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TCAD-Assisted Development of Technology-Independent Device Models

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BACKGROUND

Circuit simulators use device models that provide a compact representation of electrical behaviour. The parameters associated with compact models are normally extracted from experimental measurements. The parameters can also be extracted from the results of device simulation. The extraction of compact device models from simulated electrical behaviour provides an important bridge between TCAD and circuit design.

There are many different approaches to the development of compact device models. For example, models can be specialized for DC or small-signal AC conditions, and can be physics-based or empirical. Within the overall spectrum of approaches, there is considerable interest in *technology-independent* device models that associate voltage-dependent current and charge functions I_i and Q_i with each device terminal. A good description of the basic technique has been given by Corbella et. al. [1].

The label *technology-independent* is misleading. A more accurate description would be "applicable to any well-behaved FET technology when used at sufficiently low frequencies." Extensions are required to handle bipolar technologies, frequencies that are not small with respect to the unity current gain cut-off frequency of the device and the presence of surface or bulk traps.

Industrial practice has shown the need to use pulsed I-V measurements, rather than DC I-V characteristics, to determine the terminal current functions. The device temperature (T) then becomes an explicit variable of the model. Non-quasi-static effects can be described by associating delay times τ_i with the evolution of the charge functions (see, e.g. [2].) Measurement-based extraction of the parameters of IQ(T,τ) models requires pulsed measurements of small-signal s-parameters as a function of frequency, up to the region of the unity current gain cut-off frequency. Such measurements are difficult and expensive. These problems can be overcome by the judicious use of TCAD.

APPROACH

This paper describes the use of TCAD in the implementation of a computer-controlled IQ(T,τ) model development and parameter extraction system. The system uses experimental pulsed I-V measurements to determine the I(T) functions, TCAD simulation to determine the Q(T,τ) functions, and low-frequency small-signal AC measurements to calibrate the TCAD results. This hybrid approach provides an excellent trade-off between accuracy, generality, simplicity, and ease of use.

Fig. 1 shows the experimental set up used to determine the I(T) functions. Fig. 2 depicts a test of whether trap effects are negligible. Figs. 3 and 4 show examples of charge surfaces extracted from simulated results. Fig. 5 shows the ability of the model to reproduce several breakpoints in the frequency-dependent roll-off of y_{21}.

The role of TCAD will expand in the future as it is used for additional purposes, e.g.:

- As a test reference to evaluate alternative non-quasi-static model formulations
- As a test reference to evaluate and extract parameters for bipolar extensions
- As a test reference to evaluate and extract parameters for trap-related extensions.

ACKNOWLEDGEMENT

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REFERENCES

[1] I. Corbella, J. M. Legido and G. Naval, “Instantaneous Model of a MESFET for use in Linear and Nonlinear Circuit Simulations,” IEEE Trans. Microwave Theory and Techniques, vol. 40, pp. 1410-1421, 1992

[2] R.R. Daniles, A. T. Yang and J. P. Harrang, “A Universal Large/Small Signal 3-Terminal FET Model Using a Nonquasi-Static Charge-Based Approach,” IEEE Trans. Electron Devices., vol. 40, pp. 1723-1729, 1993

Fig. 1. The experimental I(T) modeling system incorporates a computer-controlled pulsed I-V instrument and thermal chuck.

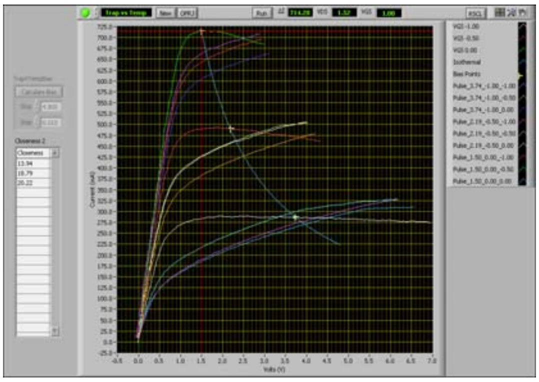

Fig. 2. The system software can test for the impact of traps. This data shows that traps are significant for a CLY5 MESFET.

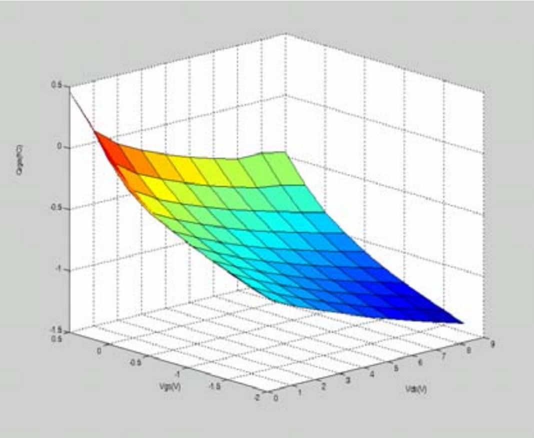

Figure 3: A simulated isothermal gate charge surface calculated as a function of gate and drain bias.

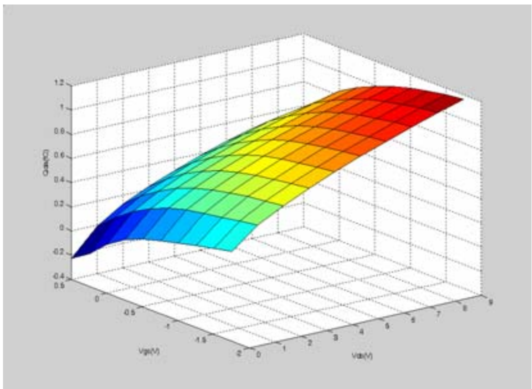

Figure 4: A simulated isothermal drain charge surface calculated as a function of gate and drain bias.

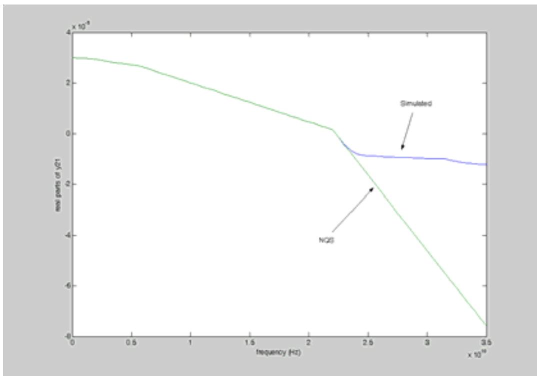

Fig. 5: Data for y_{21} shows how the model handles frequency-dependent break points.