Prediction and reconstruction of Scanning Kelvin Probe Microscope measurements on Organic Ambipolar Field Effect Transistors

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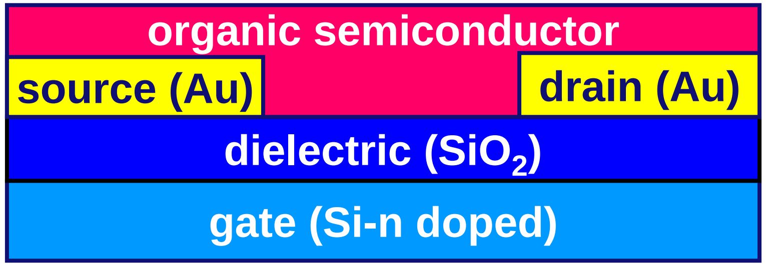
Plan

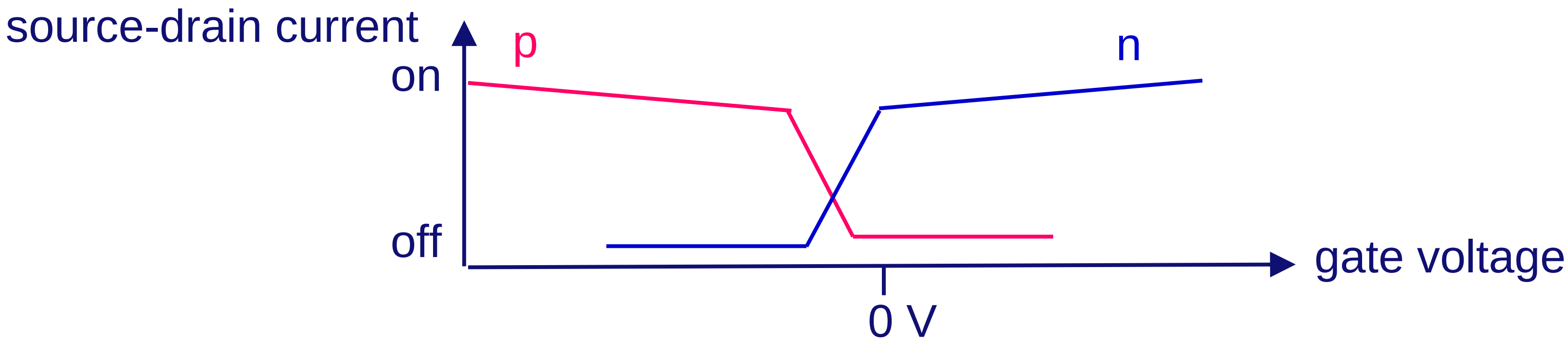
- Organic Ambipolar Field Effect Transistor

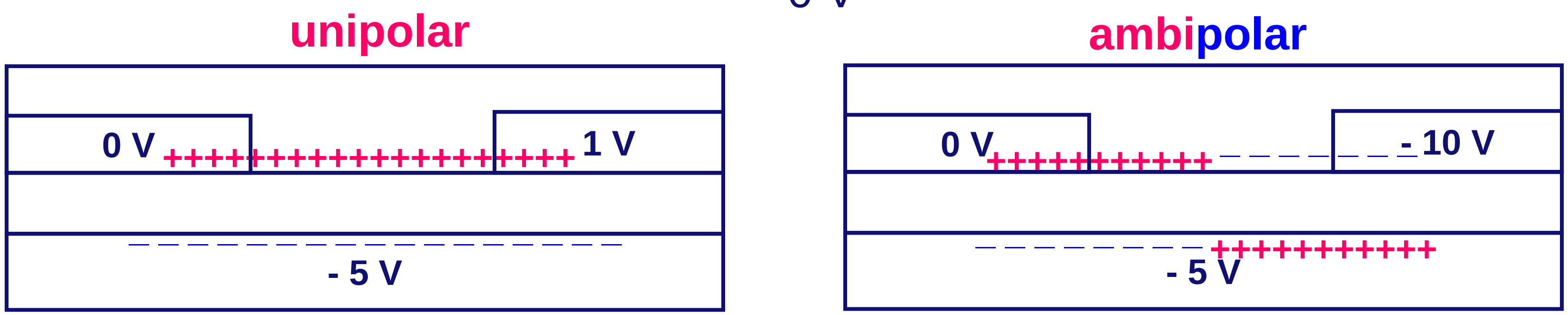
- Recombination width
  - Langevin recombination
  - Experiments

- Simple prediction/reconstruction model
  - Step edge model
  - Prediction
  - Reconstruction

Organic Ambipolar Field Effect Transistor



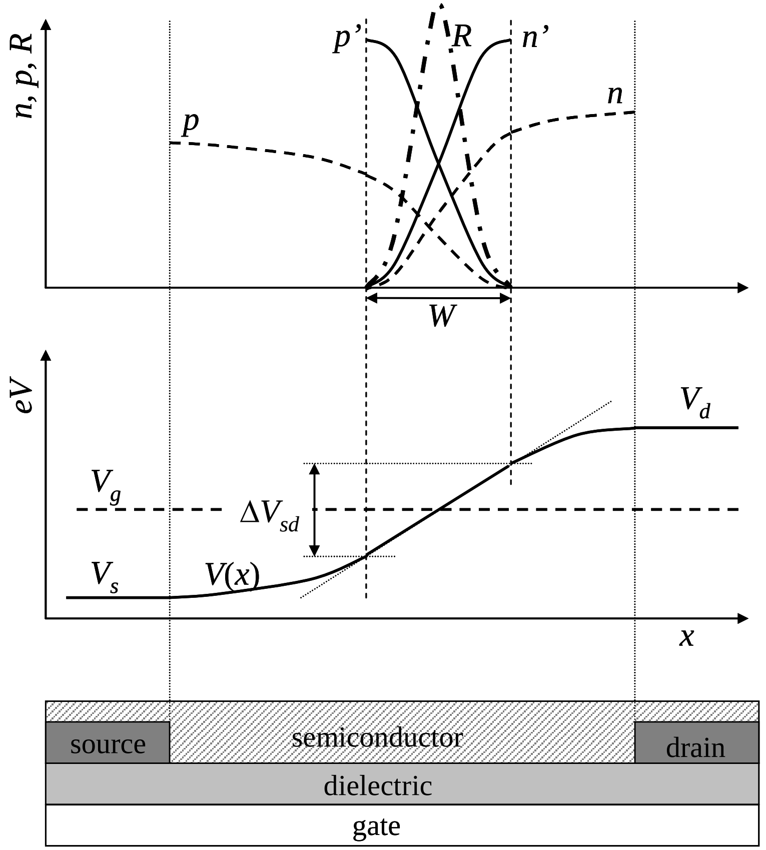




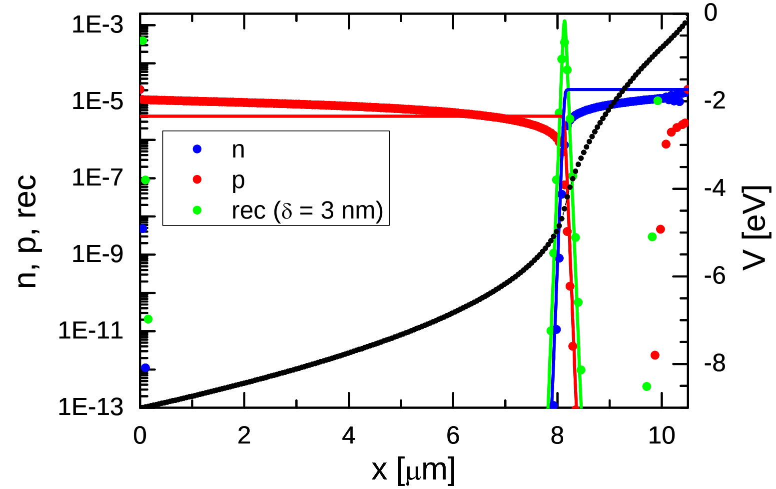
Potential applications: organic laser if good performances.

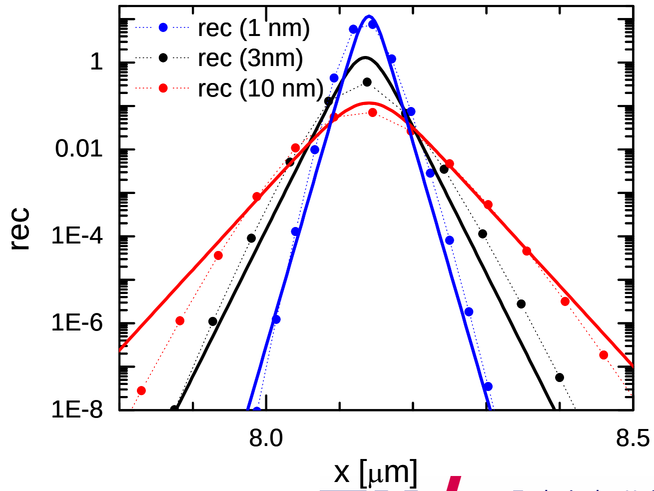
Important parameters: carrier densities *n* *p*, width *W*.

Langevin recombination



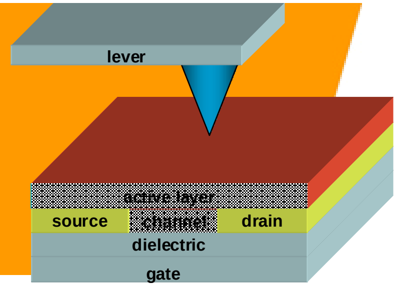
$$W_{theoretical} = \frac{\sqrt{4.34 d\delta}}{\sqrt{\beta}} \approx 20-200nm$$





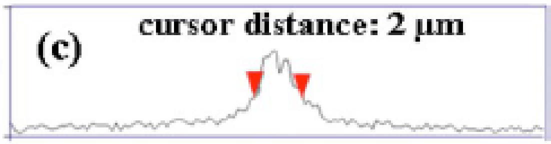
M. Kemerink *et al*, Appl. Phys. Lett. **93**, 033312 (2008)

Reported experimental results



Optical technique

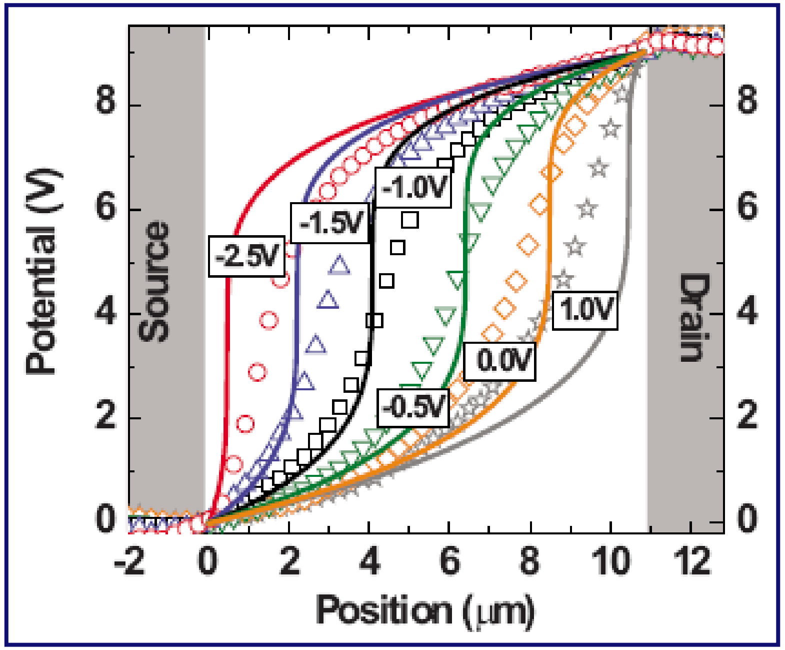
Confocal microscope / High fields
PPV



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

Electrostatic technique

Scanning Kelvin Probe Microscope (SKPM)
NiDT

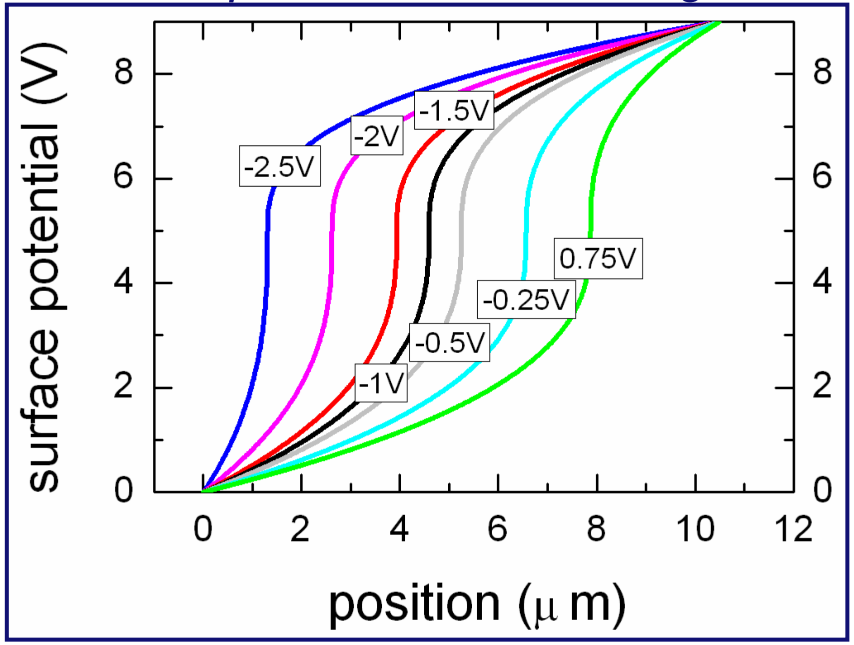


E.C.P. Smits *et al*, Phys. Rev. B **76**, 125202 (2007)

$W_{experimental} \sim 2\ \mu m$

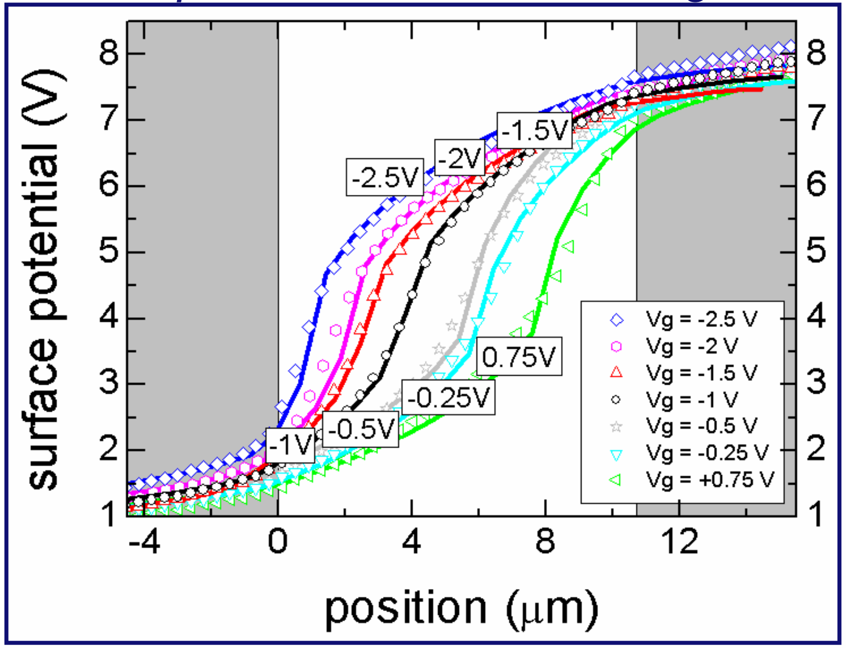
SKPM Response for FET

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



Assumption:
W = “0” nm

SKPM
experiments + 3D modeling

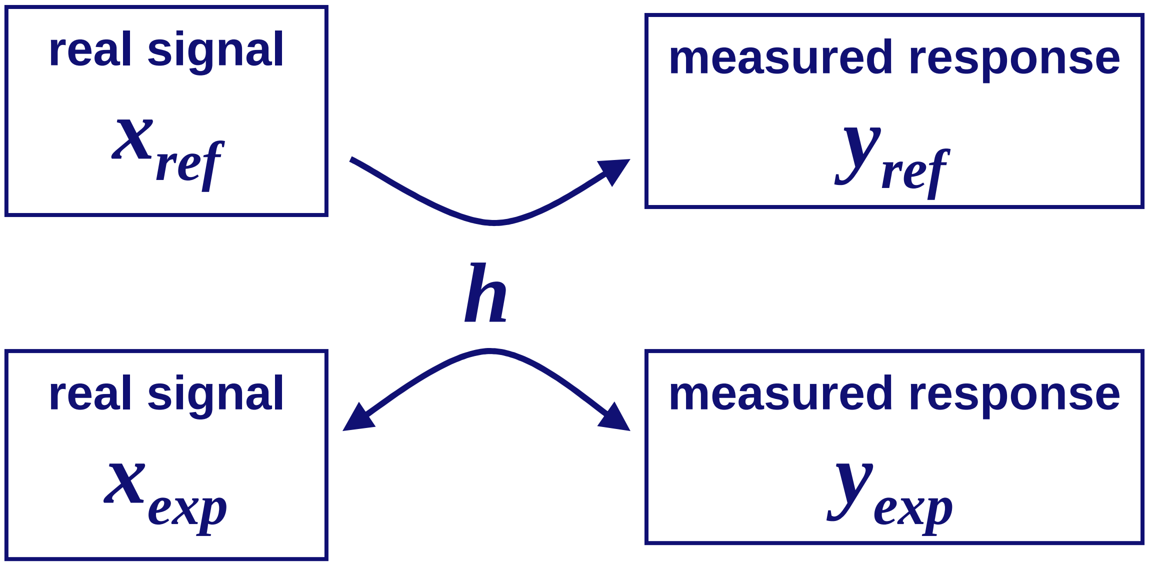


‘real’ *W* < 0.5 micron

One curve = 13 hours !

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

Simple prediction/reconstruction



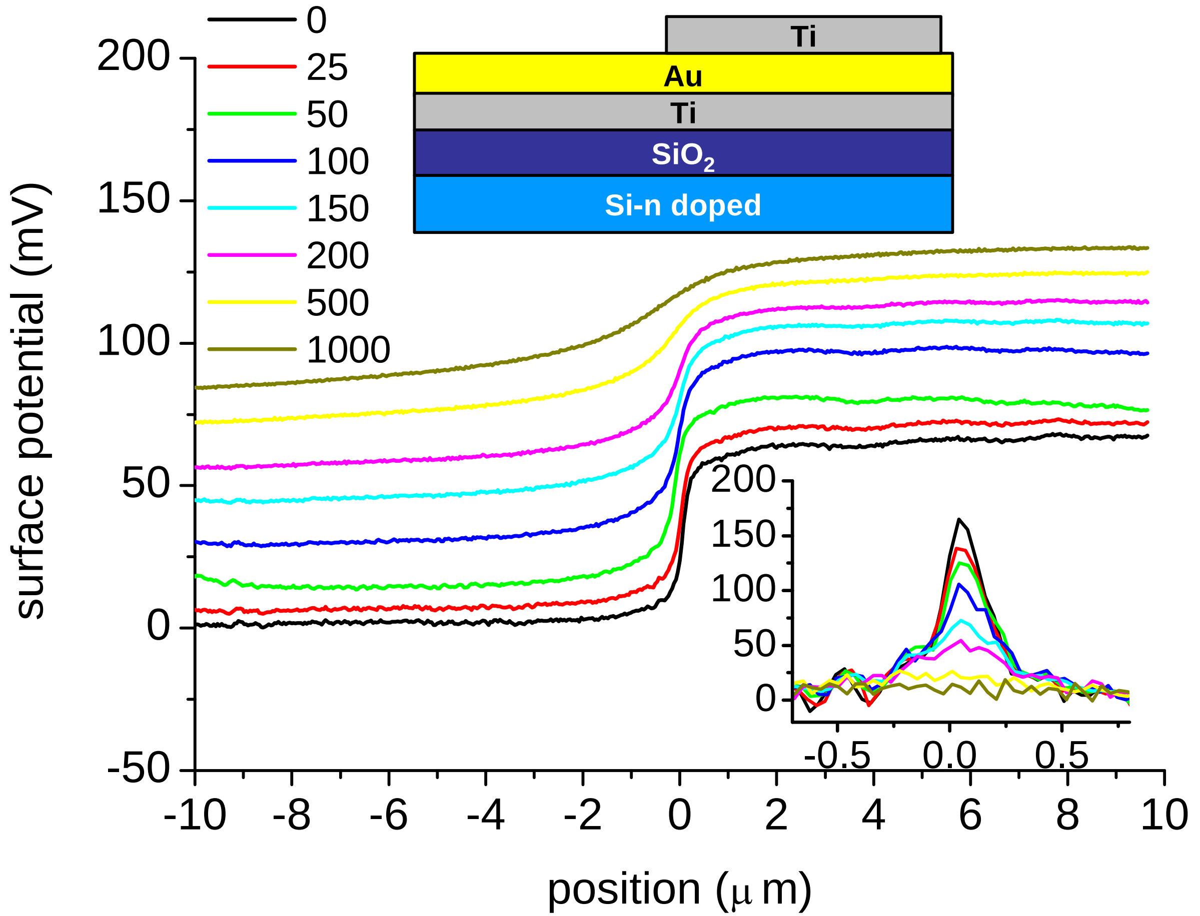
$$y_{ref}(x) = h_{ref}(x) \otimes x_{ref}(x)$$

$$F(y) = F(h)F(x)$$

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



$$F(h) = Y_{step}$$

prediction:

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

inversion:

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

Prediction from step edge response

real signal

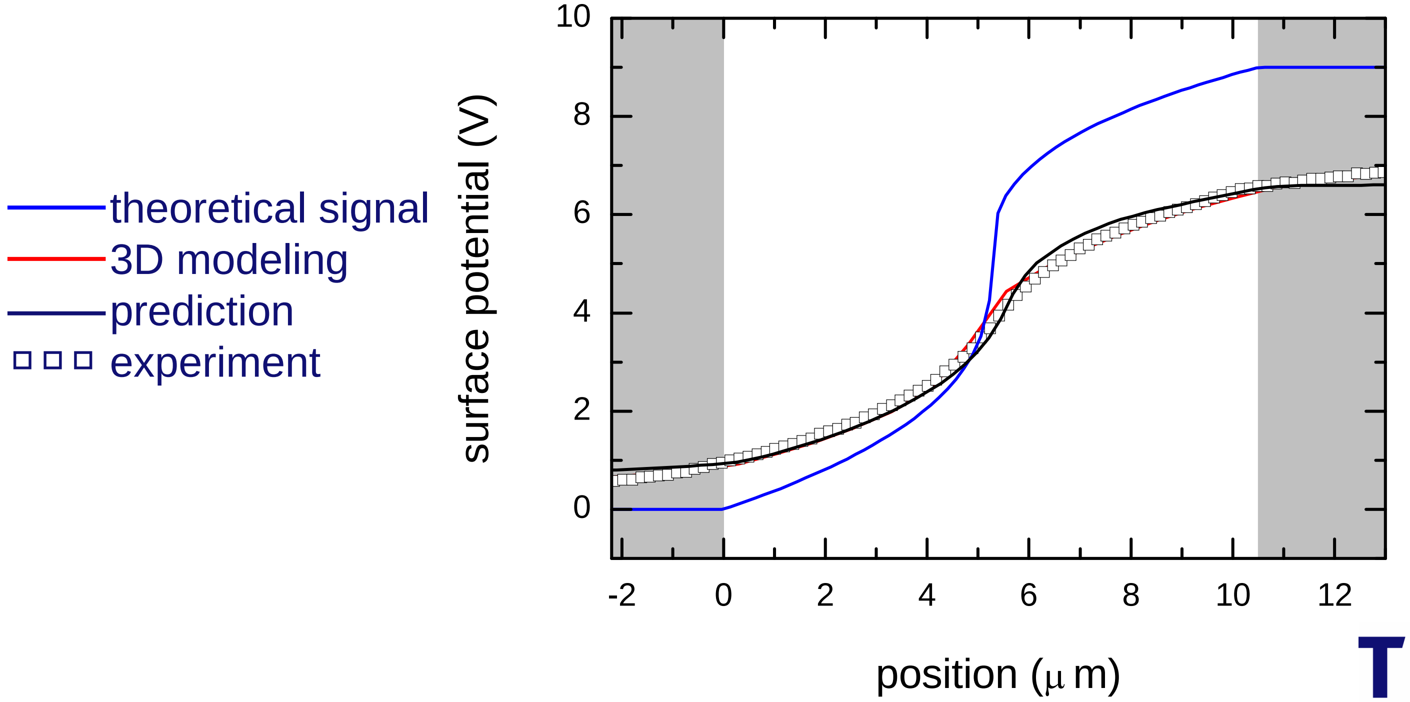
x_{exp}

W = “0” nm

measured response

y_{exp}

$W_{predicted}$ < 700 nm



Reconstruction from step edge response

$W_{inversed} - W_{theoretical} = 0.5 - 0.5 = 0\ \mu m$

real signal

x_{exp}

$W_{inversed} = 0.5\ \mu m$

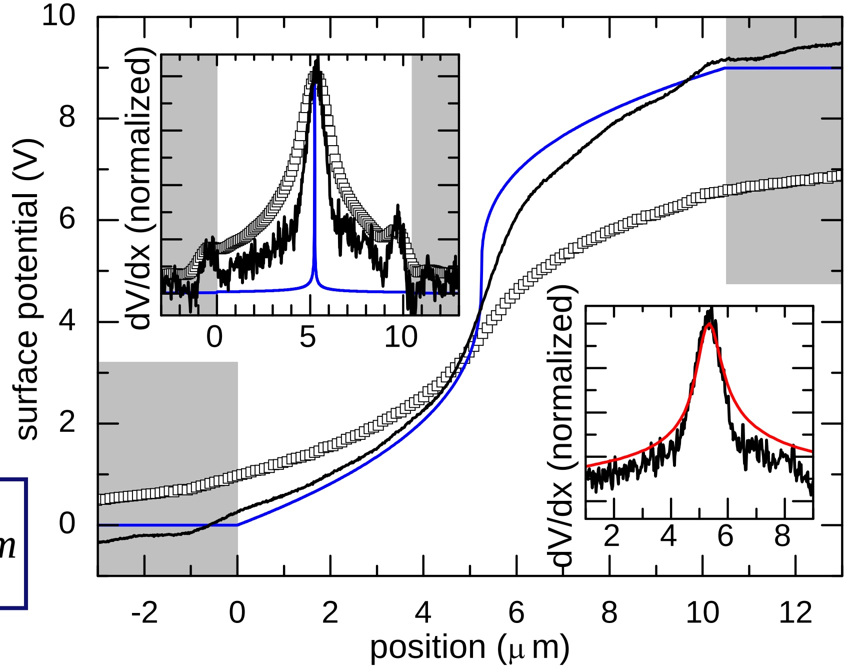
measured response

y_{exp}

$W_{experiment} \sim 2\ \mu m$

- theoretical signal
- calculated with β = 100 μm
- reconstruction
- □□□ experiment

$$W_{theoretical} = \frac{\sqrt{4.34 d\delta}}{\sqrt{100}} = 0.5\mu m$$



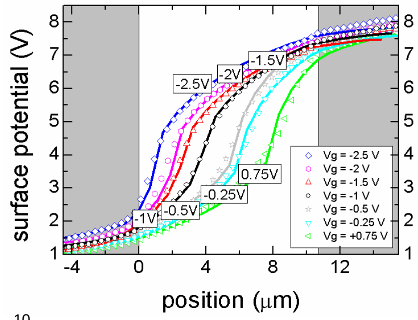
Summary

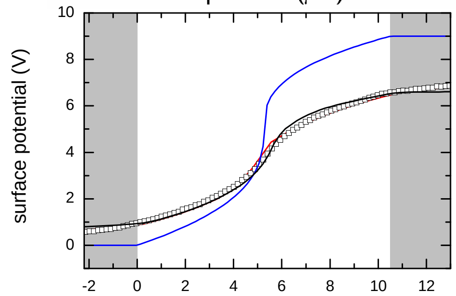
- **Electrostatic tip-electrodes convolution leads to amplitude loss of measured surface potential with SKPM. Good agreement between experiments and 3D modeling.**

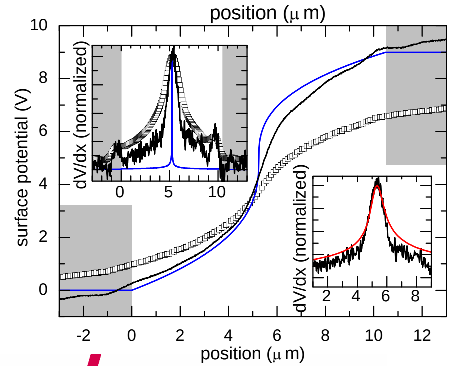
- **Prediction and Reconstruction methods successfully working using the step edge response tool.**

- **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 (β=100) 0 µm**







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