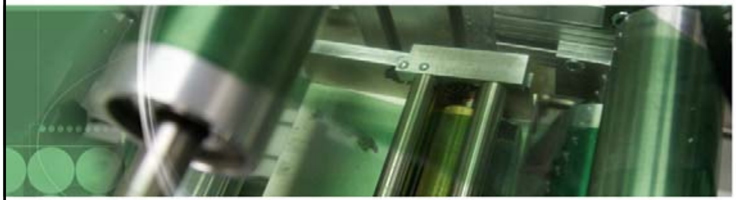
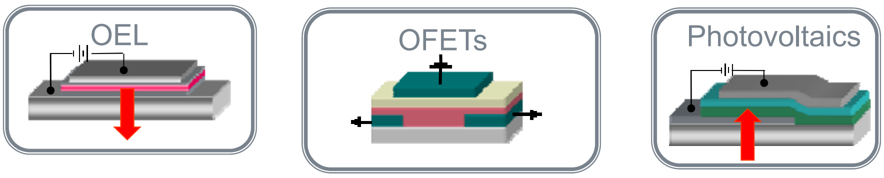
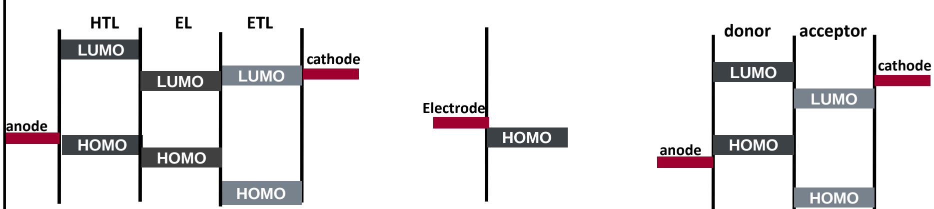


Organic Electronics using Functional Materials

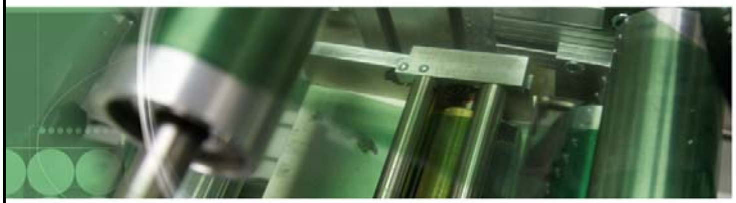
Ronald Österbacka
Physics / Department of Natural Sciences
Center for Functional Materials
Åbo Akademi University

Organic Electronics – Importance of Energy Levels





Slide courtesy prof. I McCulloch, Imperial College London



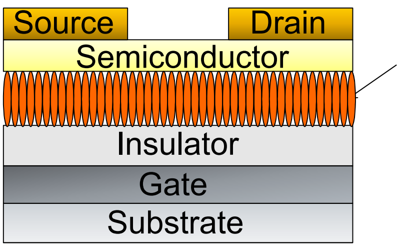
Controlling Device Properties by Interfacial Dipoles

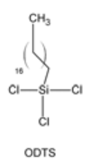
Åbo Akademi University

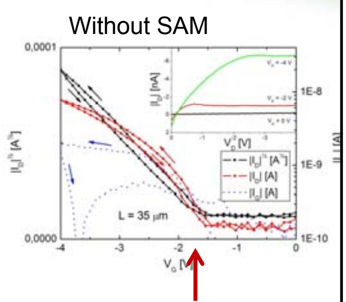
University of Helsinki

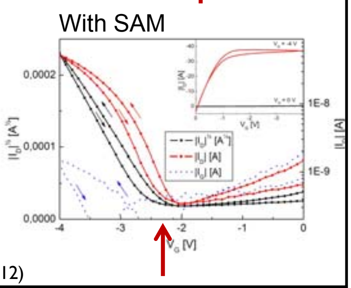
Al_2O_3/SAM-based Low-Voltage OFET

- SAMs are widely used to modify the insulator/SC interface
- Well known to improve OFET performance
- Effects still not fully understood





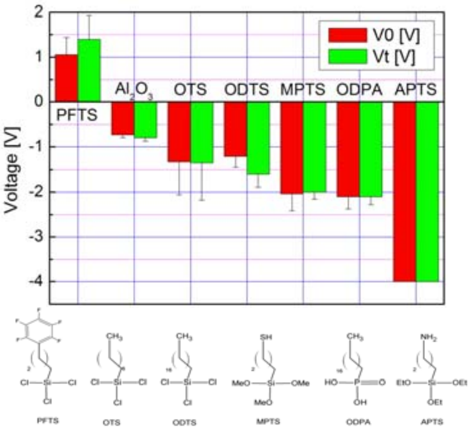




N. Björklund, F. S. Pettersson, D. Tobjörk and R. Österbacka, Synthetic Metals (2012)

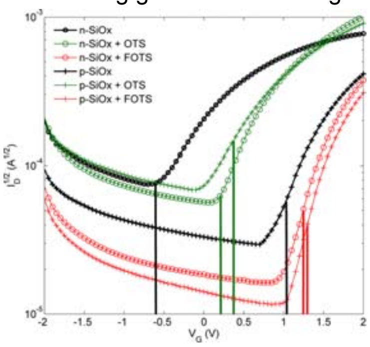
Effect of SAMs on metal-oxide gate electrodes

Threshold voltage shifts



N. Björklund, F. S. Pettersson, D. Tobjörk and R. Österbacka,

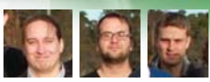
Reducing gate-current leakage

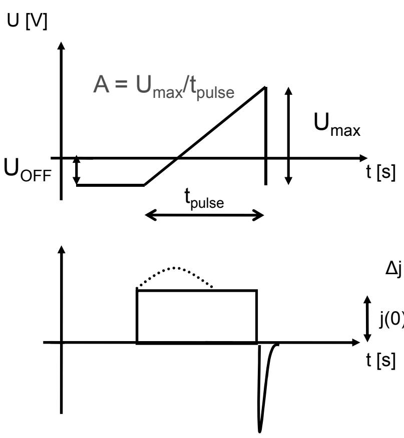


J.F. Martinez-Hardigree, et al., *ACS Appl. Mater. Interfaces*, in press

JOHNS HOPKINS UNIVERSITY

CELIV



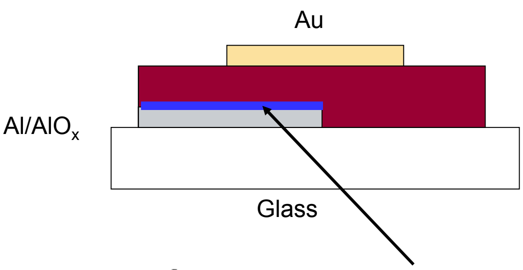


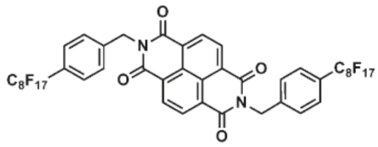
- A linearly increasing voltage ($A = U_{max}/t_{pulse}$) is applied over a sample with blocking contacts
- The resulting current transient consists of a time independent part (displacement) and a time dependent part
- An offset voltage can be used to tune the steady state potential

$$j = \frac{dQ}{dt} = \frac{dC}{dt}\cdot U + A\cdot C = \Delta j + j(0)$$

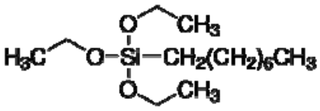
Juška et al. *Phys. Rev. Lett.* **84**, 4946 (2000)
Juška et al. *Phys. Rev. B* **62**, 16 235 (2000)

Sample structure





naphthalene tetracarboxylic acid diimide (NTCDI)



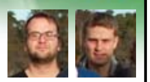
OR

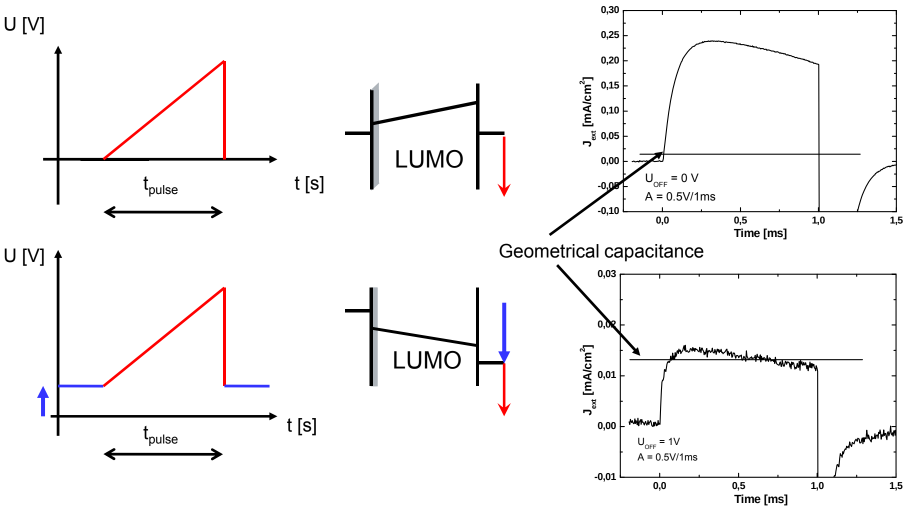
triethoxy(octyl)silane (OTS)

perfluorooctyltriethoxysilane (FOTS)

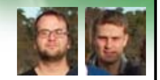
B. J. Jung et al, *Chem. Mater.* **21**, 94–101 (2009)

CELIV with varying offset voltages

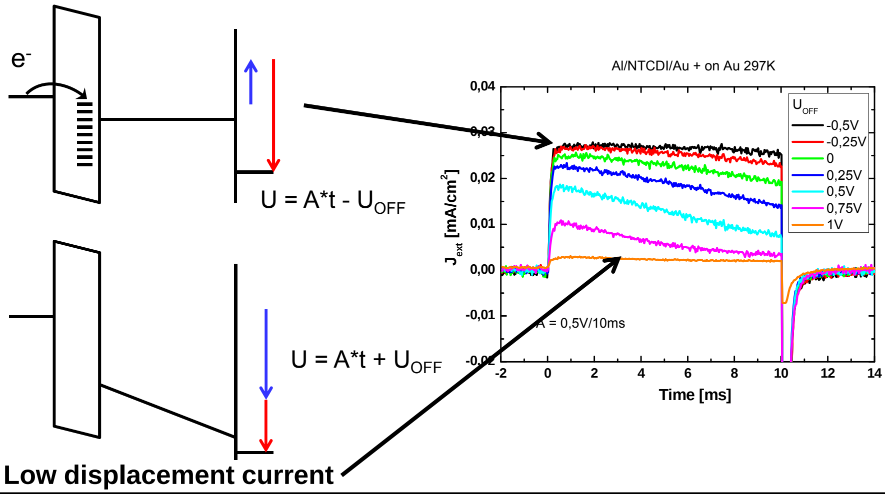




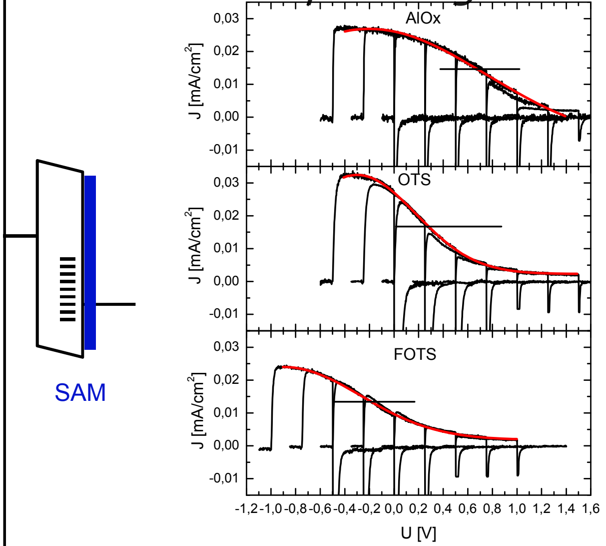
Displacement current due to charge trapping in AlO_x



High displacement current



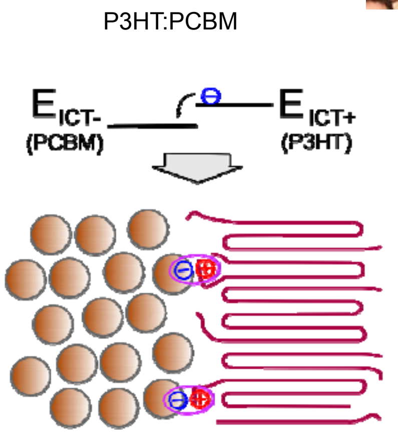
Displacement current to measure vacuum level shift in *operating* devices



- Saturation regions not clearly seen; the point were the (trapping) displacement current has decreased to half of its maximum value is used as an assay for the vacuum dipole shift
- Vacuum level shift by SAMs causes shift in trap-DOS
- OTS ~ −0,45 V
  FOTS ~ −0,85 V
- AlOx gate dielectric will be slow due to charging!

Level shifts also in organic blends

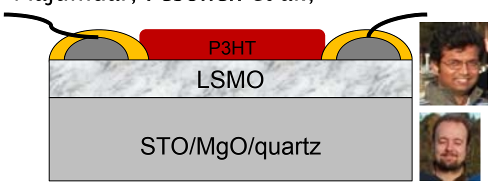
- Energy level alignment at interfaces by charge transfer
  - Charge transfer from the P3HT E_{ICT+} to PCBM E_{ICT-}
  - Dipole formation!
  - Complex interfacial energetics
- Effect on recombination?
  - Reduction in the geminate recombination



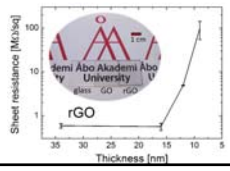
Aarnio et al., Adv. Energy Materials, 2012

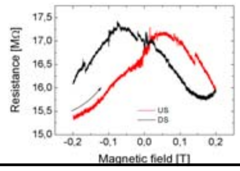
Interfacial understanding and control of device behavior

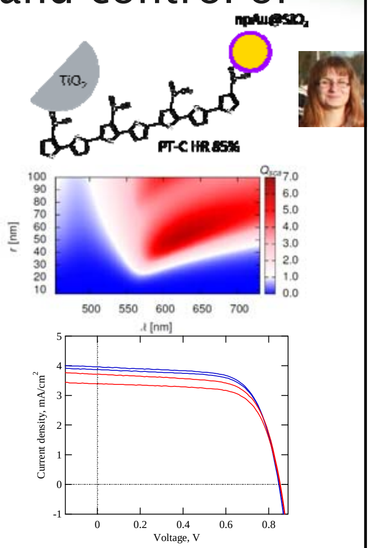
Magnetotransport in spin valves
Majumdar, **Pesonen** et al.,



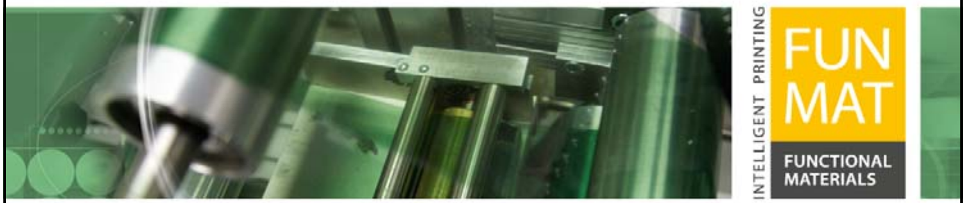
Graphene oxide for electronic applications
Majumdar, Pesonen et al.,







(Sanden, **Smått**, **Ylinen** et al.,)



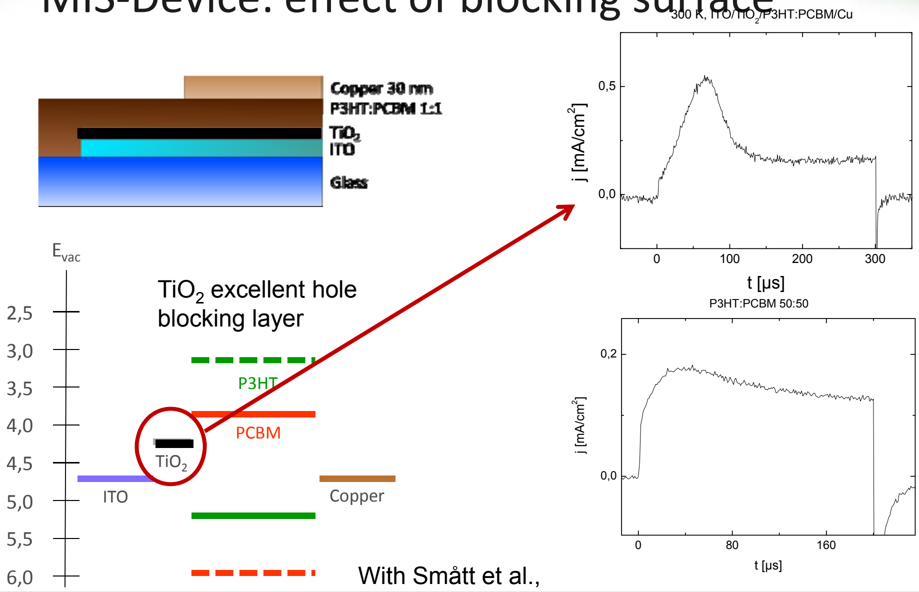
New ways to measure and understand charge transport in devices

– Metal–Insulator–Semiconductor CELIV

Åbo Akademi University

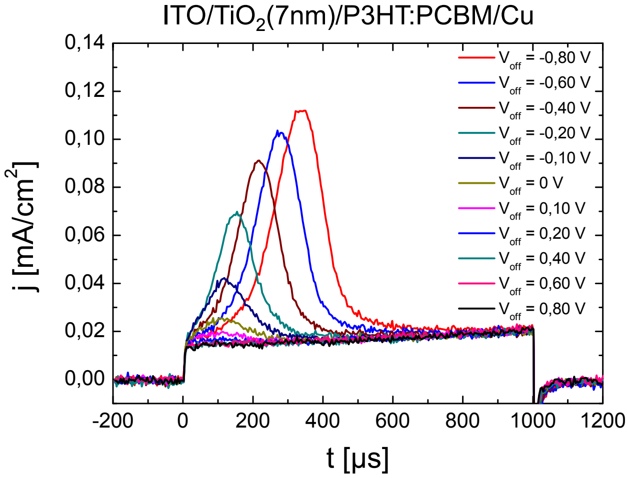
UNIVERSITY OF HELSINKI

MIS-Device: effect of blocking surface



With Smått et al.,

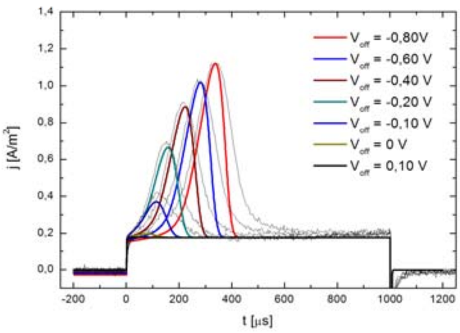
Dark MIS-CELIV as a function of V_{off}

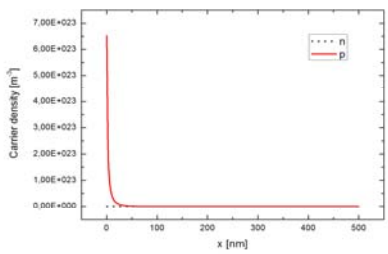


S. Sandén, et al., PCCP **14**, 14186–14189 (2012); Sandén et al., submitted

Device understanding by 1D drift-diffusion modelling

(Koster et al., Wagenpfahl et al.,)





Hole reservoir located within ~10 nm!

Simulated dark transients using these parameters for the modeled ITO(anode)/TiO_2(7nm)/P3HT:PCBM/Cu(Cathode) device

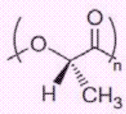
S. Sandén, et al., PCCP **14**, 14186 (2012); O. Sandberg et al., in preparation

Electronics on Paper

Functional Materials as the Enabler

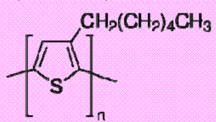
Thinner SC -> faster OFET

Poly-(l-lactic acid)

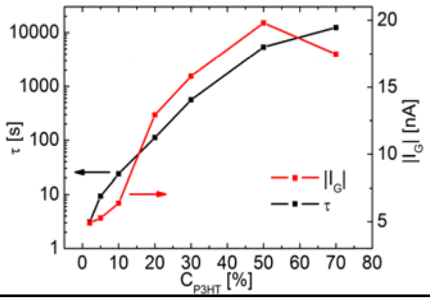


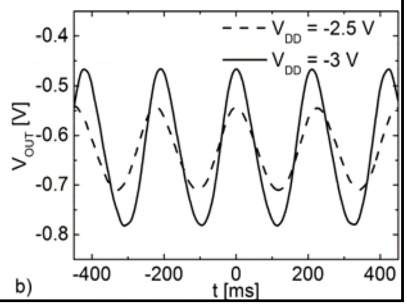
+

Poly-(3-hexyl thiophene)



Oscillation @5Hz

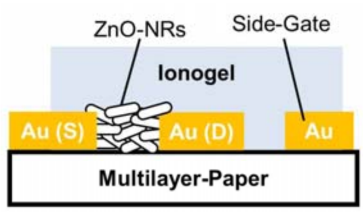


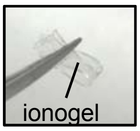


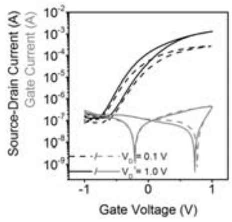
ZnO-Nanorods on Paper

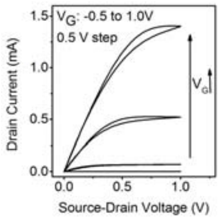
ZnO-Nanorods (NR):

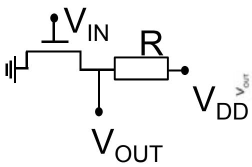
- N-channel materials (CMOS logic!)
- Length of 14 nm and diameter of 5 nm
- Dropcast on multilayer-paper
- Microcellulose based ionogels

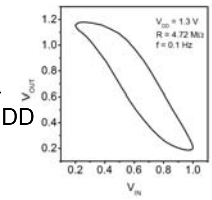












S. Thiemann, S. Sachnov, F. Pettersson, R. Bollström, R. Österbacka, P. Wasserscheid, and J. Zaumseil, *Adv. Funct. Mater*, in press

Summary

- Energy level engineering crucial for organic electronic devices
- Energy levels may shift at interfaces between organic materials and
  - Metals
  - Oxides
  - Organics
- Device properties will be altered!
- New ways to measure and understand charge transport and interfacial properties
  - › Important to understand for making better devices
- Electronics on Paper
  - › Functional materials enables electronics also on paper!


ORGEL group, fall 2012
Åbo Akademi University