48. Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
22.-25. September 2003

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A study on the influence of different carrier life-time profiles on the properties of 1.2kV NPT IGBTs

Carrier Lifetime Control

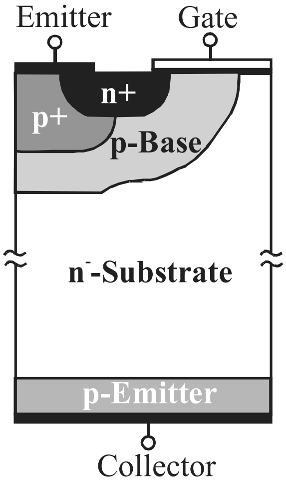

Figure 1: 1.2kV NPT IGBT

Irradiation techniques are widely used for carrier lifetime control in power devices. The stationary and turn-off properties of manufacturing samples of state-of–the-art 1.2kV NPT IGBTs as shown in figure 1, developed in previous work [1], are studied using 2D device simulation. Based on the carrier distribution during the turn-off of the device, shown in figures 2a/2b, different homogenous and local recombination center profiles are considered:

a - No carrier lifetime control (NPT12N)

b - Homogenous lifetime reduction by electron irradiation (NPT12E)
Due to the decreased carrier lifetimes, the initial carrier concentration distribution at t_1, equally to the stationary carrier distribution in the devices on-state, is lowered. Consequently, the number of excess carriers is lower which results in a clear increase of the forward voltage and a faster turn-off process. Therefore, turn-off losses are expected to decrease, enabling the device for applications using higher switching frequencies.

c - Shallow recombination center profile by low-energy helium radiation (NPT12H1)
The recombination center peak is placed in the pn-junction region of the backside emitter. This reduces the emitter-efficiency, leading to a lower carrier concentration at the physical emitter of the device. Expectations are reduced turn-off losses and a faster turn-off in connection with

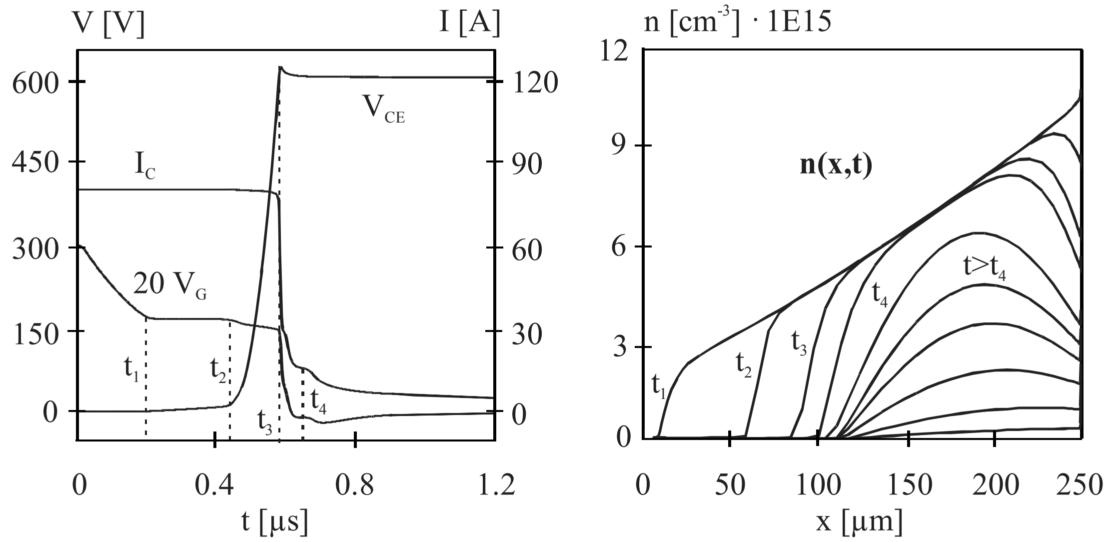

Figure 2: a) Turn-off characteristics b) carrier distribution during turn-off

an only slightly increased forward voltage drop.

d - Deep recombination center profile by high-energy helium radiation (NPT12H2)

As shown in figure 2b, for $t>t_4$ a remaining carrier hill is found with a maximum in a depth of app. 190µm. These carriers are responsible for the tail current which contributes significantly to the turn-off losses of an NPT IGBT. Therefore, the recombination center peak is placed in depth of 190µm to reduce the stored charge. This should result in drastically reduced turn-off losses. Nevertheless, since carrier lifetime is not only reduced in the peak region but also in the region before, on-state losses will increase.

Experimental and simulation results

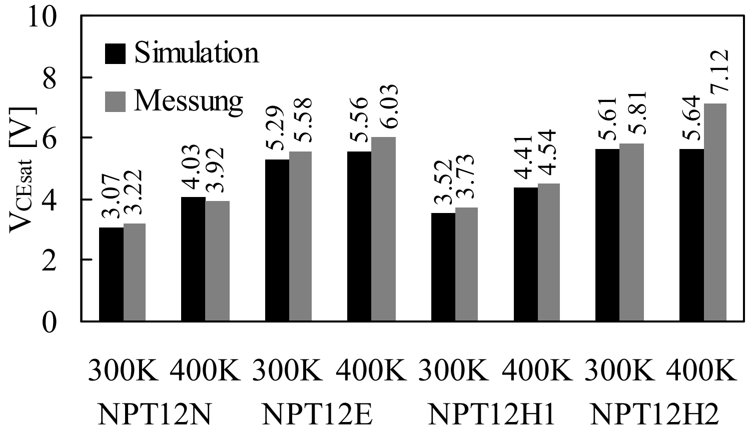

Figure 3: V_{CEsat} of IGBTs (V_G=15V, I_F=25A)

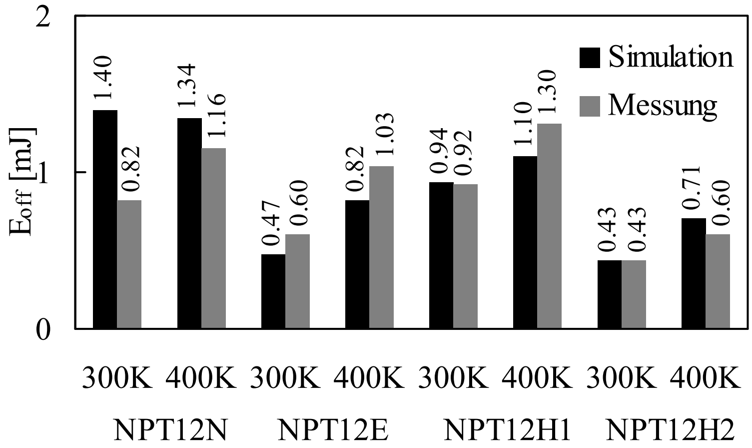

Figure 4: E_{off} of IGBTs (V_R=600V, I_F=15A, R_G=33Ω)

The sensitivity of the parameters stationary and turn-off losses in dependence of the realized recombination center profile is investigated in experiment and simulation using an extended recombination model for considering several radiation-induced deep centers and a set of previously determined parameters [2]. A reduction of turn-off losses was gained, but related to an increase of the on-state losses (see figures 3 and 4). The accordance of simulation and experiment is sufficient. Device simulation is capable to support the development and optimization process. Irradiation processes might be used for an optimization of devices concerning the targeted switching frequency. Furthermore, the use of electron irradiation is recently reported for the optimization of reverse-blocking IGBTs, especially for reducing the reverse leakage current [3].

References

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[3] Takei,M., Naito,T., Ueno,K.: The Reverse Blocking IGBT for Matrix Converter With Ultra-Thin Wafer Technology, Proc. ISPSD 2003

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