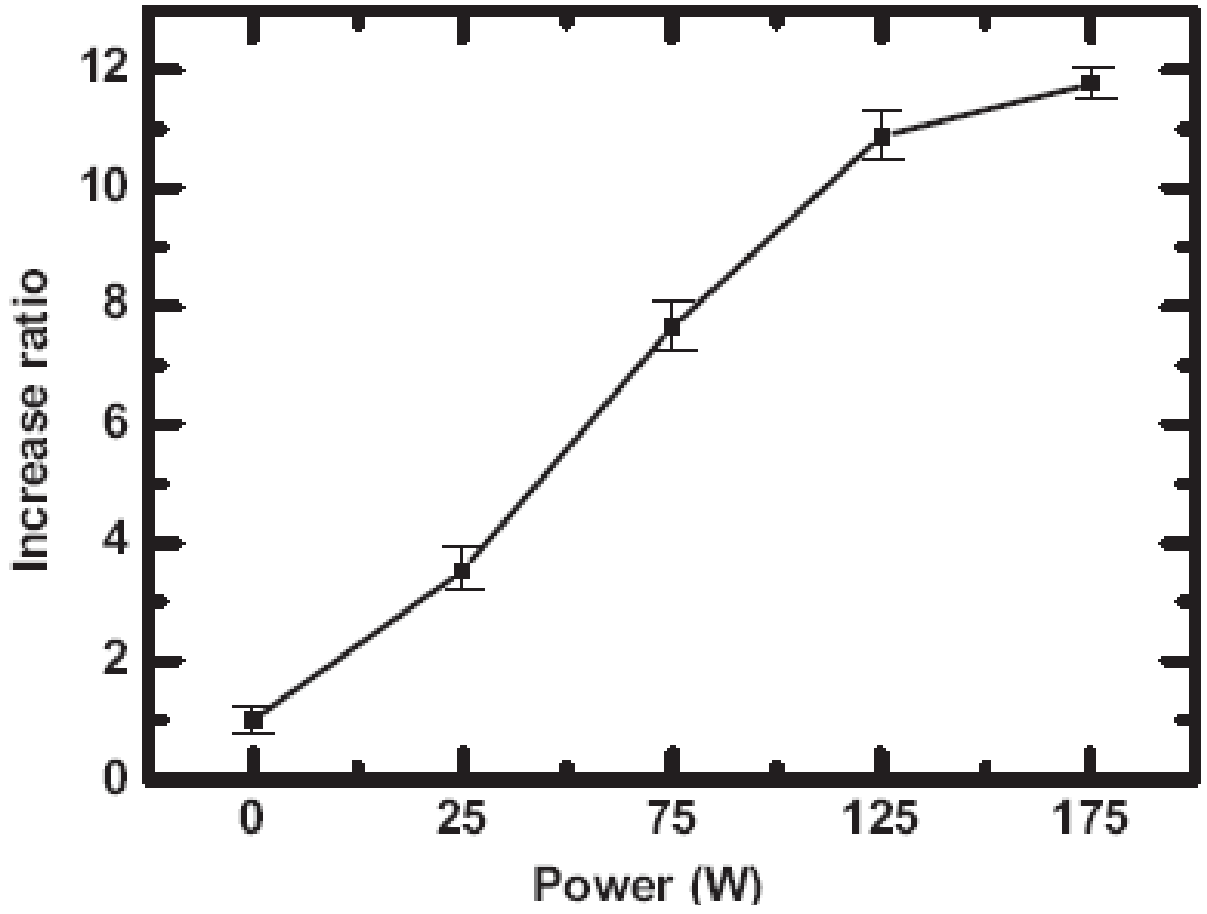
Device characteristics of a device made by drop-casting in the dark and under irradiation with visible light after annealing



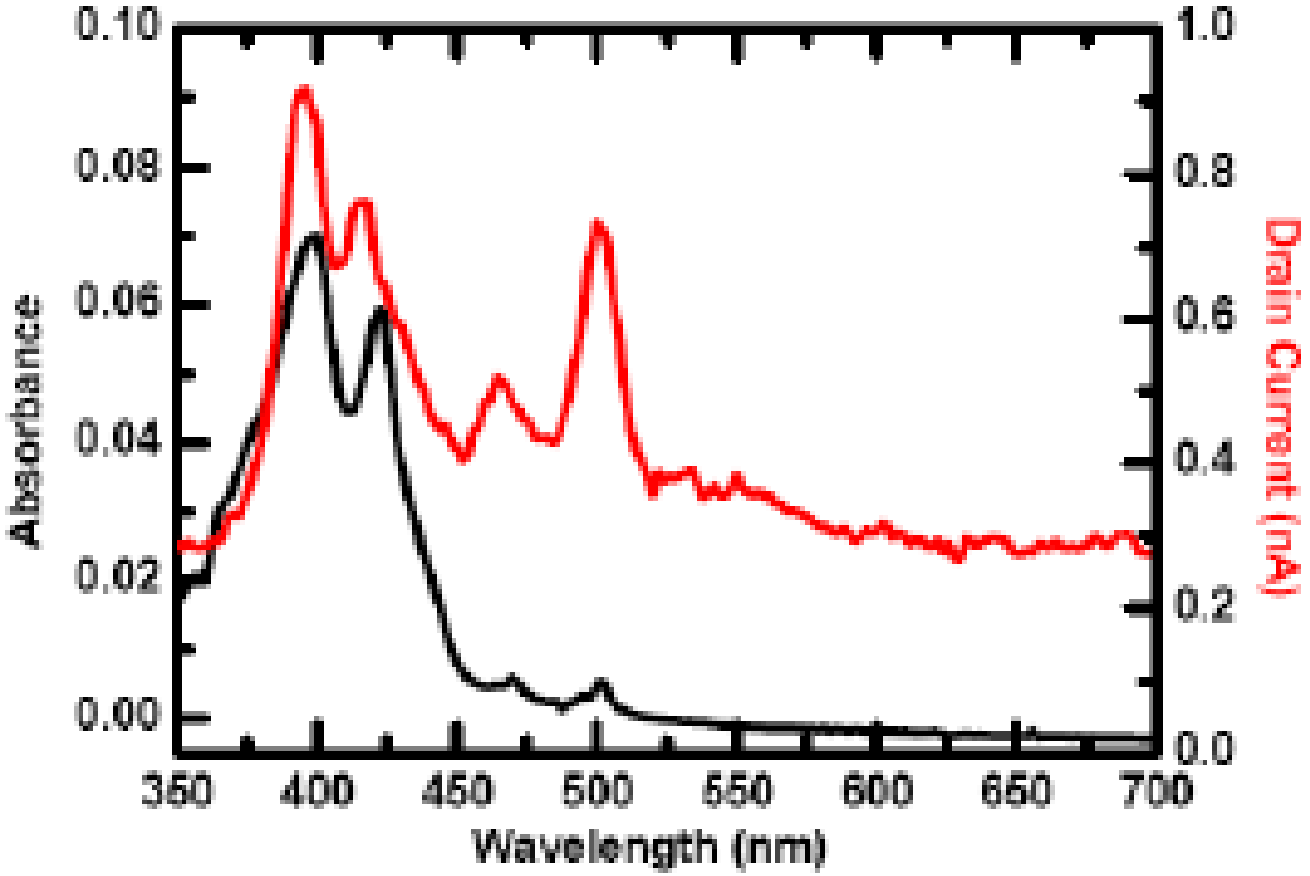
The drain current as a function of time whereas the same device measured in Fig. 4 is held at −20 V source-drain bias and −8 V gate bias by switching on/off light.



Power dependence of the photocurrent of a device. Halogen lamb power was gradually increased with V_{ds} & V_g = 20 V. Saturation of the I_{ds}, indicating that the photo-induced carrier density reaches its maximum.



Demonstration of the wavelength dependence of a device made by drop-casting. The red curve shows the wavelength dependence of the current responses of the device while the device is held at -20V source-drain bias and 0-V gate bias. The black curve shows the UV/vis absorption spectrum of HBC thin film on quartz.



Summary

- Demonstration of the integration of molecular functionalities into mol. Electronics

- Combining top-down device fabrication with bottom-up self assembly.

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- 1D ballistic SWNTs (point contacts) + Self assembled Liquid crystal columns of contorted aromatic HBCs Stable FETs

- FETS of high response to stimuli such as Temperature and Photons

- Environmental sensing / solar energy harvesting

- Integration with SWNT electrodes - optoelectronic devices with molecular dimensions

Thank You All

Robin John

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