ELECTRICAL CHARACTERIZATION OF THIN-FILM FIELD-EFFECT TRANSISTORS

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In this work we model the electrical characteristic of thin-film field-effect transistors (TFTs) of any semiconductor material, with emphasis on organic TFTs.

It is common to describe the organic TFTs with standard MOS-FET theory, originally designed for silicon devices in the 1980's. However, for thin films, this model cannot be maintained for two simple reasons. 1) The active layer in TFTs is thin. It has been shown that the active layer can be as thin a one monolayer, without losing functionality. As such, band bendings, an essential element in MOS-FETs, are absent in TFTs, 2) Even if the film is thick, as long as it is working in accumulation mode, there are no states to maintain band-bending.

We propose here a model ("The Algarve model of TFTs") in which all charge is directly at the interface and the relation charge-bias is fully linear. See Figure 1 for a cross-section of a TFT. The result of this assumption is electrical characteristics that are fully compatible with MOS-FET curves.

To explain experimentally observed deviations from this theory, trap states are added to the model. The result of these traps is that the as-measured mobility (mFET) can now strongly depend on gate bias or temperature or both, depending on the energetic distributions of trap states and conduction states, see the summary in the table below.

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

An interesting additional observation is that when the traps states are exponentially distributed in energy, the mobility becomes bias and temperature dependent in such a way as to follow the Meyer-Neldel Rule: the curves in Arrhenius plots for various gate biases all point towards a single point (see Figure 2).

Summarizing, the model explains how, different devices of the same material, but with different growth parameters or different storage and handling conditions, can behave radically different. In the model it just implies a different density and distribution of traps.

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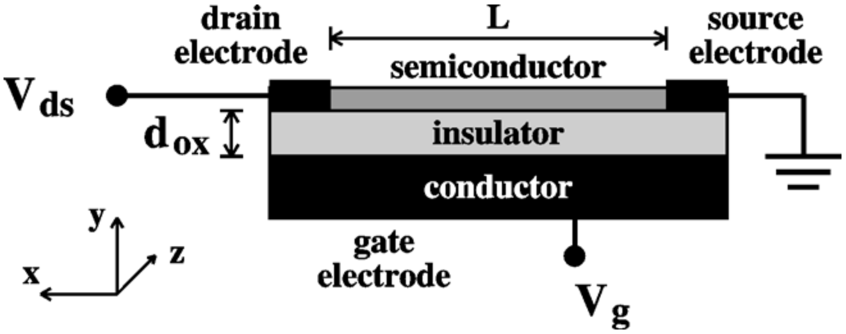

Figure 1 – Cross-section of a TFT, the active layer is treated as purely two-dimensional.

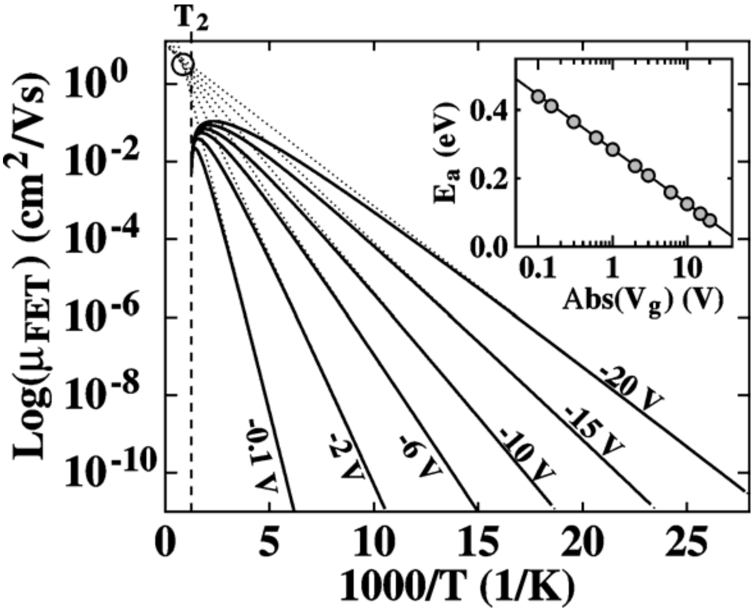

Figure 2 – Arrhenius plots of mobility for various gate biases. As can be seen, this follows the Meyer-Neldel observation. The curves are a result of a high density of traps, exponentially distributed in energy, while maintaining discrete conduction states.