Thermal Dependence of $E_{off}(V_{ceon})$ trade-off performance for TIGBT with Localized Lifetime Control

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Introduction

Trench insulated gate bipolar transistor (TIGBT) is a semiconductor device, which is typically used as an electronic switch in various high power applications. One of the most important parameter for those applications is power efficiency. This parameter depends on turn-off power losses Eoff and on-state voltage drop Vceon [1]. One of the ways to improve $E_{off}(V_{ceon})$ trade-off performance is a localized lifetime control (LLC), which can be realized by a helium implantation into a field stop layer.

The helium implantation technique for better $E_{off}(V_{ceon})$ performance has been already described in literature [2], [3], [4]. The benefit of LLC could be affected by operation temperature. This effect has not been discussed in literature yet.

TIGBT active cell with LLC area generated by helium implantation at field stop layer

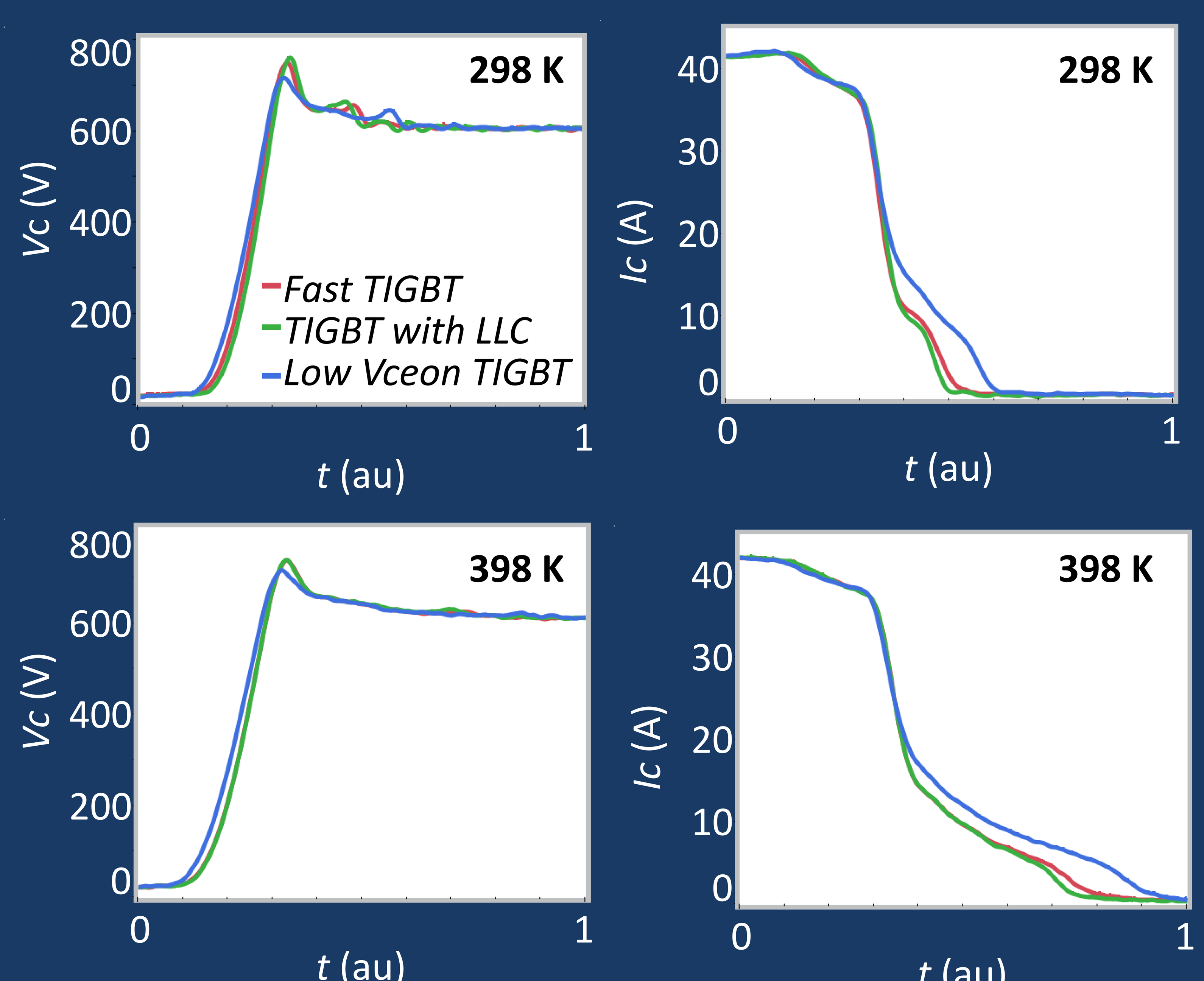
[1] Baliga, B. J: *The IGBT device: physics, design and applications of the insulated gate bipolar transistor*, William Andrew, 2015.
[2] Akiyama, H., Harada, M., Kondoh, H., and Akasaka, Y.: *Partial lifetime control in IGBT by helium irradiation through mask patterns,* Power Semiconductor Devices and ICs, 1991. ISPSD'91., Proceedings of the 3rd International Symposium, IEEE, 1991.
[3] Konishi, Y., Onishi, Y., Momota, S., and Sakurai, K.: *Optimized local lifetime control for the superior IGBTs*. Power Semiconductor Devices and ICs, 1996. ISPSD'96 Proceedings., 8th International Symposium, IEEE, 1996.
[4] Saggio, M., Raineri, V., Letor, R., and Frisina, F.: *Innovative localized lifetime control in high-speed IGBTs*, IEEE Electron Device Letters, 18(7), 333-335, 1997.

Experiment

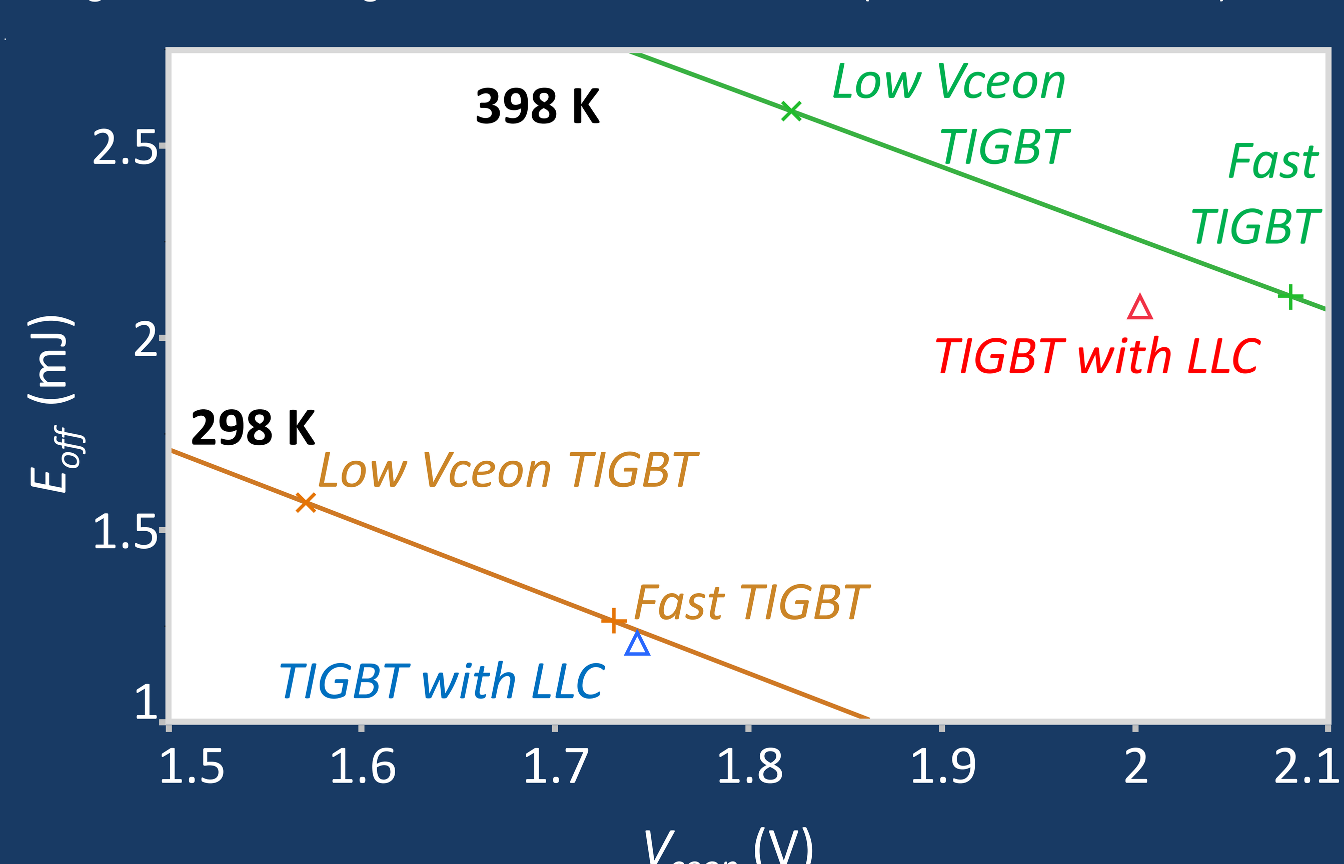
Three TIGBT devices have been used for an experiment:

- *Fast TIGBT*: 1200 V, 40 A, Fast UltraFS TIGBT
- *Low Vceon* TIGBT: 1200 V, 40 A, Low Vceon UltraFS TIGBT
- *TIGBT with LLC*: 1200 V, 40 A, UltraFS TIGBT with helium LLC

On-state voltage drop *Vceon* (collector current I_c = 40 A) and turn-off power losses E_{off} (gate voltage V_{gate} = 15 V → 0 V, collector current $i_c(t{=}0) = I_c$ = 40 A → 0 A, collector voltage $v_c(t{=}0)$ = 0 V → V_c = 600 V) have been measured for each devices at room temperature (298 K) and higher operation temperature (398 K).

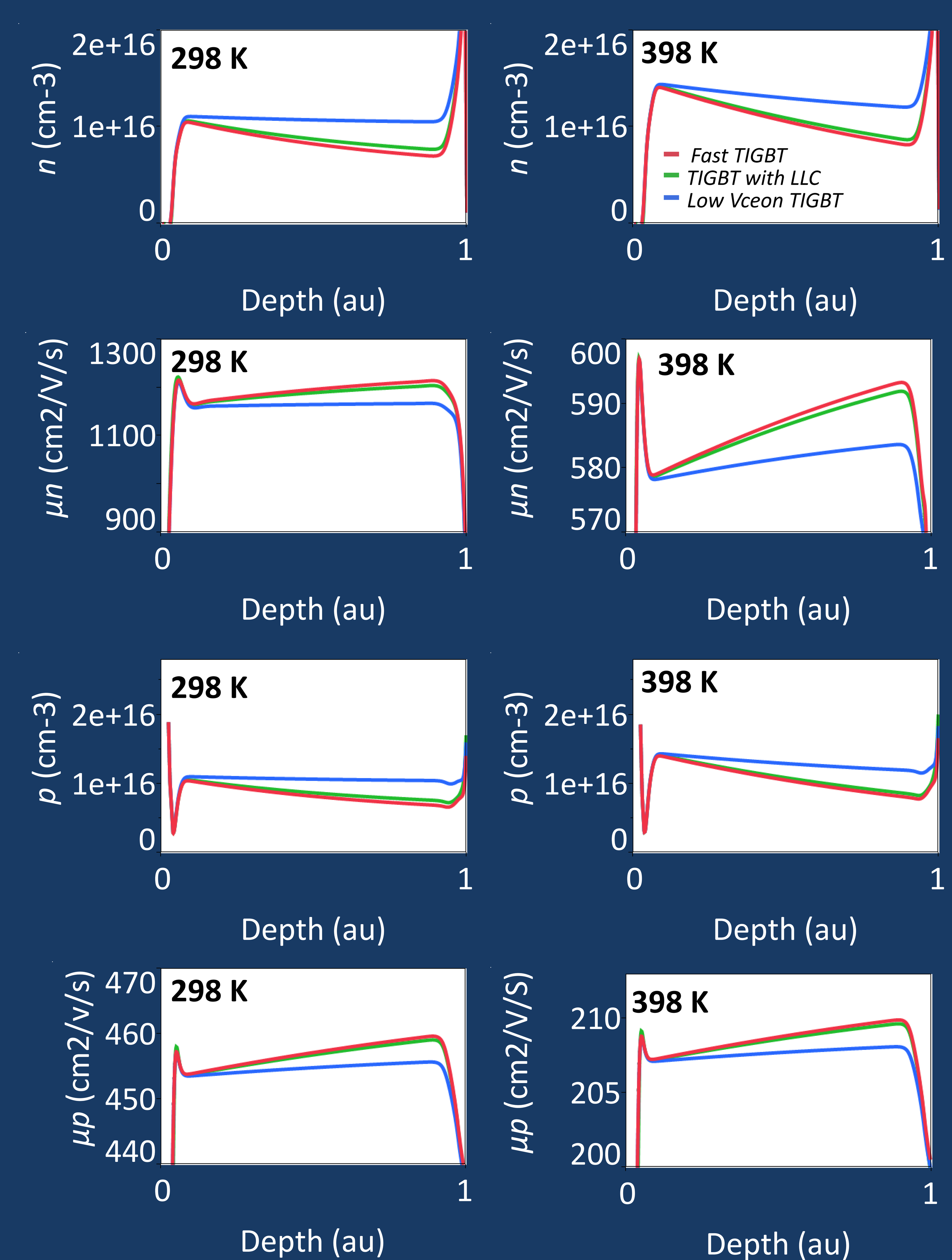


Switching waveforms during turn-off for 298 K and for 398 K (real measurement data)



$E_{off}(V_{ceon})$ trade-off chart for *Low Vceon TIGBT*, *Fast TIGBT* and *TIGBT with LLC* for 298 K and for 398 K (real measurement data). All three devices were manufactured with an identical active cell and field stop. *Low Vceon TIGBT* and *TIGBT with LLC* were processed with the same collector dose. *Fast TIGBT* was processed with a lower collector dose.

TCAD Simulation



n, p, μ_n, μ_p profiles for three types of TIGBTs (Sentaurus TCAD simulation)

Summary

TIGBT with localized lifetime control realized by damage induced by helium implantation has been prepared. Better $E_{off}(V_{ceon})$ was observed according to literature. Effect of the LLC was significant for higher temperature (398 K). Effect at room temperature was negligible. This phenomena could be explained by electron and hole concentrations and turn-off switching waveforms. Due to higher carrier concentration the lifetime is more significant for higher temperature and bi-polar current tail could be reduced significantly.

Acknowledgement

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