A Compact Model for Carbon Nanotube Network TFTs

R. PICOS, A. SCHINDLER[*], B. IÑIGUEZ[+], M. ROCA, AND E. GARCIA-MORENO
GTE, UNIVERSITAT DE LES ILLES BALEARS, PALMA DE MALLORCA, SPAIN
[*] CHAIR OF DISPLAY TECHNOLOGY, UNIVERSITAET STUTTGART, STUTTGART, GERMANY
[+] DEEEA, UNIVERSITAT ROVIRA I VIRGILI, TARRAGONA, SPAIN

Abstract

Thin-film transistors are the preferred choice for large-area electronic systems, such as displays. However, due mainly to their poor performance, they are usually used only as switching elements. This implies that the main part of the processing power needed to run the displays must be placed outside and fabricated using other technological process, thus increasing the whole cost. There have been some proposals in the literature to increase the performance. Due to the fact that the main limiting factor is the low field effect mobility, a trend is the use of carbon nanotubes (CNT) to raise it. However, there are many technological problems linked to this approach. An alternative is the use of CNT networks, as proposed in the literature. This idea tries to combine the ease of fabrication of TFTs, while at the same time profiting of the high mobility of CNT.

In this work, we will propose a compact model for this kind of transistors. Due to the fact that the structure is quite similar to that of an amorphous TFT (a-TFT), we will extend an a-TFT model to take into account the effect of embedding the CNT. The model is compared with experimental measurements, and the fitting is quite good, even when comparing the transconductance.

Model:

Three Regions (plus sub-threshold):

Regional Saturation Voltage Model:

$$V_{DSat} = \alpha_S \left(V_{GS} - V_T\right)$$

Regional Mobility Model:

$$\mu_{FET} = \mu_0 \left(\frac{V_{GS} - V_T}{V_{aa}}\right)^{\gamma_a} = \mu_{FET0}\left(V_{GS} - V_T\right)^{\gamma_a}$$

Regional Current Model:

$$I_{DS} = \frac{W}{L}\cdot C_{diel}\,\frac{\mu_{FET}\left(V_{GS} - V_T\right)}{1 + R\frac{W}{L}\cdot C_{diel}\,\mu_{FET}\left(V_{GS} - V_T\right)}\cdot\frac{V_{DS}\left(1 + \lambda V_{DS}\right)}{\left(1 + \left(\frac{V_{DS}}{V_{DSat}}\right)^m\right)^{1/m}} + I_0$$

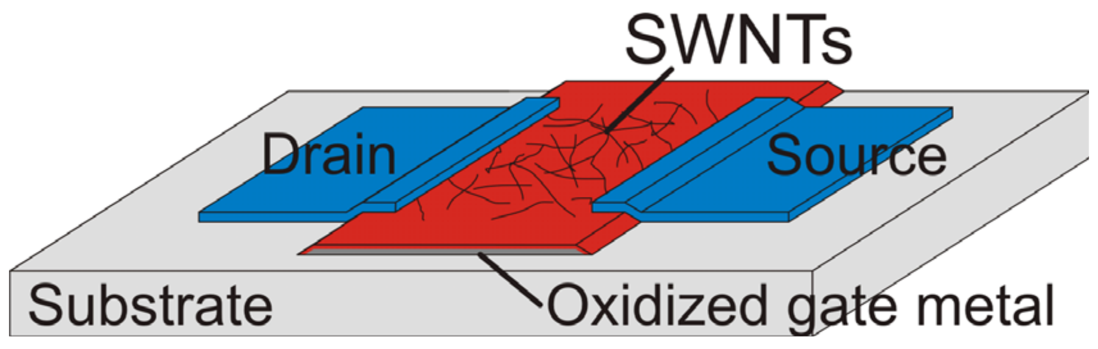
Current Model:

$$\begin{aligned} I_{DS} &= \left(I_{DS1}\cdot f^-(V_{GS},V_P) + I_{DS2}\cdot f^+(V_{GS},V_P)\right)\cdot f^-(V_{GS},V_S) \\ &\quad + I_{DS3}\cdot f^+(V_{GS},V_S) \end{aligned}$$

$$f^+(V_{GS},V_0) = \frac{1}{2}\left(1 + \tanh(2.5\frac{V_{GS} - V_0}{V_0})\right) \qquad f^-(V_{GS},V_0) = \frac{1}{2}\left(1 - \tanh(2.5\frac{V_{GS} - V_0}{V_0})\right)$$

A. Cerdeira, M. Estrada, B. Iniguez, J. Pallares and L.F. Marsal, *Modeling and parameter extraction procedure for nanocrystalline TFTs*, Solid-State Electronics **48**, 2004.

Results

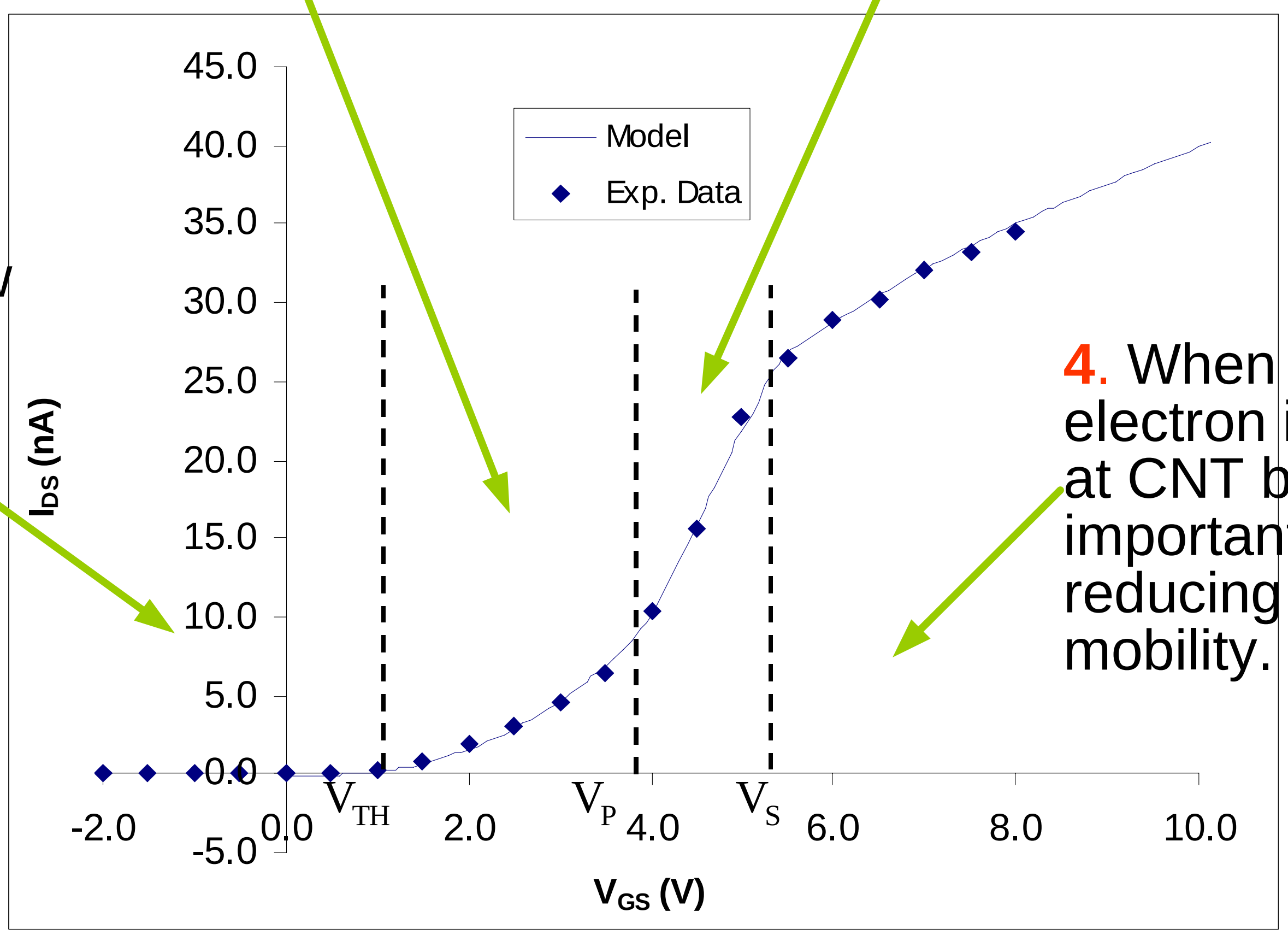


Four Modeled Regions:

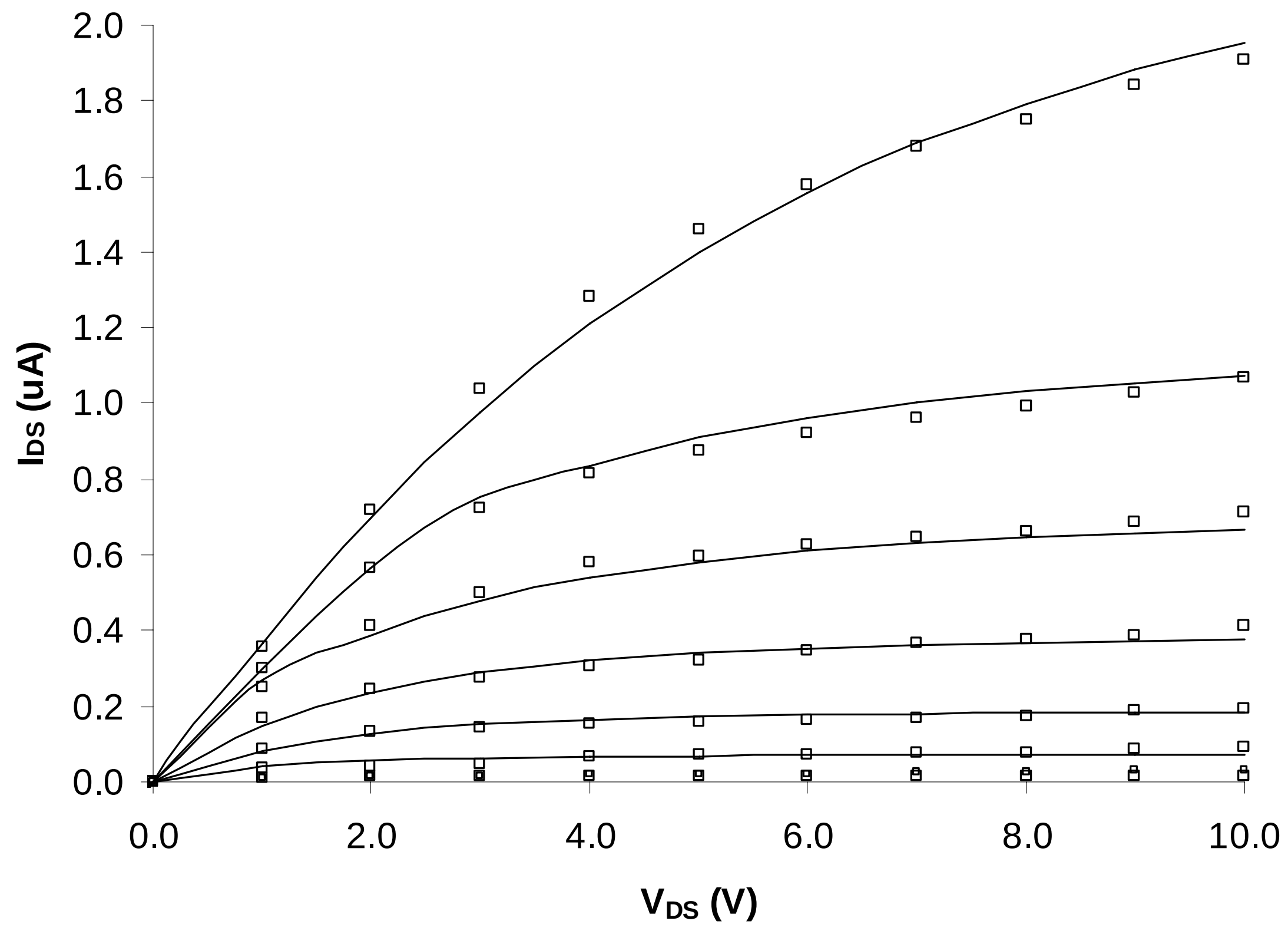
2. The region where the channel starts, and is for V_{GS} between V_{TH} and V_P.

3. Begins when the potential barrier that keeps injection out of the CNT is surpassed and the field effect mobility is greatly improved.

1. The zone for V_{GS} below the threshold voltage V_{TH}.



4. When the electron-electron interactions at CNT begin to be important, thus reducing effective mobility.



Experimental data (♦) and modeled curves (-) for a CNT network TFT.