Hydrodynamic and Drift-Diffusion modelling of GaN-based Gunn diodes

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INTRODUCTION

The negative differential mobility caused by the transferred electron effect is one of the promising mechanisms in semiconductors capable, in principle, of generating microwave and possibly THz radiation. Development of Gunn microwave oscillators has hitherto been focused on the utilization of traditional III-V semiconductors like GaAs, achieving a maximum emission frequency around 100 GHz. The recent success of the III-V nitrides technology (in particular GaN, InN, AlN) has led to the development of a range of novel microelectronic and optoelectronic devices based on these materials that due to non-monotonous velocity-field (v-F) characteristics, record-high peak velocities and very high breakdown fields are able to generate high-power, and high-frequency radiation. In this work, we investigate the electron transport in GaN-based Gunn diodes in the transient regime using hydrodynamic (HD) and drift-diffusion (DD) transport models. A comparative analysis is presented.

METHODS

Two types of GaN-based Gunn diodes were simulated using Sentaurus Device: (i) one sample consisted of n^+-n^--n-n^+ regions in which the notch (n^-) length (L) is varied; see Fig. 1a, and (ii) another sample with a similar doping profile in which the notch region is detached (a distance d) from the n^+ region near the cathode; see Fig. 1d. HD and DD transport models were used for evaluating the electron transport in 2 µm thick samples under transient regime at room temperature. We have used the same material parameters and biasing method as the ones described in [1].

RESULTS AND DISCUSSION

Fig. 1b shows the electron density dynamics calculated with the HD (solid lines) and with the DD (dash-dotted lines), both models generate accumulation layers that propagate from the cathode (-) to the anode (+). This is, to the best of our knowledge, the first report of this situation using a HD approach in the context of GaN; other authors have also observed this situation with Monte Carlo simulations [2, 3]. Moreover, when the notch region is increased, dipole domains are created instead of accumulation layers and travel along the sample as depicted in Fig. 1c. Furthermore, we conducted simulations with a fixed notch length, that when attached to the n^+ region yields accumulation layers, and systematically detached it. When the separation is short, the HD yields weak domains during the first moments of time (Fig. 2e) whereas the DD produces dipole domains. In turn, when the separation is long enough, both the HD and DD generate dipole domains as seen in Fig. 2f.

CONCLUSION

For the nucleation and propagation of dipole domains in GaN-based Gunn diodes it is important to have a doping notch wide enough. As well, detaching the notch might produce sustained dipole domains.

REFERENCES

[1] E. Momox, N. Zakhleniuk and N. Balkan, "Overshoot mechanism in transient excitation of THz and Gunn oscillations in wide-bandgap semiconductors," *Nanoscale Research Letters,* vol. 7, no. 647, 2012.

[2] R. F. Macpherson and G. M. Dunn, "The use of doping spikes in GaN Gunn diodes," *Applied Physics Letters,* vol. 93, p. 062103, 2008.

[3] Y. P. Teoh, G. M. Dunn, N. Priestley and M. Carr, "Monte Carlo modelling of multiple-transit-region Gunn diodes," *Semiconductor Science and Technology,* vol. 17, p. 1090, 2002.

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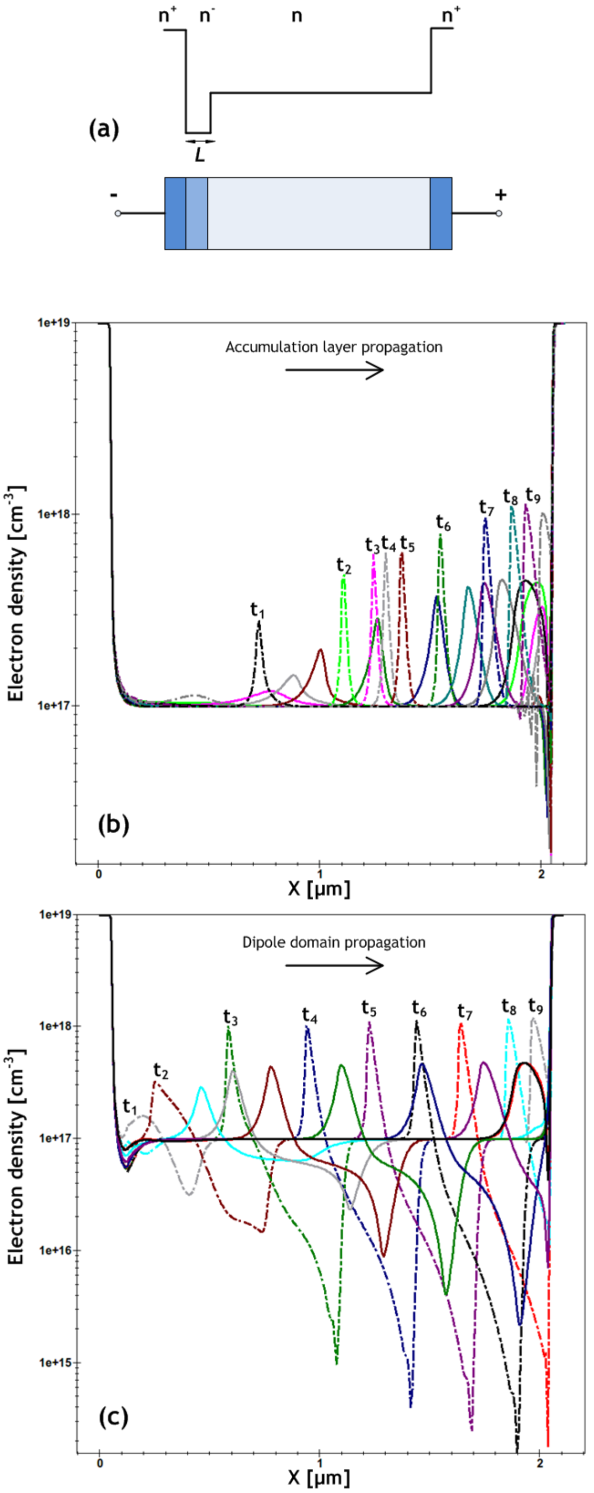

Fig. 1. (a) doping profile (b) HD (solid lines) and DD (dash-dotted lines) transient simulations of a GaN Gunn diode with a 0.2 µm wide notch, and (c) with a 0.8 µm wide notch for different instants in time (t_i).

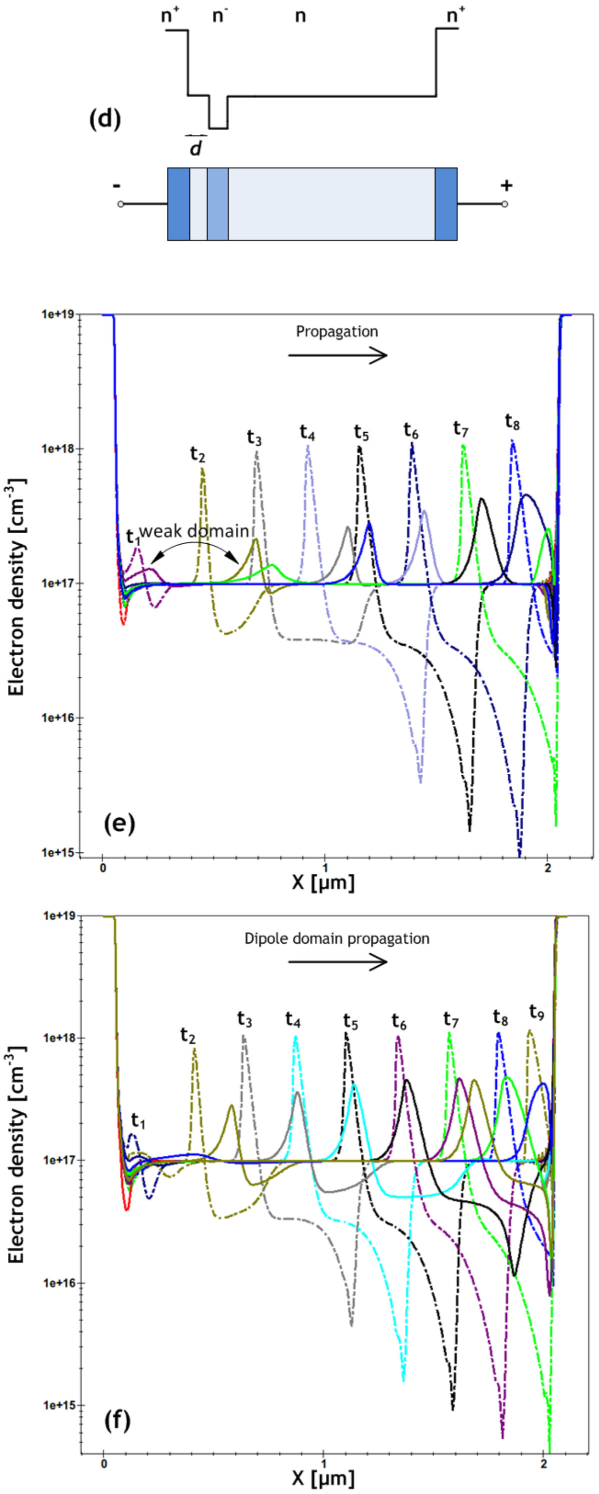

Fig. 2. (d) doping profile (e) HD (solid lines) and DD (dash-dotted lines) transient simulations of a GaN Gunn diode with a 0.4 µm wide notch detached by 0.015 µm, and (f) detached by 0.03 µm for different instants in time (t_i).