SYNOPSYS®

SUCCESS STORY

Sentaurus™ Calibration Workbench with proven calibrated accuracy on IGBT and diode

"With Sentaurus Calibration Workbench in TCAD Sentaurus, we were able to automatically calibrate process and device simulations for our IGBT product, Side-Gate HiGT. We are looking for power DTCO, which realizes our concept of "fully digitalized development".

~Mr. Tomoyasu Furukawa Chief Researcher, Manager, Hitachi

HITACHI
Inspire the Next

Business

Hitachi is the world's leading company for high-voltage power semiconductors such as Si IGBTs, Si diodes, and SiC devices. These devices are key components of electric vehicles (EV) and hybrid electric vehicles (HEV) and are much anticipated to expand the market.

Challenges

- Rising structural complexity of high-voltage power devices requires simulation-based optimization
- Difficulties of the modeling carrier recombination process in the bipolar device, especially with carrier lifetime control process.

Synopsys Solution

- Sentaurus™ Calibration Workbench for automated, workflow-oriented process and device calibration
- Additional trap modeling to accurately reproduce switching waveforms

Benefits

- Sentaurus Calibration Workbench allows for the calibration of process and device simulations for IGBTs. Hitachi's TCAD tools become much more accurate and highly predictable. It reduces development time and cost, and improves production quality.

Overview

Si IGBTs and Si diodes are commonly used in high-voltage power electronics applications such as EV, HEV, railway traction, wind turbine generators, and industrial robots. TCAD simulation has been used for modeling and performance optimization of these bipolar devices for over 30 years. Recently, high-precision process simulation is required for these devices to improve their performance. Accurate process simulation is expected. Furthermore, precise modeling for complex carrier recombination physics is also expected to adapt various carrier lifetime control technologies.

In this project, we established calibrated TCAD setups for Hitachi's side-gate high-conductivity IGBT (side-gate HiGT [1]) and diode. The calibration setups are based on Sentaurus Calibration Workbench, which was developed to increase the value of TCAD by allowing users to rapidly calibrate TCAD models. We also included modeling of recombination physics for their electron beam irradiation (EBI) process. Eventually, we provided well-calibrated process and device models to Hitachi. The models precisely represent actual device performance, not only DC characteristics but also switching waveforms.

Modeling and Calibration by Sentaurus Calibration Workbench

Sentaurus Calibration Workbench is a tool designed to perform efficient calibrations for TCAD simulation tools. It provides evaluation, sensitivity analysis, search, calibration, and machine learning functionality. Although Sentaurus Calibration Workbench is a standalone tool, it interacts with Sentaurus Workbench for setting up and running simulations. It utilizes the job scheduler of Sentaurus Workbench to speed up simulations by using distributed heterogeneous computing resources.

Figure 1 shows the structure of the side-gate HiGT. In this project, Sentaurus Calibration Workbench was used initially for the calibrations to reproduce the doping profiles of ion implantation and diffusion. The profiles of boron, phosphorus, and arsenic were accurately fitted to SIMS measurement results. We performed additional work for the geometric calibration of the gate structure at the front side and the modeling of melting laser anneal to reproduce the backside impurity profiles.

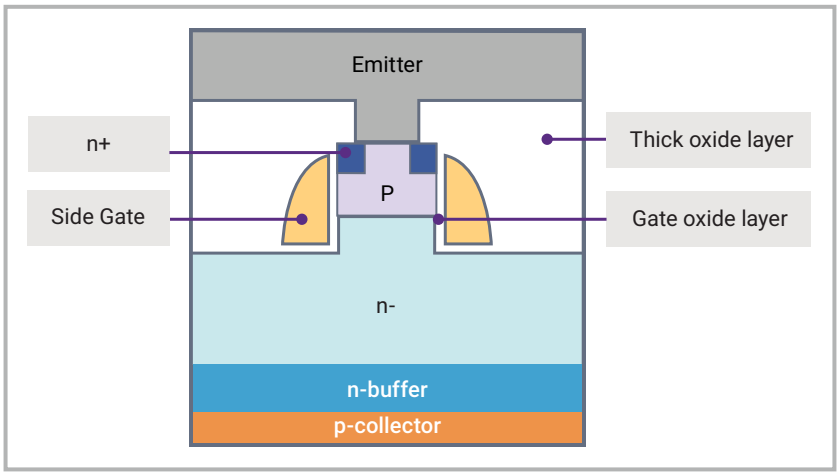

Figure 1: Cell design of side-gate HiGT[1].

Then, Sentaurus Calibration Workbench was applied to calibrate the DC characteristics of the IGBT. Various parameters of the mobility models and gate oxide interface charge were adjusted. In addition, we intensively studied carrier recombination physics by traps, which is introduced to the diode by the EBI process. Eventually, we succeeded to accurately reproduce the switching waveforms by applying a "temperature-dependent capture cross section" to existing trap models.

[1] M. Shiraishi et al., "Side Gate HiGT with Low dv/dt Noise and Low Loss," in Proceedings of ISPSD, pp. 199–202, June 2016.

“With the calibrated parameter set which is established by Sentaurus Calibration Workbench, we can accurately predict our device performance. It improves the quality of our products.”

~Mr. Masaki Shiraishi Senior Engineer, Hitachi Power Semiconductor Devices

Figure 2 shows the I–V and switching characteristics of measurements and TCAD simulations.

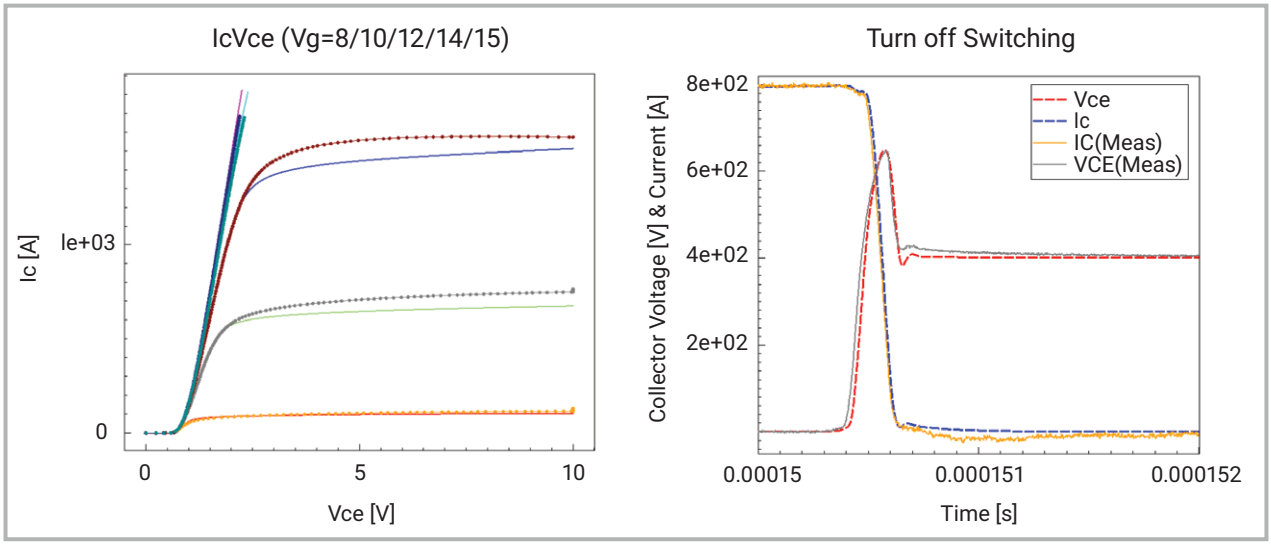

Figure 2: Calibration results of I–V characteristics (left) and switching waveforms (right).

Conclusion

We established calibrated TCAD setups for Hitachi’s silicon high-voltage IGBT/Diode devices. Our new tool, Sentaurus Calibration Workbench, worked well to calibrate the model parameters for the process and device simulations. It allows users to perform complex calibration tasks by themselves and to use the well-calibrated TCAD tools to significantly increase their development efficiency.