The Fabrication of an Inverter using Rubrene Single Crystal Organic Transistors

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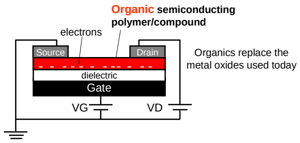
Introduction:

Currently researched thin-film organic field effect transistors are not suitable for studies of the various physical and electronic properties of organic transistors. Thus, it is necessary to study the underlying physical limitations of organic transistors using single crystal devices. This project fabricates an inverter device using organic single crystal transistors. Single crystals of rubrene were grown by a physical vapor transport method with a nitrogen flow. Inverter devices were fabricated by laminating thus grown rubrene single crystals on SiO2/Si substrates, on which gold electrodes were lithographically patterned for inverter characteristics. The characteristics of this inverter and the transistors were measured with a semiconductor parameter analyzer (HP VEE).

Organic Field Effect Transistors:

What is an Organic Field Effect Transistor?

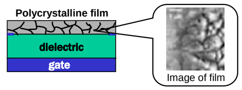


Advantages:
- Cheaper than Si
- Printable
- High mobilities
- Flexible Substrates

Disadvantages:
- Easily destroyed
- Short lifetimes
- n-type OFET - lower capabilities

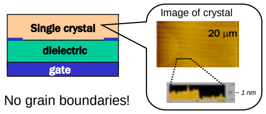
Why Single Crystals?

Thin Film Organic Field Effect Transistors



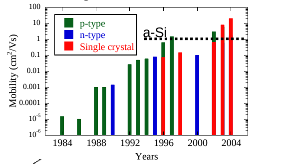
Grain boundaries create electron traps and decrease potential mobility

Single Crystal Organic Field Effect Transistors



No grain boundaries!

Mobility advances



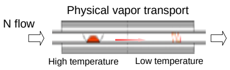
Increasing mobilities combined with organic materials can yield **awesome applications**

OFET large area circuits are used in flexible screen technologies

Fabrication of the Inverter:

Single Crystal Fabrication:

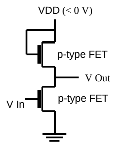
Conditions used:
290 → 220 C gradient
for 2hrs at .125 L/min



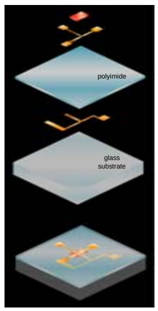
Physical Vapor Transport
- Sublimation of organic
- Transportation by noble gas
- Fast change in temperature
- Deposition of organic
- Formation of single crystal

- Dependant on conditions
  - Temperature gradient
  - Gas flow speed
  - Duration of process

Device Fabrication:



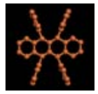
The Inverter Circuit



Fabrication Steps:
1. Schematic design
2. Create electrodes on glass substrate (lithography)
3. Crystal lamination onto electrodes

Crystal Quality:

Quality indicators:
- Semi-translucent
- Film like color shifts
- Very thin (~1µm – 5µm)
- *Not* thick and red



Single crystal
µ ~ 10 cm²/Vs

Good

Bad

Lamination:

High quality crystals laminate *easily* onto the electrodes. Just placing the crystal on the electrodes should be enough.

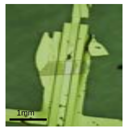
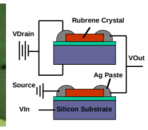
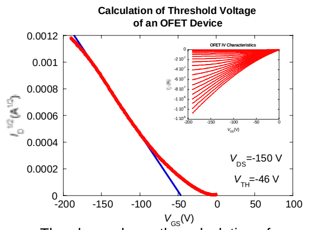


Image of the lamination (note poor electrode quality)



Depiction of the device used (failed lithography)

Characterization of Devices:



The above shows the calculation of a bipolar organic field effect transistor's threshold voltage using its I-V characteristics (inset).

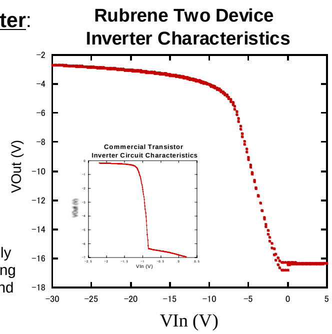
$$I_d = \left(\frac{\mu_s C_{ox} W}{L}\right)(V_{gs} - V_T)\,V_{ds}$$

Rubrene Two Device Inverter:

- *Successful* inversion
- The 'off' state is still 'high'
- Long period of inversion
- High threshold voltage
- No positive input voltage data

How to Improve:

All lithographed devices were short circuited and therefore immeasurable. Being able to use these would drastically decrease channel width, thereby lowering inversion time, the threshold voltage, and the 'off' state voltage.



Conclusions and Future Work:

The field of organic electronics is rapidly progressing past the capabilities of their traditional silicon counterparts. Continued research into the physical limits of these electronics will bring an increased understanding of the technology, leading to higher quality advanced applications.

The Iwasa lab will continue to work on OFET characterization, and will measure the inverter when better electrodes are available. Personally, I will begin senior thesis research on nanotube spectroscopy in the Kono group at Rice University.

Acknowledgements:

I would like to thank Rice University's NanoJapan Program, which was generously funded by a grant from National Science Foundation. Additional regards go to Professor Yoshihiro Iwasa and his group for supporting me in Japan.