Modelling electrical characteristics of TFTs

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INTRO

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

William of Occam, 1288-1348

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

Saint-Exupéry 1900-1944

With the credo of the two persons above in mind, a model is established to describe the electrical characteristics of thin-film field-effect transistors (TFTs).
It is common to describe such devices with standard MOS-FET theory in spite of the fact that this model is designed for bulk silicon devices. There are two fundamental differences between a MOS-FET transistor and a TFT:

1) The film in a TFT is thin and cannot accommodate band bendings needed in the MOS-FET model
2) A (organic) TFT works in accumulation instead of inversion (no immobile charge possible)

Hence there is no room for band bending, nor are there states to create band bending

MOSFET

The MOS-FET model is widely used in organic TFTs because it can adequately describe the electrical behavior.

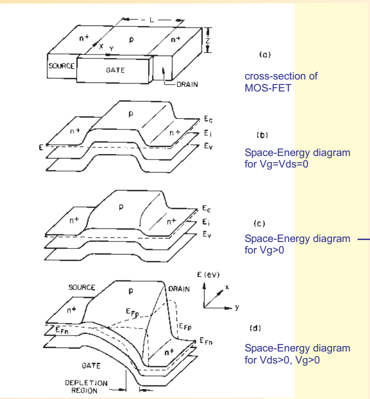
(a,b) A MOS-FET consists of back-to-back pn junctions.

(c) The field of the gate causes band bending, thereby pulling the Fermi level up and putting the channel into inversion and later into strong inversion

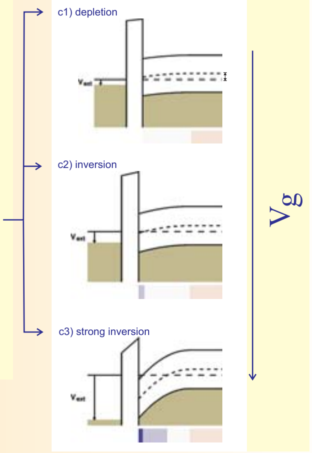
At threshold, $V_g = V_T$
- the pn-barriers disappear.
- The Fermi level is resonant with the band at the interface.

$$I_{ds} = \frac{Z}{L}\mu C_{ox}\left[(V_g - V_T)\,V_{ds} - \left(\frac{1}{2} + \frac{\sqrt{\varepsilon q N_A/\psi}}{4C_{ox}}\right)V_{ds}^2\right]$$

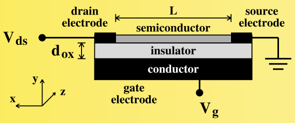
Sze, "Physics of Semiconductor Devices":



P. Stallinga,
http://www.ualg.pt/fct/deei/optoel/theory/fet:



RESULTS



1) TFTs do not have band bending (no flat band voltage, etc.)
All charge is directly at interface

$$\rho(x) = [V(x) - V_g]\,C_{ox}$$

2) In TFTs there are no electronic levels to store immobile charge (for example N_A)
All charge is free charge

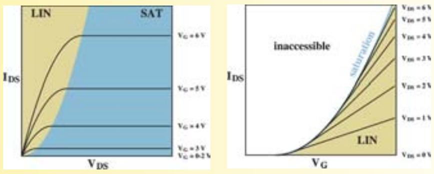
$$(x) = p(x)$$

3) Currents follow from differential equation

$$\begin{aligned} I_x(x) &= qWp(x)\mu\frac{dV(x)}{dx} \\ p(x) &= C_{ox}\,[V(x) - V_g)]\,/q \end{aligned}$$

With boundary conditions
1: $I_x(x) = I_{ds}$ 2: $V(0) = 0$, $V(L) = V_{ds}$

$$\boxed{I_{ds} = -\frac{W}{L}C_{ox}\mu\left(V_g V_{ds} - \frac{1}{2}V_{ds}^2\right)}$$



This is virtually indistinguishable from the MOS-FET equation, but is more adequate for TFTs. Further remarks:
- All current is drift current (no diffusion component)
- Sub-treshold current is zero
- TFT can be made from any material, limiting is
- No junctions (pn or Schottky) at electrodes
- Less parameters (V_{FB}, N_A, V_T eliminated)
- Active layer can be as thin as one ML
- A device can be made of three molecules

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