A close look at the recombination width in Organic Ambipolar Field Effect Transistors

Technische Universiteit Eindhoven University of Technology
Molecular Materials and Nanosystems

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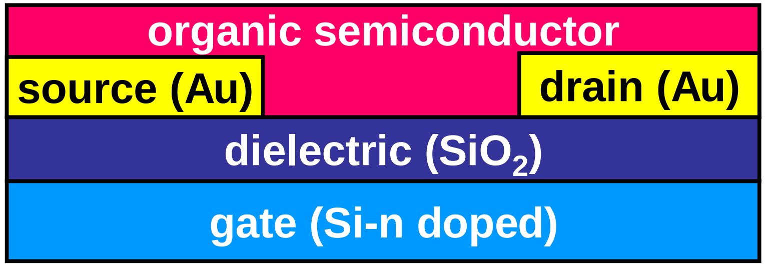
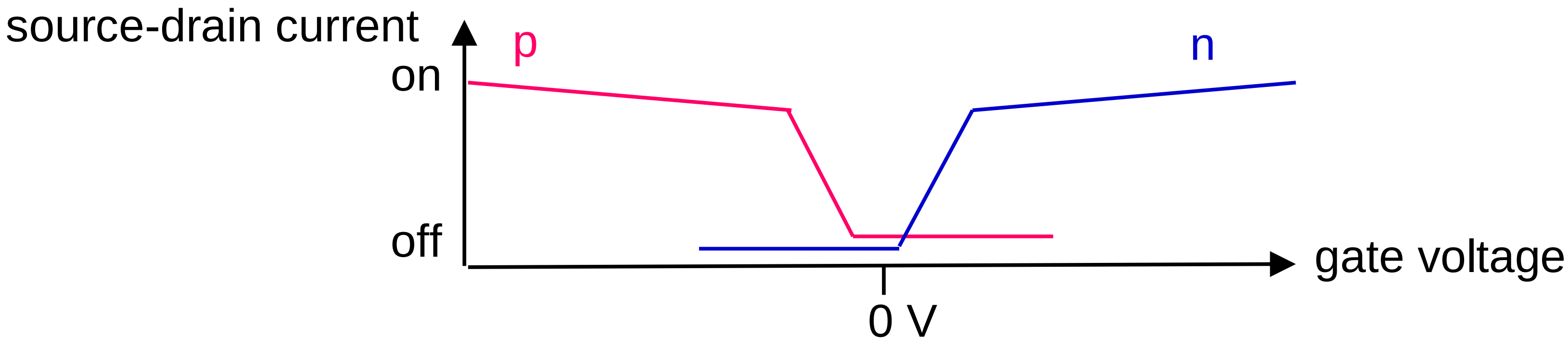
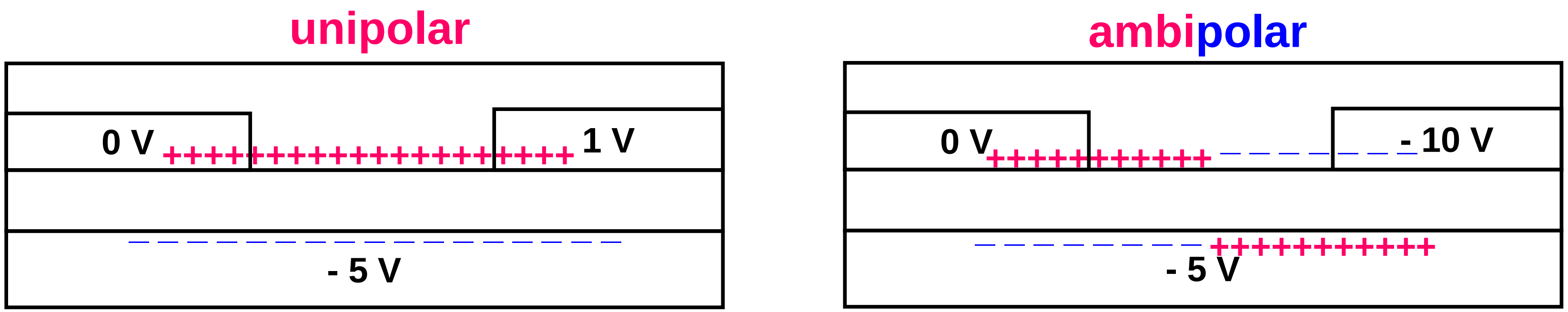
Organic Transistor

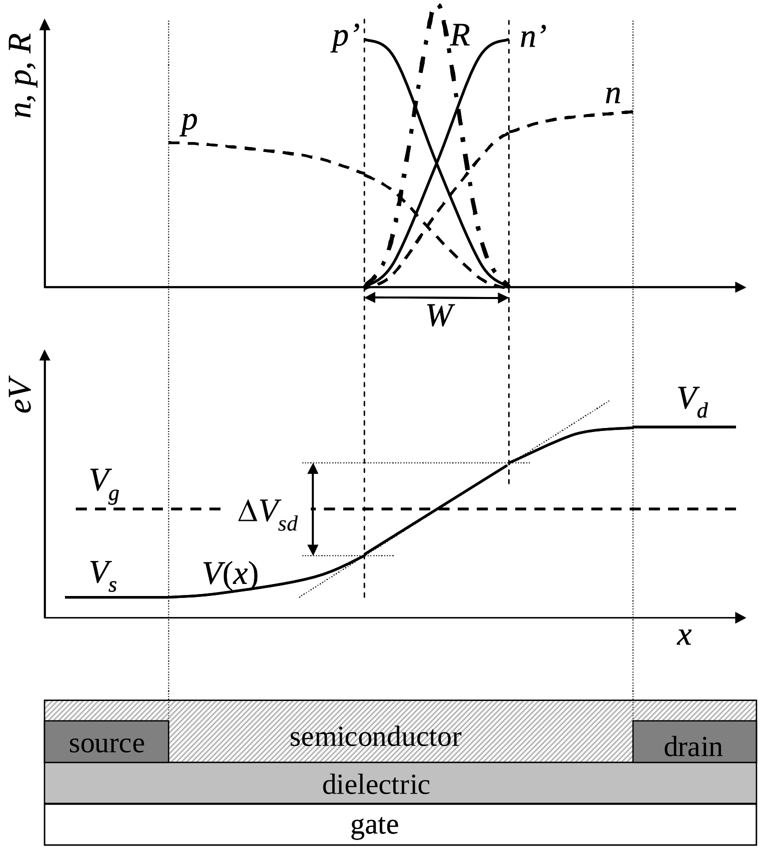






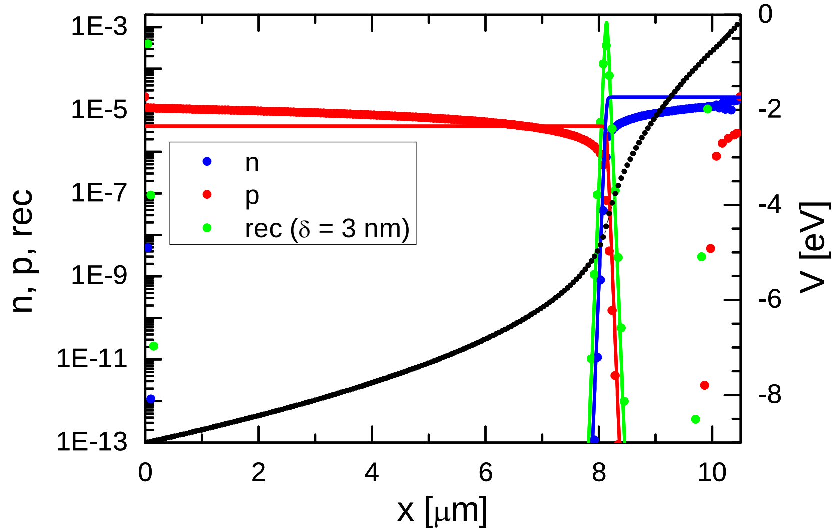
Potential applications: organic laser if good recombination performances.
Important parameters: carrier densities *n* *p*, width *W*.

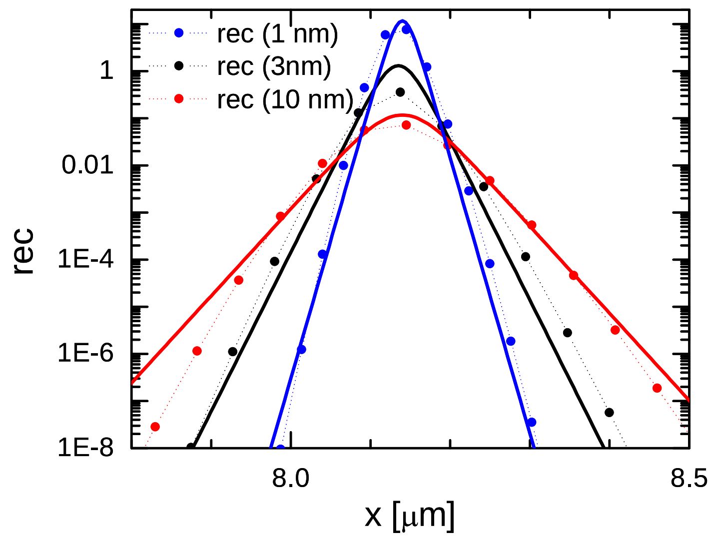
Theoretical Predictions



$$W_{theoretical} = \sqrt{4.34 d\delta} \approx 20 - 200nm$$

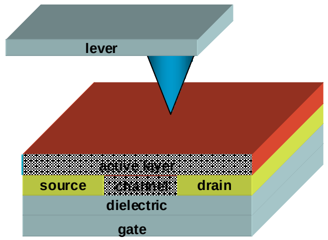
Numerical drift/diffusion model
vs. Analytical drift-only model
(recombination according to Langevin)





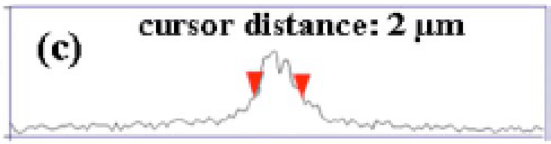
M. Kemerink *et al*, Appl. Phys. Lett. **93**, 033312 (2008)

Experimental Results



Optical technique

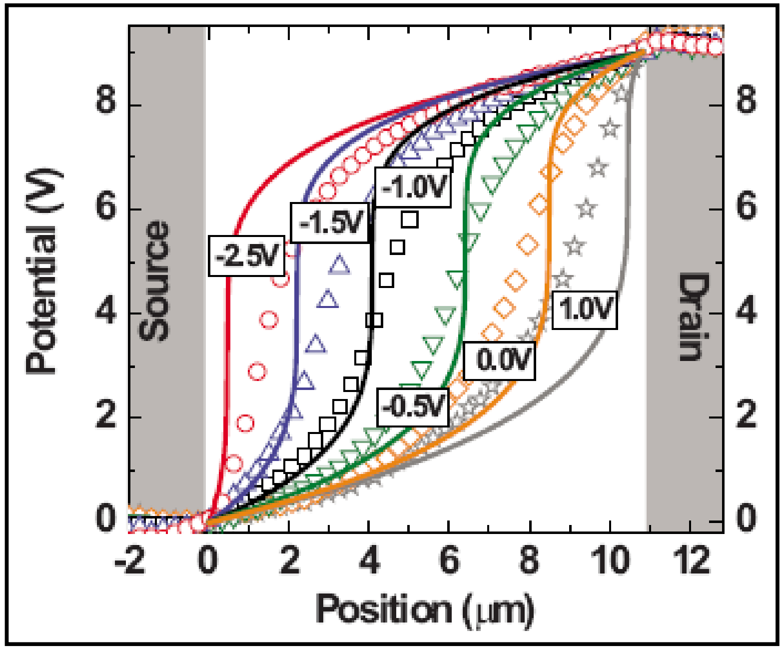
Confocal microscope / High fields
PPV



J.S. Swensen *et al*, J. Appl. Phys. **102**, 013103 (2007)

Electrostatic technique

Scanning Kelvin Probe Microscope
NiDT
Should see a potential drop at x_0

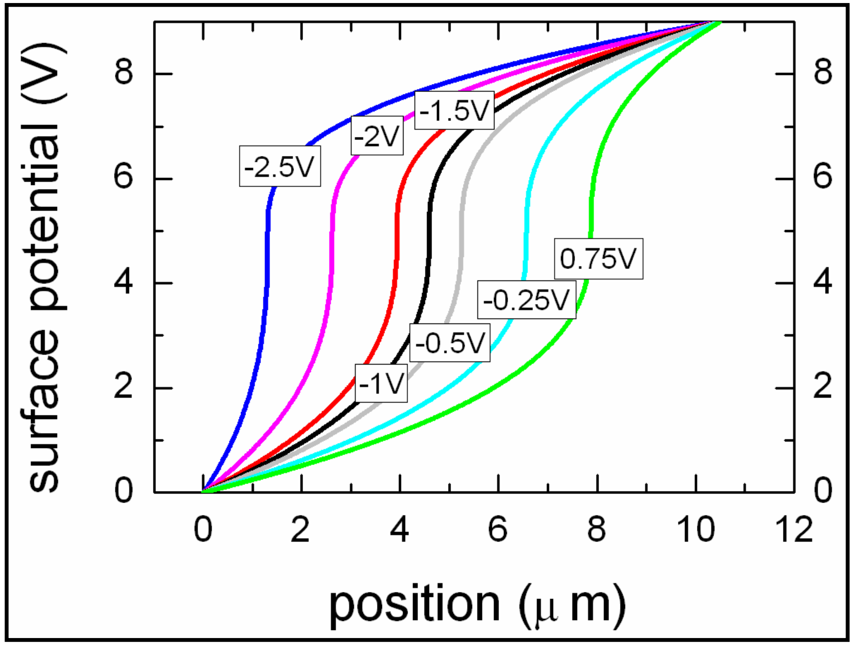


E.C.P. Smits *et al*, Phys. Rev. B **76**, 125202 (2007)

$W_{experimental}$ ~ 2 μm

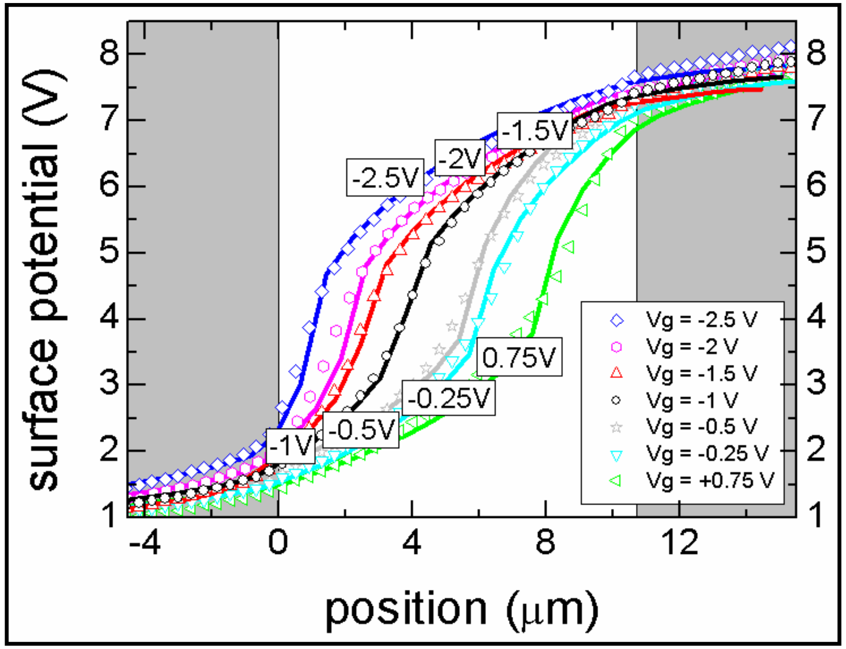
SKPM Response for FET

Theoretical predictions (drift) from Smits
= input of SKPM modeling



Assumption:
W = “0” nm

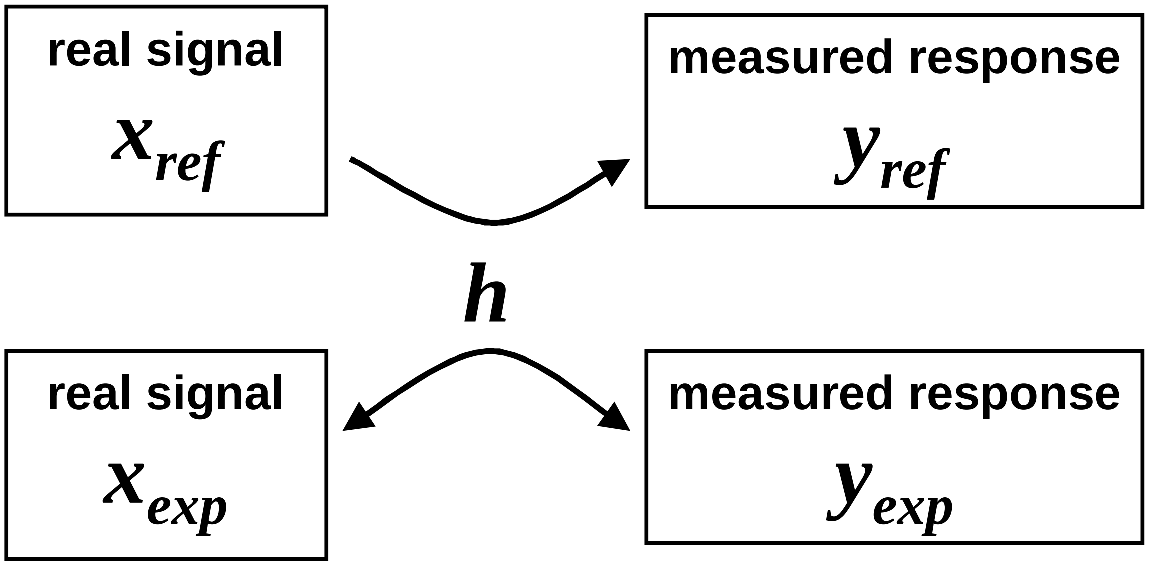
SKPM
experiments + 3D modeling



‘real’ *W* < 0.5 micron

Note: We checked that the SKPM probe influence only few % the source drain current.

What about the inverse?
What about a ‘simple’ prediction?



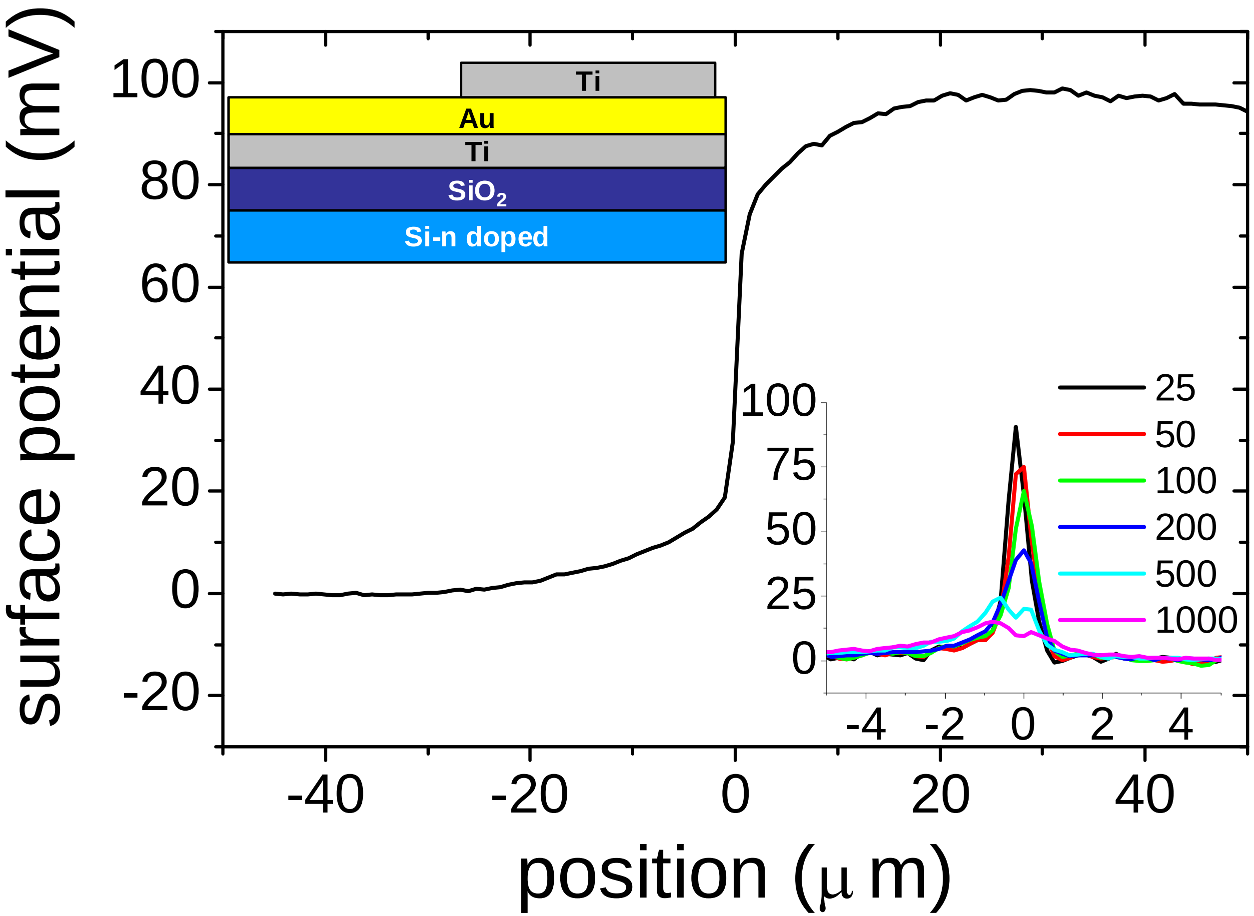
$$y_{ref}(x) = h_{ref}(x) \otimes x_{ref}(x)$$

$$F(Y) = F(H).F(X)$$

h = Apex(x,y,z) + Cone(x,y,z) + Lever(x,y,z) = electrostatic convolution

Hypothesis: one single reference measurement contains all electrostatic interactions

Step edge convolution = impulse response properties

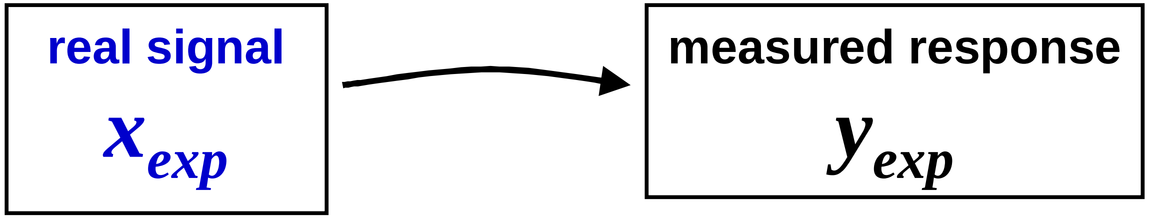


$$F(h) = F(y'_{step})$$

inversion: $x_{\exp} = F^{-1}\left(\frac{Y_{\exp}}{Y'_{step}}\right)$

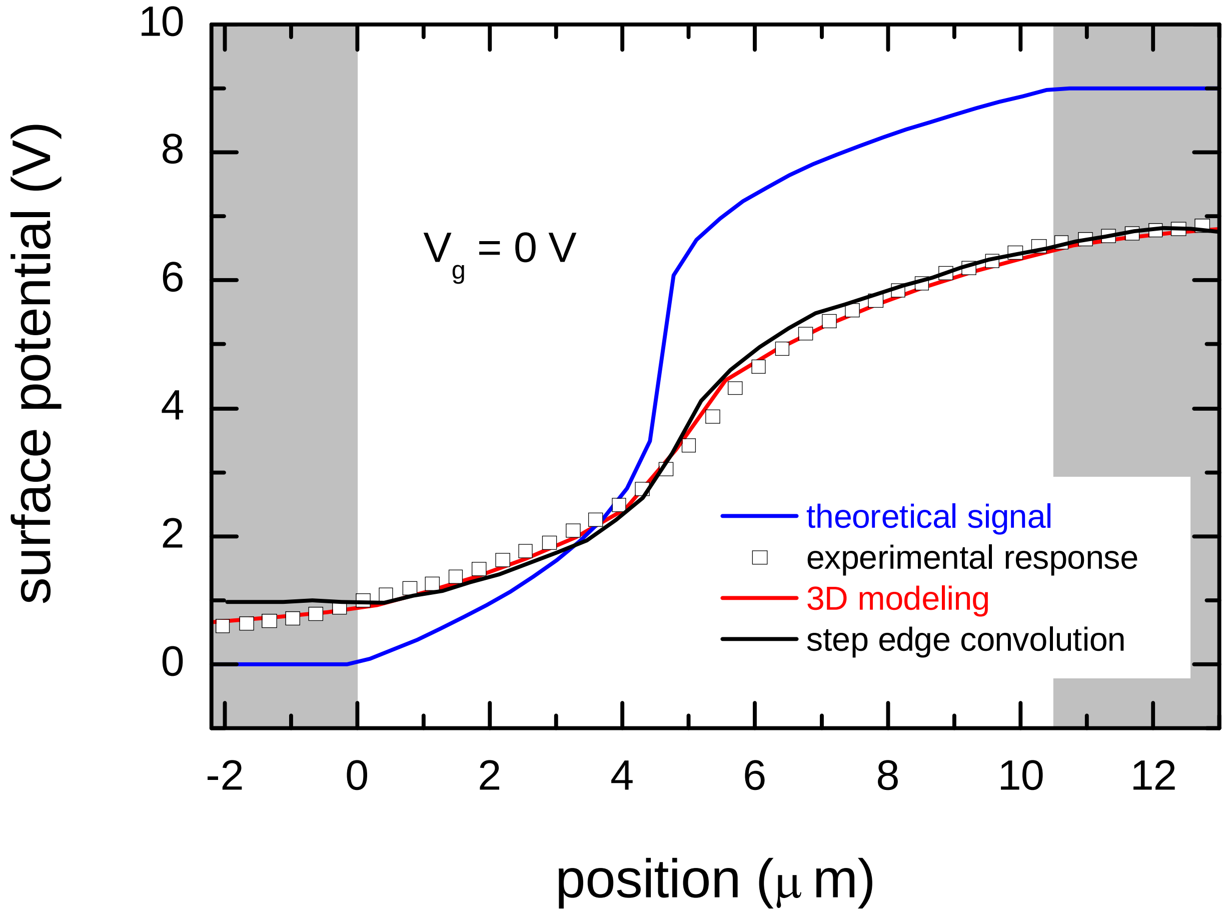
prediction: $y_{\exp} = F^{-1}(X_{\exp}.Y'_{step})$

Prediction from step edge response



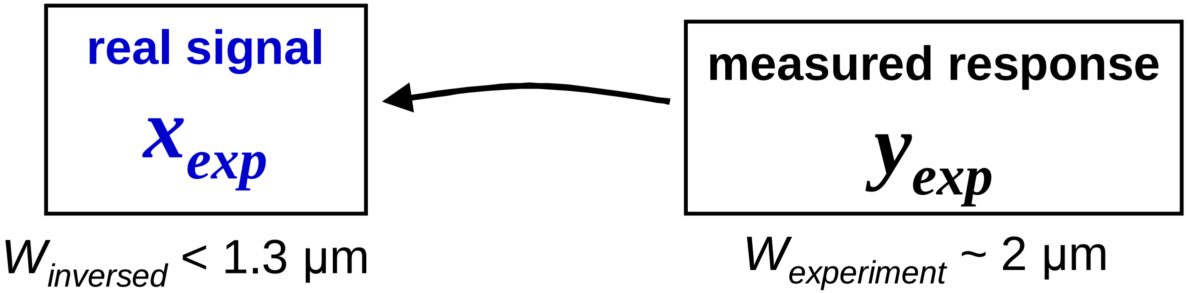
W = “0” nm

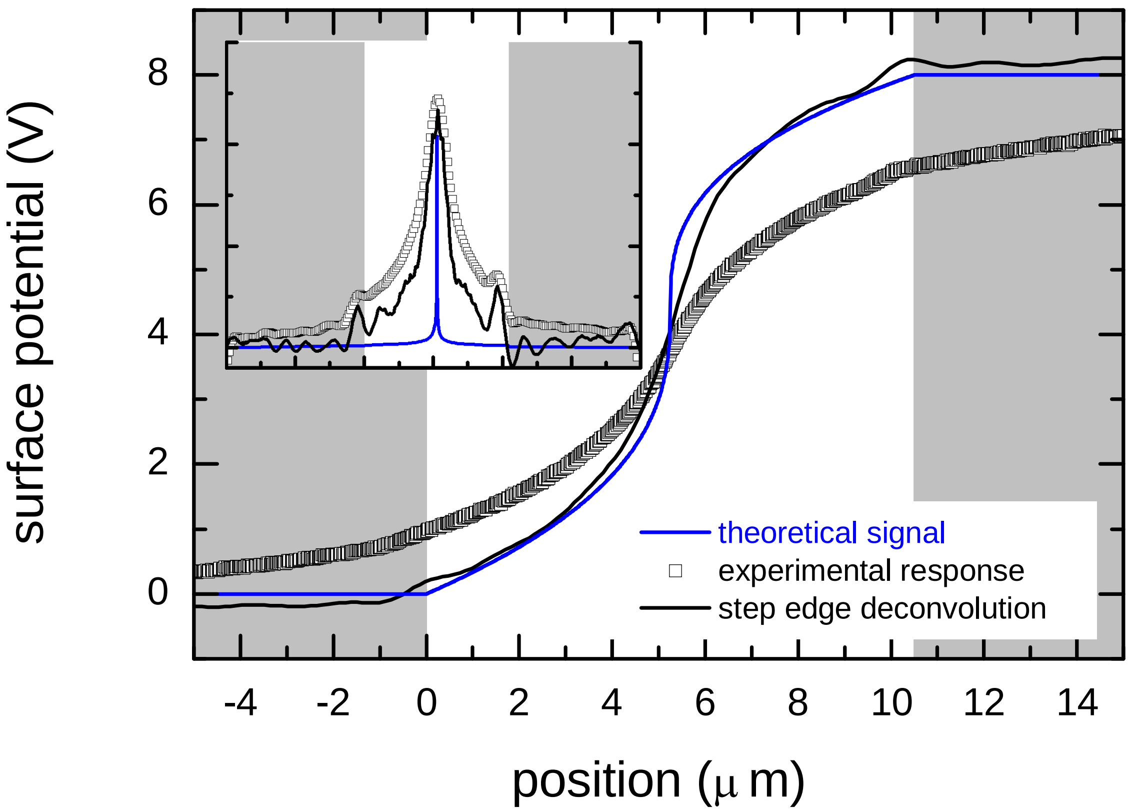
$W_{predicted}$ < 700 nm



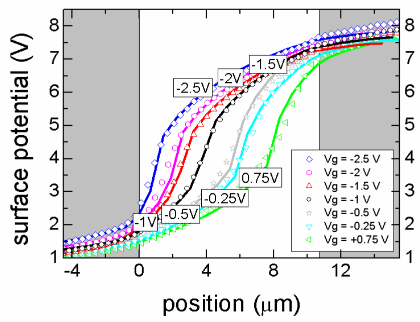
Inversion from step edge response

$W_{inversed} - W_{theoretical} = 1.3 - 0.2 = 1.1$ µm

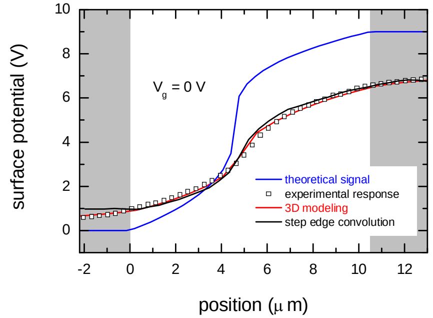




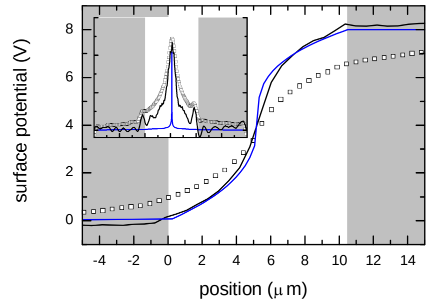
summary



- Severe SKPM experimental limitations are overcome using step edge response tool – good agreement with experiment and 3D calculations.



- Reverse (or inversion or reconstruction) problem successfully working using the step edge response tool.



- A higher resolution of SKPM is reached with the step edge response tool.

- *W* recombination:
  - theoretical (Langevin) ~ 200 nm
  - experimental SKPM response
    - raw ~ 2 µm
    - difference with model < 0.5 µm

Thanks to

nano ned

TU/e

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Erik-Jan Geluk

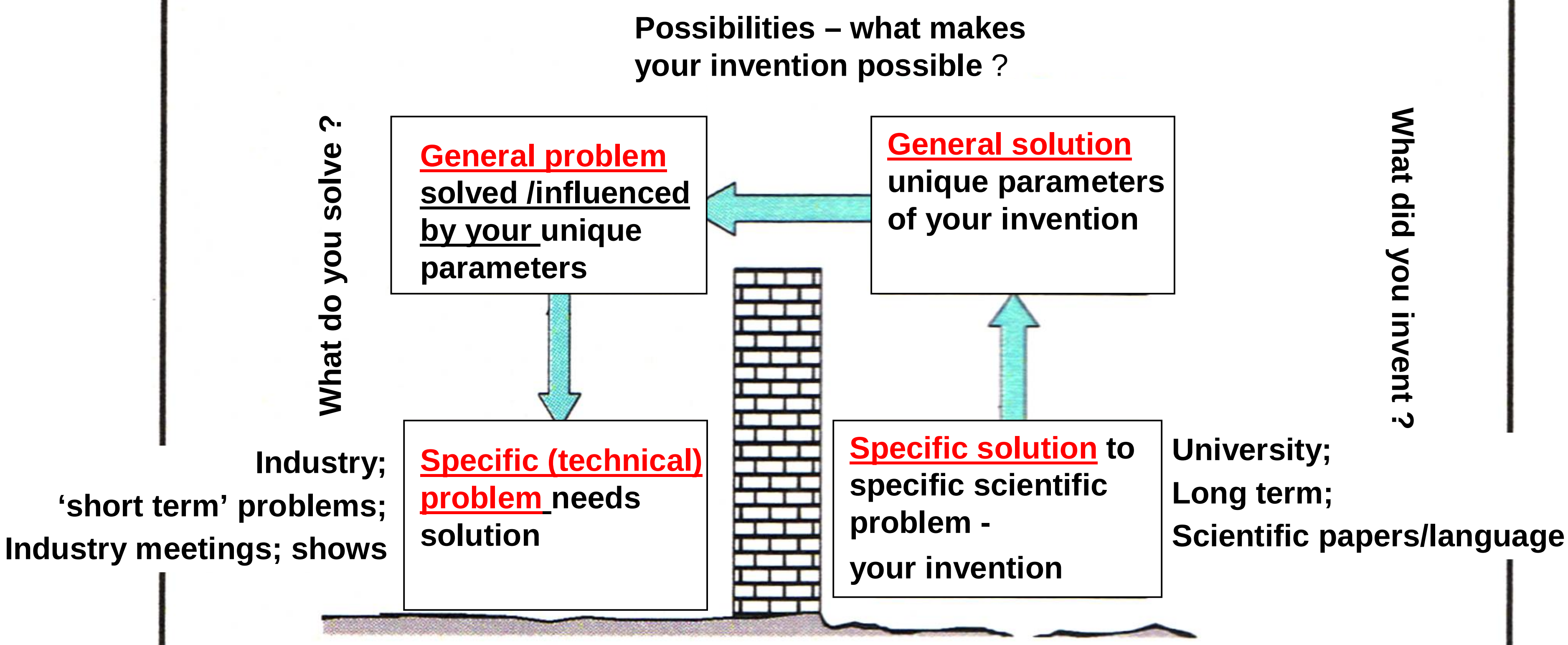
PHILIPS

Data, discussions, samples

Edsger Smits
Reinder Coehoorn
Dago de Leeuw

Invention = Solved Problem

= Specific Solution



University:

Eindhoven University of Technology

Long term:

Probing the channel potential in organic transistors

Scientific papers:

D. Charrier *et al.*, ACS Nano **2**, 622-626 (2008).

M. Kemerink, D. Charrier *et al.*, Appl. Phys. Lett. **93**, 033312 (2008).

D. Charrier *et al.*, in preparation.

Conferences:

D. Charrier *et al*., *EMRS*. Strasbourg, France, May 2008.

D. Charrier *et al*., *EMRS*. Strasbourg, France, May 2008.

D. Charrier *et al*., *SPIE Photonics Europe*. Strasbourg, France, April 2008.

D. Charrier *et al*., *NanoNed Conference*. Nijmegen, The Netherlands, December 2007.

D. Charrier *et al*., *NanoNed internal meeting.* Utrecht, The Netherlands, September 2007.

D. Charrier *et al*., *MRS Conference*. San Francisco, USA, April 2007.