# Metal contacts in TFTs

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## INTRO

In a previous work, a model for thin-film field-effect transistors (TFTs) was developed. One of the issues not addressed in that model is the effect of the contacts.

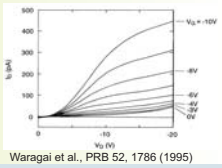
Conventionally, (organic) TFTs are analyzed with the standard MOS-FET model.
In a MOS-FET, the contacts are pn-junctions (p-type and n-type same-material junctions) but TFTs normally have metallic electrodes.

Attempts for MOS-FETs with metallic contacts have been made to model them with Schottky barriers or the generic term "contact resistance" to describe any deviations from standard MOS-FET theory.

Diodes (pn-junctions or Schottky barriers) do not make sense when the active layer is two-dimensional (TFTs).

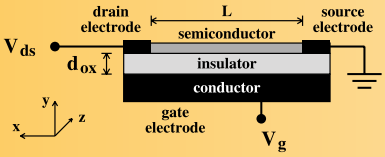
Diodes or resistances cannot explain non-linear effects (see Figure) .
Non-linear effects of curves can easily be explained by traps.

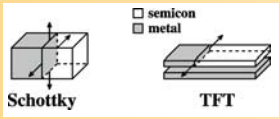
*"Contact effects"?*
*Traps!*



Waragai et al., PRB 52, 1786 (1995)

## MOSFET

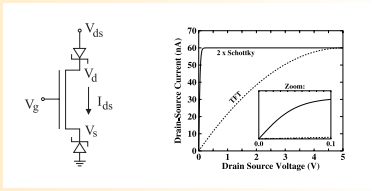


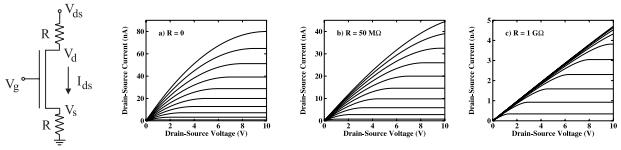




The above figure (right) shows why Schottky barrier (or pn junction) analysis is less adequate for TFTs:
In a Schottky barrier the dimensions perpendicular to current ($x$,$z$) can be imagined to stretch to infinity and Poisson's Equation can be applied: $d^2V(x)/dx^2 = \quad (x)$
In a TFT, only one direction ($z$) is infinite. Poisson's Equation cannot be applied

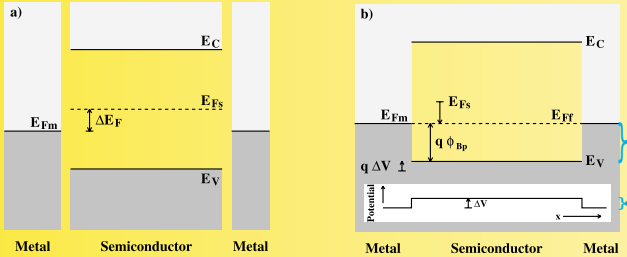
Sometimes also the generic term "contact resistance" is used to explain any deviations from standard MOS-FET theory.
Simulations of these elements (see right panel) show simulations.

*Simulations of contact resistance and Schottky contacts*




## RESULTS




*Metal-semiconductor-metal structure before and after contact*

Because of difference in Fermi level (left), charges (holes) move into the semiconductor.
These charges
- redefine the Fermi level (pull it towards valence band)

$$p = N_V \exp\left[-\frac{E_F - E_V}{kT}\right]$$

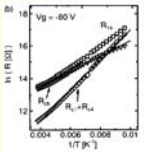
- Increase the potential in the channel $V(x)$ and the entire band structure with it, according to

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

This will continue until equilibrium is reached (Fermi levels are aligned, see right picture). The steady state solution is a constant potential in the channel (see inset)

bias-dependent barrier:

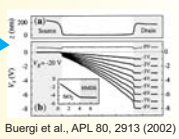
$$q\phi_{Bp} = kT \ln\left(\frac{C_{ox}(\Delta V - V_g)}{qN_V}\right)$$




Yagi et al., APL 84, 813 (2004)

$$\Delta V = \frac{kT}{q} W\left(\frac{q}{kT} A\right)$$

W is Lambert-W Function




Buergi et al., APL 80, 2913 (2002)

$$A = \frac{qN_V}{C_{ox}} \exp\left(\frac{E_V - E_{Fm}}{kT}\right)$$

( V of order 10 mV to half band-gap)