Temperature dependence of carrier mobility of thin-film field effect transistors

“$\mu_{\mathrm{FET}}(V_g, T)$“

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Inspiration

"Perfection is reached not when there is nothing left to add, but when there is nothing left to take away"

Saint-Exupéry 1900-1944

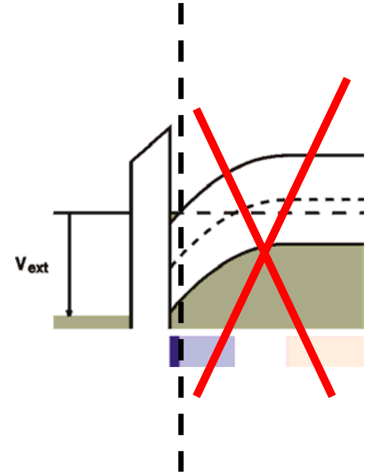
"One should not increase, beyond what is necessary, the number of entities required to explain anything"

William of Occam, 1288-1348

The MOS-FET model

Why a TFT is not a MOS-FET?

1. A TFT is made of a thin film and cannot accommodate band bendings.



2. A TFT normally works in accumulation and thus cannot store the immobile charge needed for band bendings (there are no electronic states, N_A^-).

There are no band bendings!

Not even in thick film transistors! Not even at contacts!

(contacts: poster Tu174)

The Algarve TFT model

1: All charge is directly at interface

2: Charge can be free charge (p) or trapped charge (T^+)

3: Sum of them is depending on bias ($p + N_T^+ \sim V_g$)

4: Relative densities (can) depend on temperature and bias (Fermi-Dirac distribution)

5: Thermal equilibrium reached instantaneously

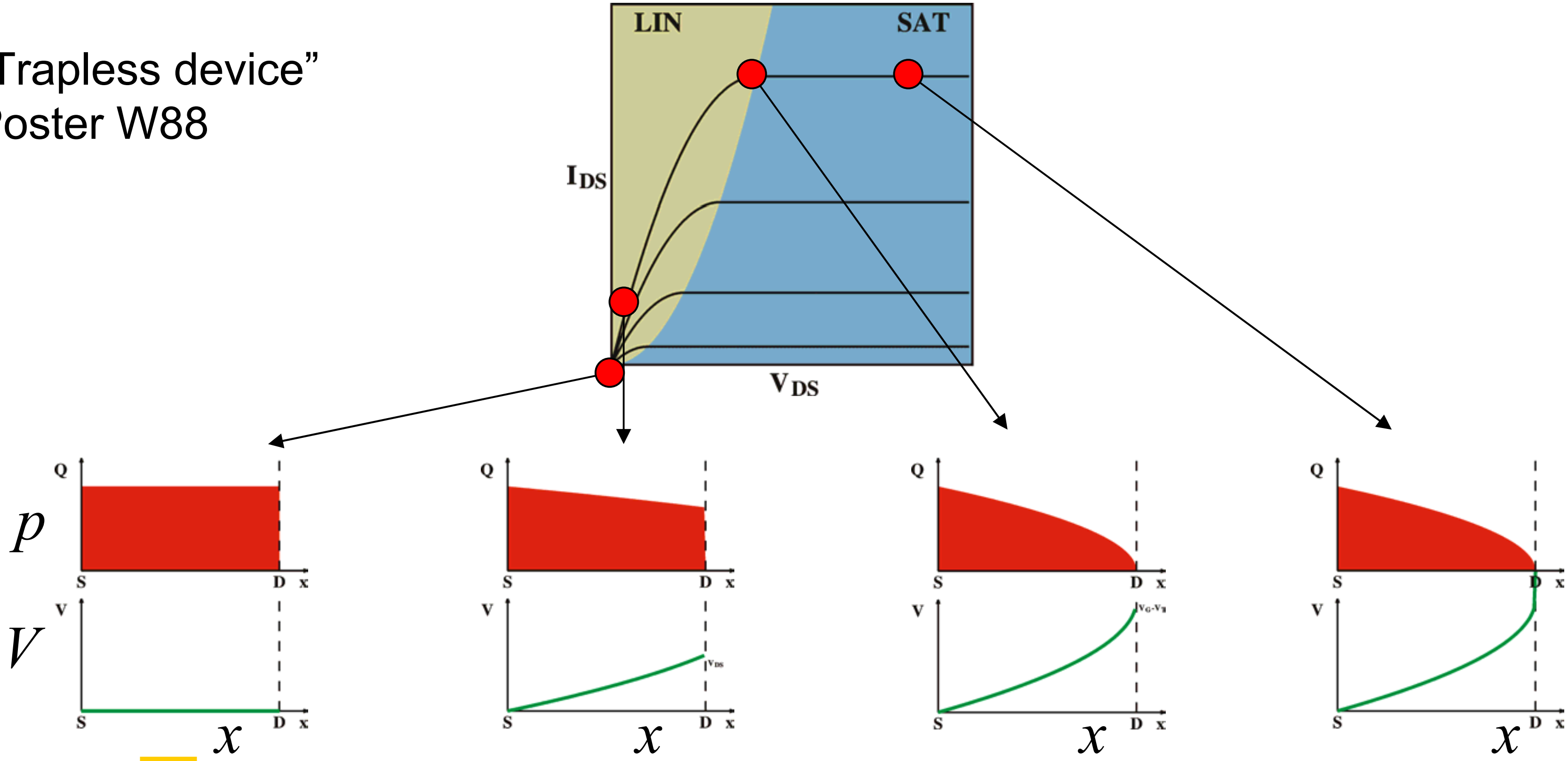
6: Currents are proportional to free charge only ($I_{ds} \sim p$)

7: Mobility is defined via derivative of transfer curve in linear region ($\mu_{FET} \sim dI_{ds}/dV_g$)

No parameters. No N_A, V_T, V_{FB}, etc.

The Algarve TFT model

"Trapless device"
Poster W88

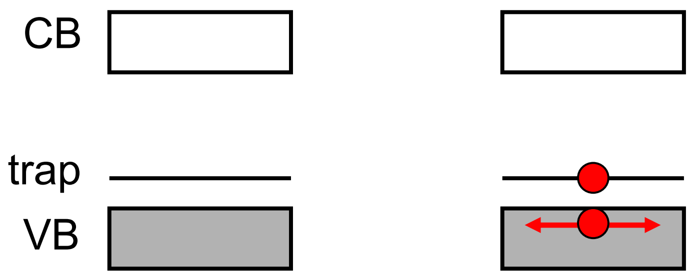


At small V_{ds},
homogeneous device

$$I_{\text{ds}}(V_{\text{g}}) \sim p(V_{\text{g}})$$

Calculate p as a function of V_{g} will yield mobility μ_{FET}

Traps

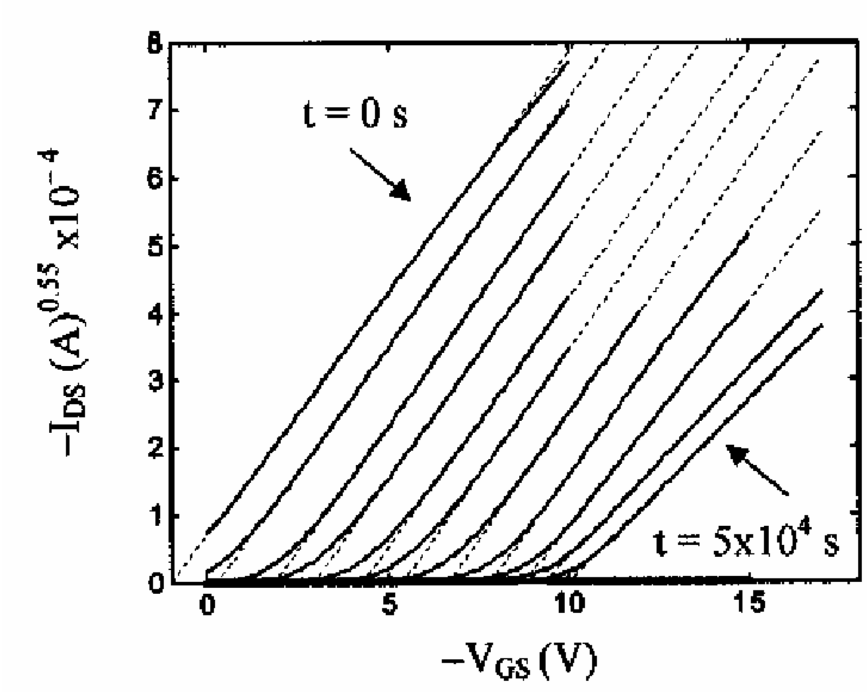


$V_g = 0$ $V_g < 0$

$$p(V_g) + N_T^+(V_g) = -C_{ox}V_g/q$$

"Stressing"

If thermal equilibrium is not reached instantaneously,
the device characteristics change during the measurements



This is called "stressing". $h + T^0 \longrightarrow T^+$

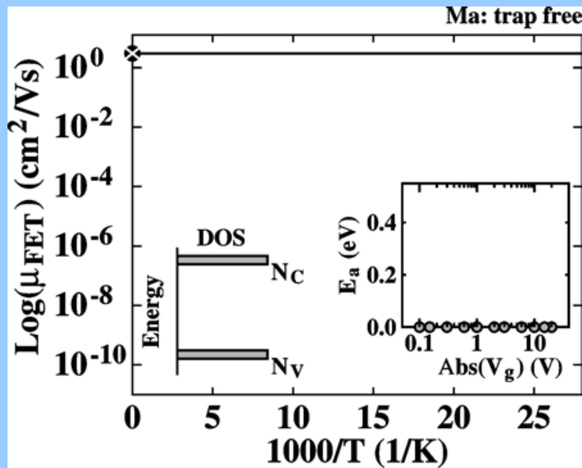
Traps

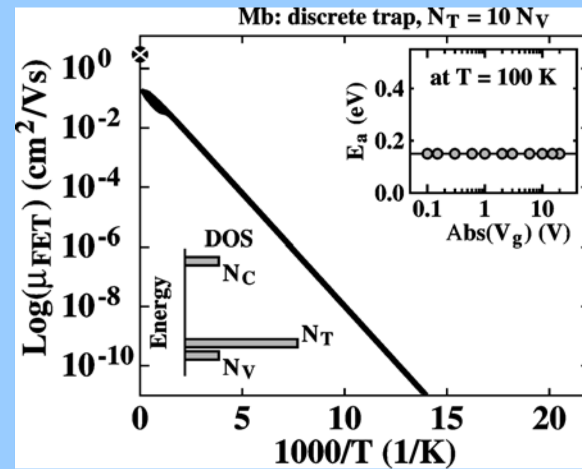
p and N_T^+ can depend on temperature and bias in a different way, thus the mobility can depend on temperature and bias

$\mu_{FET}(V_g, T)$ →

- discrete trap
- abundant discrete trap
- exponential trap
- exponential trap and band

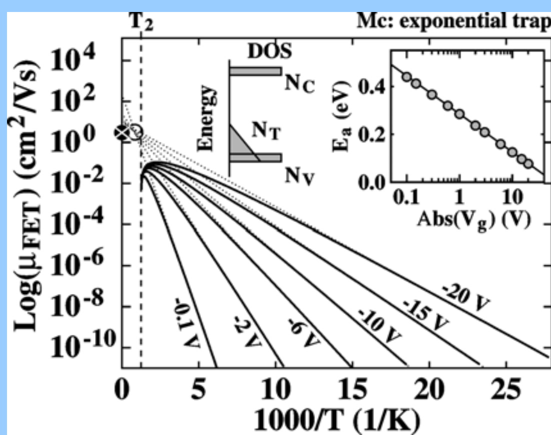
Summary, Arrhenius plots

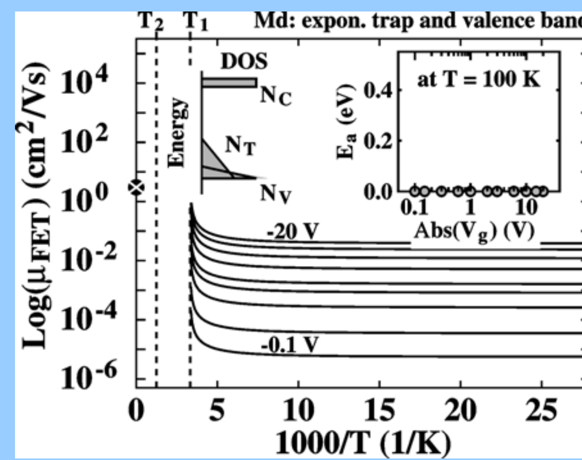




Trap free: "Standard MOS-FET"

Abundant trap: "Poole-Frenkel", $\mu = \mu(T)$

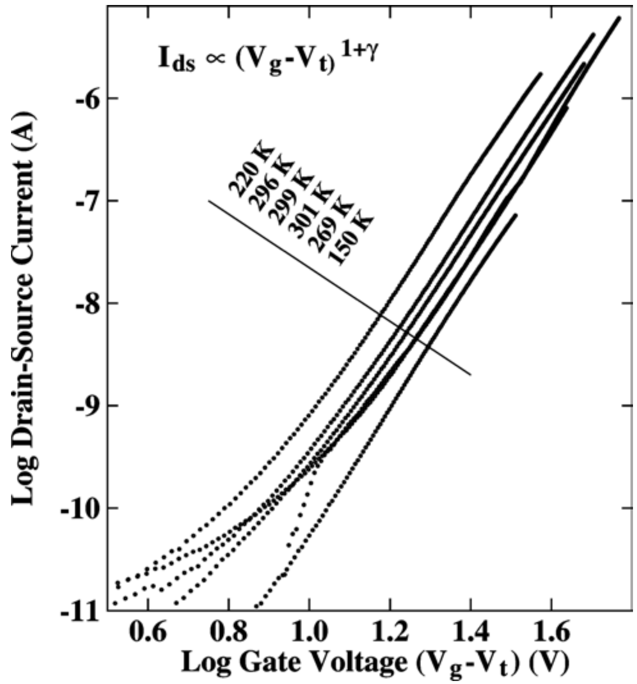




Expon. trap: Meyer-Neldel Rule

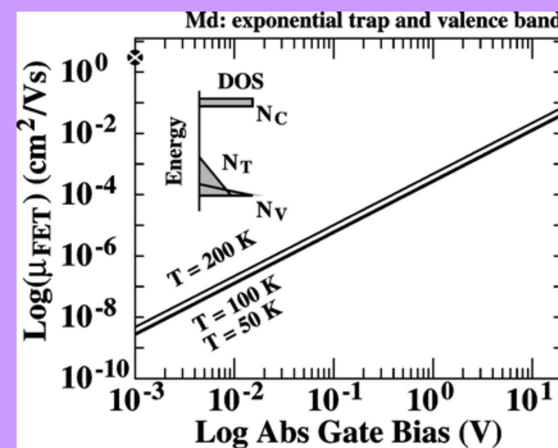
Expon. trap & VB: $\mu = \mu(V_g)$

Summary, Arrhenius plots



Stallinga et al, JAP **96**, 5277 (2004)

The only model that explains our experimental data



Expon. trap & VB: $\mu = \mu(V_g)$

Conclusions

Conduction states (N_V)	Trap states (N_T)	Temperature dependent mobility	Bias dependent mobility
discrete	absent	no	no
discrete	discrete	yes	no
discrete	exponential	yes	yes
exponential	exponential	no	yes

Algarve TFT model

Is very, very simple

Can explain mobilities in wide range (10^{-8} – 10^{2} cm^2/Vs) …
… without change in conduction mechanism.

Can explain bias dependent mobility (!)

Can explain temperature dependent mobility

Can explain bias-and-temperature-dependent mobility (Meyer-Neldel Rule)

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