University of Alberta Graduate Student Uses NI AWR Design Environment to Design Graphene FETs

AWR Success Story

UNIVERSITY BACKGROUND

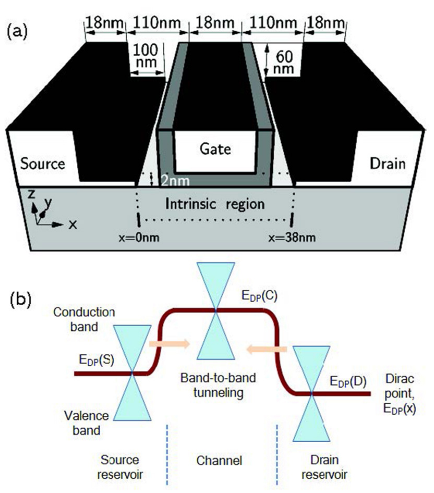
The [Department of Electrical and Computer Engineering at the University of Alberta,] Edmonton, Canada is home to ground-breaking engineering research. ECE graduate students work with an internationally-recognized faculty in world-class facilities. Graduate students are an integral part of the department, acting as researchers and teaching assistants. The experience gained is directly transferable to future academic work, public research, or a career in the industry.

Application:
Graphene FETs
Software:
Microwave Office®

THE DESIGN CHALLENGE

The excellent electronic properties of graphene make it a promising alternative to silicon (Si) for use in future electronics, particularly for analog circuit applications. As the down-scaling of graphene channels continues, compact modeling approaches that can tractably predict terminal behavior, including effects arising from the zero bandgap such as variations in the densities of states between the channel and source and drain regions and band-to-band tunneling, are essential to exploring graphene's circuit capabilities.

Ahsan U. Alam, an ECE graduate student, set out for his doctoral program to develop a modified top-of-the-barrier model (TBM) for graphene field-effect transistors (GFETs) that includes variations in the reservoir versus channel densities of states and band-to-band tunneling. The model needed to show excellent agreement with state-of- the-art, quantum-mechanical approaches based on non-equilibrium Green's function (NEGF) and allow for the develop-ment of accurate, practical circuit models. It also had to capture band-to-band (Klein-Zener) tunneling, which is important in zero-bandgap materials, and account for variations in the densities of states between the channel and the source and drain regions.



(a) Device geometry of the simulated GFET. (b) Dirac-point energy E_{DP} (x) versus position x, where the superimposed cones represent graphene's band structure.

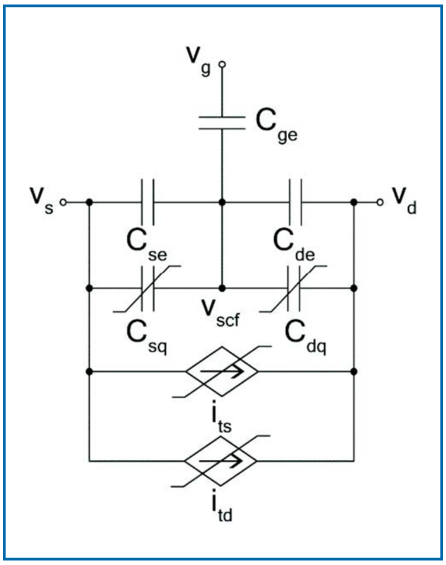
> "We, the Nanoelectronics Research Group at the University of Alberta, have been using Microwave Office in our research. Thanks to your great support, the software has been very helpful to our cause. We have recently published an article in the IEEE Transactions on Nanotechnology entitled, "RF Linearity Potential of Carbon-Nanotube Transistors vs. MOSFETS," based on our simulations in Microwave Office and further work is in progress."

Ahsan U. Alam
Graduate Student
University of Alberta
www.ualberta.ca

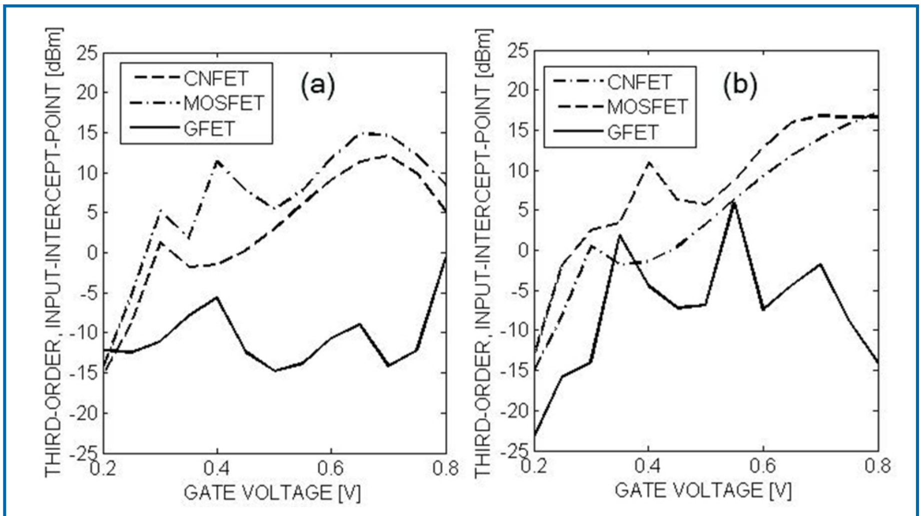
THE NI AWR DESIGN ENVIRONMENT SOLUTION

Alam used Microwave Office® circuit design software and worked with technical support as part of the AWR University Program to develop the TBM for simulating graphene FETs.

The graduate student developed a way to simulate electronic transport in GFETs through a modified TBM that captures both variations in the densities of states and band-to-band tunneling, while remaining numerically efficient. The new model was shown to produce accurate results when compared to a more rigorous, self-consistent, quantum-transport solver based on NEGF, and its potential was demonstrated by investigating the RF linearity of GFETs using Microwave Office. RF linearity is an important transistor property that is relevant for a variety of circuit applications, but which is notoriously difficult to predict, requiring both accuracy and tractability in the modeling approach. In addition, because of the nonlinear components in the GFET equivalent circuit, the designer needs to employ a nonlinear solver. The nonlinear solver in Microwave Office (in this case harmonic balance) proved to be the perfect tool for simulating such nonlinear circuits.



Nonlinear small-signal equivalent circuit of a ballistic GFET.



IIP3 versus gate voltage, with the drain voltage held fixed at (a) 0.5 V and (b) 0.8V, of the graphene FET compared to its CNFET and MOSFET counterparts.

The model was benchmarked against a sophisticated self- consistent NEGF solver and showed excellent quantitative agreement. The utility of the modified TBM was demonstrated by investigating and comparing the RF linearity of GFETs to that of carbon-nano FETs (CNFETs) and conventional metal oxide semiconductor FETs (MOSFETs).

Note: An IEEE paper detailing the success of this venture was presented at the International Conference on Simulation of Semiconductor Processes and Devices (SISPAD 2013).