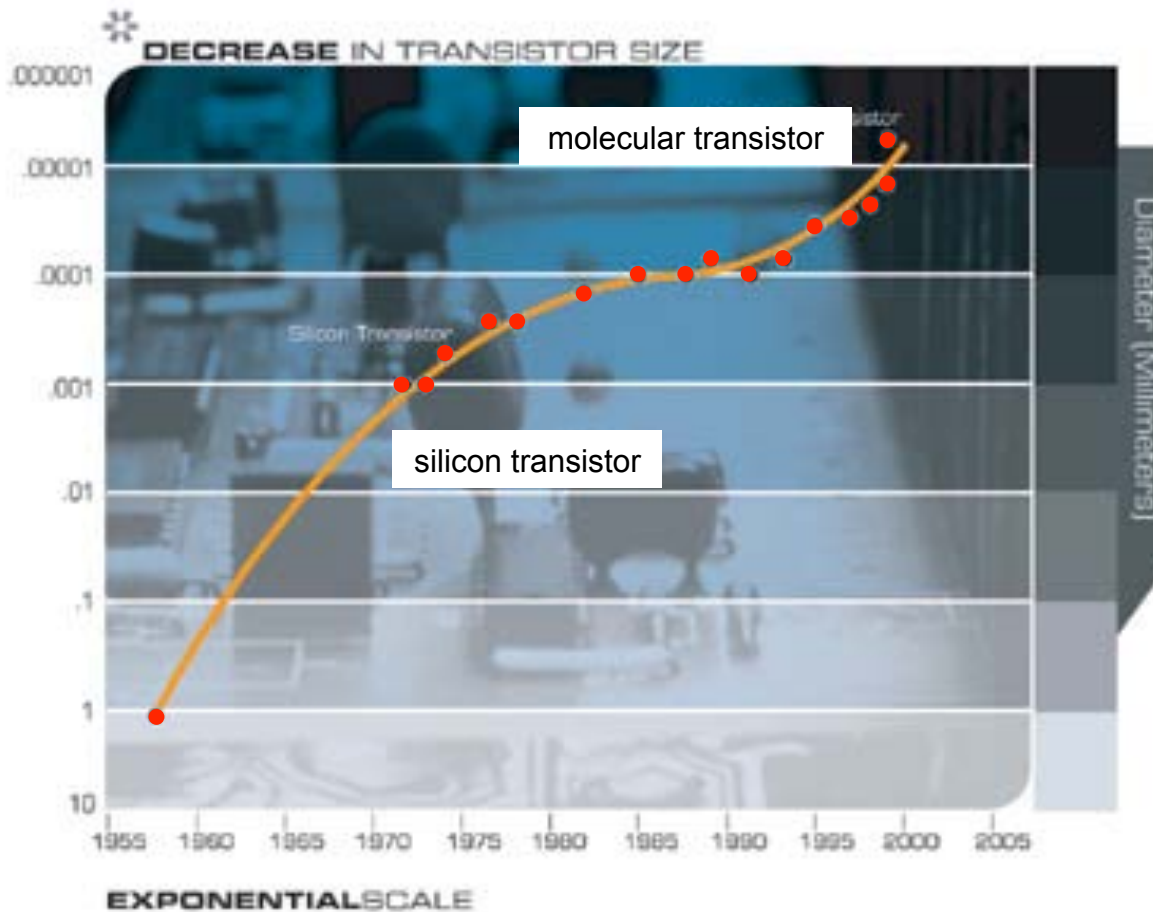




Molecular Transistors: FTIR Spectroscopy of P3HT

Zack Carson

Moore's Law



- Silicon transistors no longer able to advance at expected rates
- Molecular transistors offer return to exponential growth

www.ghandchi.com/iranscope/Anthology/chart03.jpg
Image modified for visibility

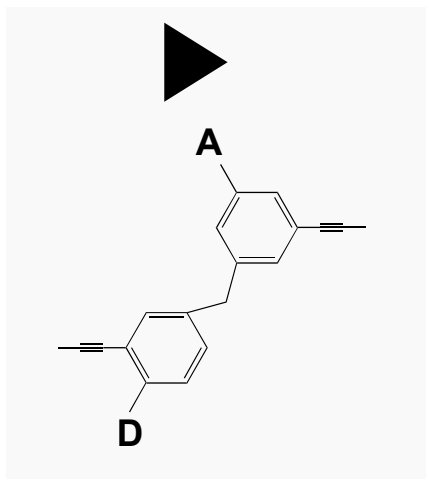
Getting Back on Track

Problem: Silicon transistors are hitting fundamental limits on size

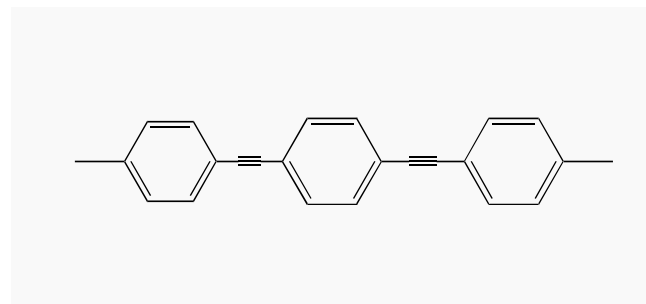
Solution: Build devices out of new materials, possibly organic materials

- First we need good characterizations of these organic materials

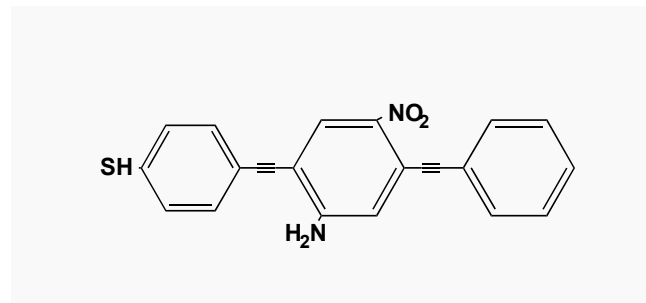
diode



Images by Christina Hacker



wire



switch

Project Goal

- **Easy**
 - Electronic response (multimeter)
 - Molecular structure (spectra)
- **Harder**
 - Structural response to applied bias
- **Goal:** Obtain electrical and structural data simultaneously to determine structural response

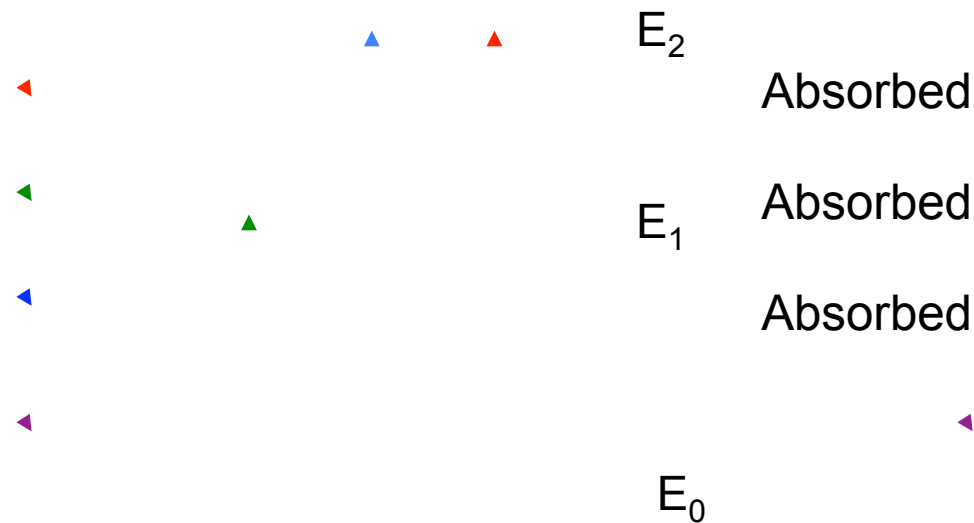
Fourier Transform Infrared Spectroscopy

- Traditional spectroscopy uses multiple colors
- FTIR spectroscopy uses an interferometer
 - Different path lengths provide different chromatic make-ups
 - Fourier Transform converts intensity vs mirror distance into intensity vs wavelength



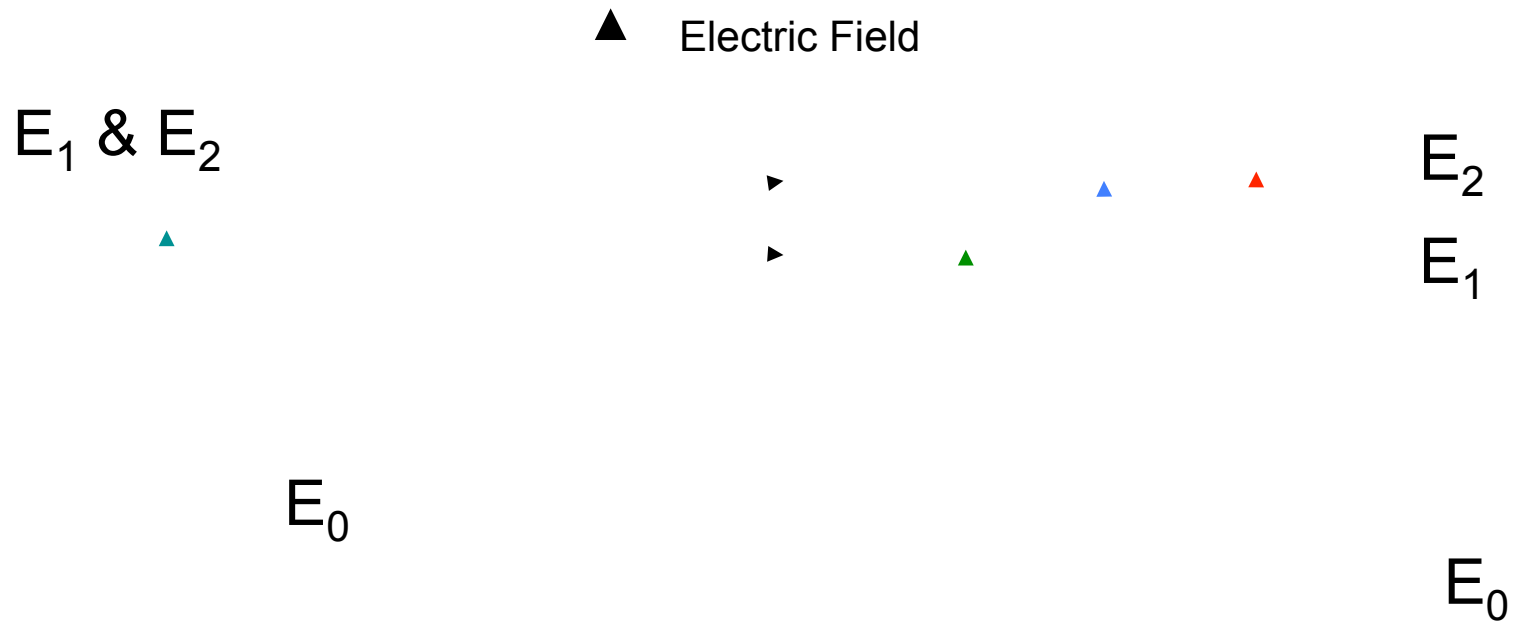
Why Look at Spectra?

- Energy levels are discrete
- Photon energy must match transition energy
- Spectra yield information about structure



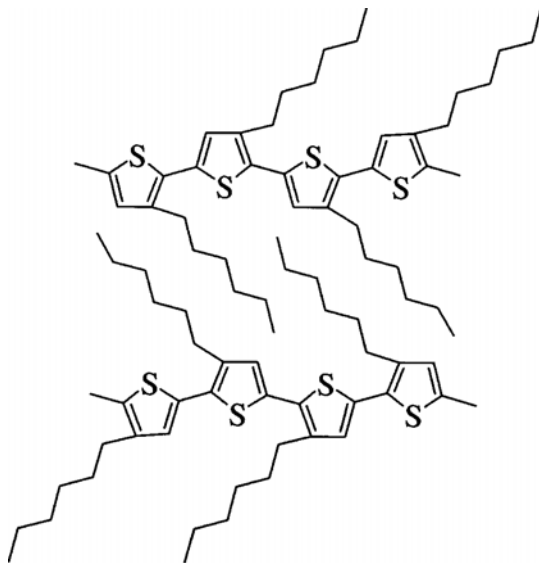
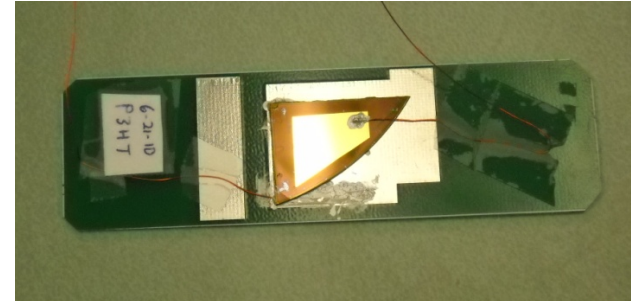
Applying a Bias: The Stark Effect

- Degenerate energy levels
- Applied electric fields split degeneracy

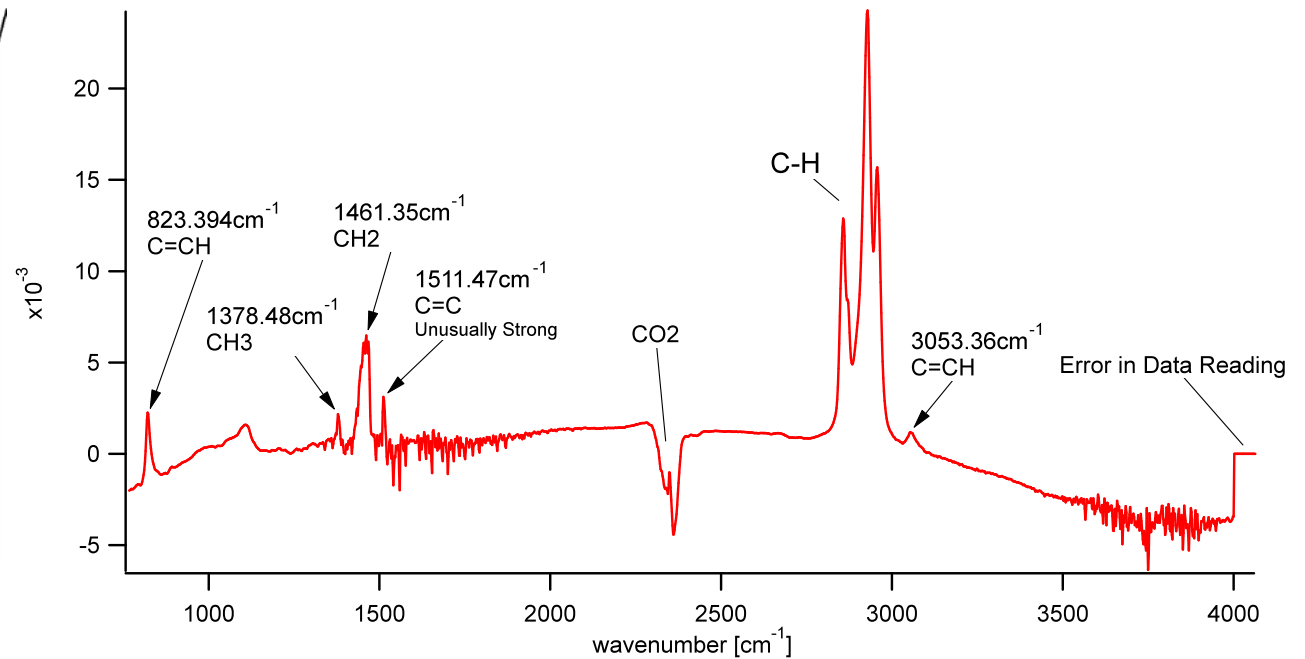


Poly (3 – Hexylthiophene)

Abbreviated P3HT



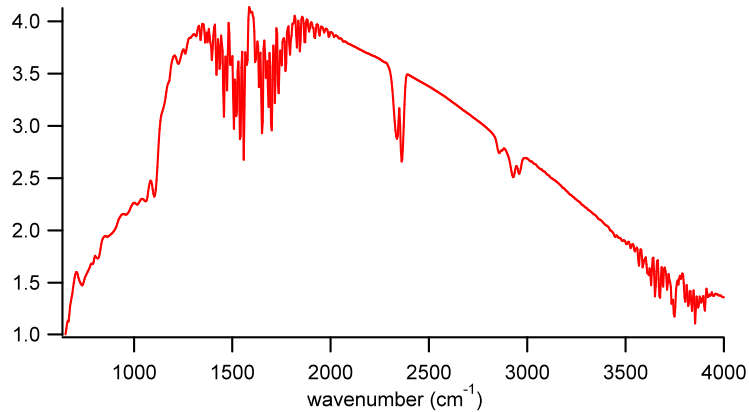
Structure of regioregular head-to-tail coupled poly~3-hexylthiophene.
PRB 63 064203 (2003)



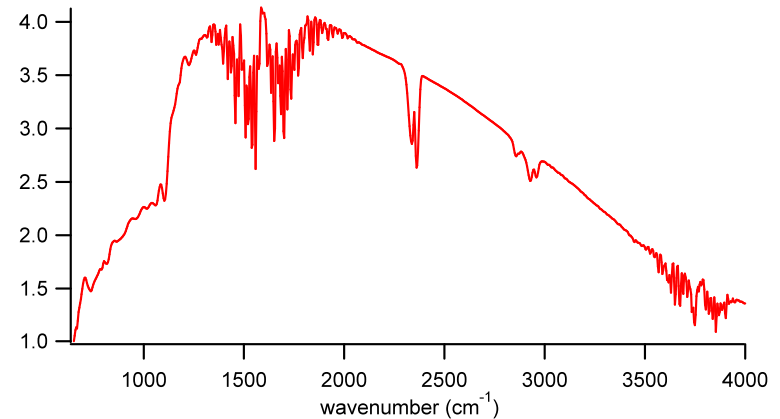
Transmission Spectrum for Poly (3-Hexylthiophene)

Stark Spectroscopy

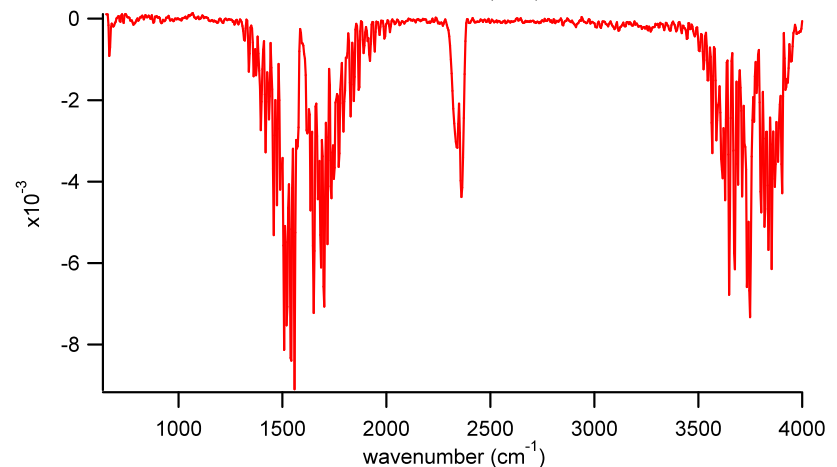
- Compare spectrum with bias to spectrum without bias to look for bias-dependent differences



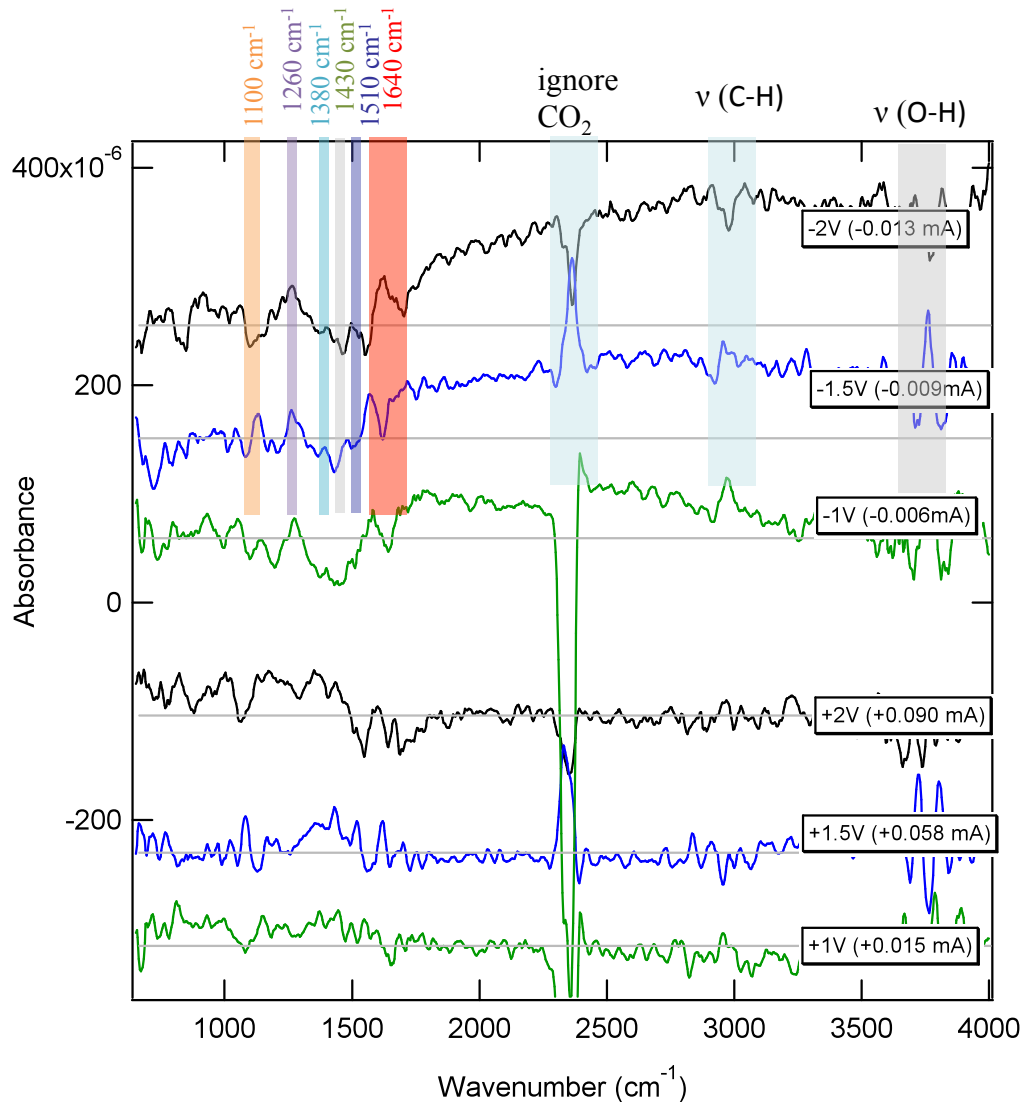
VS



$$\text{Absorbance} = -\log \left(\frac{\text{intensity with bias}}{\text{intensity without bias}} \right)$$



Observed Effects of DC Bias



1100 cm^{-1} oxidative doping
(SO features?)

1260 cm^{-1} SiO₂ LO phonon
(need to check reference)

1380 cm^{-1} ring C-C (0.171 eV)

1430 cm^{-1} sym C=C ring
stretch (0.177 eV) strongest

1510 cm^{-1} asym C=C ring
stretch (0.187 eV)

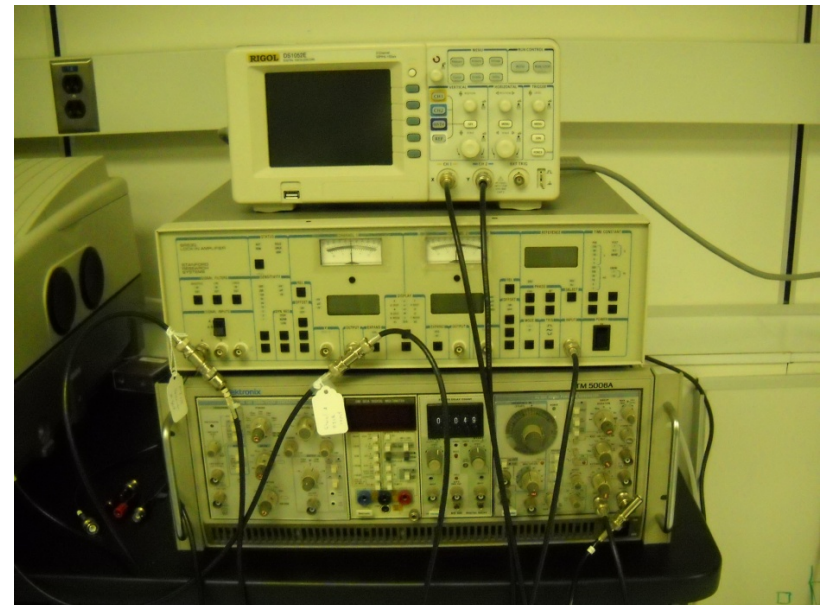
1640 cm^{-1} appears in oxidative
doped P3HT (C=O)

Conclusions

- Molecular structure of P3HT is affected by a DC bias of 1 to 2 V
- We see symmetric and asymmetric carbon ring stretching
- We are probably also seeing some effects from the SiO₂

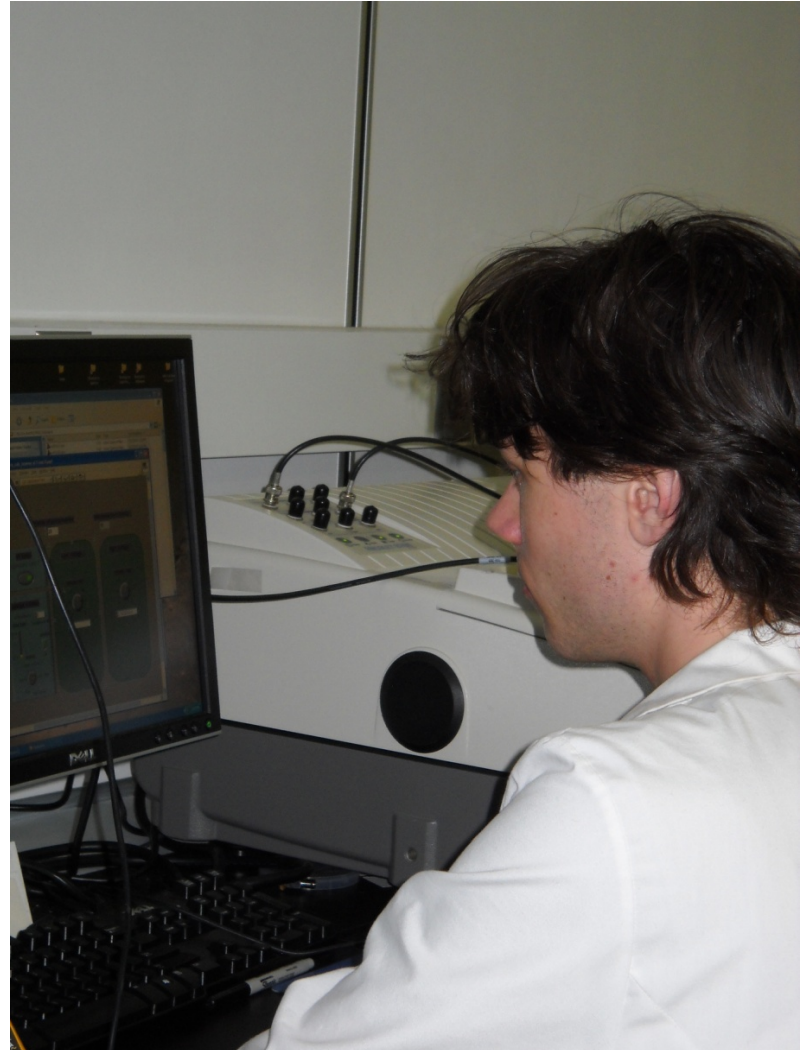
Future Work

- Measurements of Silicon sample without P3HT
- Increase range of applied bias
- Stark Spectroscopy with AC bias
 - Get signal from lock-in amplifier
- Look at other materials



Acknowledgements

- Christina Hacker
- Charles Cheung
- Kendra Redmond



Any Questions?