Electrical Measurements on FETs of T6

Faro, 29.06.2001
H.L. Gomes, P. Stallinga
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

In saturation we can easily extract the mobility

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

Linear plot

Square-root plot
Experimental $\alpha$T6 FET curves

Experimental curves are close to theoretical ……

…… but not quite!
Experimental $\alpha$T6 FET transfer curves

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

$V_{DS}=3\text{V}$

$V_{DS}=3.5\text{V}$
Experimental $\alpha$T6 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 \( \mu_p \)) 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”
6th Power law

Same data plotted as $\sqrt[6]{I_{DS}}$ vs $V_g$ gives straight line

3 times better FETs

How to explain this?!
Experimental: Mobility increases with transverse electric field

Small $V_g$

Large $V_g$

T6

free carriers with high mobility

OXIDE

GATE

free carriers with low mobility

OXIDE

GATE
Device cross section

Highly ordered (crystalline 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 $\mu_p$?)

Increasing $V_G$
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 E_y$ is no longer valid.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-threshold 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 $\mu_p$ depending on $V_g$ due to film properties.
- No short channel effects seen yet.

Faro, June 2001