LIGBT compact model

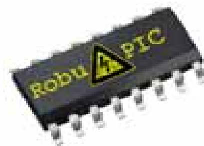
Cambridge University

Florin Udrea, Ettore Napoli, Sahan Gamage

Camsemi

Gehan Amaratunga, Tanja Trajkovic, Vasantha Pathirana

CAMBRIDGE UNIVERSITY



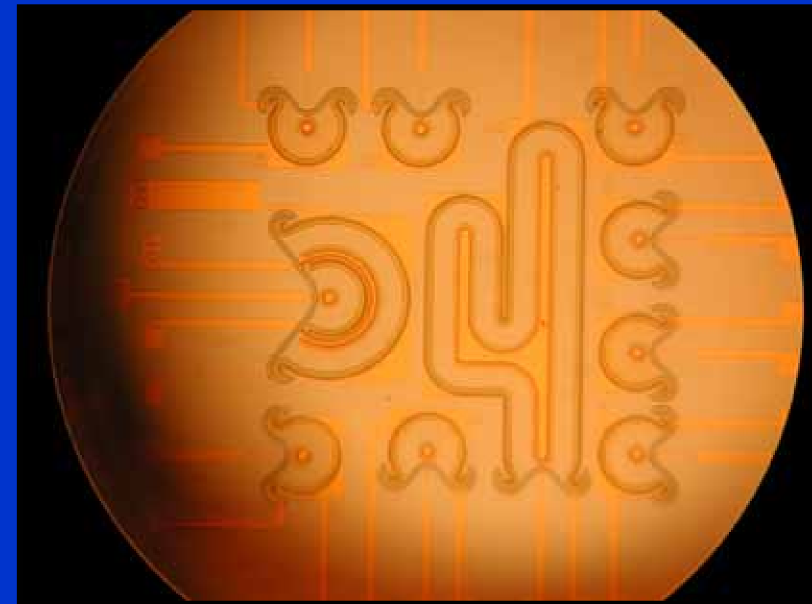
04 June 2006, Napoli

Outline

- CamSemi LIGBT technology
- Modification to IGBT Hefner's model
- Complete Thin SOI LIGBT model
- Electrothermal model
- Thick SOI LIGBT model
- JI LIGBT model
- Conclusion

Camsemi technology

- Ultra-thin fully CMOS compatible SOI (0.25 μm) on 1 μm BOX
- Fast 500 - 600 V LIGBTs with frequency ability close to 500 kHz



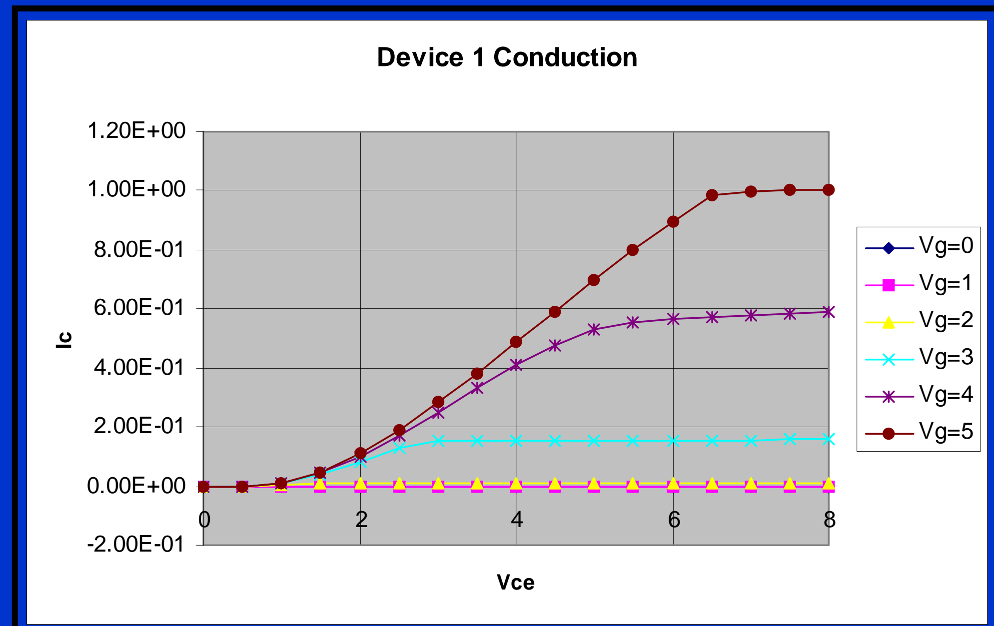
Camsemi Power IC technology

3.5 mm

High current LIGBT

Low voltage CMOS electronics :

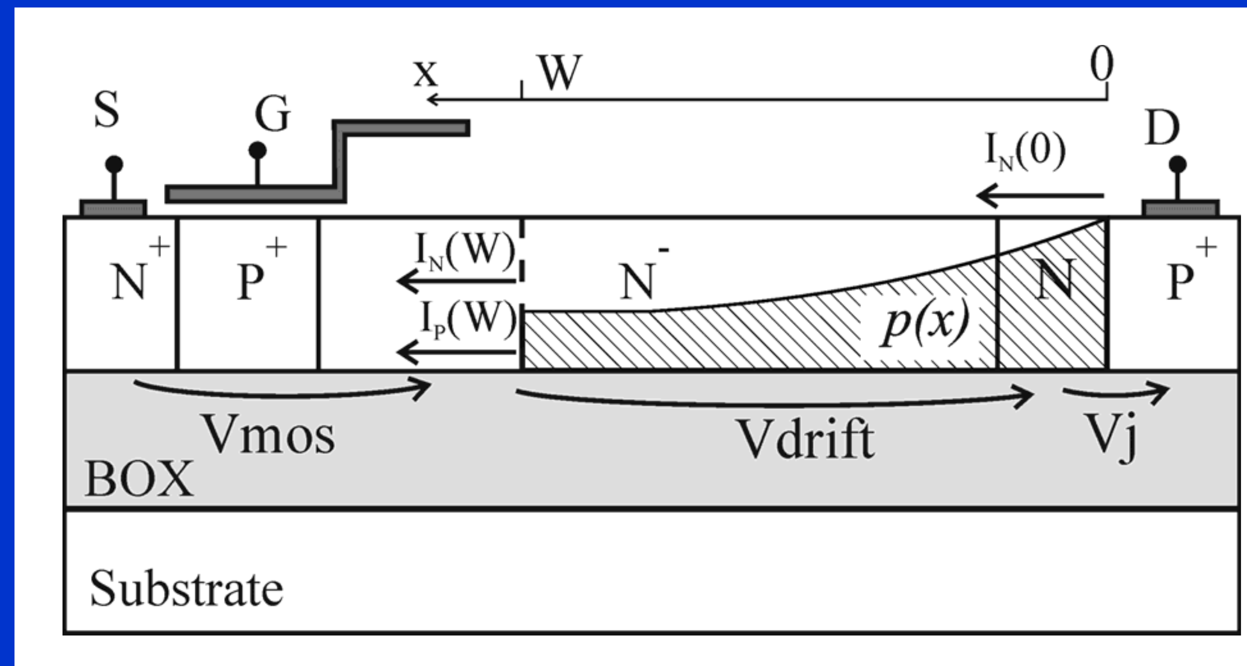
Gate driver
Protection circuits
controller



Motivation

- Available IGBT circuit models are not suited to Lateral IGBT
- Need for
  - a reliable physical based model for Lateral IGBT
  - usable in various circuit simulators
- Extension to different LIGBT technologies
- Important for smart power design

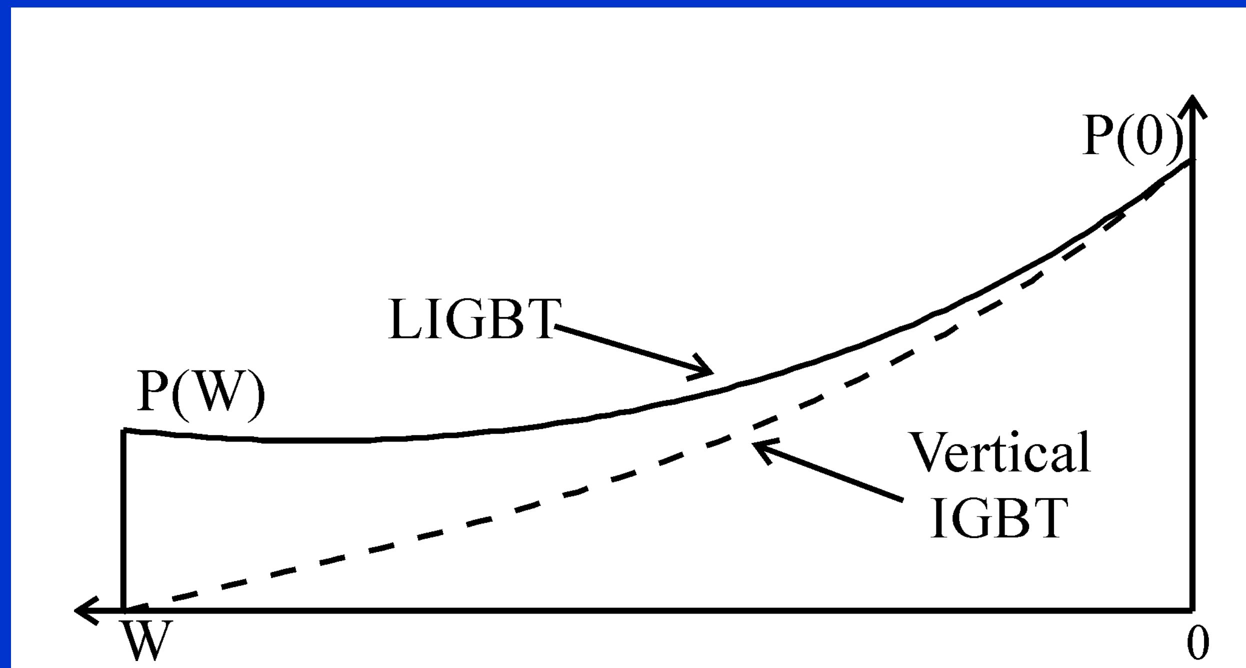
Thin SOI Lateral IGBT



- 600V PT
- Transparent buffer
- Source and Drain up to the BOX
- Current flow is horizontal and 1D

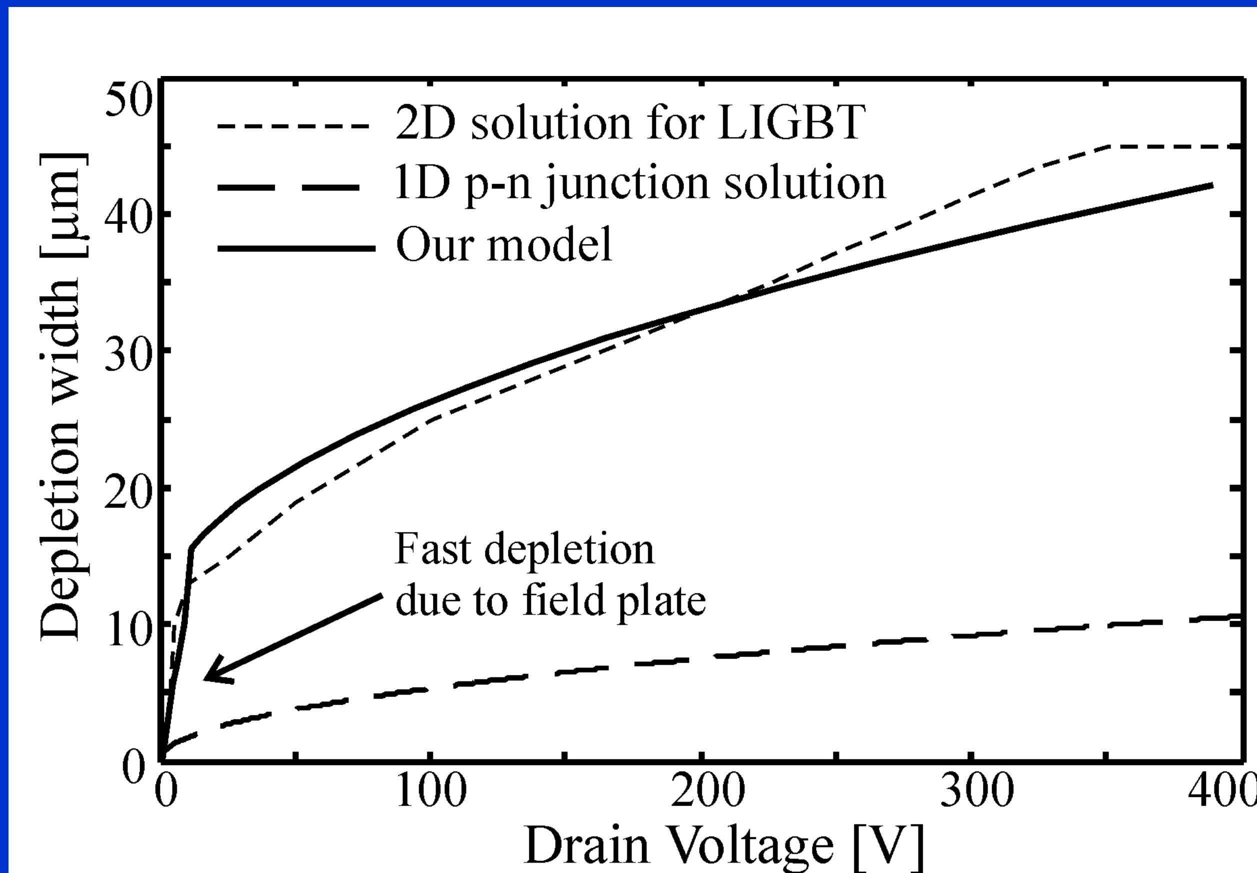
Differences with Vertical IGBT (1)

- Not zero carrier concentration at the collector edge for LIGBT



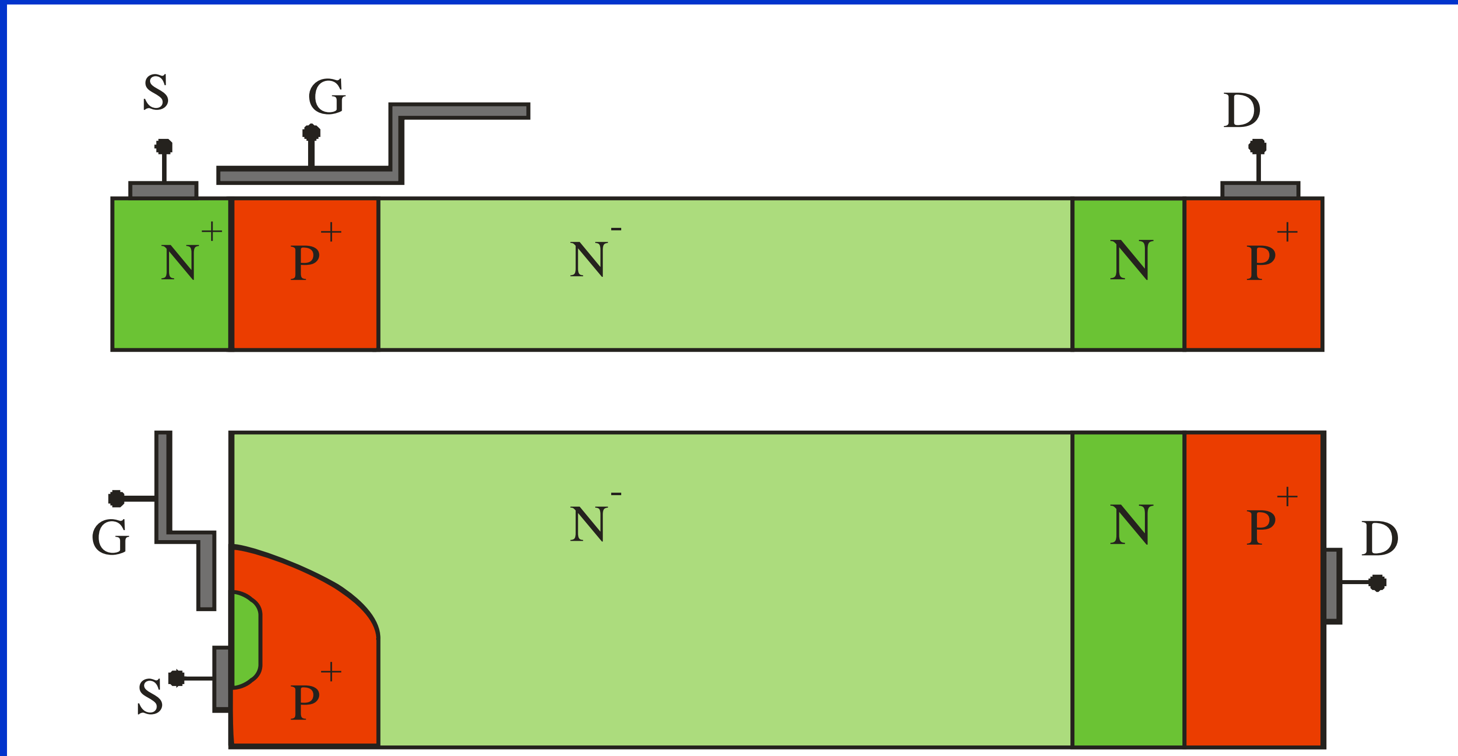
Differences with Vertical IGBT (2)

- Depletion width vs. reverse voltage is influenced by 2D effects



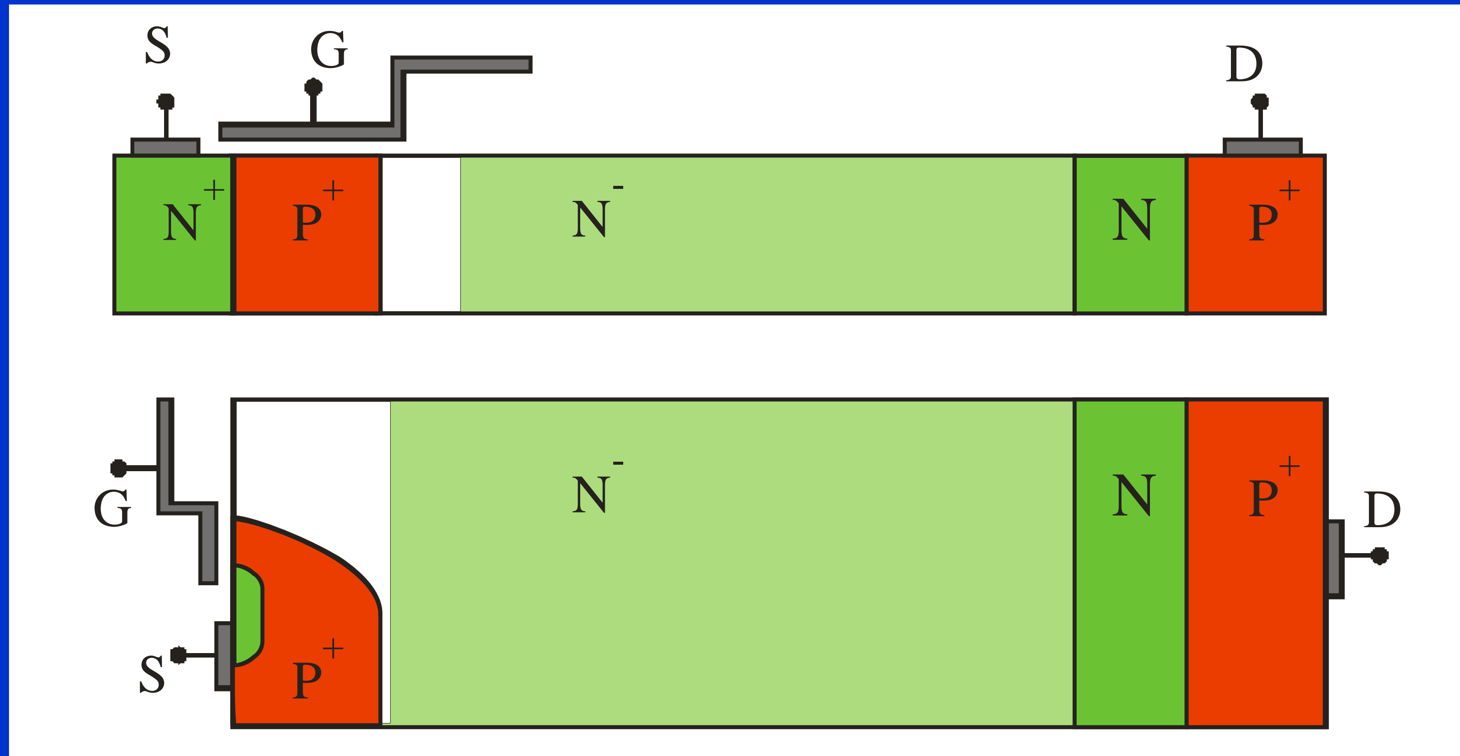
Differences with Vertical IGBT (3)

- Depletion width LIGBT vs. Vertical IGBT
- 0V



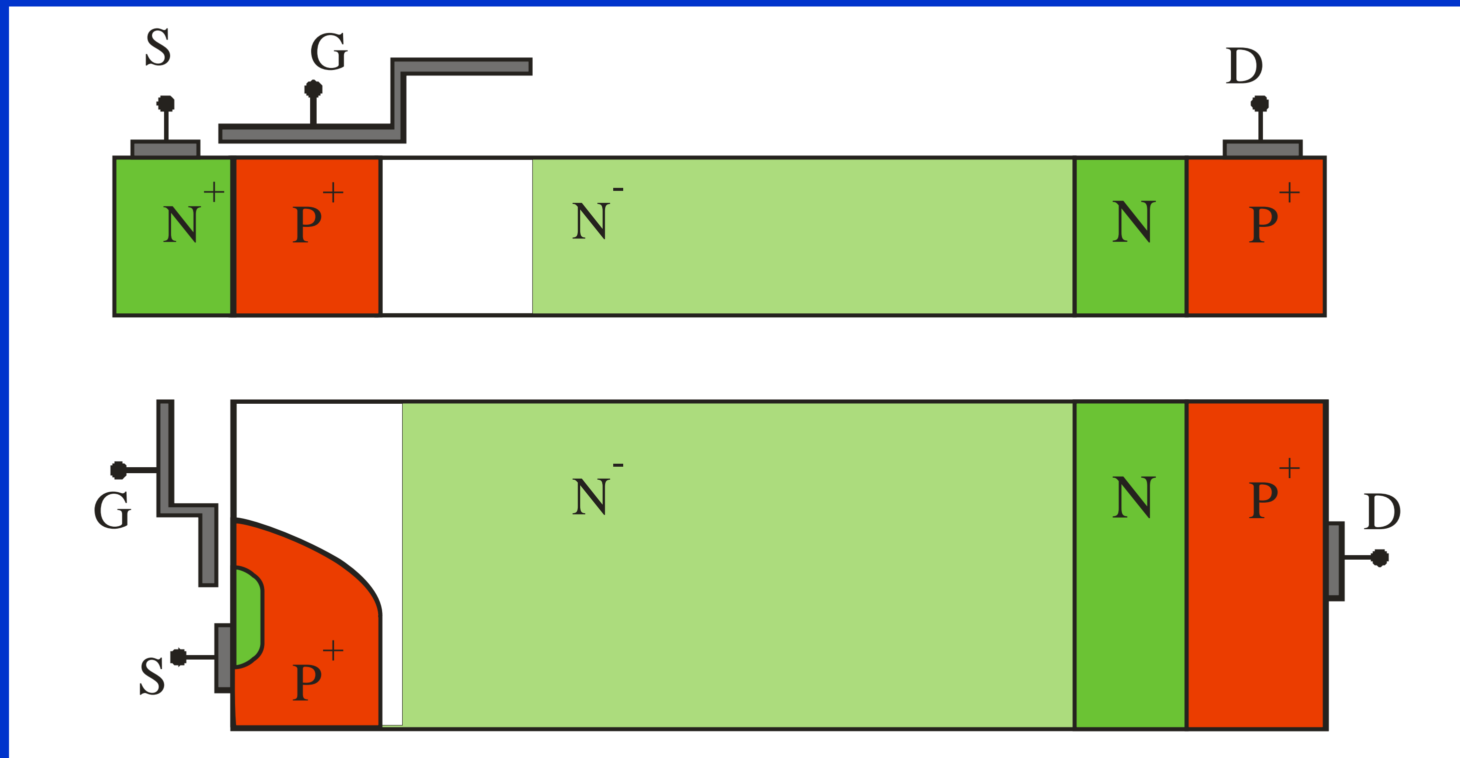
Differences with Vertical IGBT (3)

- Depletion width LIGBT vs. Vertical IGBT
- 5V



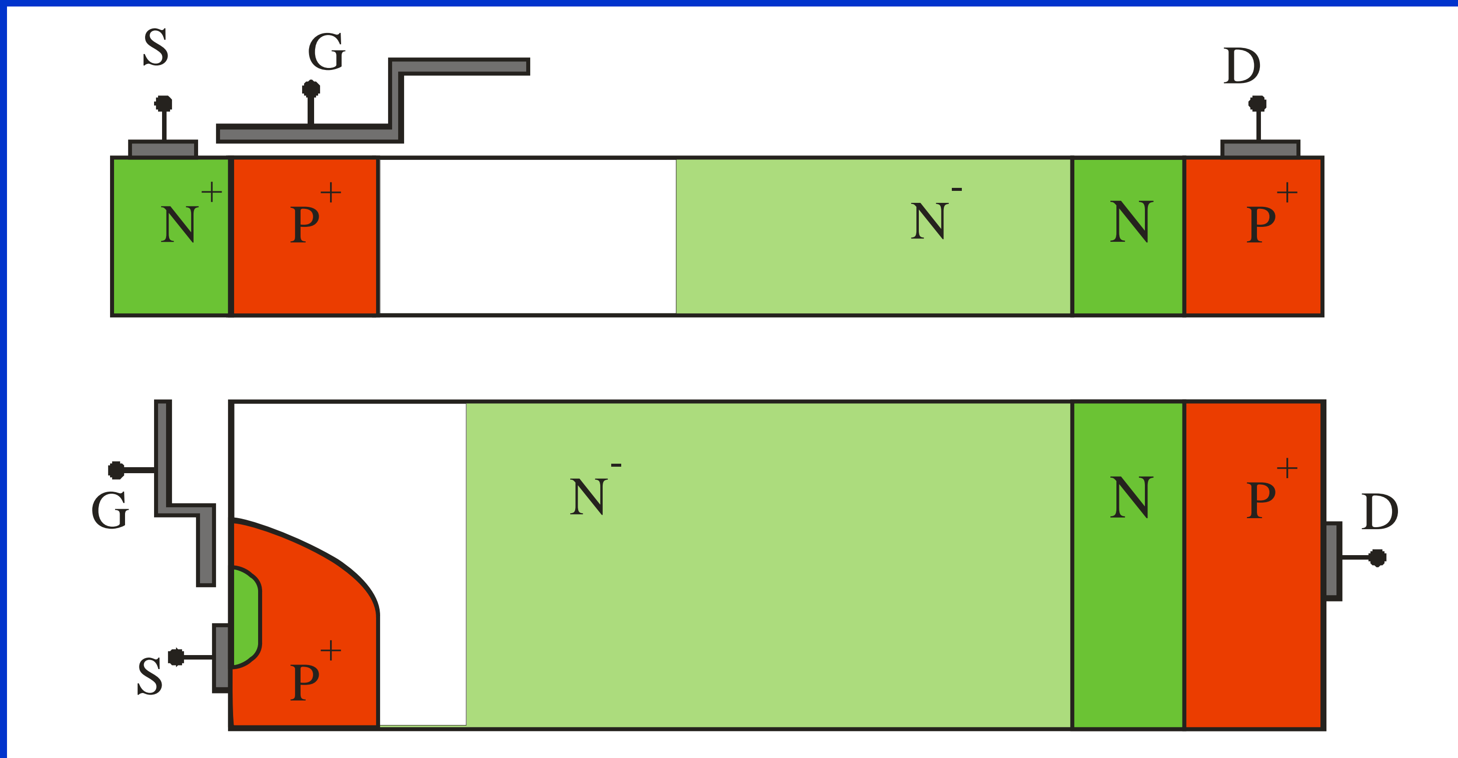
Differences with Vertical IGBT (3)

- Depletion width LIGBT vs. Vertical IGBT
- 10V



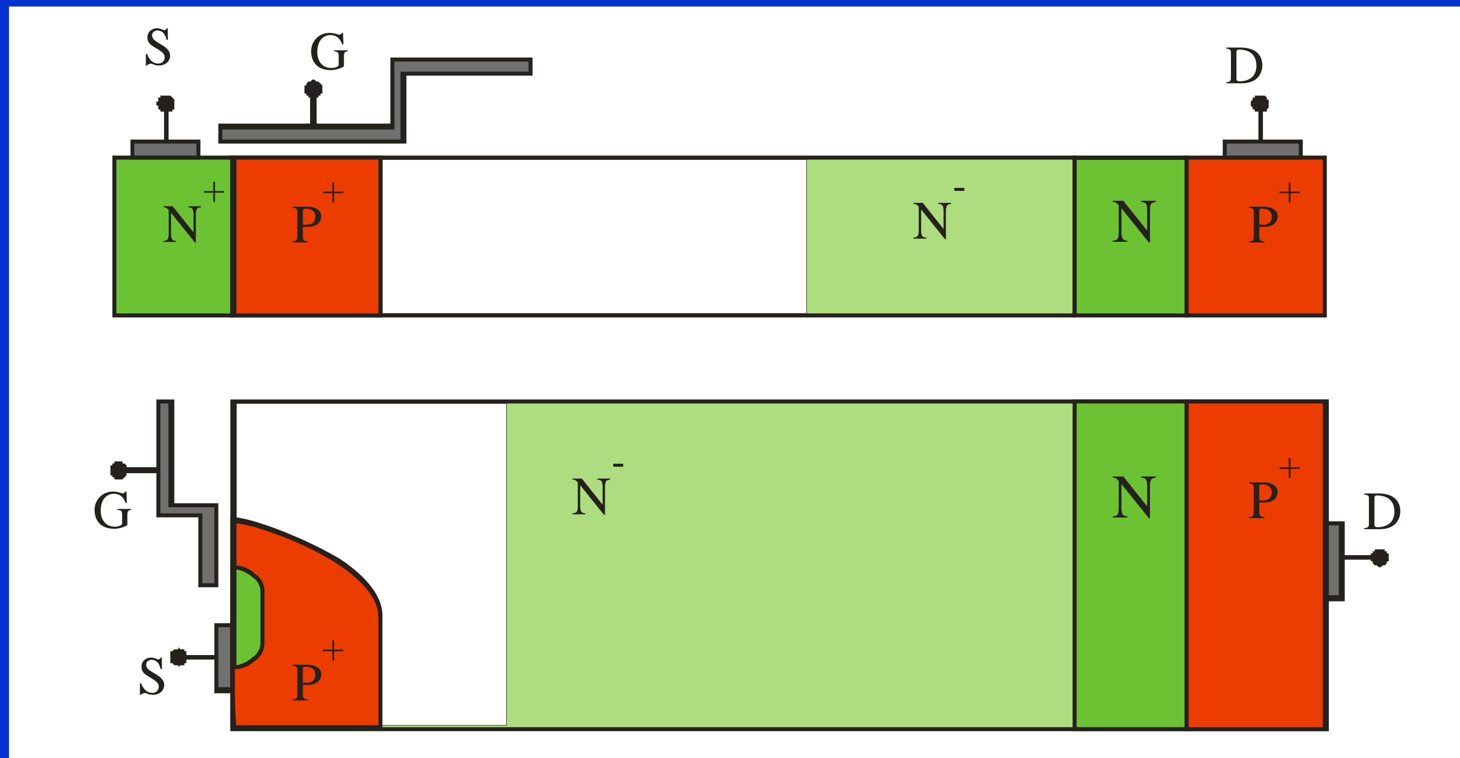
Differences with Vertical IGBT (3)

- Depletion width LIGBT vs. Vertical IGBT
- 100V



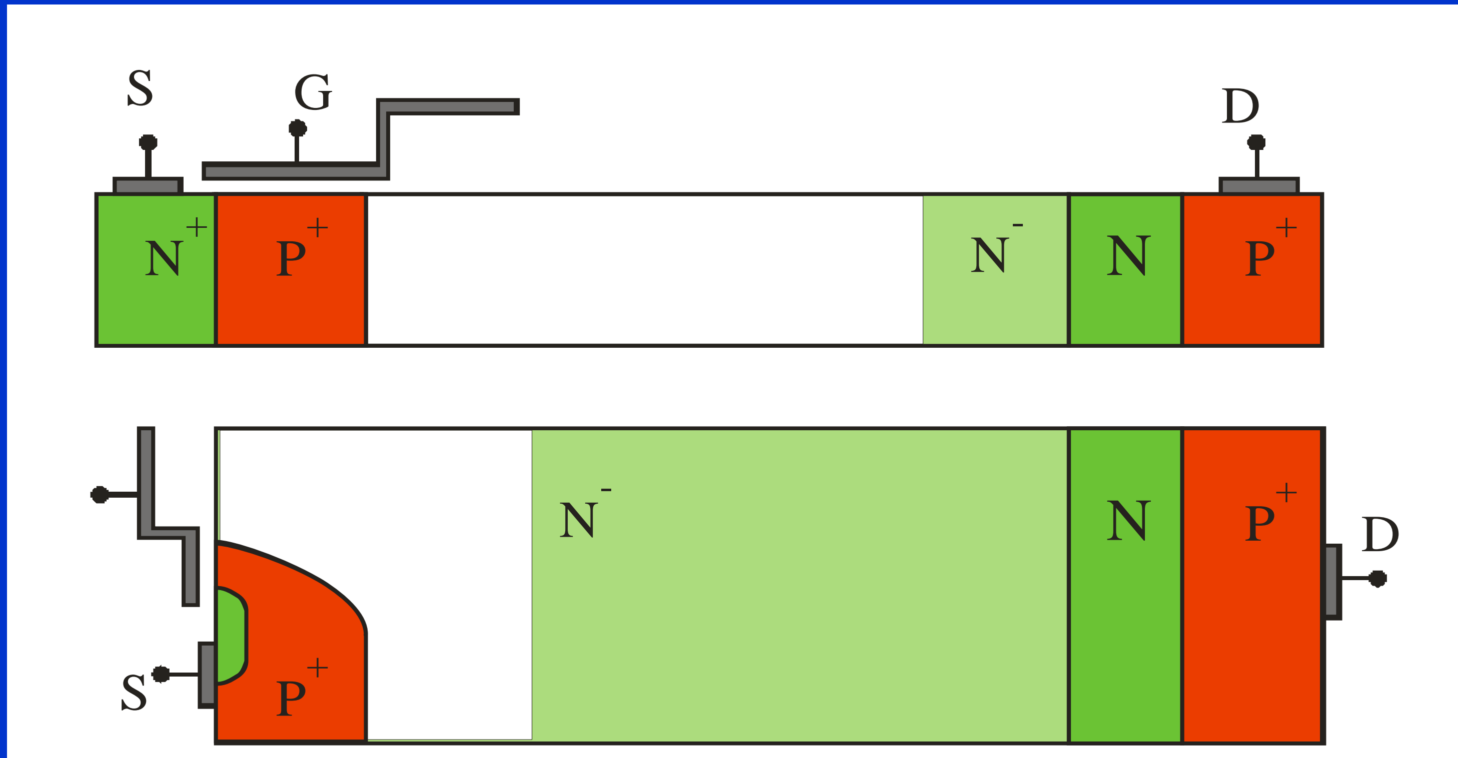
Differences with Vertical IGBT (3)

- Depletion width LIGBT vs. Vertical IGBT
- 200V



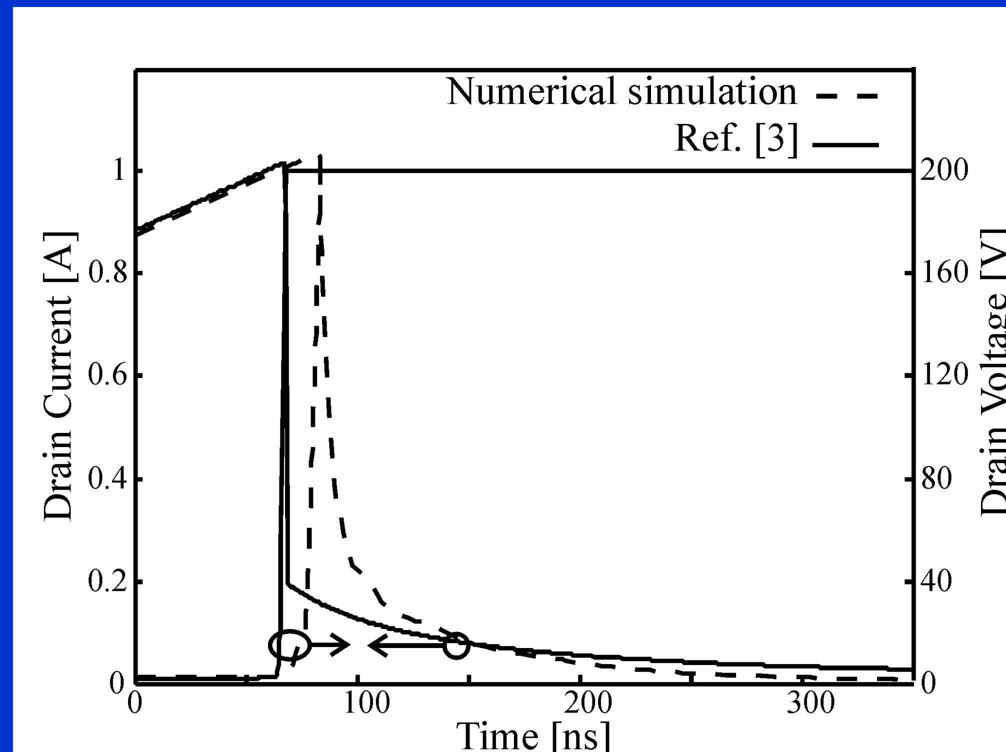
Differences with Vertical IGBT (3)

- Depletion width LIGBT vs. Vertical IGBT
- 300V



IGBT models not suited for LIGBT

- Voltage rise at turn-off is faster due to lower charge in the epilayer and slower depletion width expansion



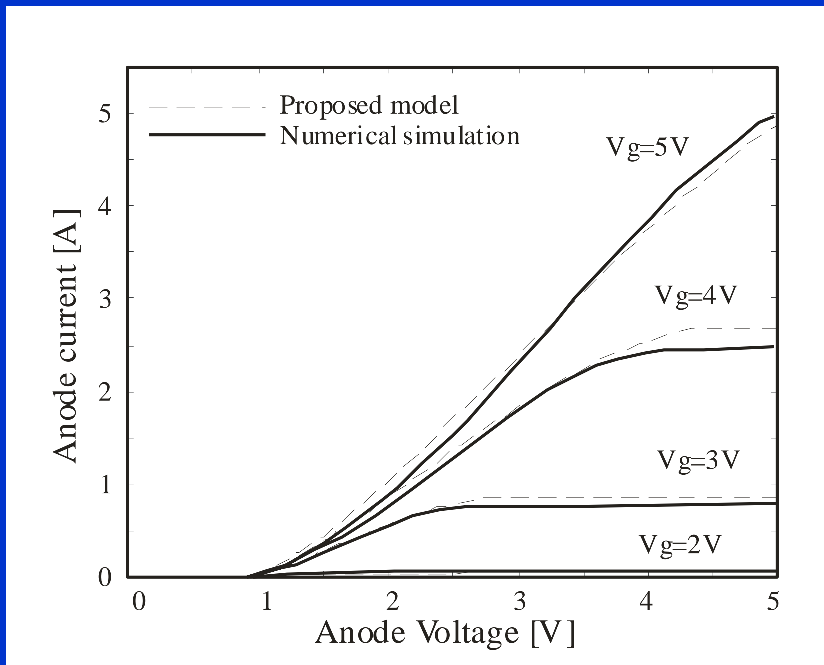
Spice sub-circuit model for LIGBT

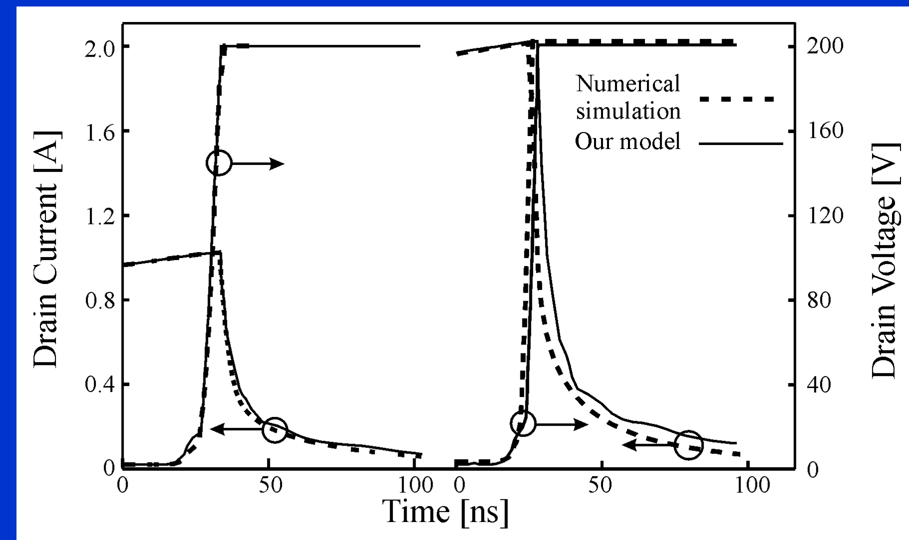
Drain
Vj
Vdrift
Cox Cdep
Gate
Vmos
$I_P(W)$
Cds
$I_N(W)$
Cgs
Source
Q
τ
$I_N(0)$
$I_N(W)$
I_{PC_TRN}

Currents and voltages

Epilayer charge equation

Model behavior

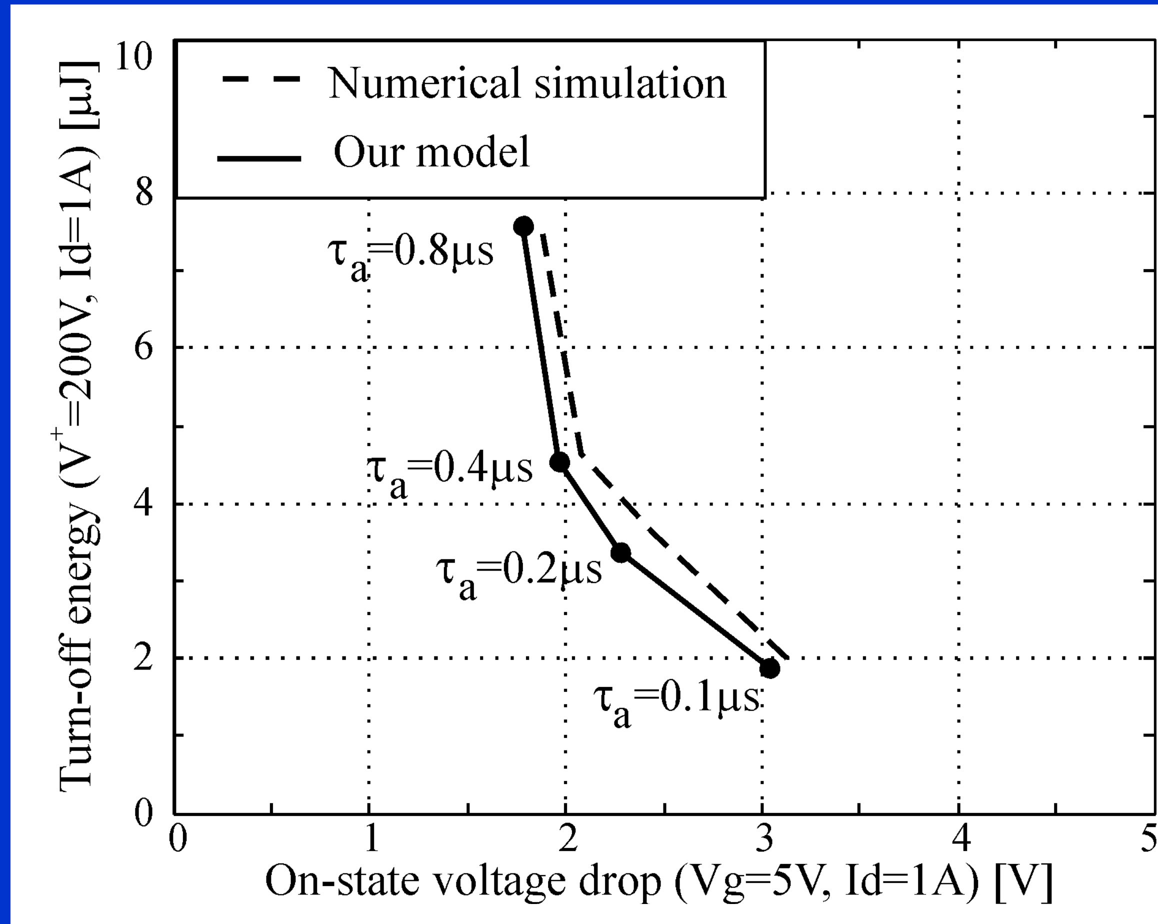




Static characteristics

Inductive Turn-off

Model behavior



- **Toff Energy vs. Von as a function of lifetime**

Half bridge circuit

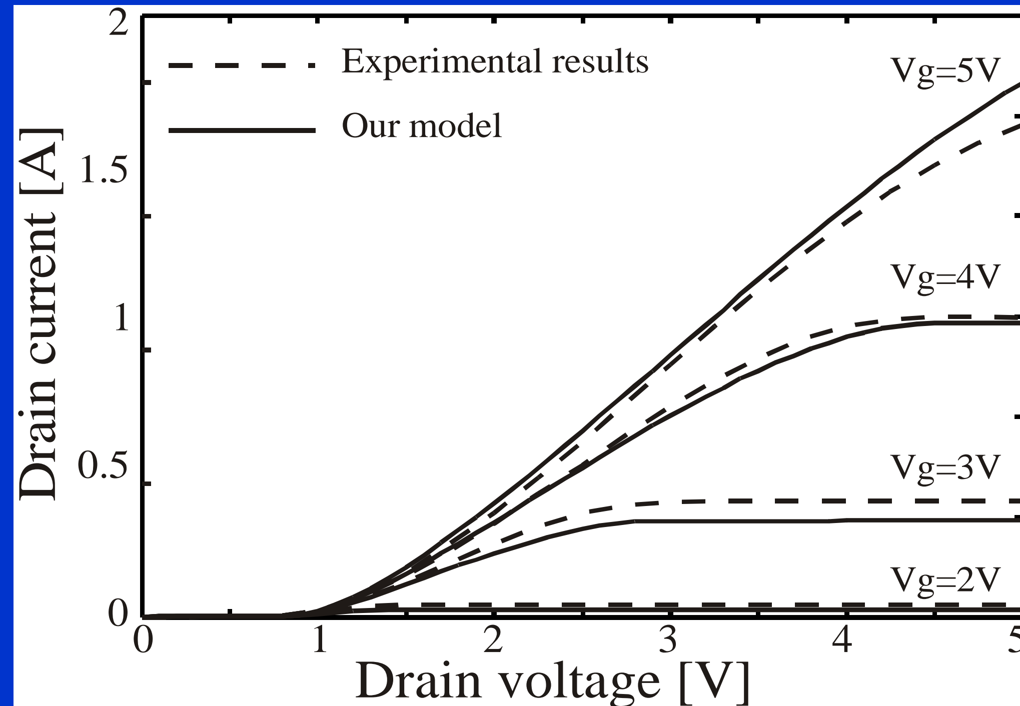
100V
S2
D2
0.25mH 45Ω
100V
S1
D1

Load Current [A]
Load Voltage [V]
Time [μs]

- **Output characteristics**

  200V; 2A; 100kHz

Experimental results on flyback circuit



Experimental results on flyback circuit

Experimental result
Our model

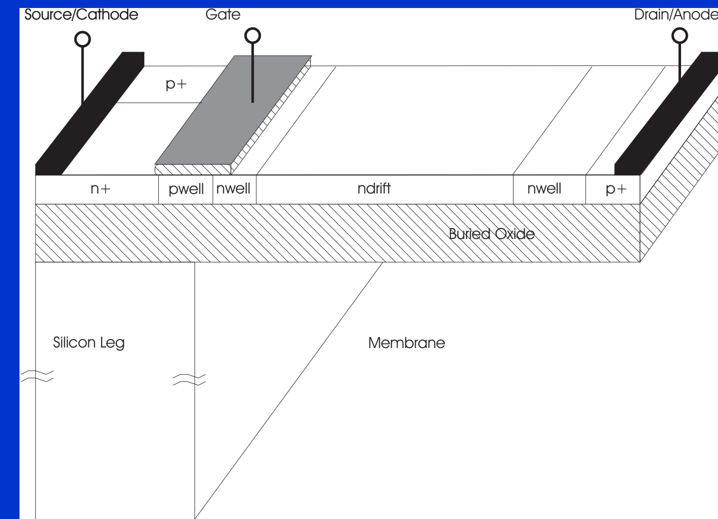
Drain Current [A]
Drain Voltage [V]

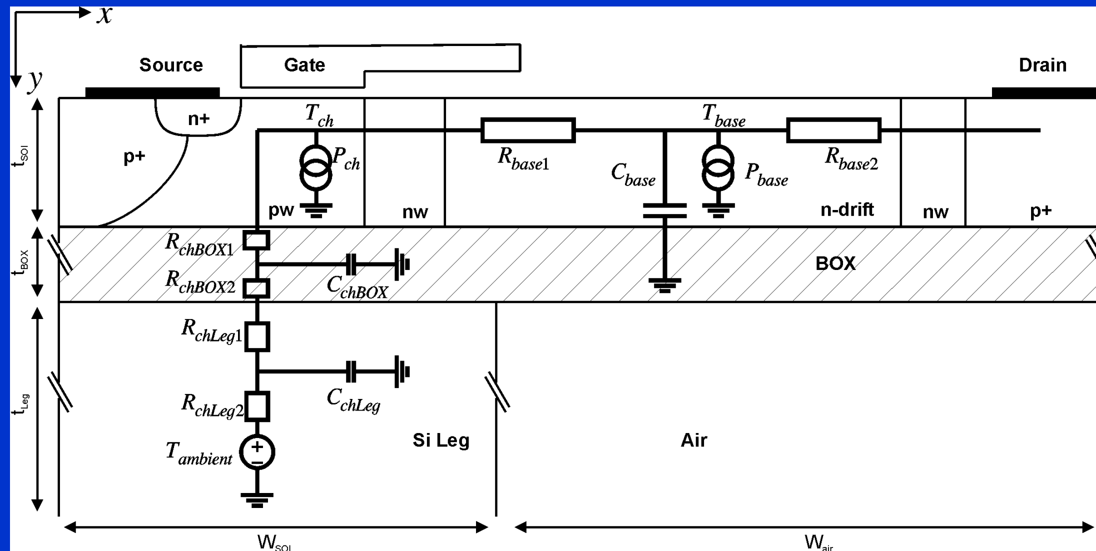
Experimental result
Our model

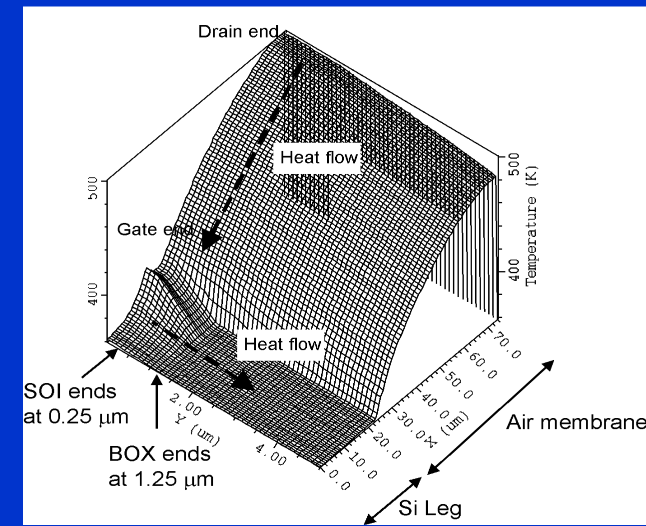
Power [kW]
Time [ns]

LIGBT device thermal model

- Anode end heat dissipate laterally through the thin silicon area and then vertically through the silicon leg
- Second large peak at gate end in saturation mode

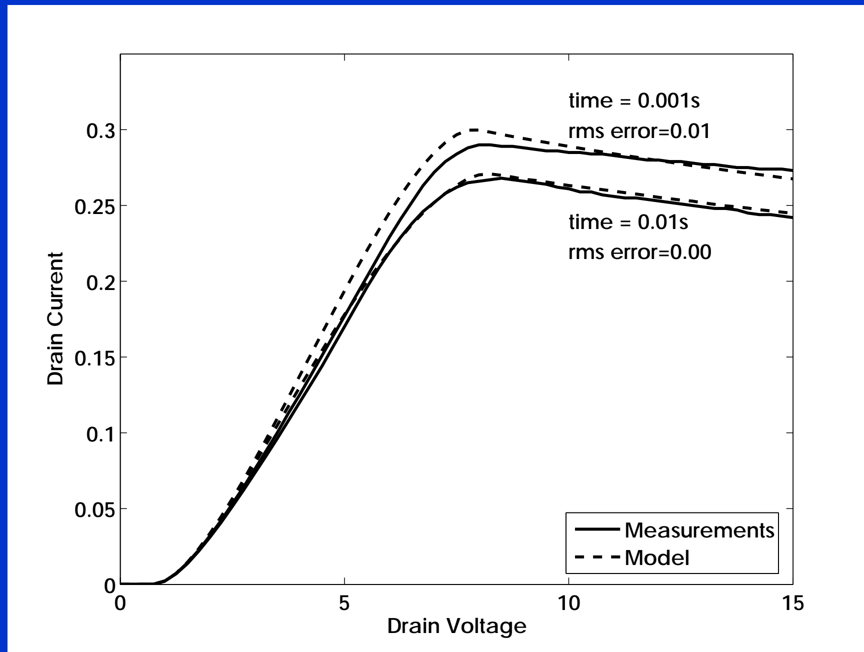




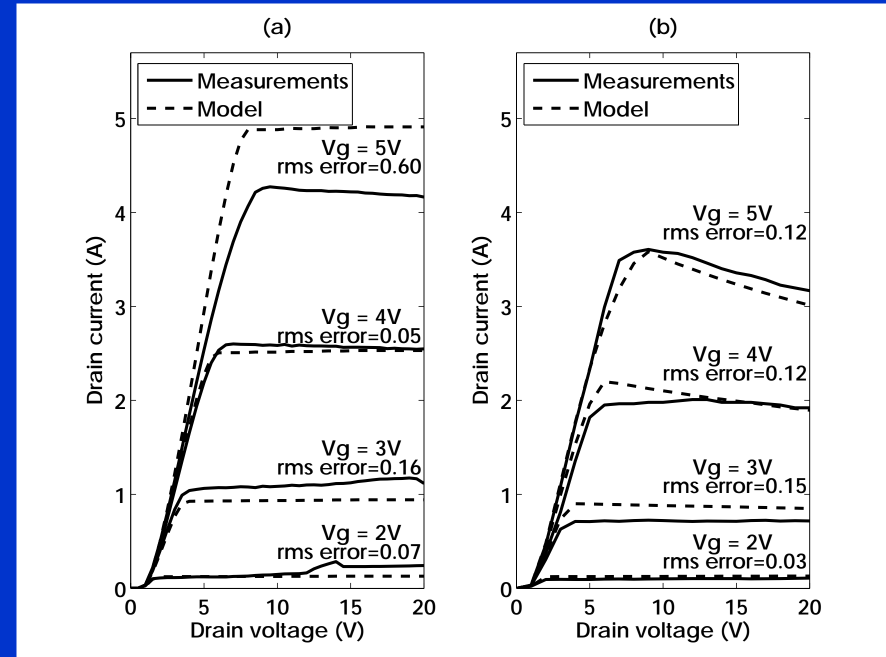


Self-Heating Results: Measures vs. Model

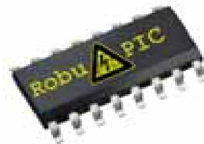
Transient results



Steady-state results
(a) no self-heating (b) with self-heating



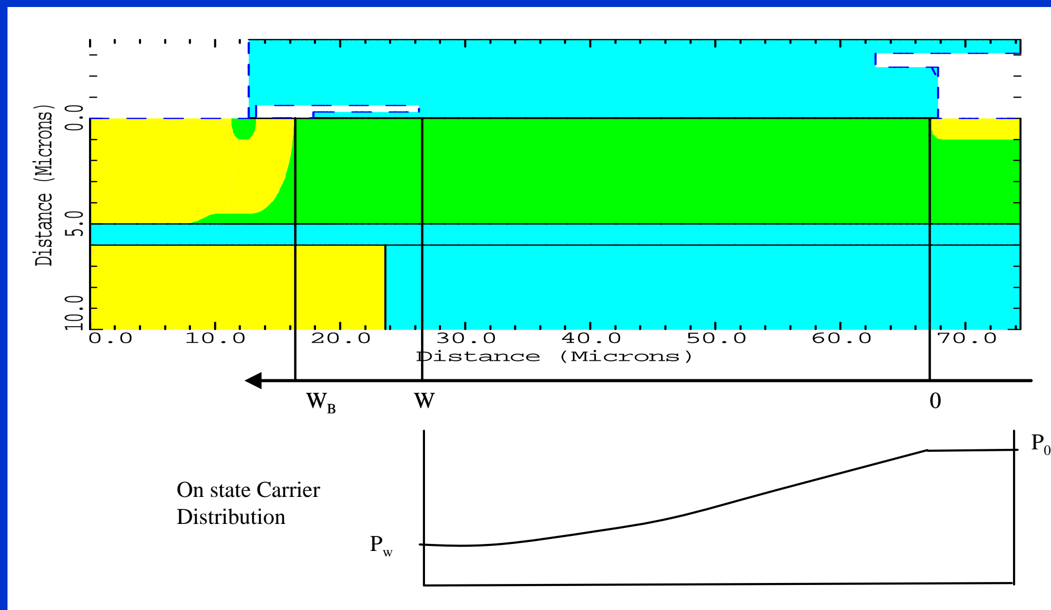
CAMBRIDGE
UNIVERSITY

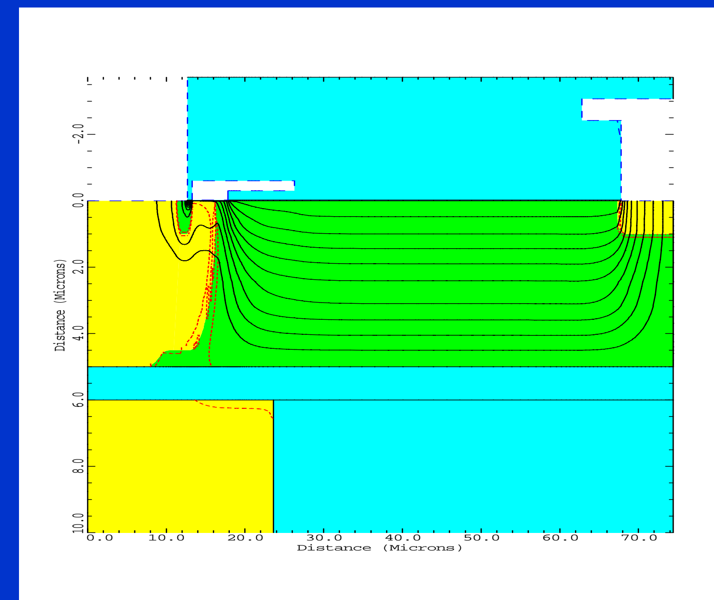


04 June 2006, Napoli

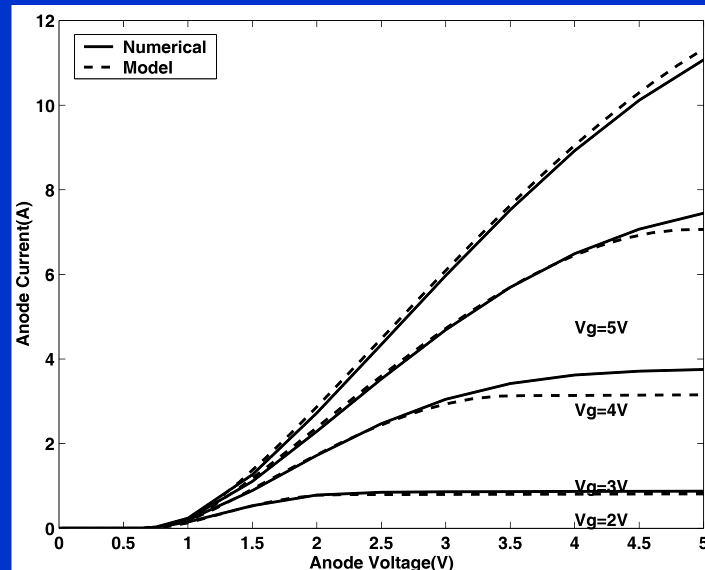
Thick SOI extension

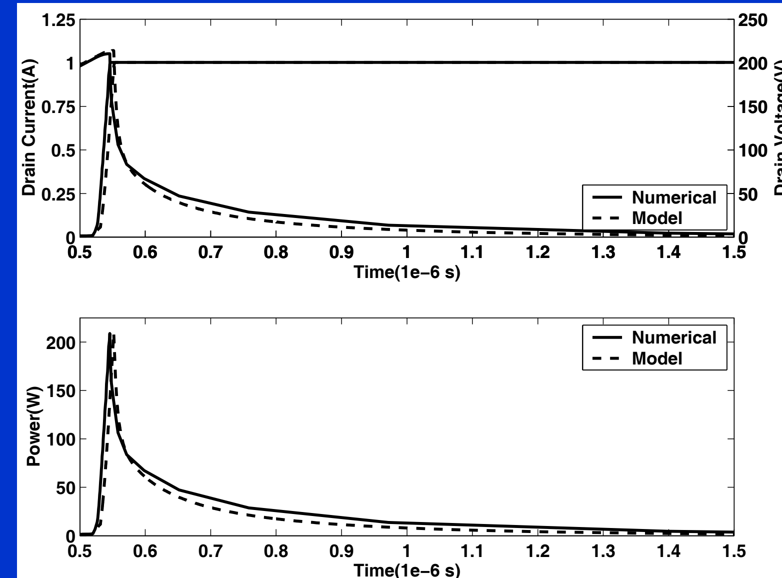
- Extension to thick SOI (0.25u->5u)
- Mainly a change on drift resistance equation





Model Results for thick SOI Extension





- Excellent matching is obtained for both steady-state and transient
- This shows how our model can be extended to thick SOI without much modification to the existing thin SOI model.

JI-LIGBT model: The circuit

Dimensions considered in the model are shown

S G D
Wdev
Lmos Atepi Ldrift
Lano
Lbuff
Tsi
Atsub Lsub
Tsub
B

JI-LIGBT model: Device

Not huge differences w.r.t. the SOI model

Ano
I_{TOT}
Vj
e
Repi
Rsub
Vohm
m
Vmob
epi+buff
i
Rinf
Vlim
I_{mos}
d
Gate
Vmos
I_{P_EPI}
I_{P_SUB}
Kat

Qepi
C_E
R_{E1}
R_{E2}
I_{mos}
αI_{nb}

Qsub
C_S
R_{S1}
R_{S2}
I_{P_IN}
I_{P_SUB}

The circuit: main circuit

Current divided into electrons through the Lev. 3 MOS and hole trhough the epilayer (Ip_epi) and the substrate (Ip_sub)

Main circuit

Ano
I_{TOT}
Vj
e
Repi
Rsub
Vohm
m
Vmob
epi+buff
i
Rinf
Vlim
I_{mos}
d
Gate
Vmos
I_{P_EPI}
I_{P_SUB}
Kat

Epilayer charge control equation

Qepi
C_E
R_{E1}
R_{E2}
I_{mos}
αI_{nb}

Qsub
C_S
R_{S1}
R_{S2}
I_{P_IN}
I_{P_SUB}

Substrate charge control equation

JI-LIGBT: 600V device Id-Vds characteristic

No convergence problems!

Good agreement w.r.t. numerical 2D simulations

1.6
1.2
0.8
0.4
0

0V 1V 2V 3V 4V 5V 6V 7V 8V 9V 10V

Model Vg10V Vg8V Vg6V Vg4V

V_Vd

dc-model-dc....

Conclusion

- Compact LIGBT models for different technologies
  - Thin SOI
  - Thick SOI
  - Junction Isolation
- Non isothermal extension of the model