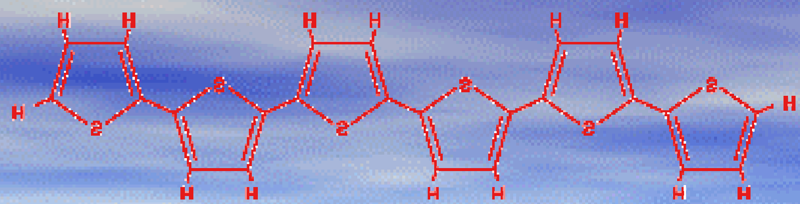
MONA-LISA

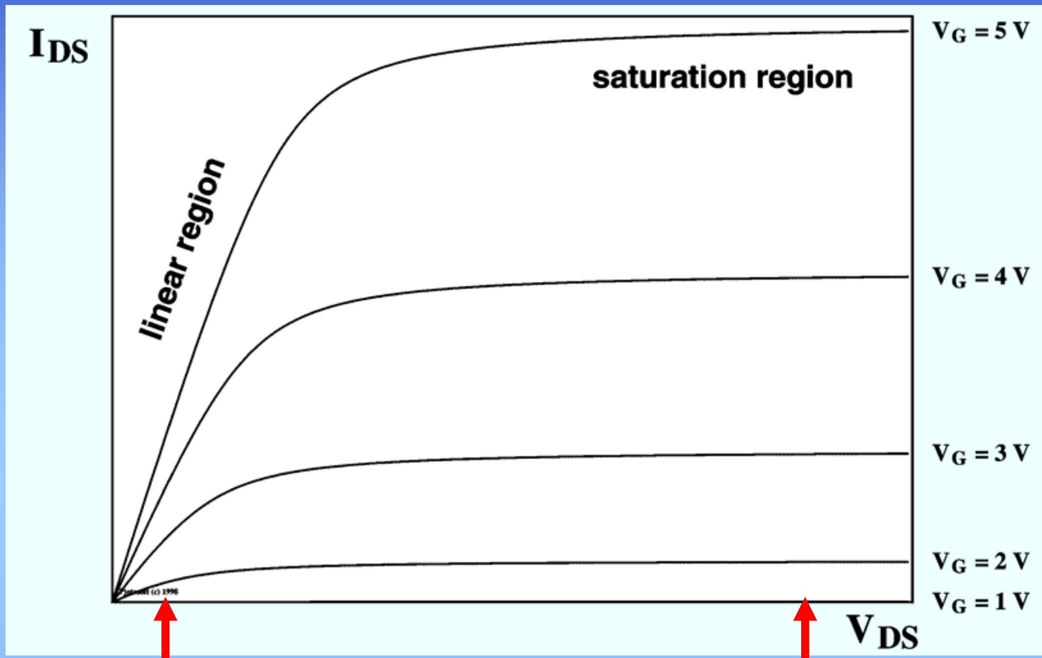


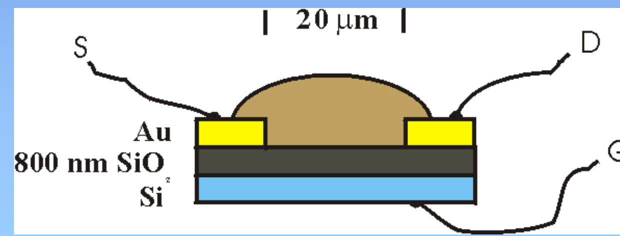
Electrical Measurements on FETs of T6

P. Stallinga, H.L. Gomes

Madrid, December 2001

Standard FETs

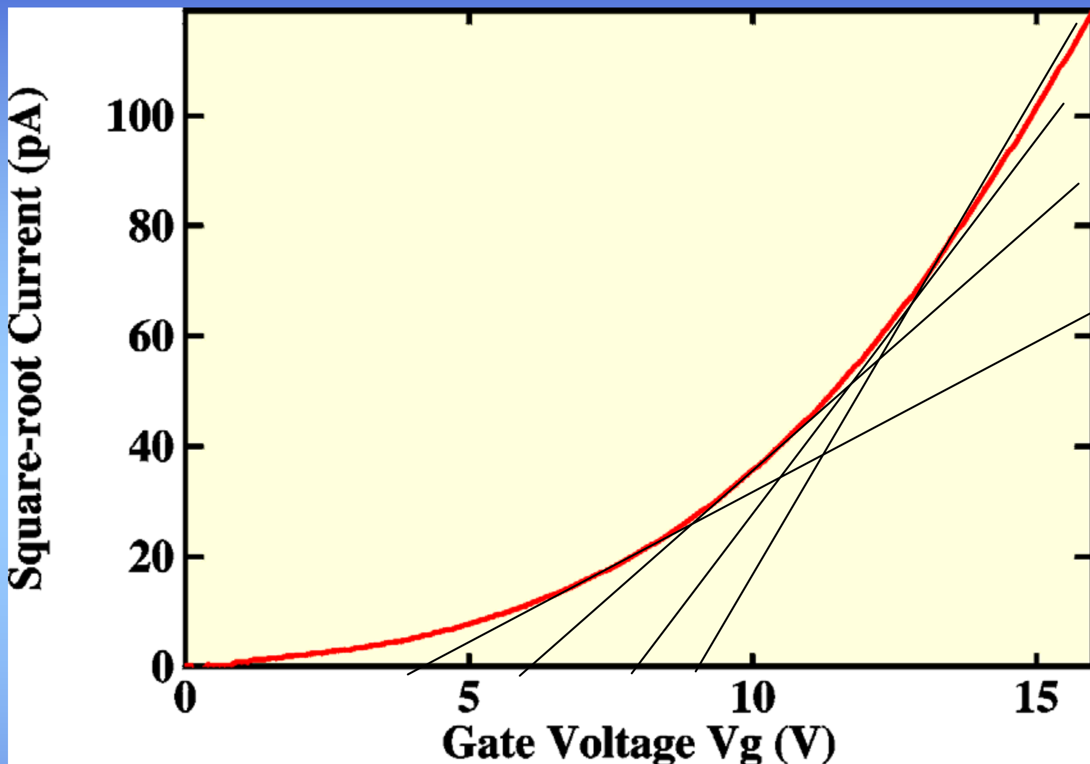




FET in linear region: $$I_{DS} = \frac{Z}{L}\mu_p C_i (V_G - V_T) V_D$$

FET in saturation region: $$I_{DS} = \frac{mZ}{L}\mu_p C_i (V_G - V_T)^2$$

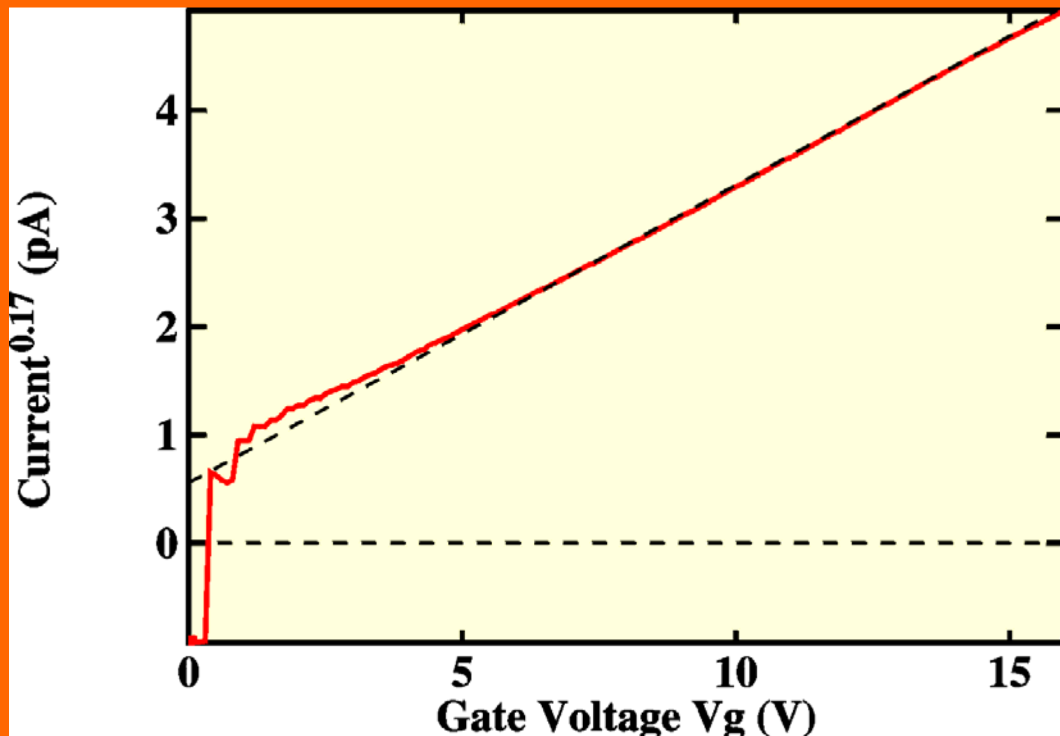
Previous results



Mobility changes as function of gate voltage

Previous results

SAT:



Perfect straight line when plotted as 6th-root of current vs. Vg

$I_{ds} \sim (V_g - V_t)^6$

Linear region

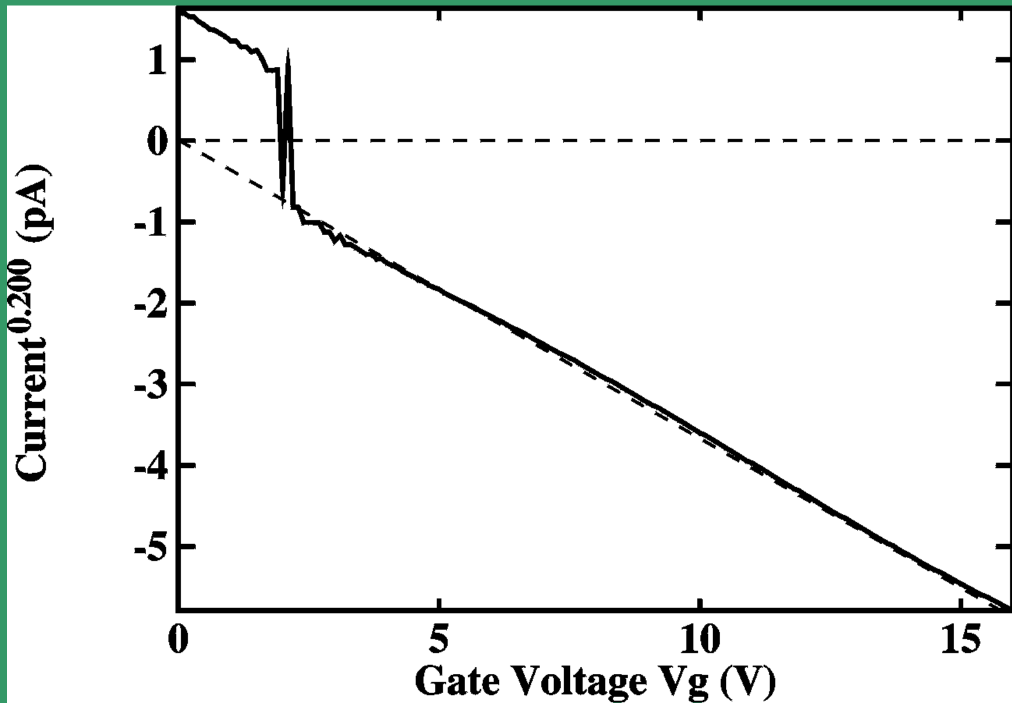
FET in saturation region: $$I_{DS} = \frac{mZ}{L}\mu_p C_i \left(V_G - V_T\right)^2$$

FET in linear region: $$I_{DS} = \frac{Z}{L}\mu_p C_i \left(V_G - V_T\right)V_D$$

SAT: $I_{DS} \sim V_G^{\,a}$ $\Longrightarrow$ LIN: $I_{DS} \sim V_G^{\,a-1}$

New results. Linear region

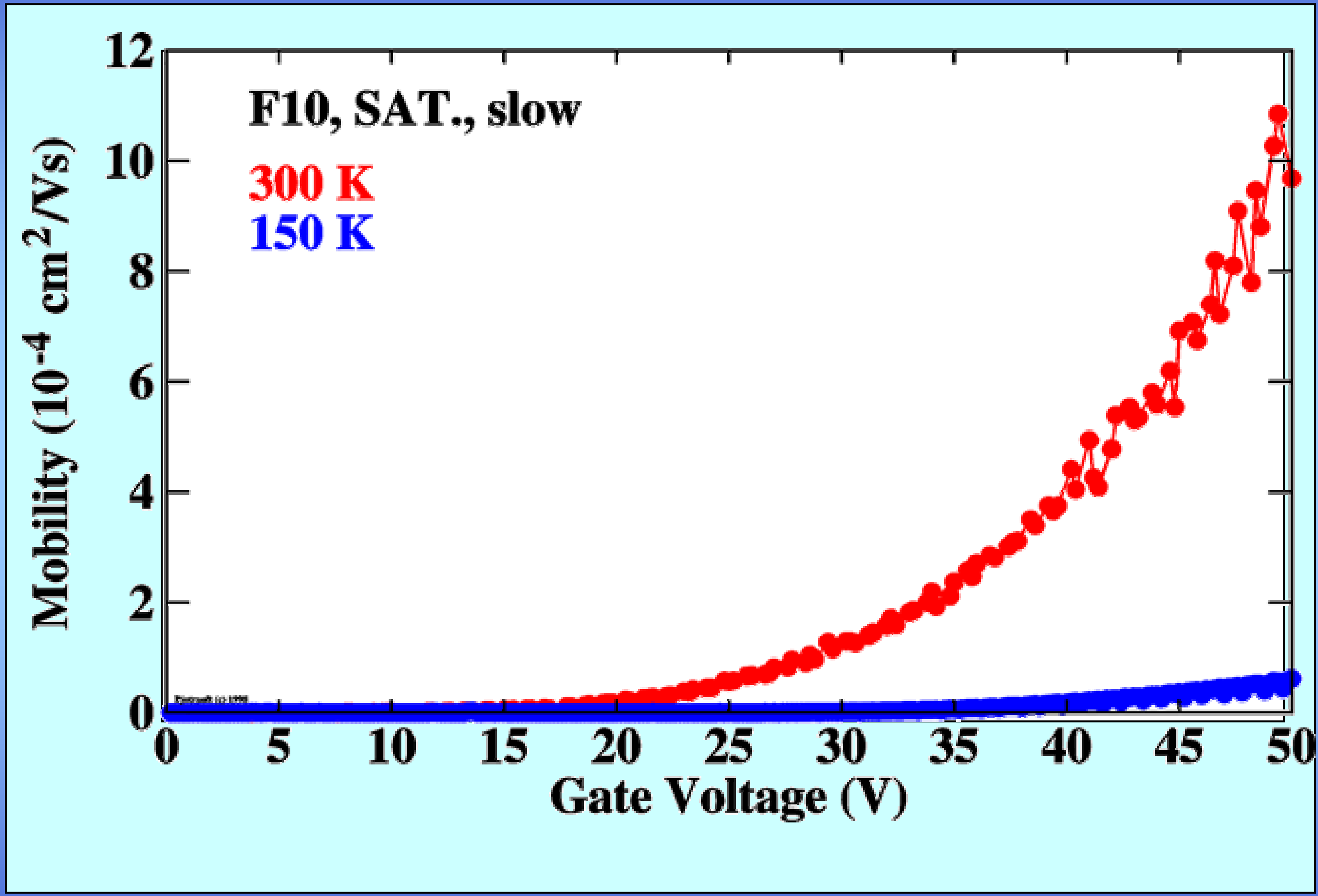
LIN:



Plotted as 5th-root. Consistent with Saturation-region data

$$I_{ds} \sim V_{ds} (V_g - V_t)^5$$

Mobility



Gate-voltage-dependent mobility up to 1×10^{-3} cm^2/Vs

Variable Range Hopping

PHYSICAL REVIEW B VOLUME 57, NUMBER 20 15 MAY 1998-II

Theory of the field-effect mobility in amorphous organic transistors

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(Received 13 January 1998)

The field-effect mobility in an organic thin-film transistor is studied theoretically. From a percolation model of hopping between localized states and a transistor model an analytic expression for the field-effect mobility is obtained. The theory is applied to describe the experiments by Brown *et al.* [Synth. Met. **88**, 37 (1997)] on solution-processed amorphous organic transistors, made from a polymer (polythienylene vinylene) and from a small molecule (pentacene). Good agreement is obtained, with respect to both the gate voltage and the temperature dependence of the mobility. [S0163-1829(98)01320-4]

JOURNAL OF APPLIED PHYSICS VOLUME 85, NUMBER 6 15 MARCH 1999

Gate voltage dependent mobility of oligothiophene field-effect transistors

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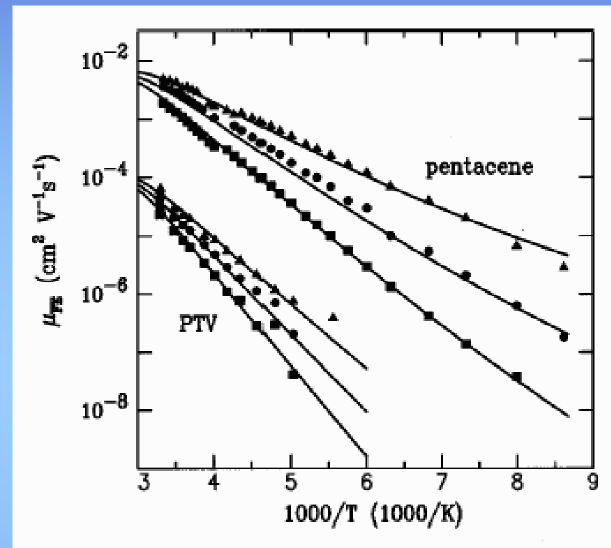
(Received 5 May 1998; accepted for publication 8 December 1998)

Organic field-effect transistors, in which the active semiconductor is made of oligothiophenes of various lengths, have been fabricated and characterized. A method is developed to estimate the field-effect mobility μ corrected for the contact series resistance. The mobility is found to increase by a factor of nearly 100 from quaterthiophene (4T) to octithiophene (8T). More importantly, μ increases quasilinearly with gate voltage. The origin of this gate bias dependence is discussed. One explanation could be the presence of traps that limit charge transport. Alternatively, the gate-voltage dependence is tentatively attributed to a dependence of the mobility with the concentration of carriers in the accumulation layer.
[S0021-8979(99)02506-2]

Variable Range Hopping

Vissenberg and Matters

$$\mu_{\mathrm{FE}}=\frac{\sigma_0}{e}\left(\frac{\pi(T_0/T)^3}{(2\alpha)^3 B_c\Gamma(1-T/T_0)\Gamma(1+T/T_0)}\right)^{T_0/T} \times\left[\frac{(C_i V_G)^2}{2k_B T_0\epsilon_s}\right]^{T_0/T-1},$$



$\mu = V_G$ ^ $2(T_0/T-1)$

SAT: $I_{ds} = V_G$ ^ $2T_0/T$

LIN: $I_{ds} = V_G$ ^ $2T_0/T-1$

	$\sigma_0(10^{10}$ S/m)	α^{-1} (Å)	T_0 (K)
Pentacene	1.6	2.2	385
PTV	0.7	0.8	380

caution

Gate-dependent mobility, Just as we need!

In saturation. Sample F10

Vissenberg

SAT: → $I_{ds} \sim V_G \wedge 2T_0/T$

$I_{ds} \sim (V_G - V_T) \wedge a$

$a = 2\, T_0/T$

$\log(I_{ds}) = a \log(V_G\text{-}V_T) + C$

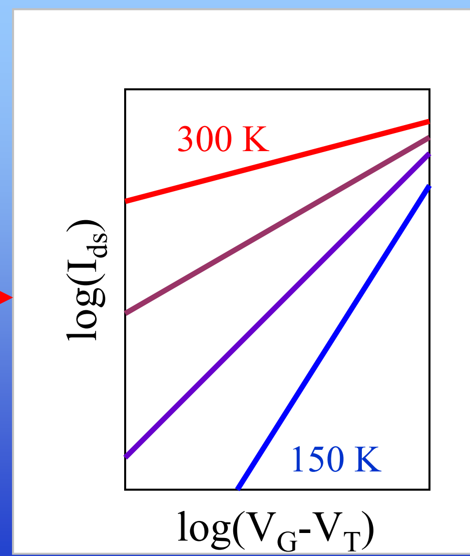
F10 300 K

Faro

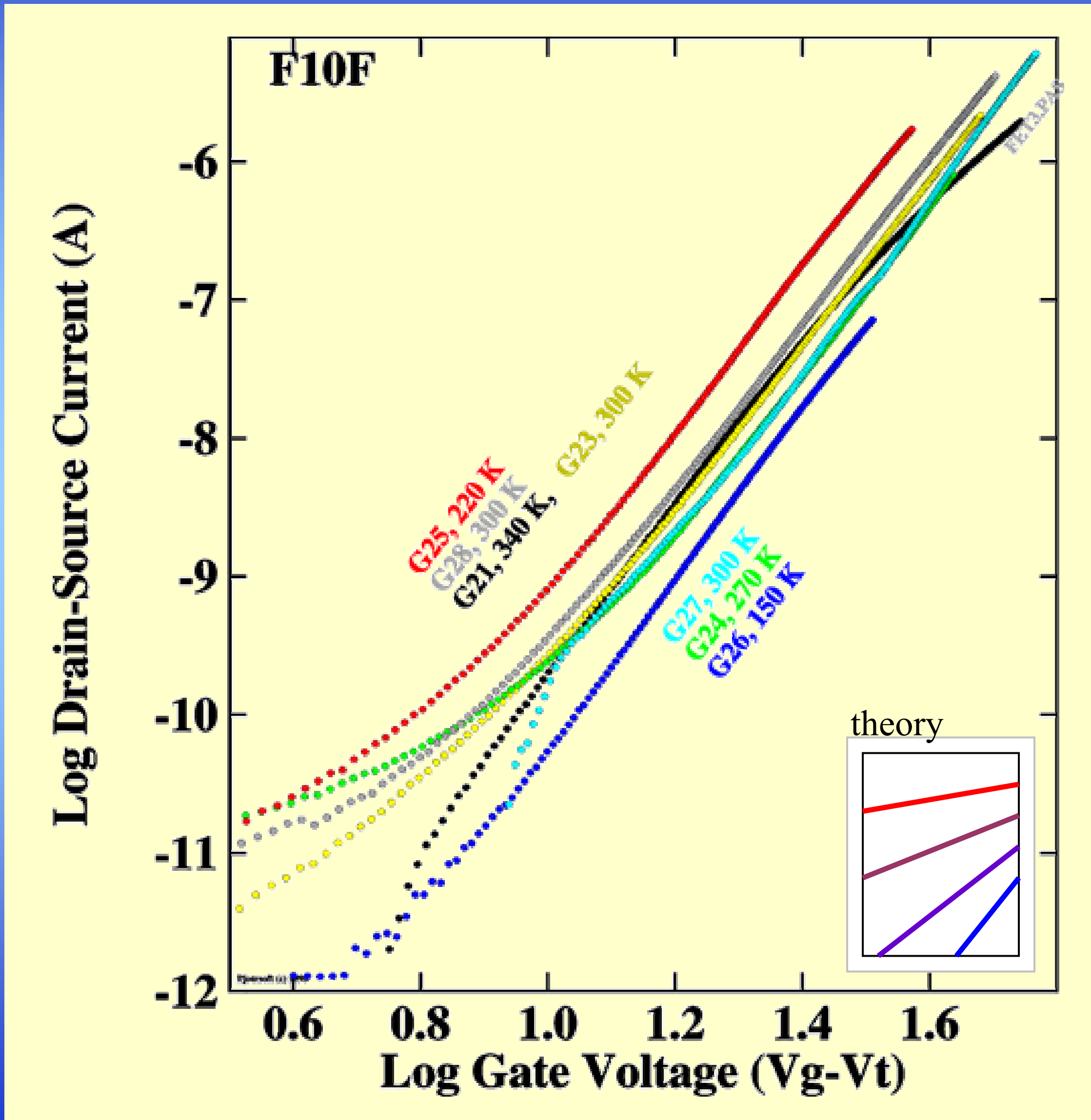
$a = 6$

$T_0 = 900$ K

Prediction



Sample F10



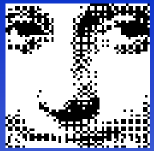
Each line represents a transfer curve at a different temperature

VRH $a = 2\ T_0/T$

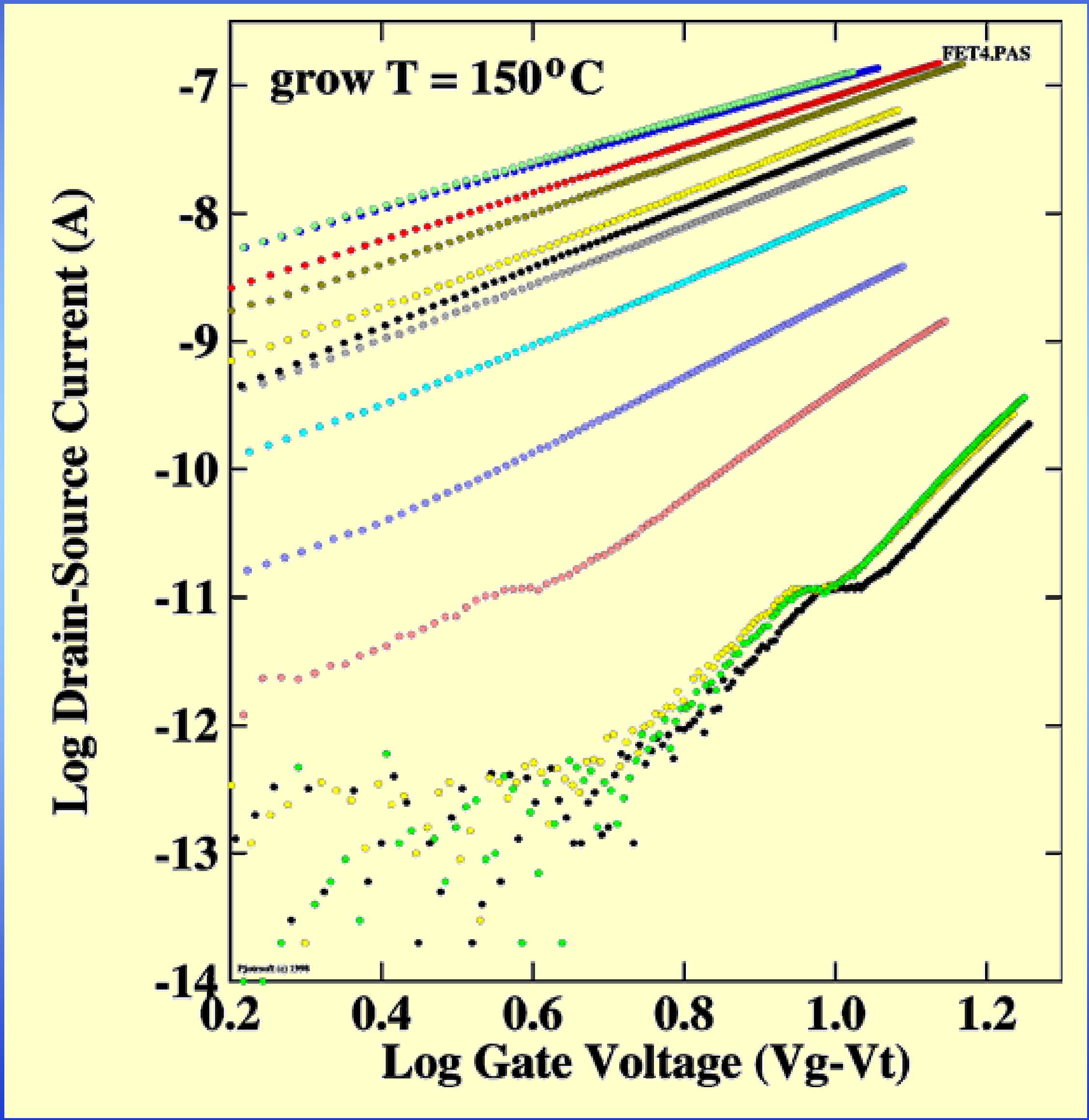
Slopes ‘a’ independent of temperature!

Failure of VRH theory!

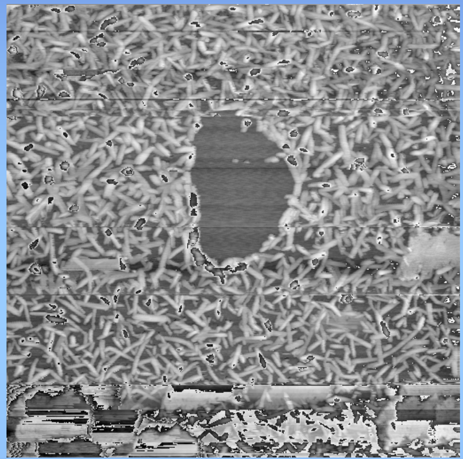
Tunneling conduction?



Sample 8 nm 150 ºC



Each line represents a transfer curve at a different temperature

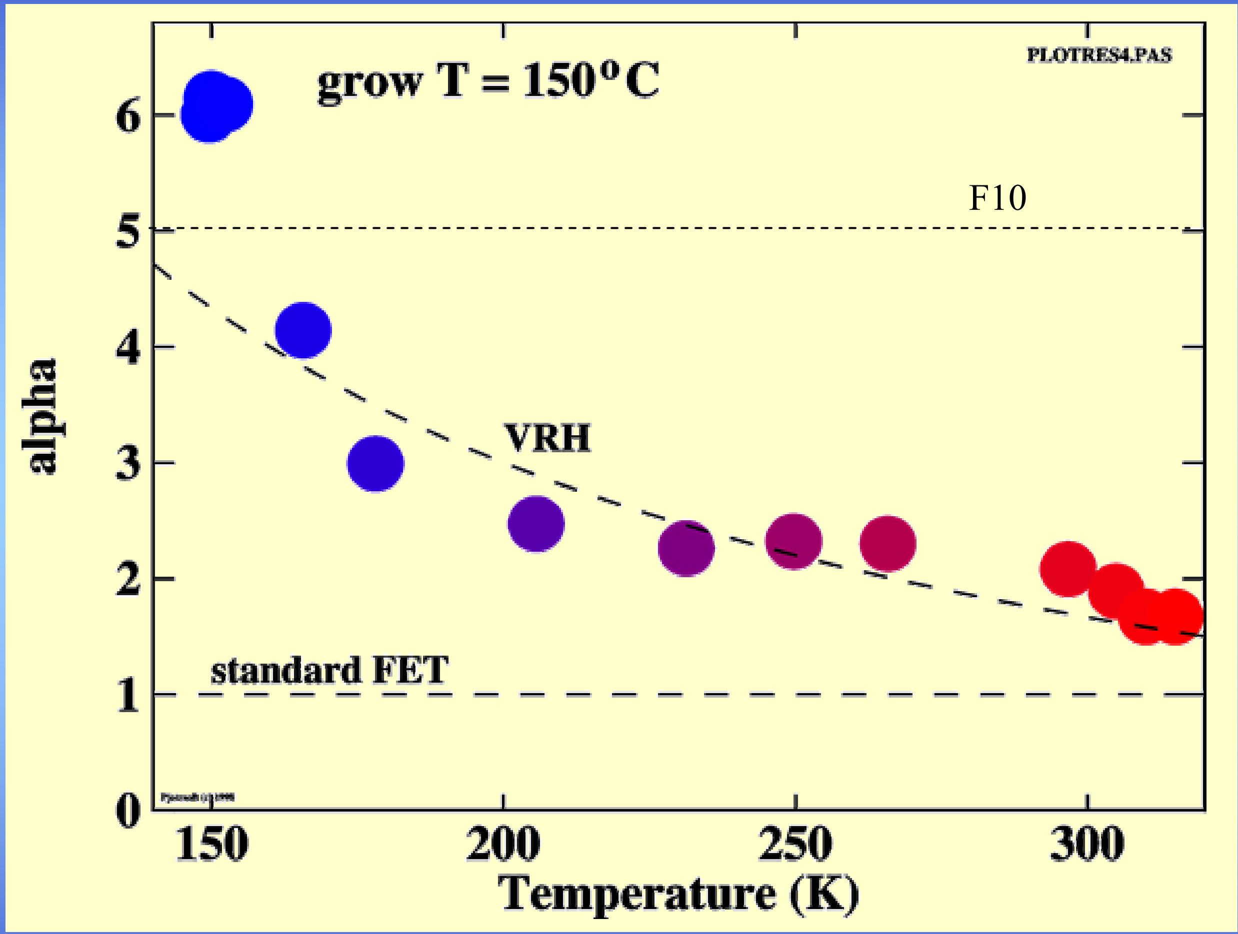


5*5 μm^2

Slopes 'a' depend on temperature!

VRH works?

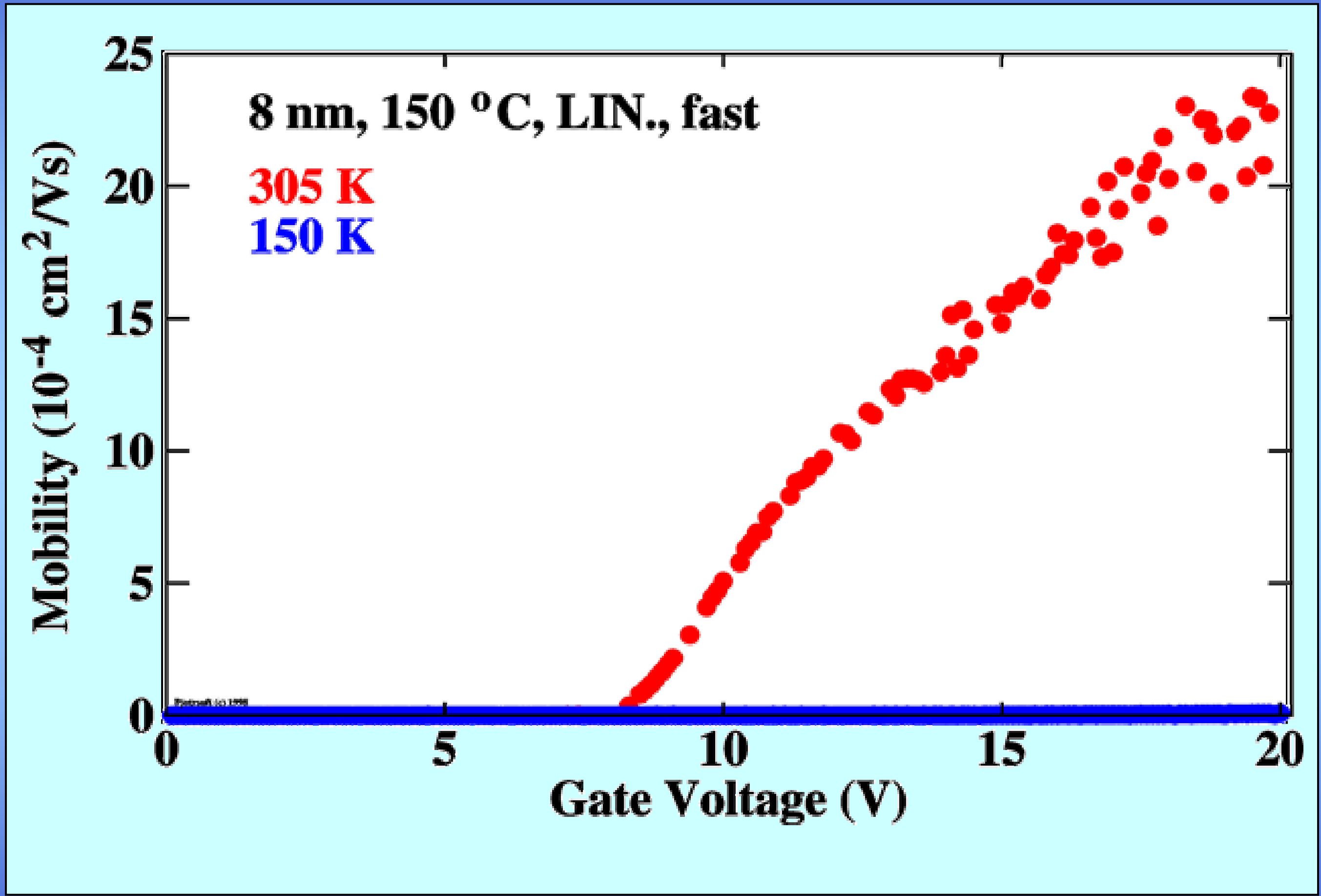
Sample 8 nm 150 °C



Each dot represents the slope in a transfer curve at a different temperature

Slopes 'a' not well predicted by VRH

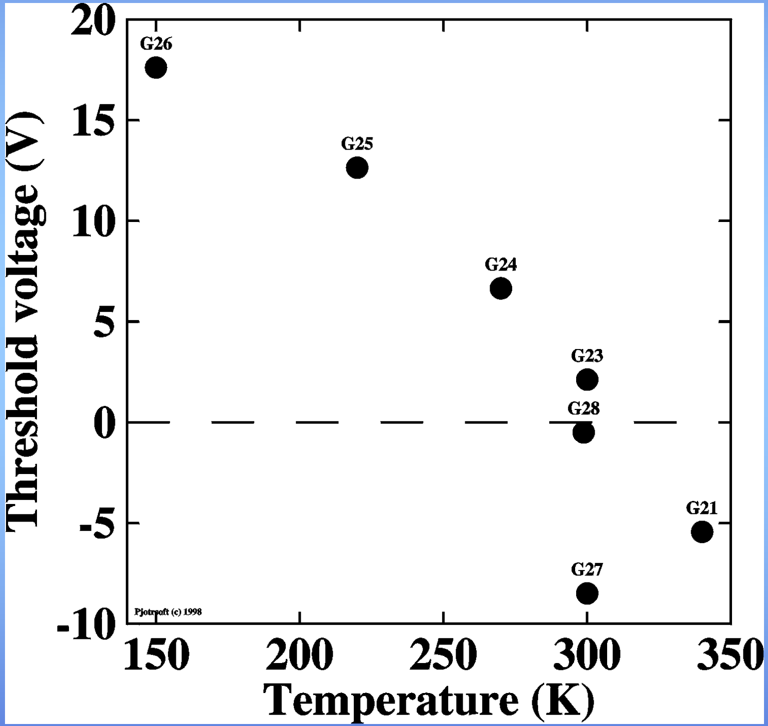
Mobility



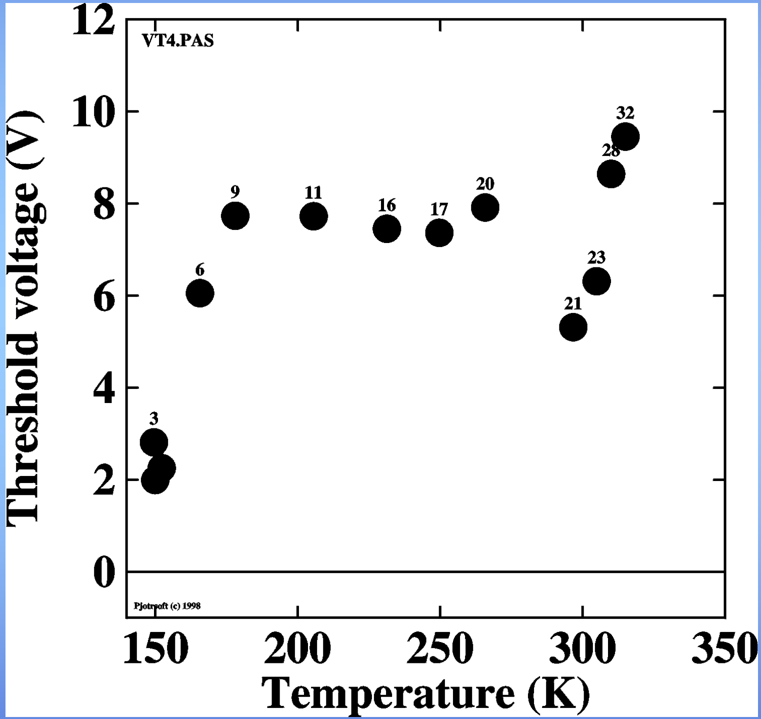
Gate-voltage-dependent mobility up to 2.5×10^{-3} cm^2/Vs

Threshold voltage

Sample F10

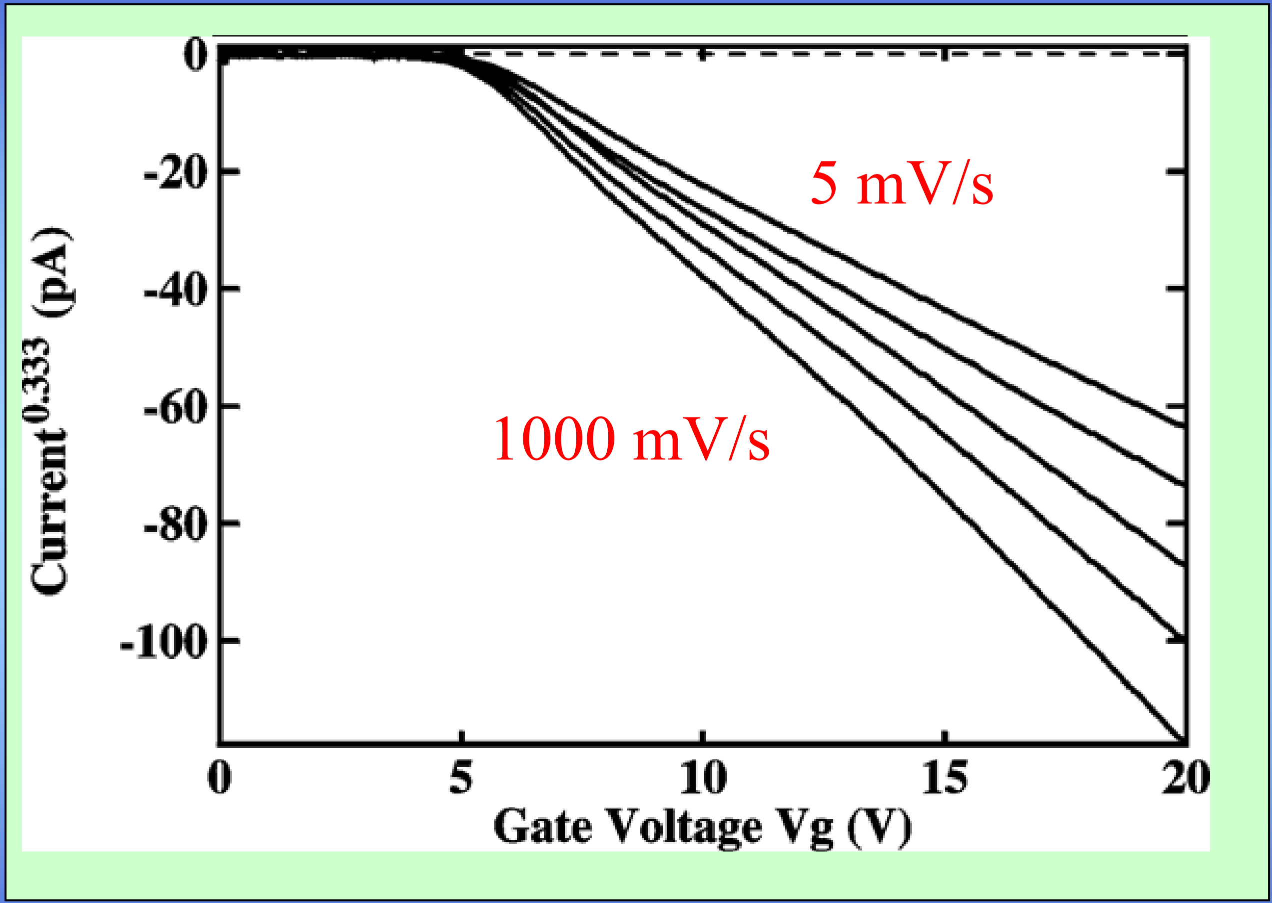


Sample 150 ^{o}C



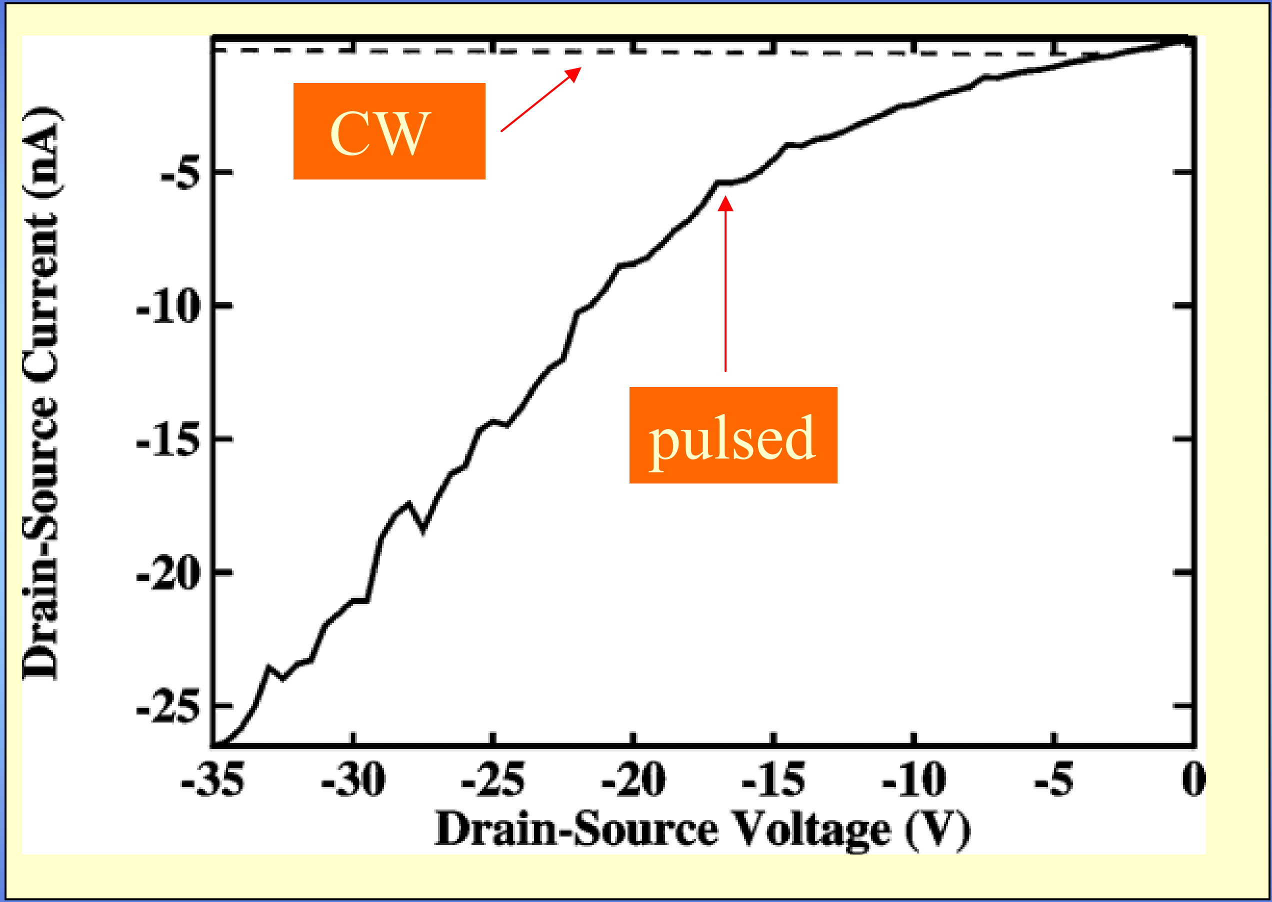
Impurity levels freeze out in F10 and not in ‘150 ^{o}C’

Measurement conditions: speed



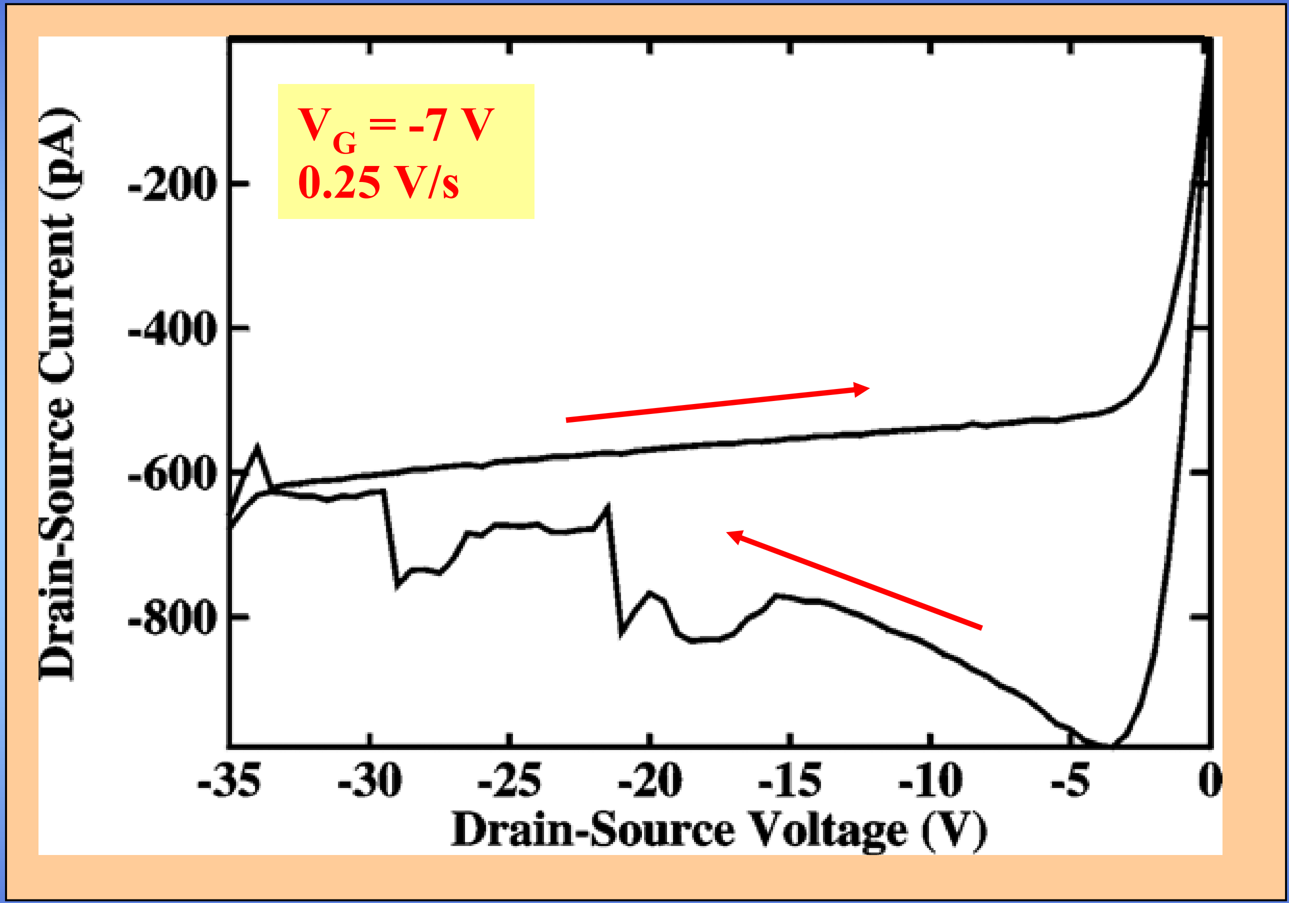
Measured mobility depends dramatically on scanning speed!

Measurement conditions: pulsed



For pulsed measurements we get even higher currents

Measurement conditions: hysteresis



Large hysteresis. Better studied with transient spectroscopy

Conclusions

- Gate-voltage-dependent mobility
- Mobilities up to 2.5 10^{-3} cm^2/Vs
- Analysed with Variable Range Hopping model
- VRH analysis result:
  - sample F10: wrong. Tunneling conduction?
  - sample 150 ^oC: not conclusive. More data needed
- Threshold voltage depends on temperature (deep level freeze-out?)
- Correlations: morphology, mobility, ‘a’, V_T
- Measurement conditions studied

Thank you

10 Q

for your attention