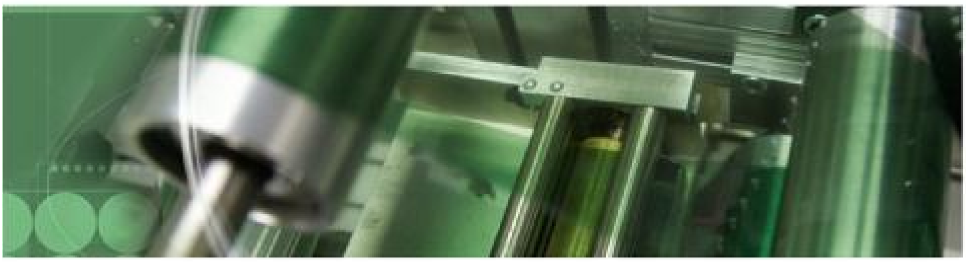

Functional Devices Using Organic Electronics

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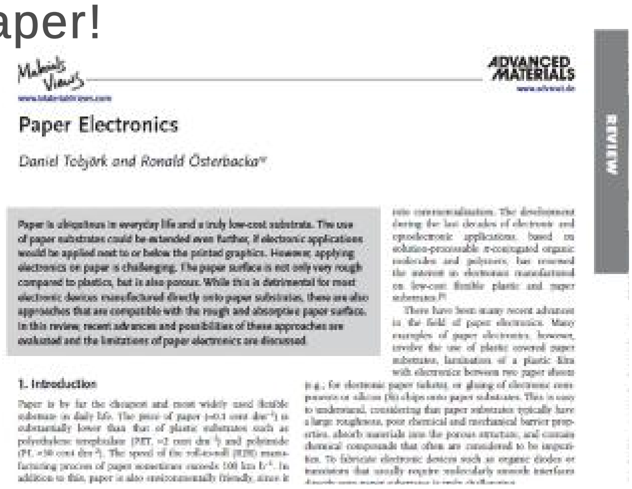
Physics / Department of Natural Sciences
Center for Functional Materials
Åbo Akademi University

Paper electronics

- Paper & Printing
  - › 2000 years old & among the greatest inventions
  - › Widely used, recyclable and low cost
- Print electronics on paper!
  - › 1960's: Inorganic TFTs
    - T.P. Brody and D.J. Page
  - › Renewed interest

Adv. Mater. 23 (2011) 1935.



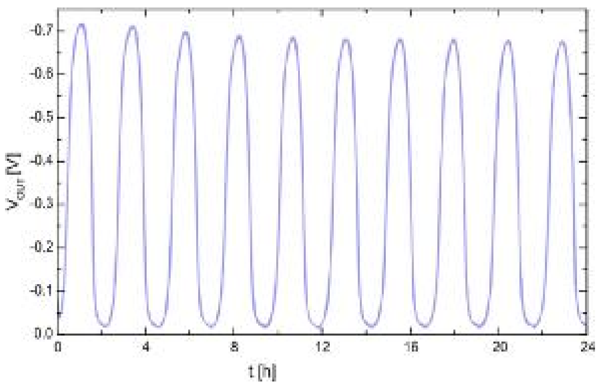
Paper Electronics

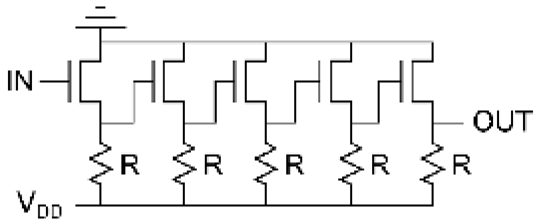
*Daniel Tobjörk and Ronald Österbacka**

Paper is ubiquitous in everyday life and a truly low-cost substrate. The use of paper substrates could be extended even further, if electronic applications would be applied next to or below the printed graphics. However, applying electronics on paper is challenging. The paper surface is not only very rough compared to plastics, but is also porous. While this is detrimental for most electronic devices manufactured directly onto paper substrates, there are also approaches that are compatible with the rough and absorptive paper surface. In this review, recent advances and possibilities of these approaches are evaluated and the limitations of paper electronics are discussed.

1. Introduction

Ring-oscillator on paper





5-stage ring oscillator made on recyclable paper-substrate.

With LPT and DPC

Oscillation @ f=100µHz

F. Pettersson, J. Koskela, et al.,

OULUN YLIOPISTO
UNIVERSITY of OULU

BUT...

› Some of the used materials used for creating the ion-modulation are toxic and environmentally not good!

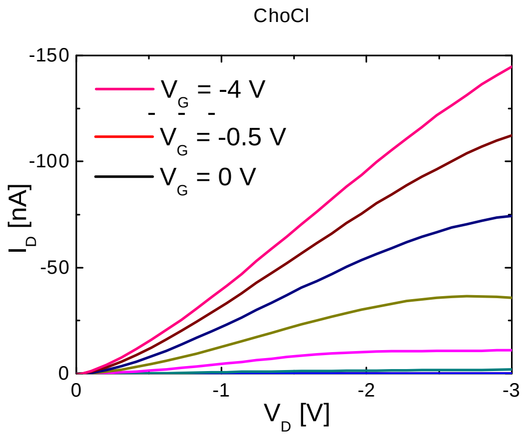
› Can we make more suitable materials for ion-modulated transistors?

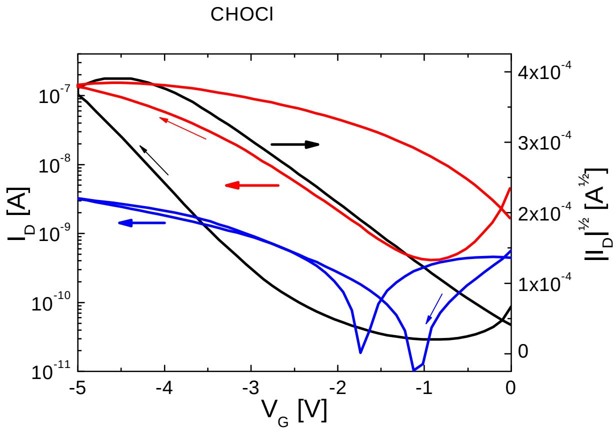
› Also suitable for food-packages?

T. Remonen et al.,

Vitamine based ionic liquids –not good...

› No good transistor curves using choline cloride!
  • Allmost no saturation, low currents (nA) and large gate leakages...

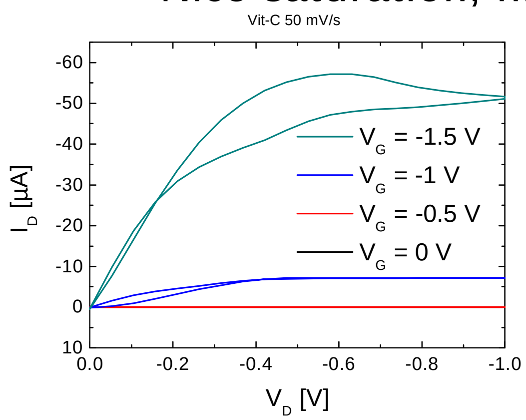


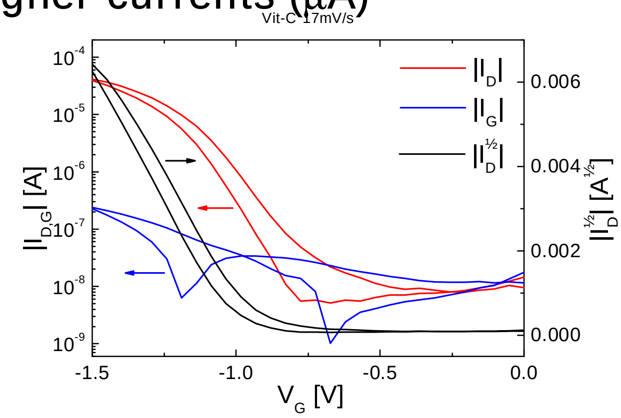


Complexing choline cloride with urea

› The complex forms ”immobile anions”

› Better transistor curves!
  • Nice saturation, higher currents (μA)



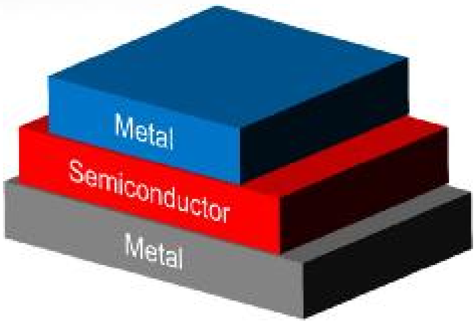


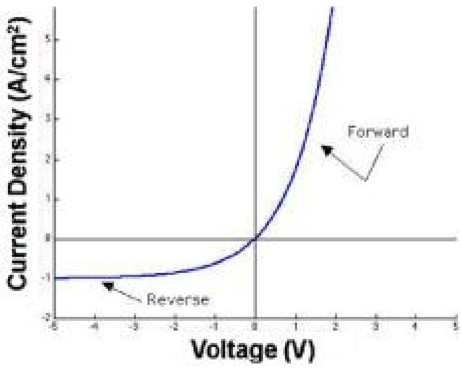
T. Remonen et al., POSTER

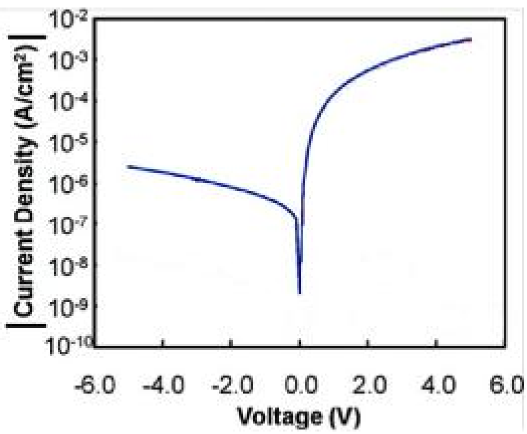
With LPT

Controlling Device Properties by Interfacial Dipoles

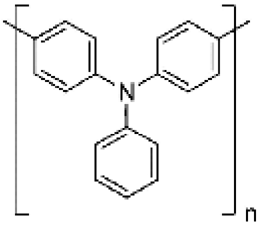
Diodes

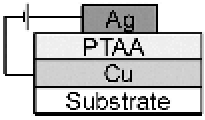


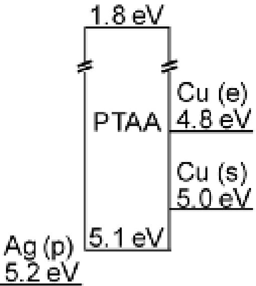


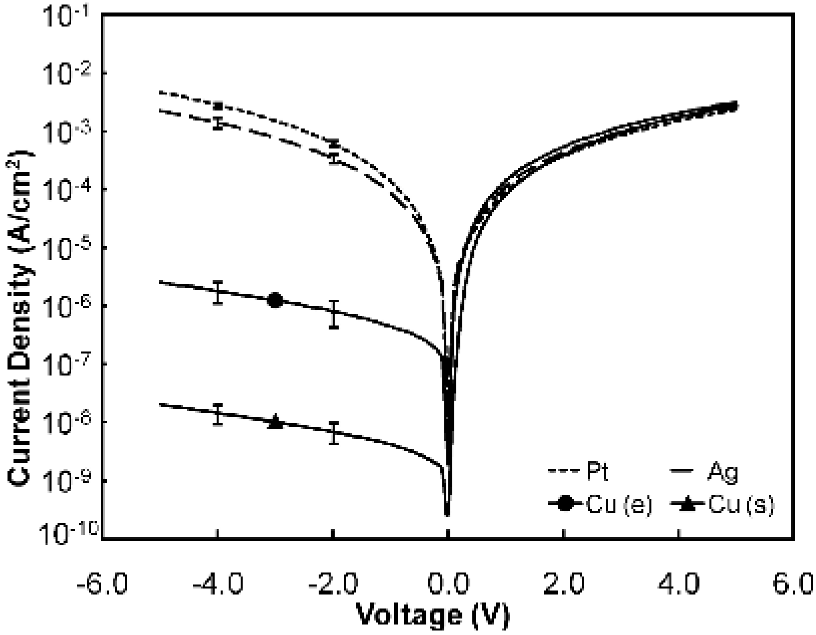


Experimental IV-curves



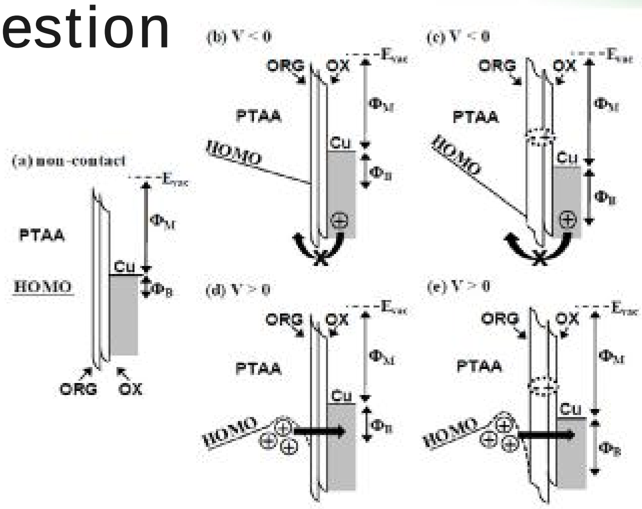




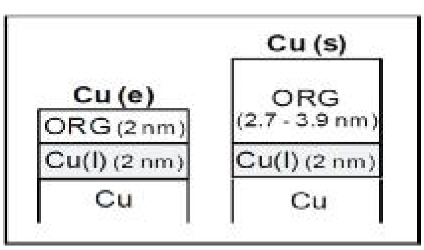


K.E. Lilja; H.S. Majumdar; F.S. Pettersson; R. Österbacka; T. Joutsenoja; *ACS Appl. Mater. Interfaces* 2011, 3, 7-10.

Experimental suggestion



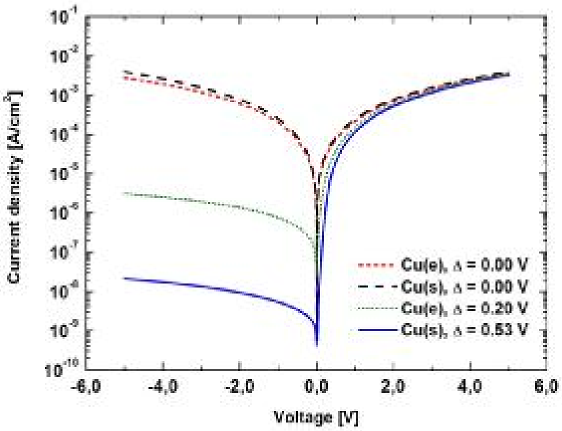
- XPS and impedance data reveal a thin dual interfacial layer
- For sputtered Cu a slightly thicker interfacial layer was observed



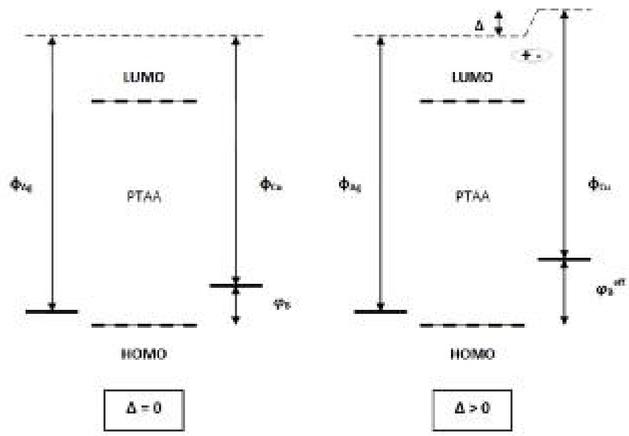
- Formation of intrinsic dipole between the dielectric layers
- Controlling the injection

K E Lilja, H S Majumdar, K Lahtonen, P Heljo, S Tuukkanen, T Joutsenoja, M Valden, R Österbacka and D Lupo, J. Phys. D: Appl. Phys. 44 (2011) 295301

Interfacial-dipole-controlled currents



Simulated JV-curves with and without interfacial dipoles



Modelling using drift-diffusion and injection barriers

O. Sandberg, et al

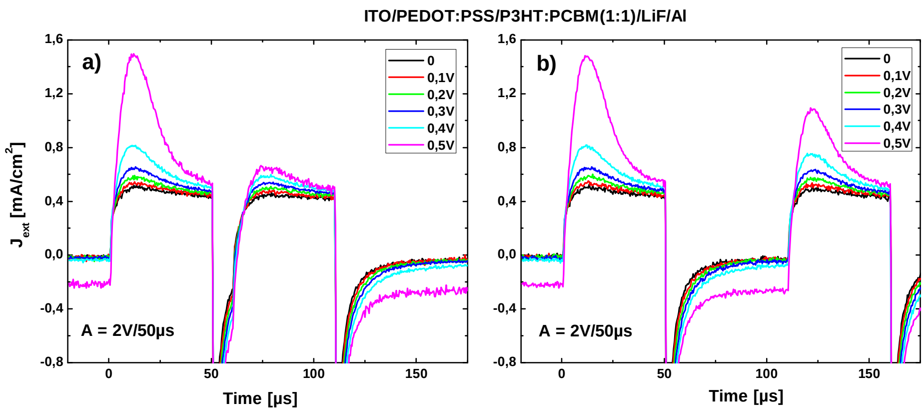
How general is the dipole concept?

Bulk-heterojunction solar cells

Åbo Akademi University

UNIVERSITY OF HELSINKI

Equilibrium carriers in solar-cell diodes

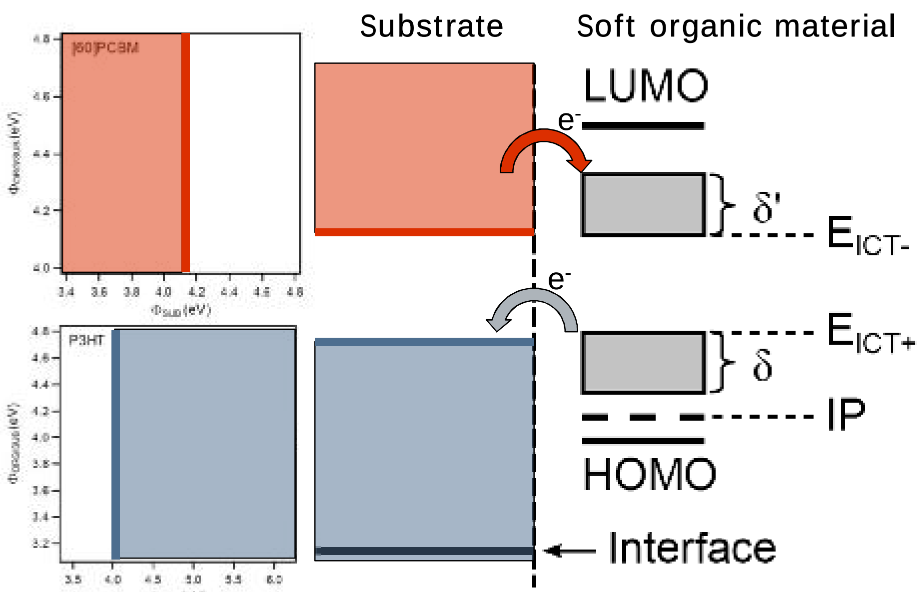


- Equilibrium charges exist at 0V

WHY?

- Extracted equilibrium charges are regenerated by a current backflow

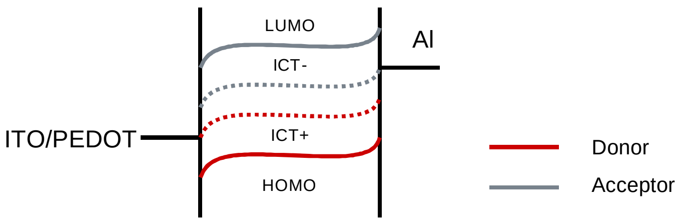
Integer Charge Transfer Model



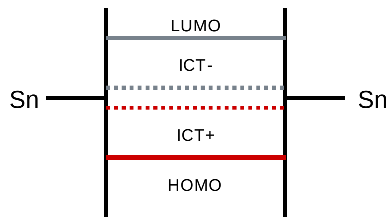
S. Braun, W. R. Salaneck and M. Fahlman, Adv. Mater. 21, 1450-1472 (2009)
P. Sehati, et al., IEEE JSTQE 6, 1718-1724 (2010)

Fermi-level pinning causing dark carriers

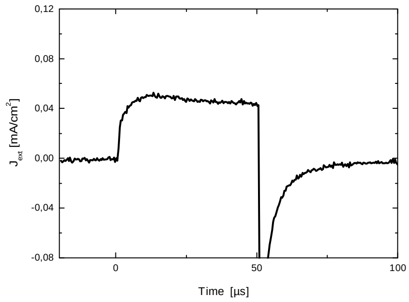
Band bending



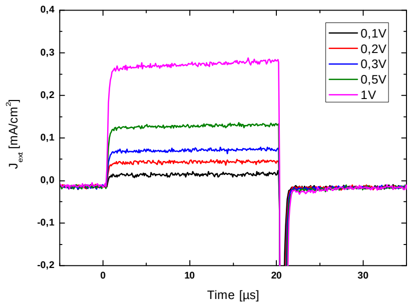
No band bending



Equilibrium charges in the dark



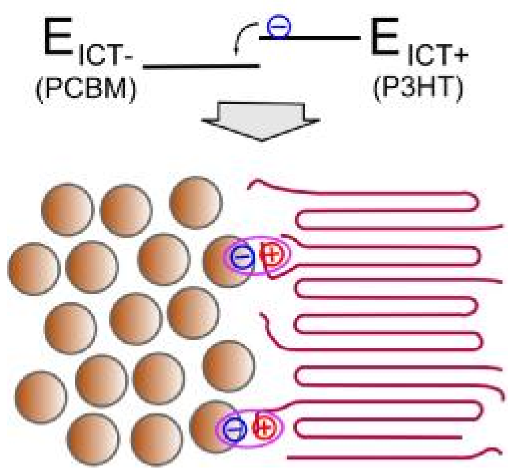
No equilibrium charges



M. Nyman et al., Chem. Phys in press

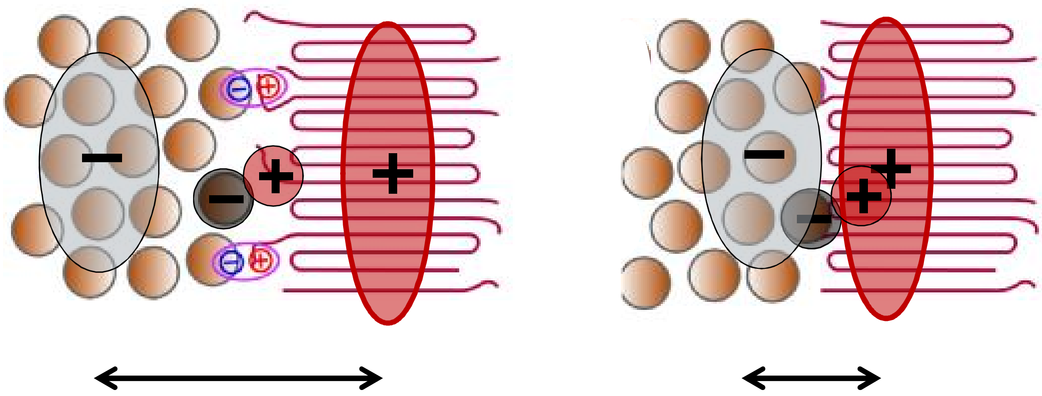
ICT also in P3HT:PCBM blends

- Energy level alignmenet at interfaces by charge transfer
  - Charge transfer from the P3HT E_{ICT+} to PCBM E_{ICT-}
  - Dipole formation!
- Effect on recombination?
  - Reduction in the geminate recombination



Aarnio et al., Adv. Energy Materials, 2012

Delocalization in 2D lamellaes

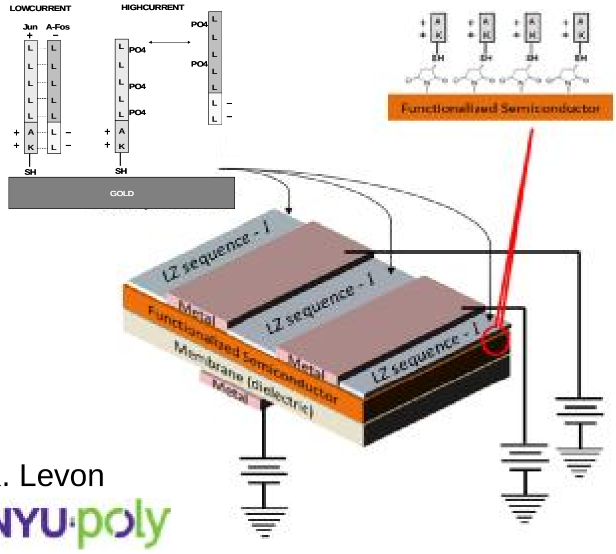


The Future?

Biolelectronic sensing using OFETs

- The membrane based OFET offers several advantages:
- Low-voltage operation
- Semiconductor OR electrodes exposed to analyte

- Novel detection scheme suggested utilizing functionalized
  - semiconductor OR
  - Electrodes



In collaboration:

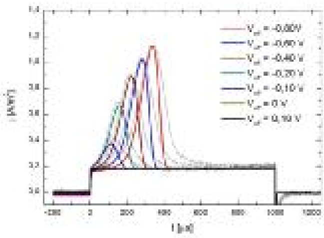
H. Härmä S. Hietala K. Levon

Turun yliopisto University of Turku

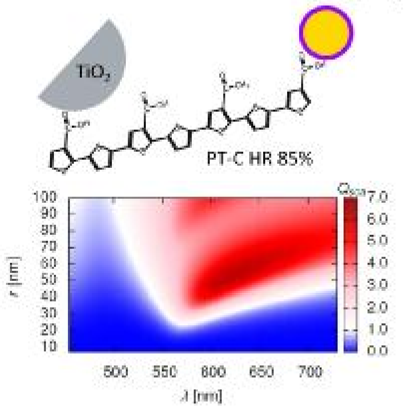
NYU-poly

Interfacial understanding and control of device behavior

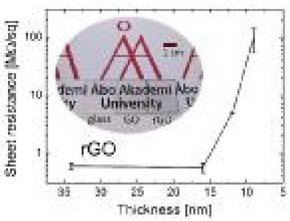
Simulated interfacially controlled transport (Sanden, Sandberg, Nyman et al.,)

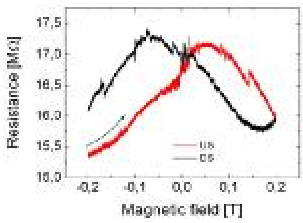


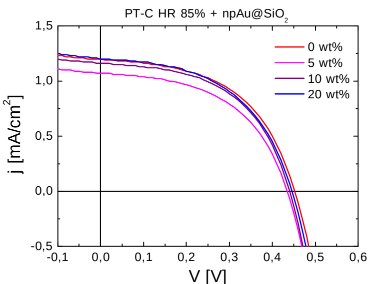
Collaborators:
J. Hardigree and H. Katz,
John Hopkins Univ



Graphene oxide for electronic applications Majumdar, Pesonen et al.,







(Sanden, Smått, Ylinen et al.,)