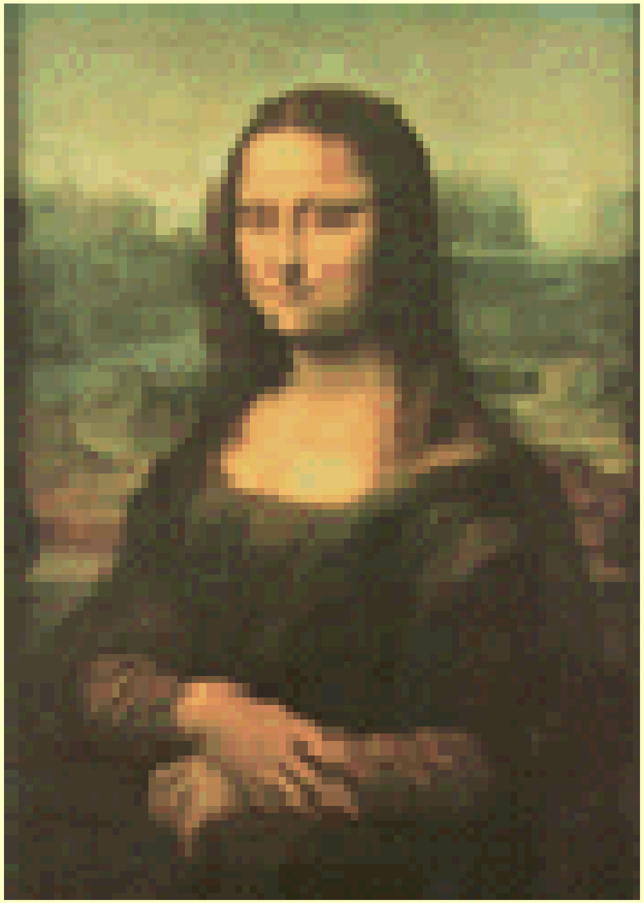
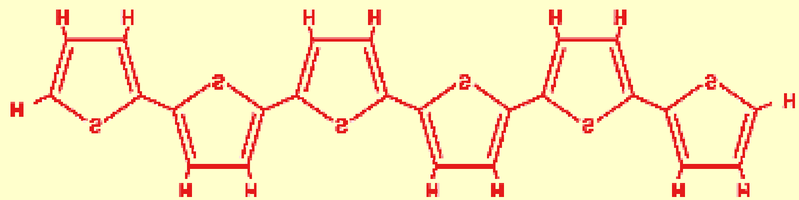
MONA-LISA



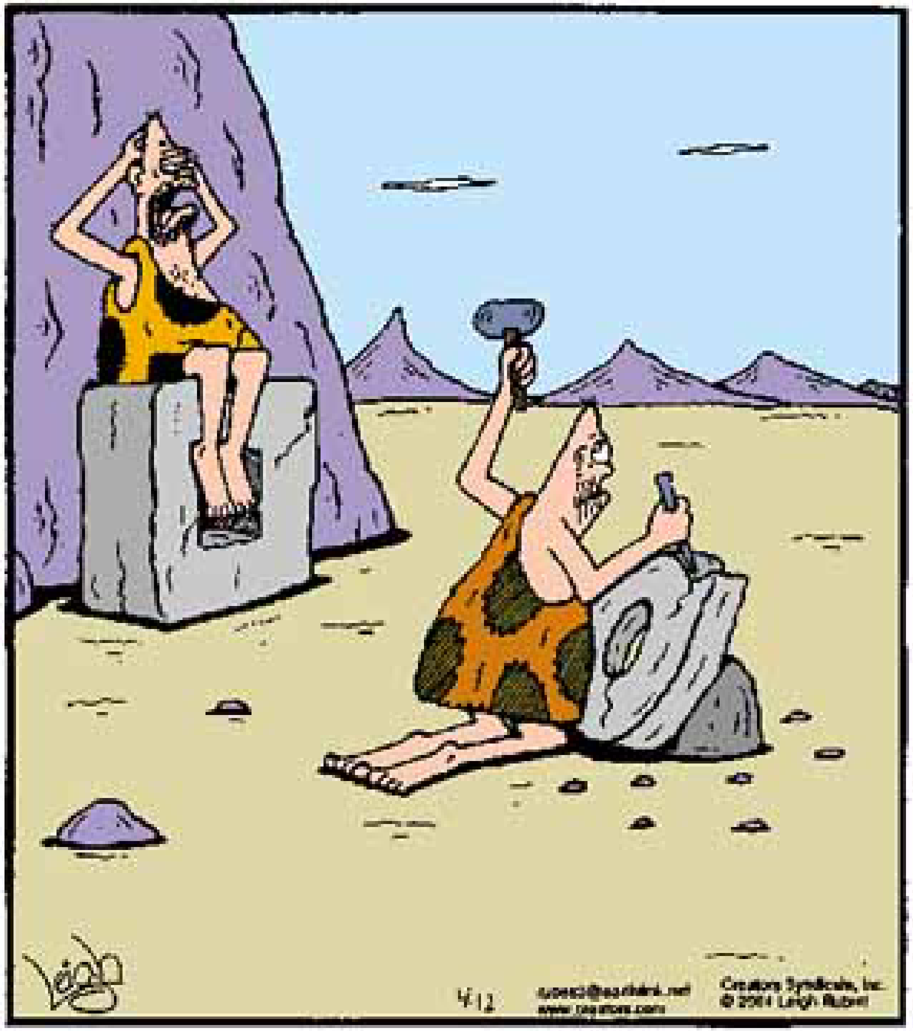
Electrical Measurements on FETs of T6



Faro, 29.06.2001

H.L. Gomes, P. Stallinga

Physics of FETs

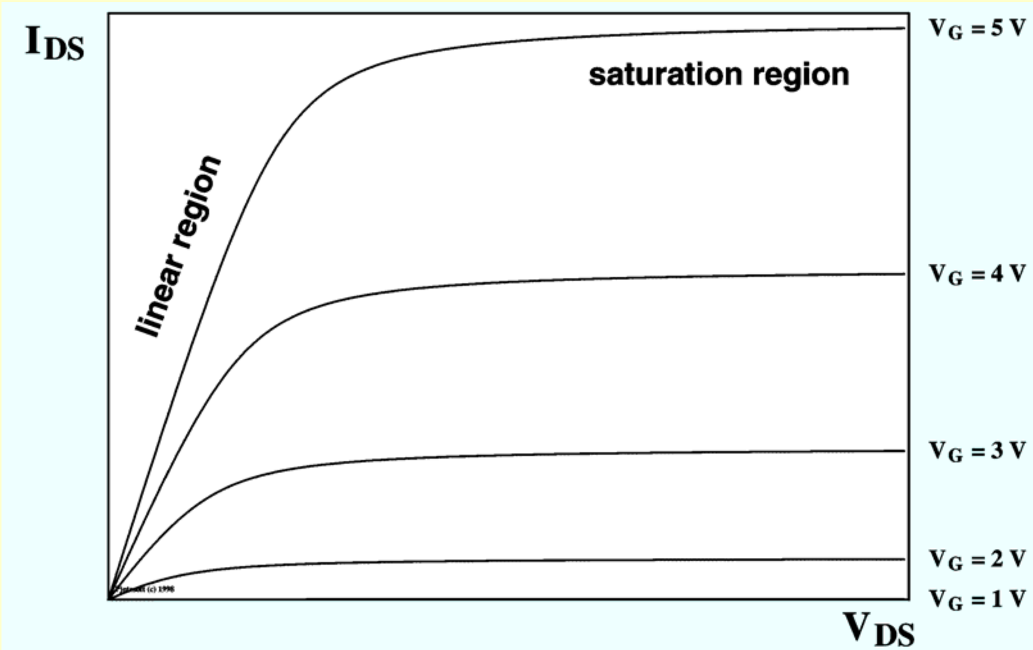


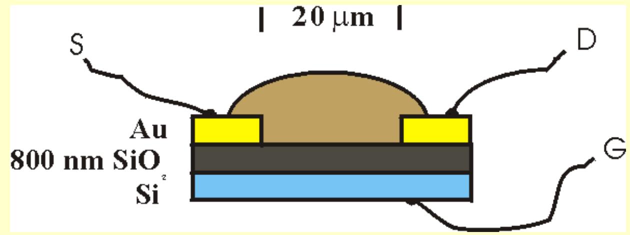
"I don't know why you're wasting your time. There's no point in reinventing the wheel."

Organic materials are like any other semiconductor

No point in reinventing the wheel

Physics of FETs

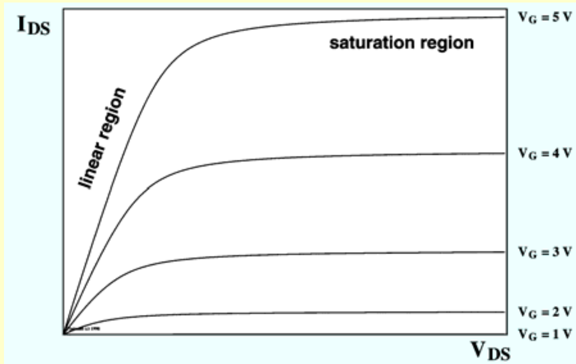




FET in linear region: $$I_{DS} = \frac{Z}{L}\mu_p C_i (V_G - V_T) V_D$$

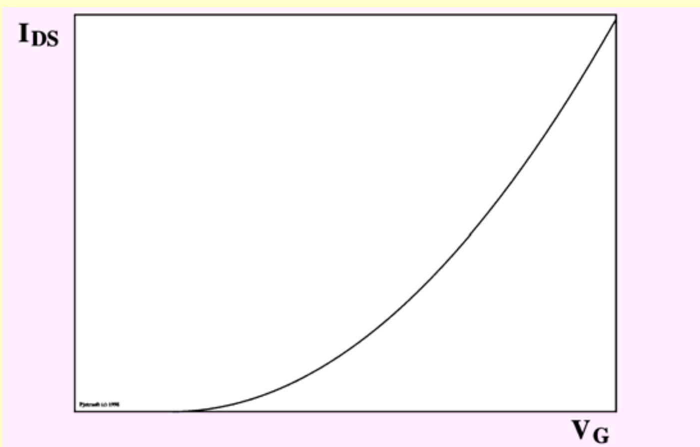
FET in saturation region: $$I_{DS} = \frac{mZ}{L}\mu_p C_i (V_G - V_T)^2$$

Standard FET curves; theory

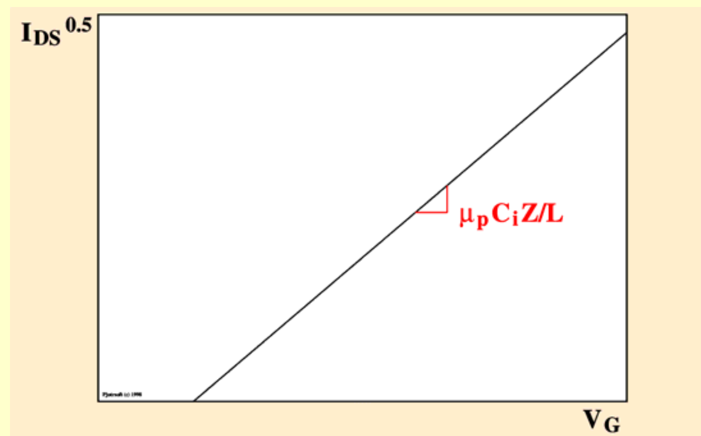


$$I_{DS} = \frac{mZ}{L}\mu_p C_i (V_G - V_T)^2$$

In saturation we can easily extract the mobility

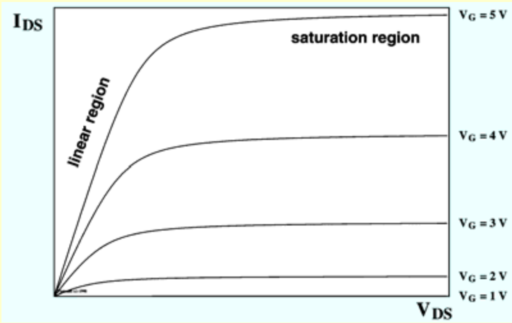


Linear plot



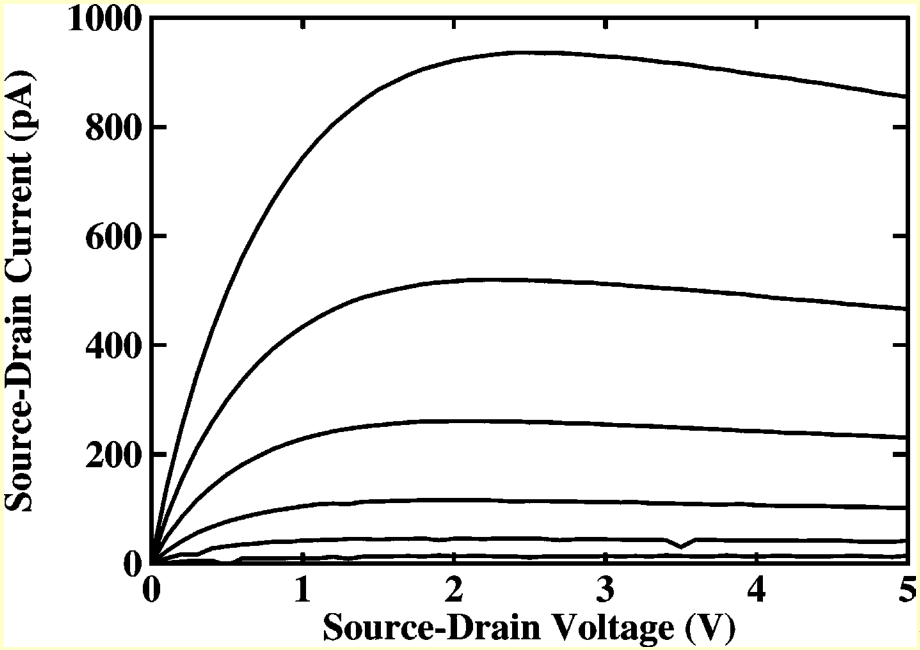
Square-root plot

Experimental αT6 FET curves



theoretical

experimental

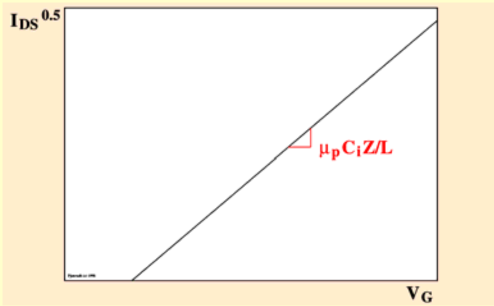


Vg = 0 … 5 V

Experimental curves
are close to theoretical ……

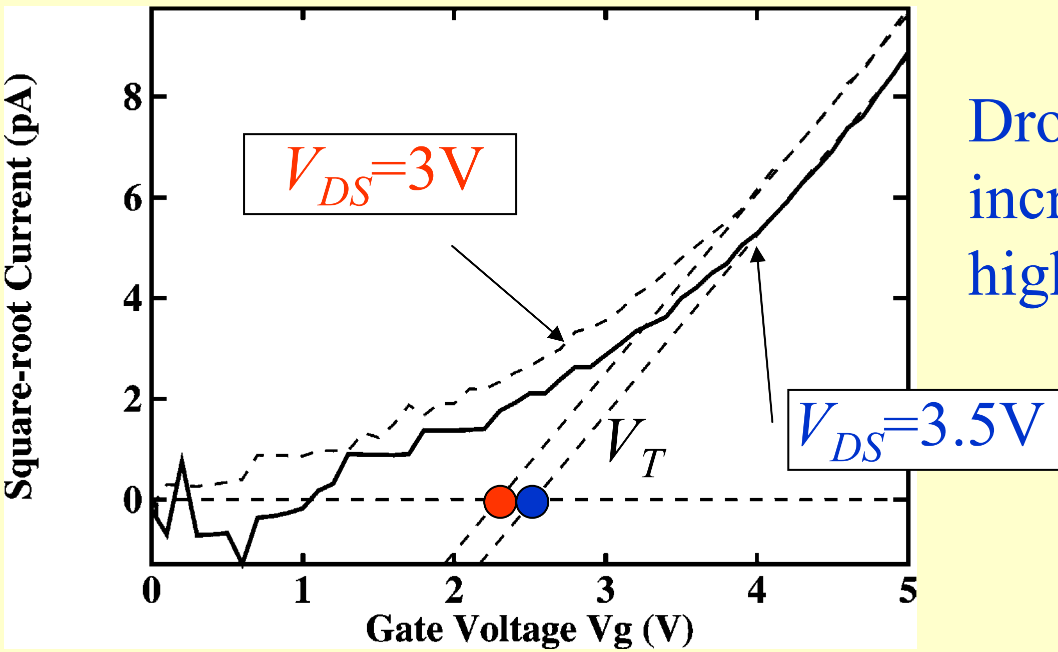
….. but not quite!

Experimental αT6 FET transfer curves



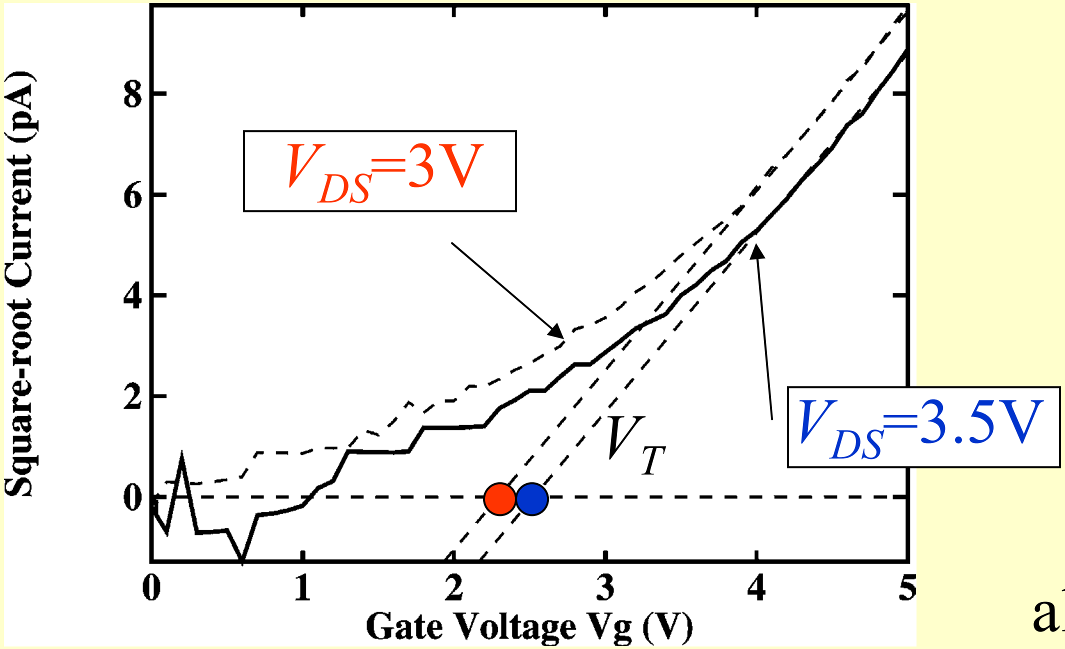
theoretical

experimental



Dropping off of current for increasing V_{DS} is due to higher threshold voltgae V_T

Experimental αT6 FET transfer curves



In saturation

V_T is V_{DS} dependent

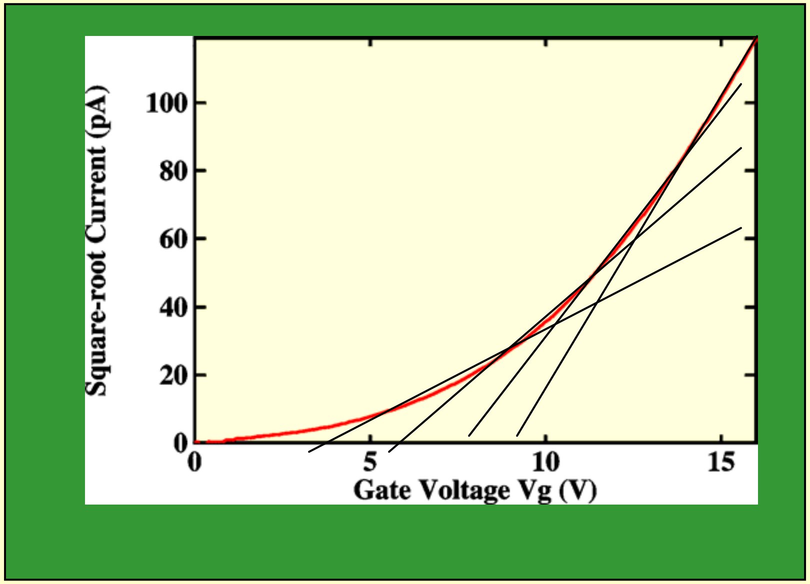
"For high(er) dopings, V_T also becomes V_G-dependent"

Sze, p. 442

$$V_T = \frac{1}{C_i}\sqrt{2\varepsilon_s q N_A (2\psi_B)} + 2\psi_B$$

For increased V_{DS} we have more free carriers N_A

Transverse Electric Field Dependence



Experimental:

Slope of transfer curve (mobility μ_p) depends on V_G (transverse electric field)

Higher field → higher mobility

Literature:
Higher field → lower mobility

Example (from Sze, p.449):

"At a given temperature, mobility decreases with increasing effective transverse field"

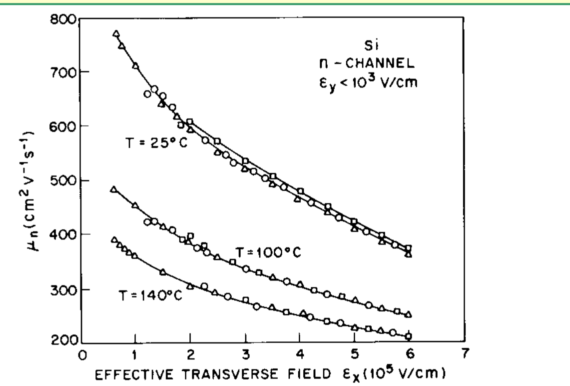
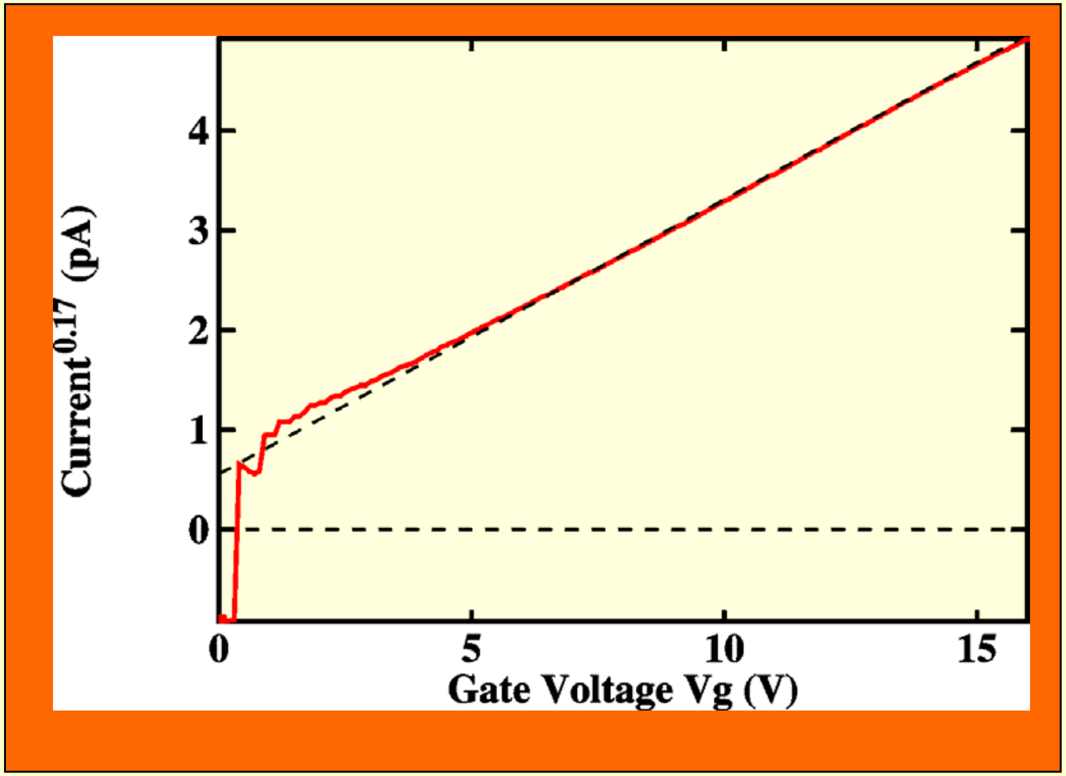


Fig. 13 Inversion layer mobility versus effective transverse field for three temperatures. (After Sabnis and Clemens, Ref. 24.)

6th Power law



Same data plotted as

$$\sqrt[6]{I_{DS}} \quad \text{vs} \quad V_g$$

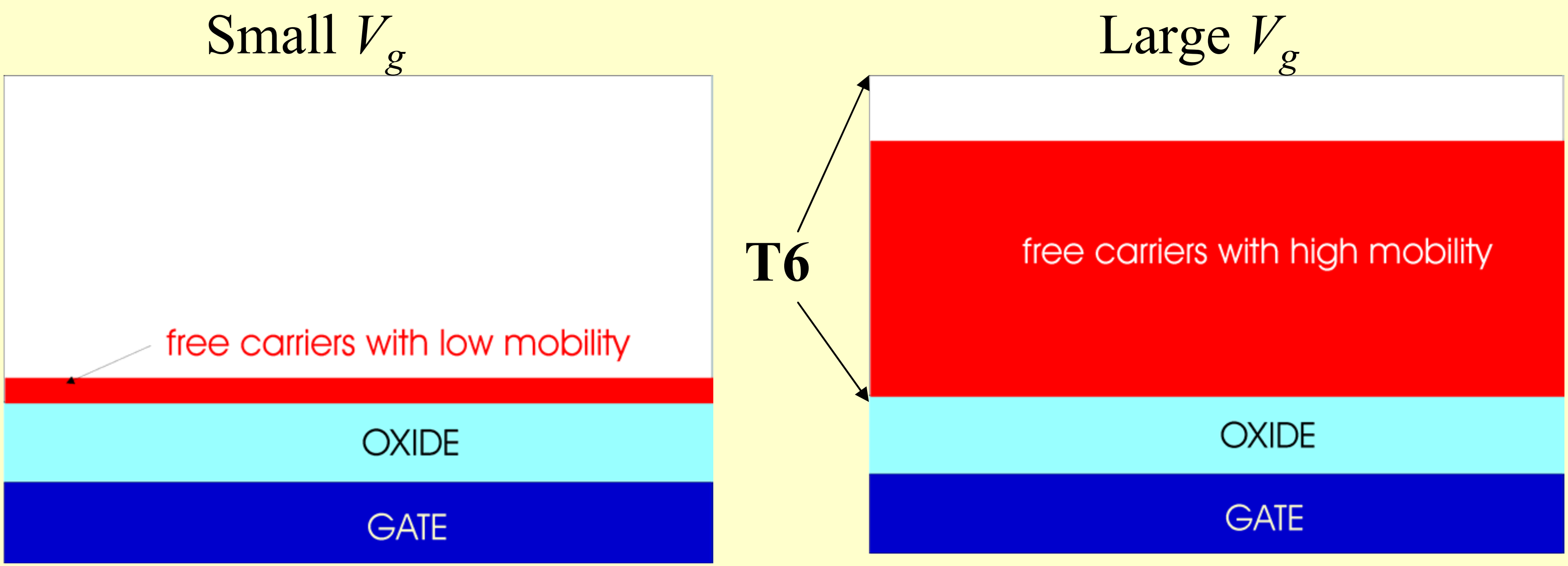
gives straight line

3 times better FETs

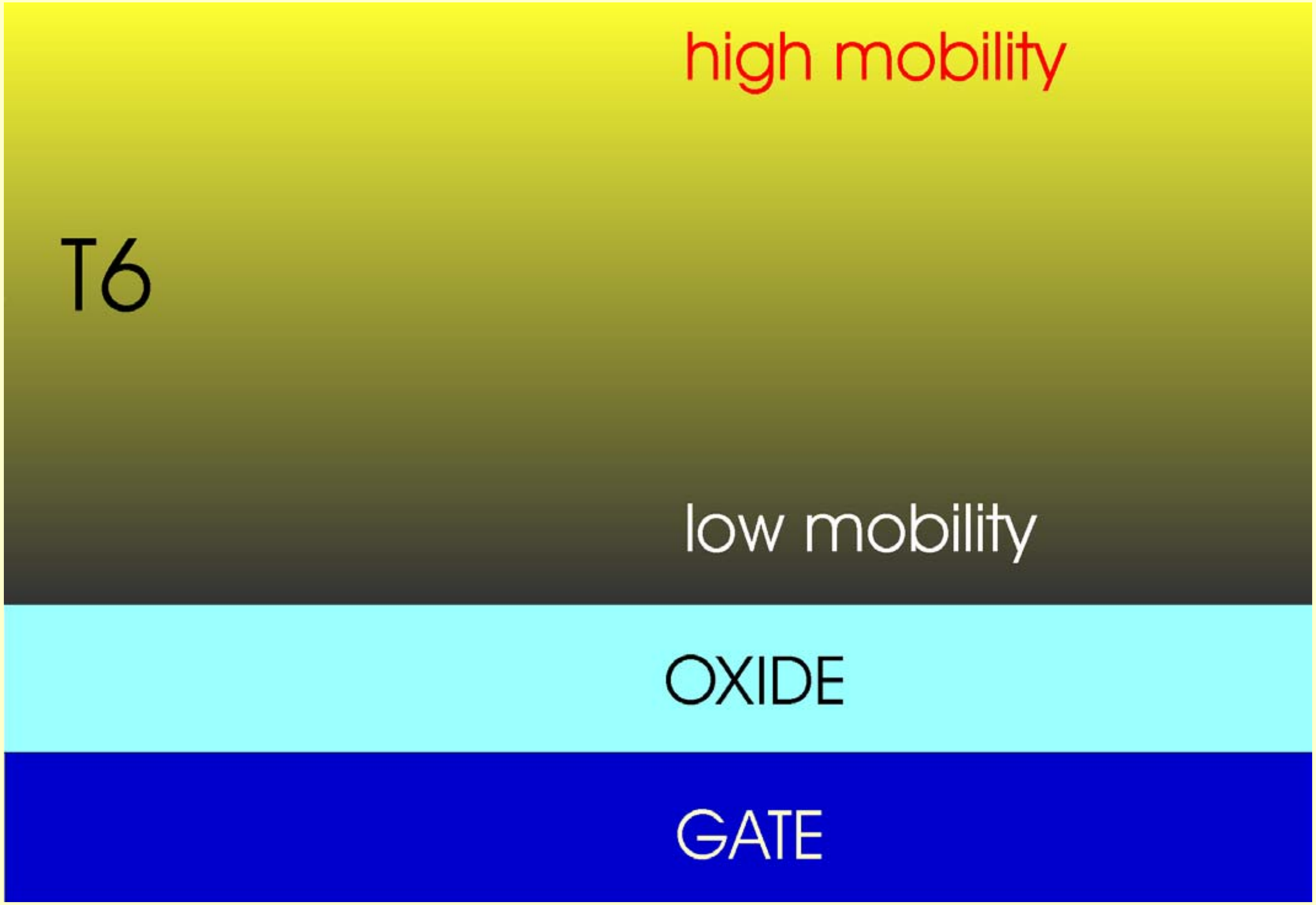
How to explain this?!

Field dependence

Experimental: Mobility increases with transverse electric field



Device cross section

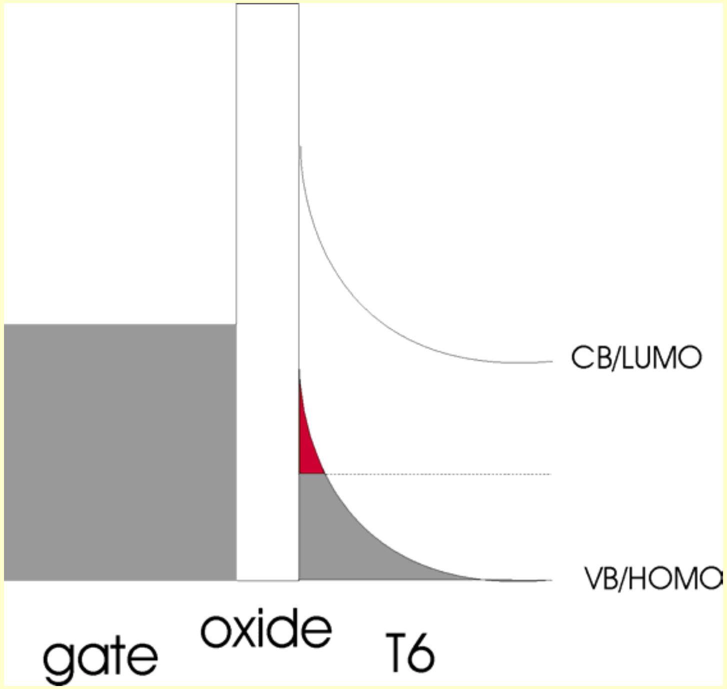


Highly ordered (crystaline material at surface

Messy layer at interface

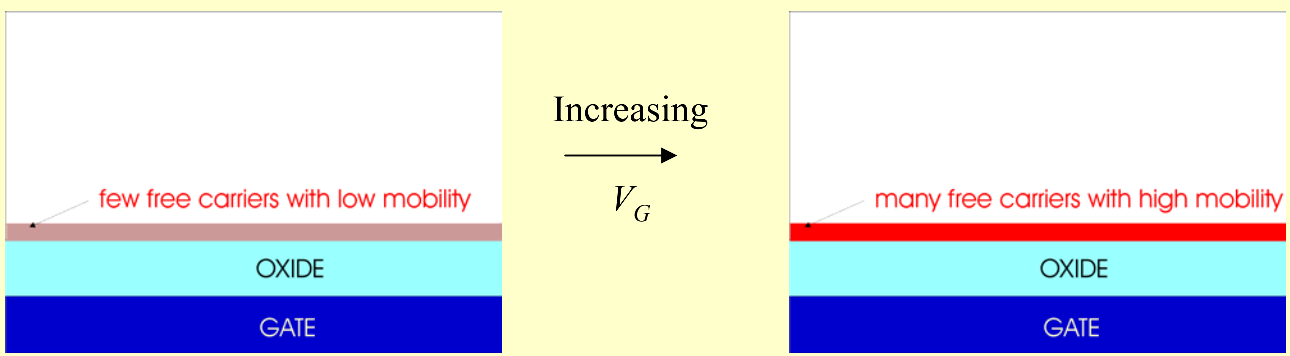
Mobility thus depends on film thickness

Device cross section



Mobility is of the first layer(s) and does NOT depend on film thickness

Increased V_G probes deeper VB states (with higher μ_p?)



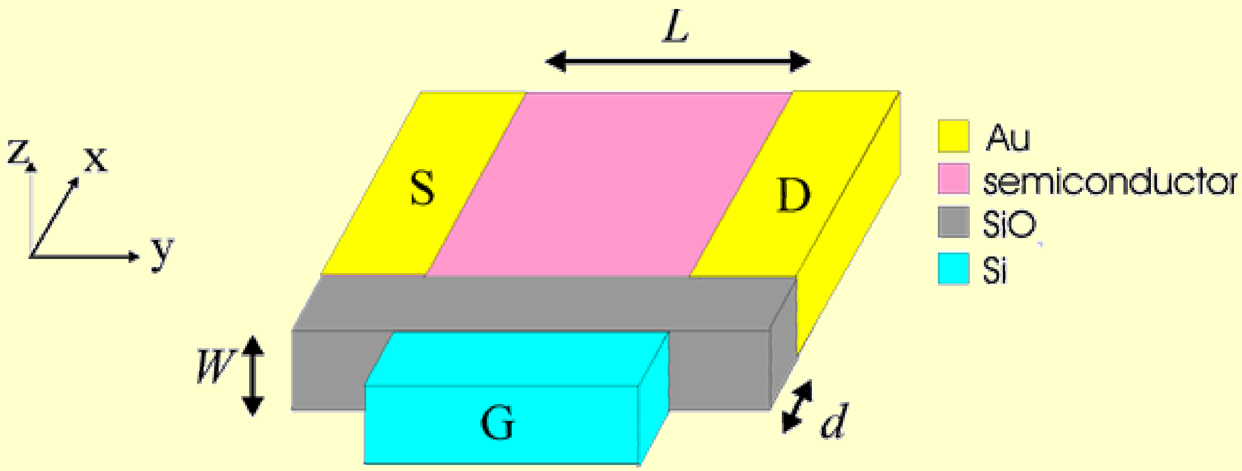
Effects of scaling down

For short channels the depletion width at the source and drain become relatively large.

The assumption $E_x >> E_y$ is no longer valid

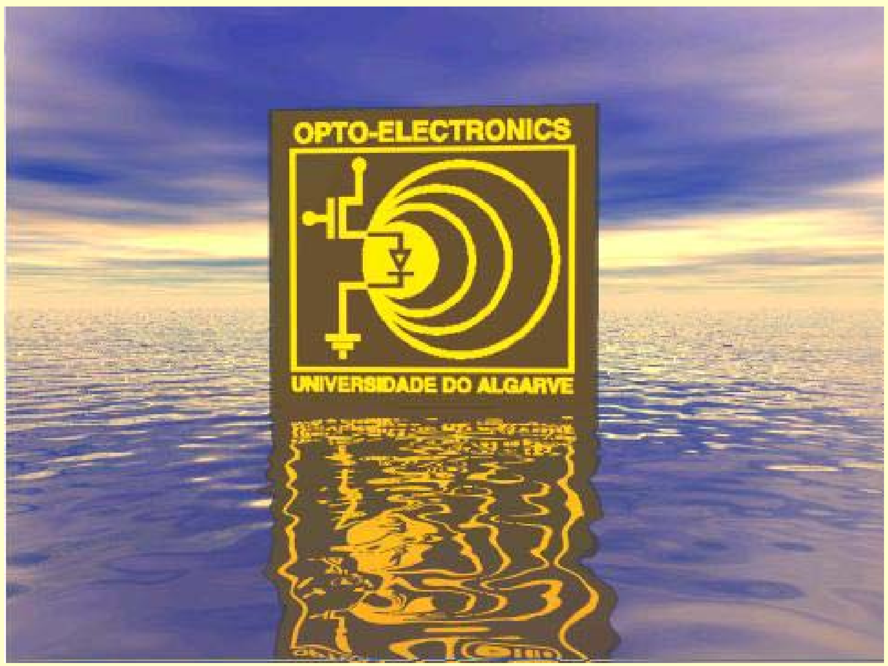
Effects:

- Degradation of sub-treshold region ($V_{DS} < V_T$)
- V_T depending on L and V_{DS}
- No saturation



Summary

- V_T depends on V_{DS}. “Doping” inhomogeneity?
- 6th power law transfer curves.
- possibly due to μ_p depending on V_g due to film properties.
- No short channel effects seen yet.



Faro, June 2001