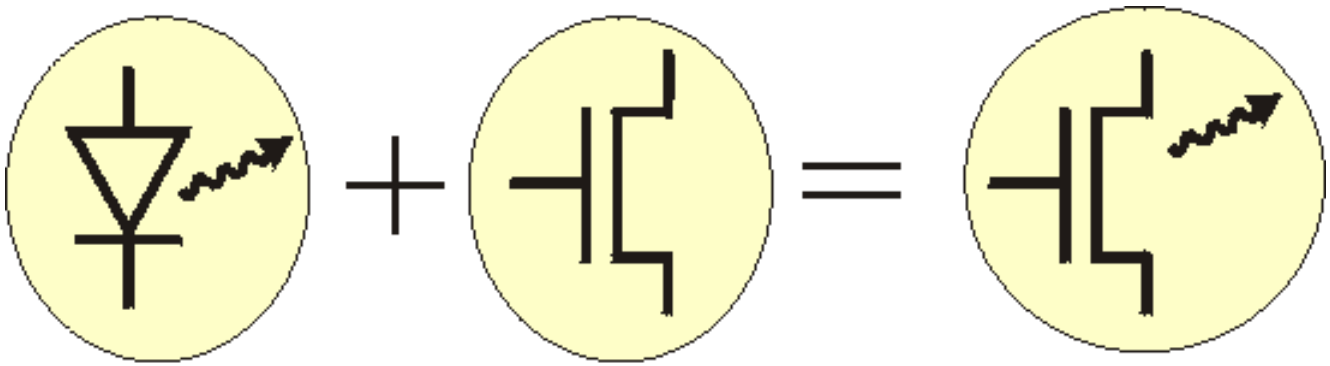

OPTO-ELECTRONICS
UNIVERSIDADE DO ALGARVE

Light-Emitting Field-Effect Transistor



Background

LEDs

Long lifetime

High efficiency

"Blue" a little bit tricky

Organic Semiconductors

OptoElectronics in Faro. Strong in "organics".
Experts on electronic measurements.

Organic means "**based on carbon**"
- polymers
- oligomers (small molecules)

"plastics" are cheap, with a wide variety of properties, flexible, strong, soft, colorful, light, heat-resistant,

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Organic materials, a.k.a. "plastics"

The world is better with plastics ….

Clothes

http://www.mischabarton.net/mbimages/misc/misc-nylon.jpg

A plastic car, because of it's light weight can get more miles per gallon than a steel car

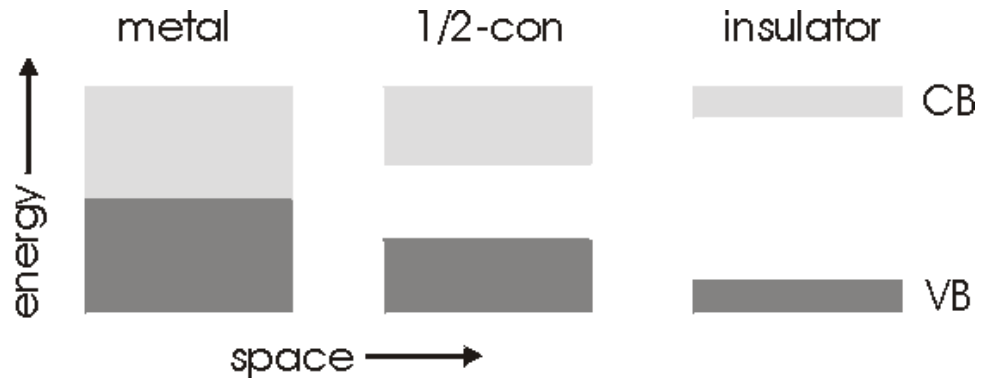
http://www.cnn.com/TECH/ptech/9902/25/plastic.cars/

Construction

http://www.solvayindupa.com.br/aplic/prod.htm

…. why not electronics ….

Semiconductor means "with electronic bandgap"



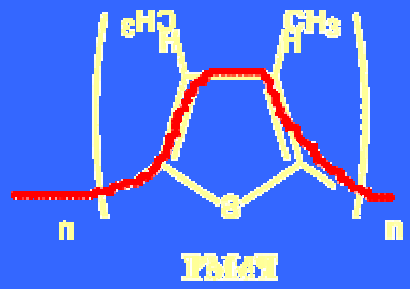
Material	Band gap
SiO_2	>10 eV
C (diamond)	5.47 eV
GaN	3.36 eV
Polymers	2.5 eV
GaAs	1.42 eV
Si	1.12 eV
Ge	0.66 eV

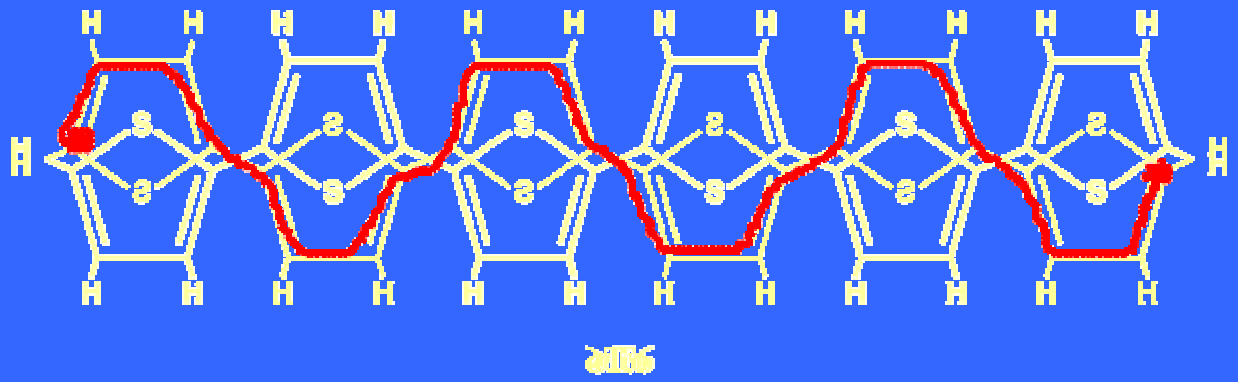
Organic semiconductors means "with conjugated backbone"

$$\cdots - C = C - C = C - C = \cdots$$

Examples

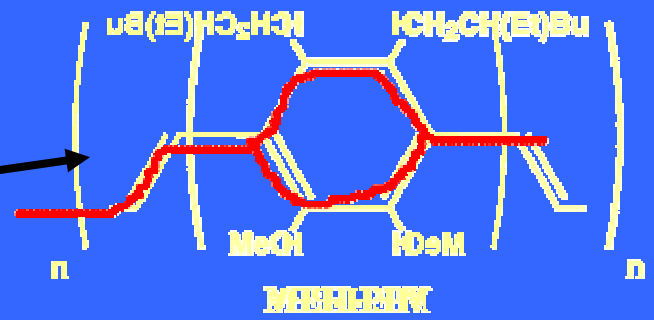
Conjugated organics have paths with alternating single and double bonds

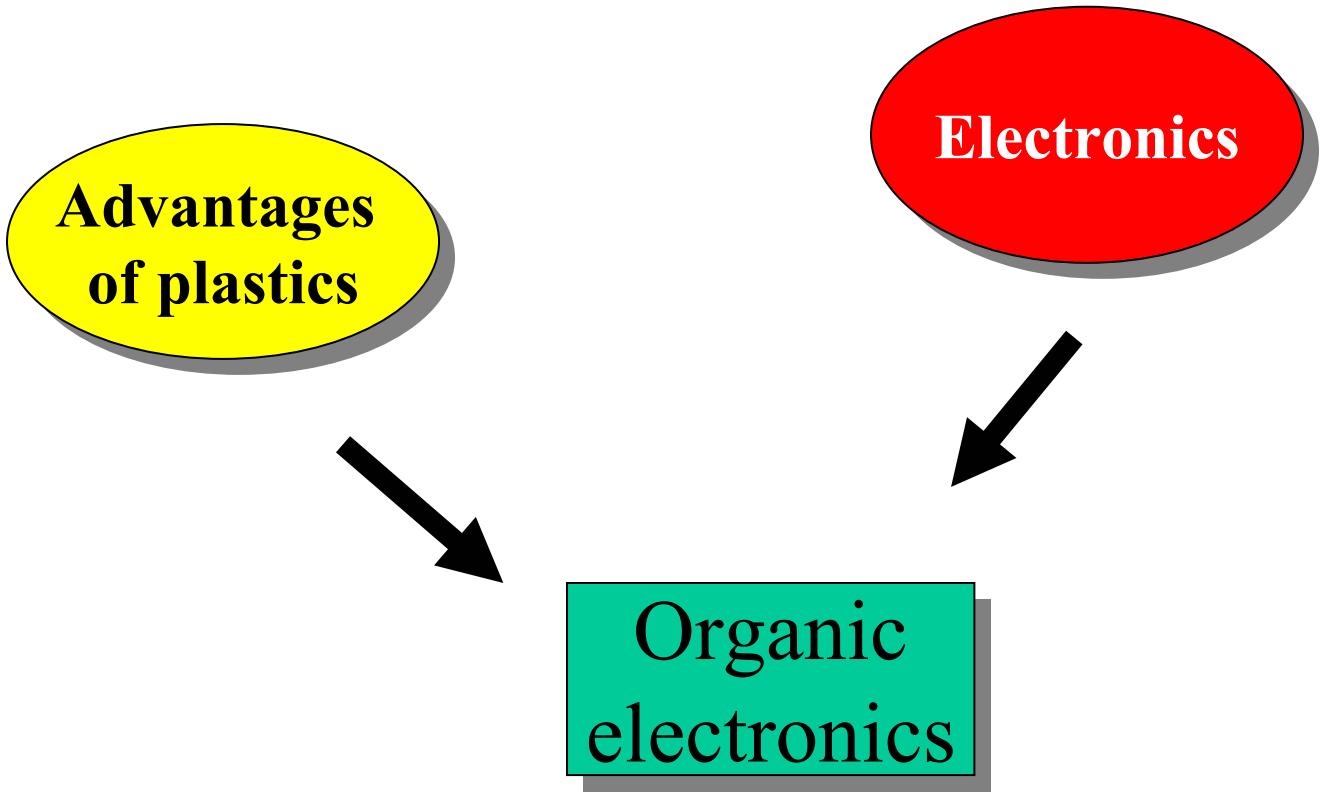




Very good for FETs

Very good for LEDs





Flexible, low cost, versatile ….

Market

Will never beat inorganic electronics:
State-of-the-art Si technology. 3 GHz
State-of-the-art org. technology. 30 kHz

Imagine your computer
100000 x slower!

Applications

Disposable electronics

Solar cells

(Large-area) light sources

Flexible Electronics

Memory devices (magnetic, electrical)

Applications: Disposable electronics

http://www.quetel.com/docs/hardware/hdwindexdw.htm

http://www.hear-it.org/forside.dsp?forside=yes&area=34

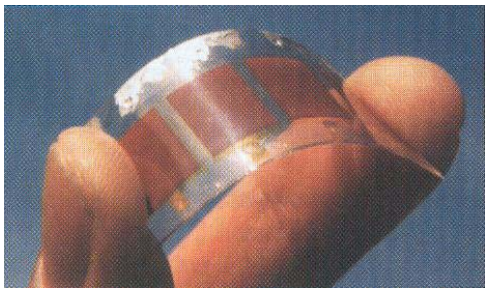
Scanning barcodes manually is time consuming!

…… Disposable electronic barcodes

Applications: Solar cells

"Conventional solar cells are expensive, therefore no-one buys them. Consequently, production volumes remain low and their unit price is high."
"In 10 years the price of electricity from solar power will be comparable to that from a conventional power plant,“

Albert Goossens, associate professor of chemistry at the University of Delft in the Netherlands
http://solar-club.web.cern.ch/solar-club/SolPV/autres/organics.html

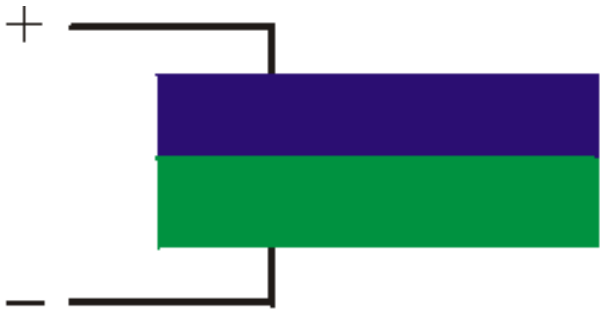


http://solar-club.web.cern.ch/solar-club/SolPV/autres/organics.html

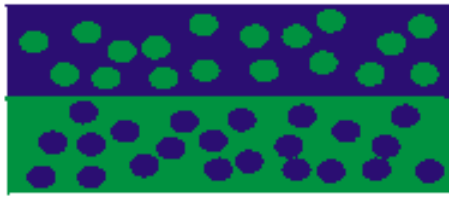
Applications: Solar cells

For high efficiency: interface area must be increased

Conventional solar cells



Next generations solar cells;

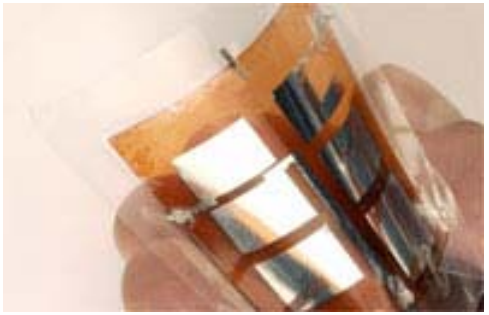


Graetzel cells
colloidal systems;
Imitating plant cells

Only organic materials can be made this way.

Applications: Flexible electronics

Flexible electronics



http://www.imec.be/wwwinter/about/images/FlexibeleceImethand.jpg

Flexible displays

http://staff.bath.ac.uk/pysabw/research/organics/organic.htm

All colors of the rainbow

http://www.ee.leeds.ac.uk/nanomsc/gfx/colours.jpg

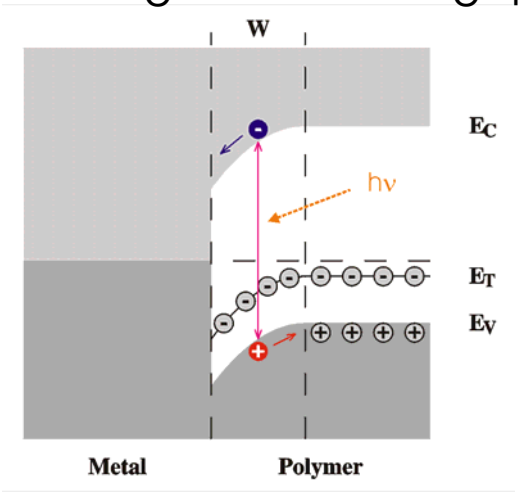
Applications: Optical detectors

http://www.sp3plus.co.uk/images/uvb1.jpg

Optical detectors can be tailor-made, suiting all colors including UV and IR.

"bandgap engineering" .....

Wavelength ←→ bandgap



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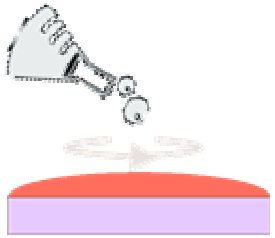
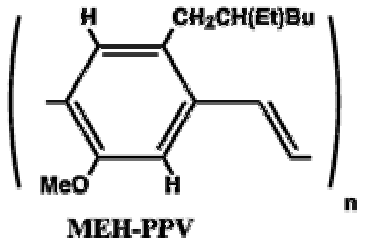
Production

Production: Spin coating

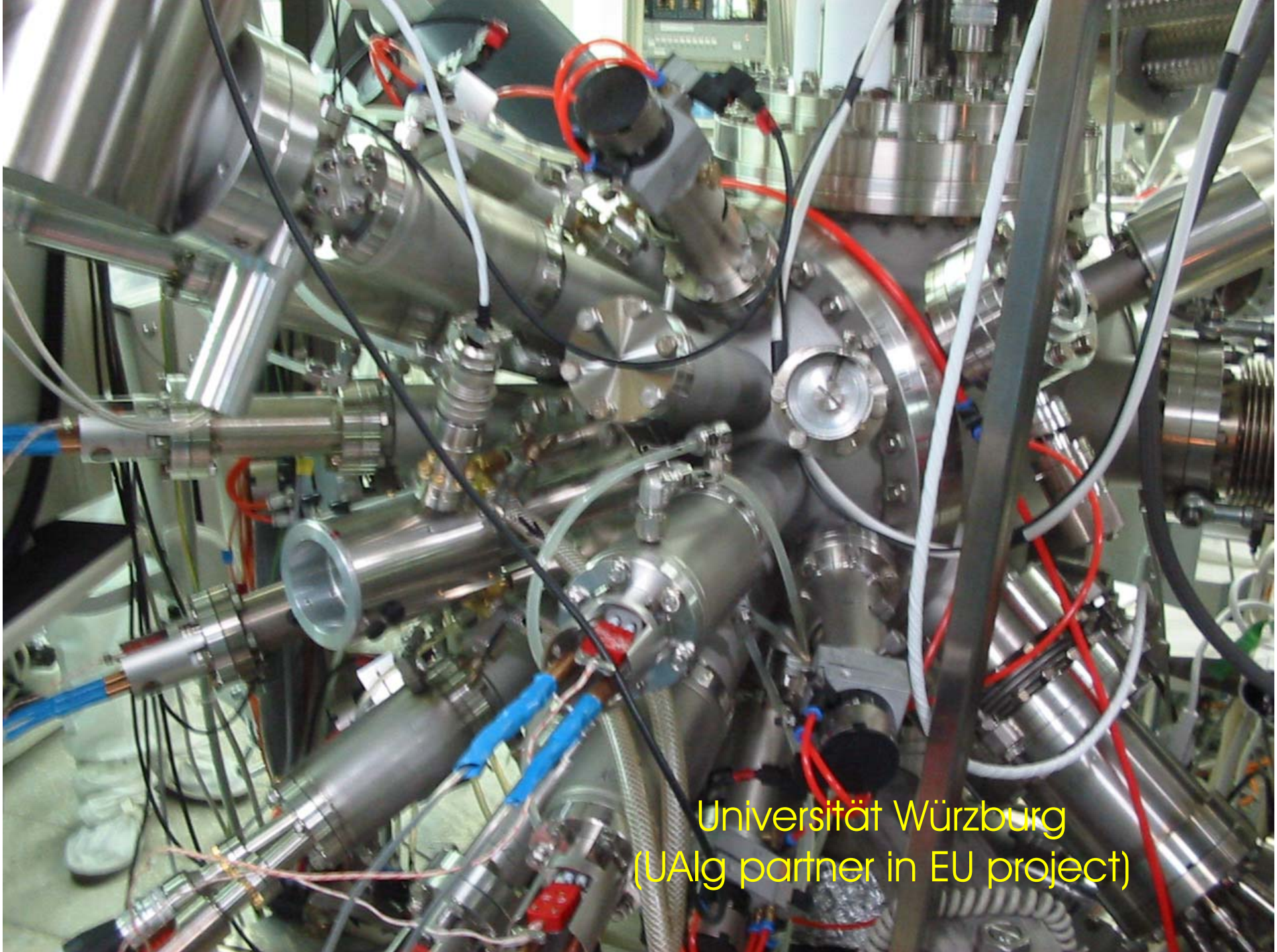
- A standard conjugated polymer is not soluble
- it can be made soluble by adding side chains. Then they can easily be spin-coated onto the substrate (glass, ITO,etc)



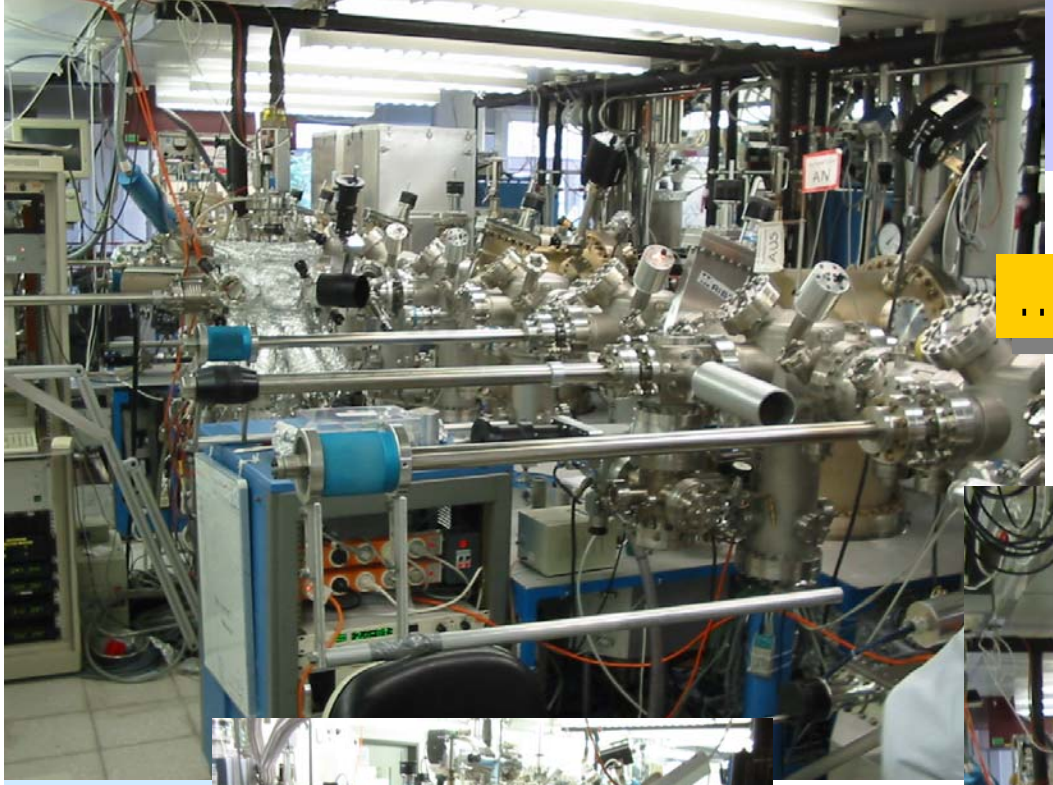


MEH-PPV

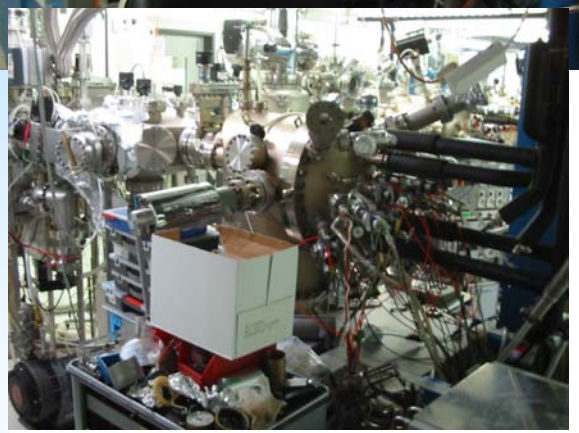
- Otherwise they can be vacuum sublimated. (more difficult)
- Or polymerized after deposition (pre-cursor route)


Universität Würzburg
(UAlg partner in EU project)

Production: Vacuum deposition

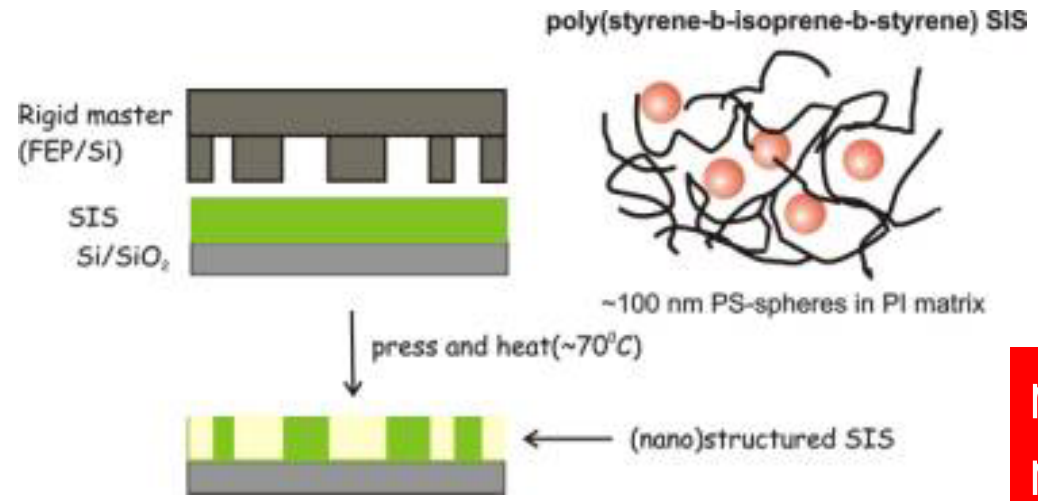


… can hardly be called cheap …



… needed to STUDY the materials/devices …

Production: stamping technique



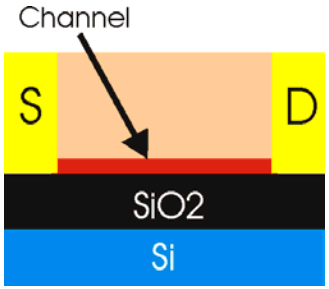
nanometer resolution!

http://www-huckgroup.ch.cam.ac.uk/research.htm

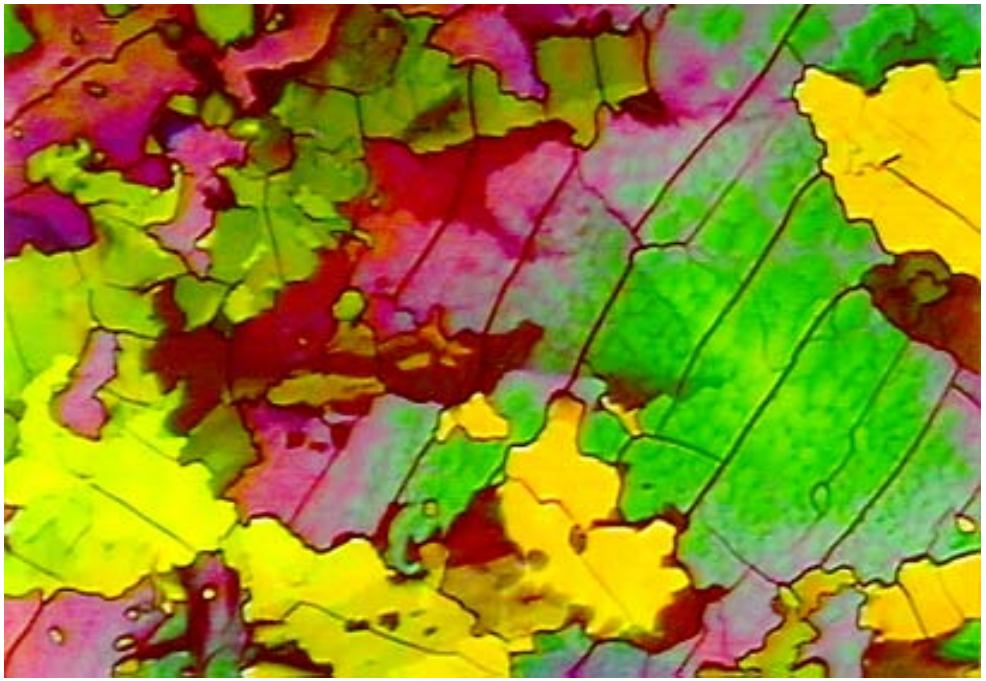
Printing electronics like printing newspapers

http://www.heidelbergusa.com/03_pro/web_press/newspaper/index.asp

Production: Aspects



For FETs, the first mono layer of molecules is most important. All current goes there!



http://www.fwn.rug.nl/fdl/organic.html

Fake-color microscopic image of an organic layer on top of silicon

Universidade do Algarve

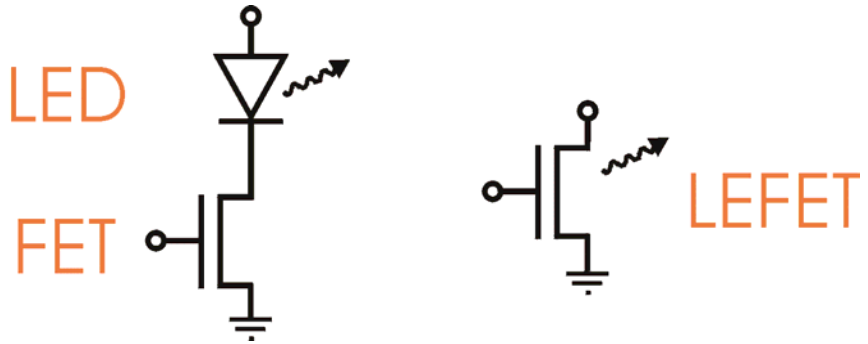
Opto-Electronics

UAlg: Light-emitting field-effect transistor

Conventional display technology:
Transistor steering an LED

This involves many production steps.

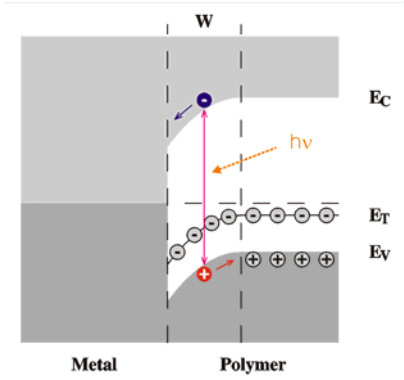
Using a Light-emitting FET, the cost of production of displays can be reduced.



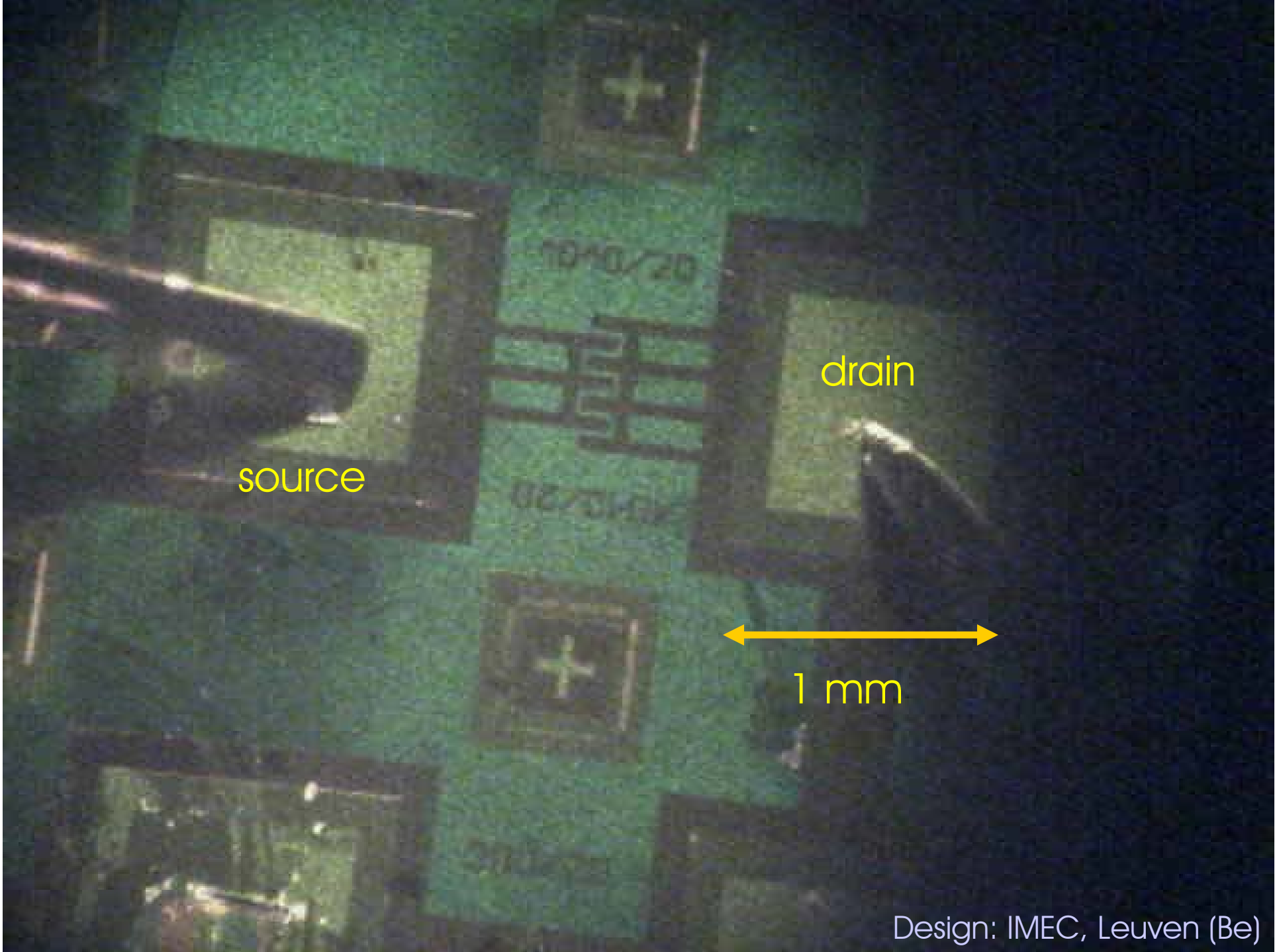
Studied in cooperation with Bologna (It)

UAlg: Light-emitting field-effect transistor

Theoretically no light can come out of an FET:



- Light needs hole AND electron
- FET is a single-carrier device (only holes or only electrons)

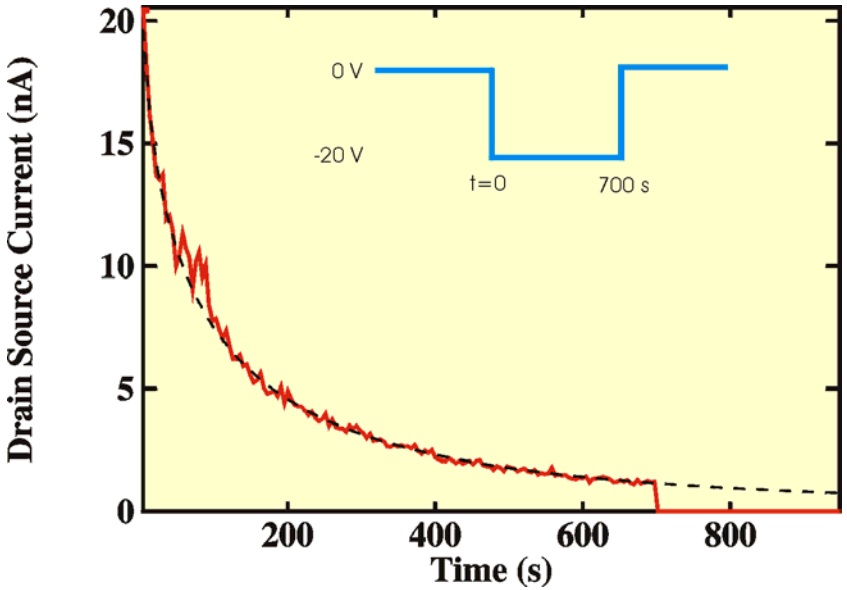

drain
source
1 mm
Design: IMEC, Leuven (Be)

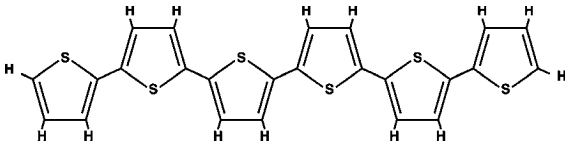
You are looking at the first picture ever taken showing light coming out of an FET … (Bologna, 2003)

UAlg: Stability

One of the biggest problems of organic electronics is stability:

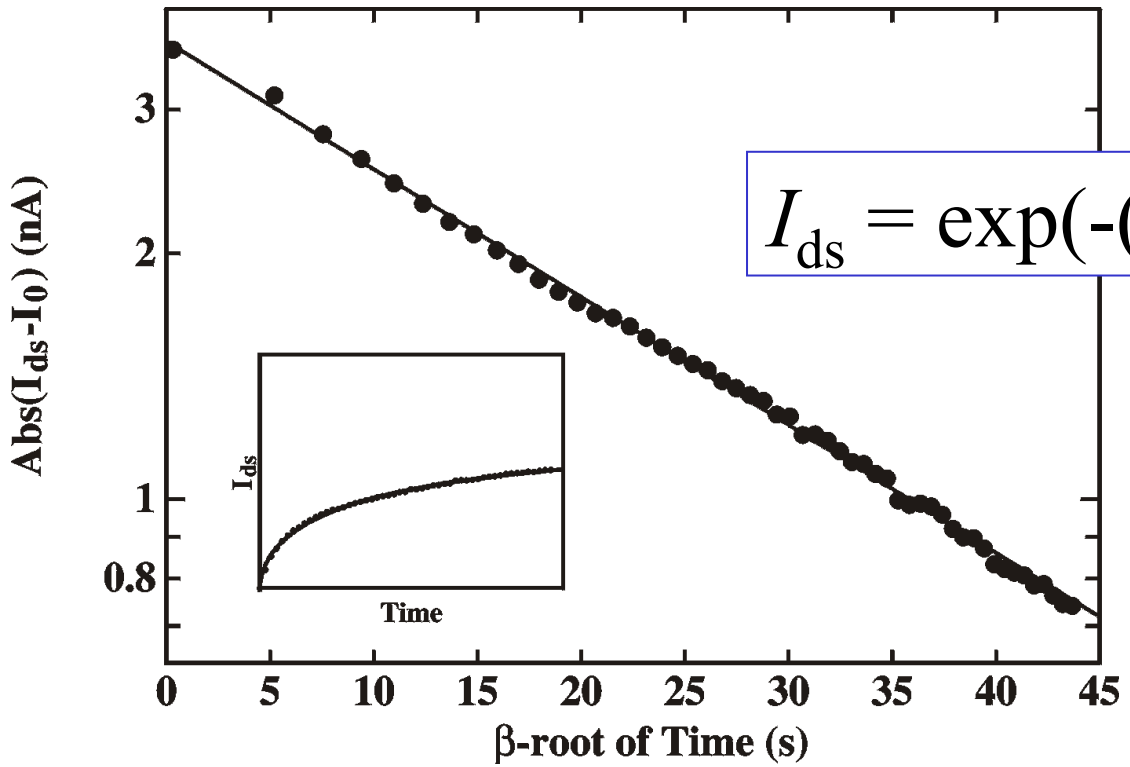
- Reversible
- Irreversible





Current completely peters out

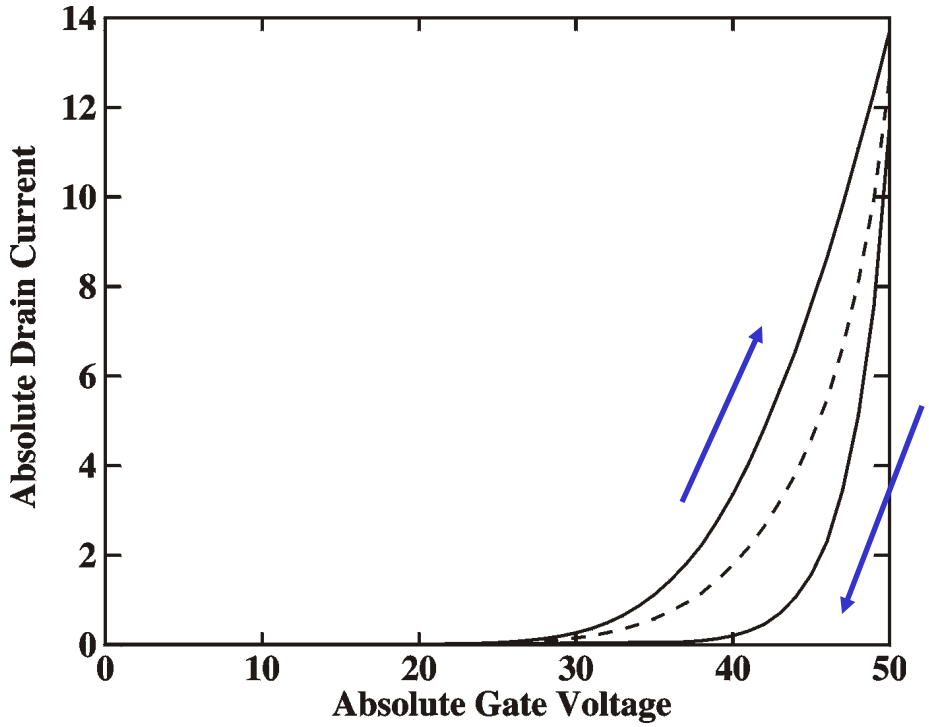
UAlg: Stability



$$I_{ds} = \exp(-(t/\tau)^{\beta})$$

… Indicating a huge density of charge traps

UAlg: Non standard FET curves



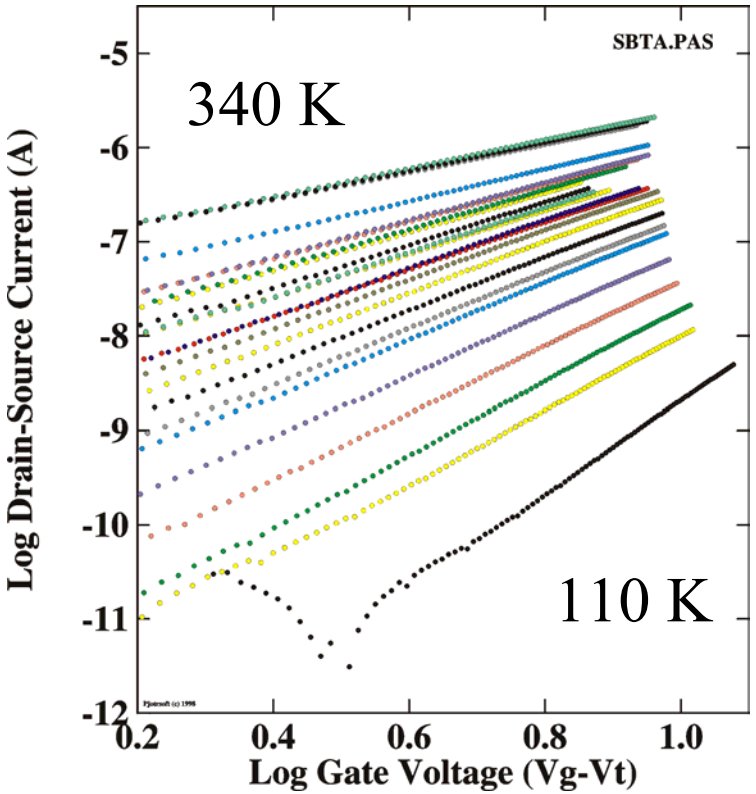
Hysteresis curve

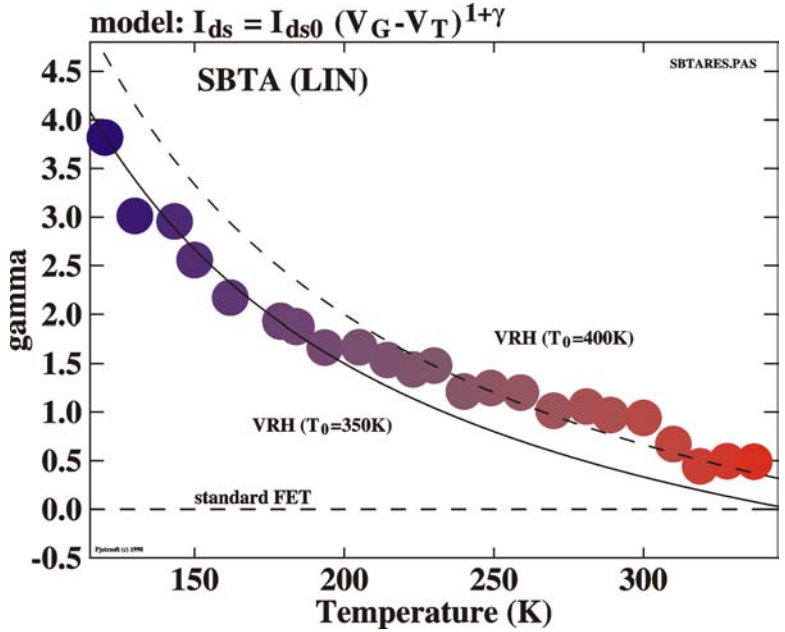
---------- average

Average fits to $I_{ds} = Vg^{1+\gamma}$

for normal FETS, these curves are linear ($\gamma = 0$)

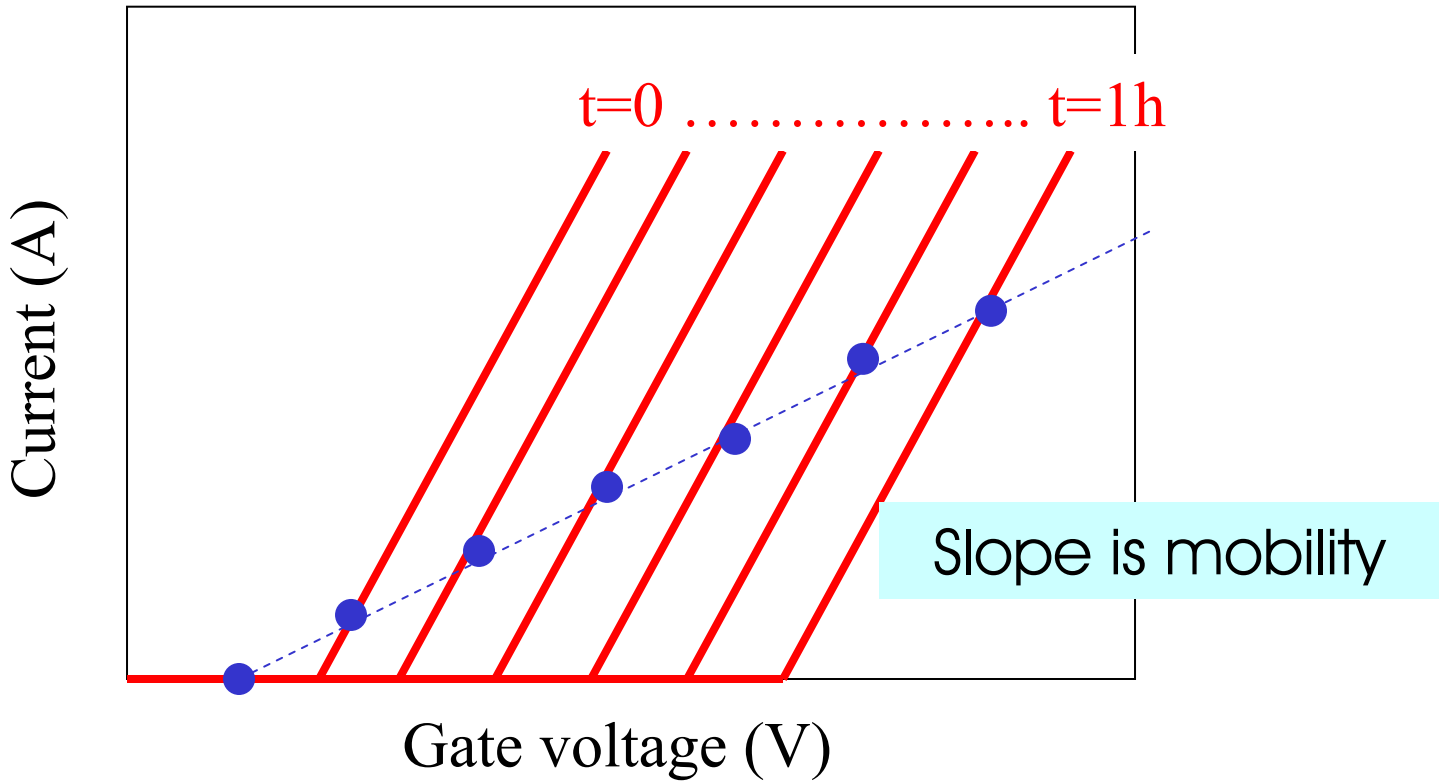
UAlg: Non standard FET curves





This indicates a large number of traps

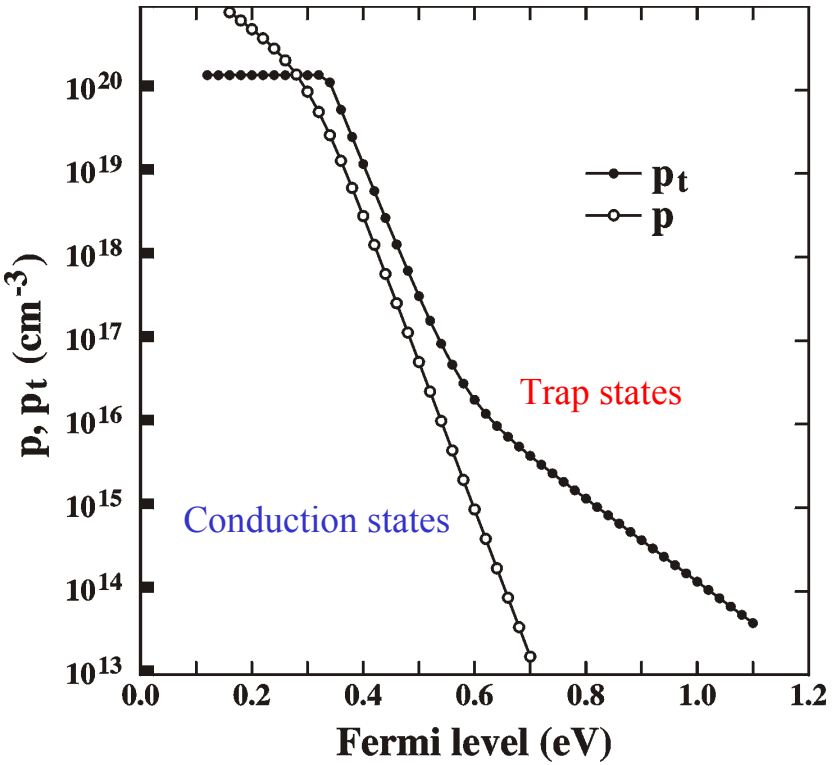
UAlg: Stressing



Maintaining (gate) bias connected causes shift of curves

Effective measured curves if shift is fast

UAlg: Conduction models



Classical conduction models do not apply!

Summary

Organic semiconductor applications

Light-emitting field-effect transistor

Opto-Electronics group Faro