Characterization of "Handmade-packaged" IGBT Chips

Internship Report

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Contents

1 Motivation

To gain time & resources economization, the ability to characterize the testing dies directly in place of developement in Rožnov would be beneficial.

Several “packaging” and measurements options are dealt with in this document as well as observed impact on the device characteristics.

2 Packaging

- Wire bonding
  - max. $\varnothing 1\,\mathrm{mil}$ ($\approx 25\,\mu$m)[1][2] contrary to $15\,\mathrm{mil}$ used for IGBTs
  - max. continuous current ≈ 1A/1wire; 8 wires tested as sufficient for double pulse current over 80 A
- encapsulation: epoxy resin - availability and simple treatment
  - dilatation harmless even for bond wires of $\varnothing 1\,\mathrm{mil}$

[1] CRESSTO s.r.o., Rožnov p. R., `www.cressto.cz`

[2] SEANT Technology s.r.o., Brno, `www.seant.cz`

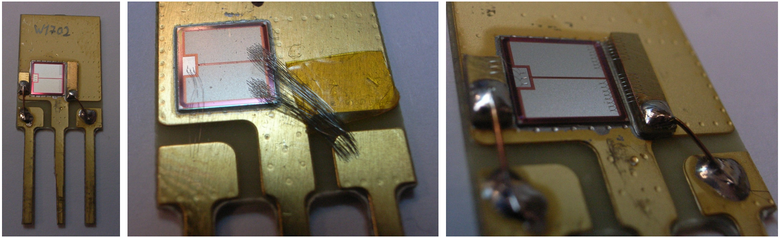
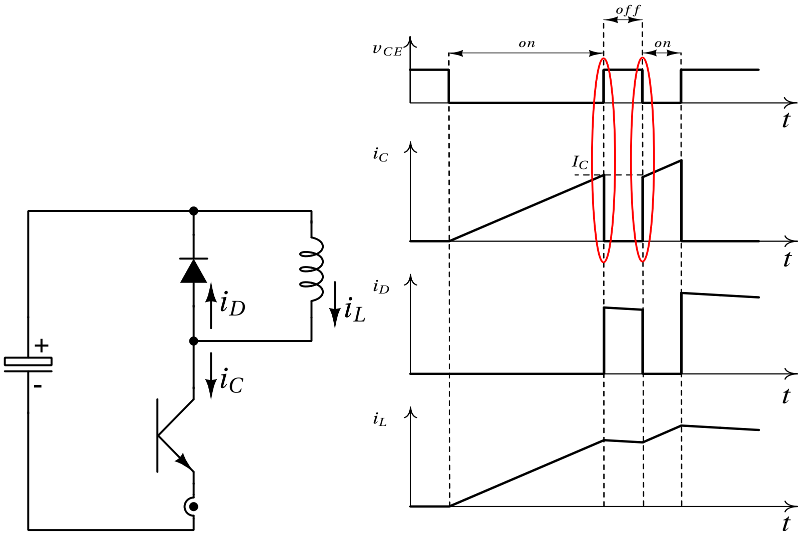


Figure 1: “TO247” package before epoxy encapsulation.

3 Measurements

3.1 Switching - Double-pulse Test



3.2 IV-curves

- temperature dependence
- low voltage (20V) induction load pulse test
- requires precise $V_{CE,sat}$ and I_C sensing

3.3 BV test

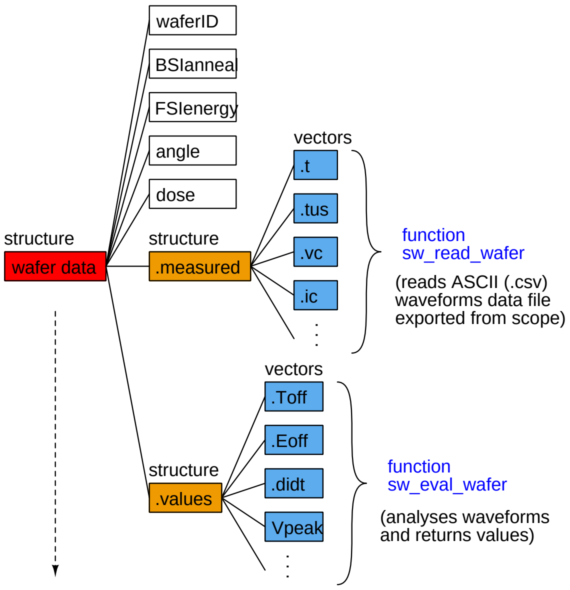
- Tektronix 370A, Programmable Curve Tracer

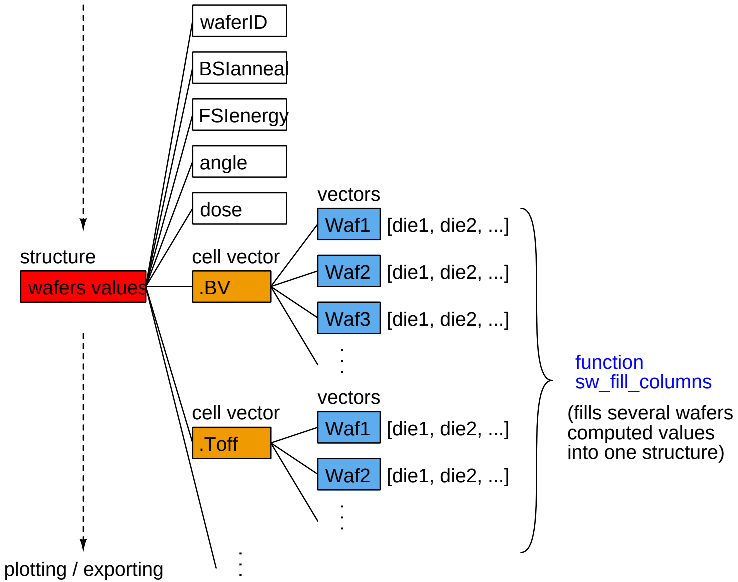
4 Strucured Processing of Measured Data

- exporting or manually editing ASCII (.csv) datafiles from oscilloscope (BV tester, etc.)
- data reading, processing and plotting/exporting using *Octave* (MATLAB)
  - useful functions library attached

4.1 Data processing flowchart

(please see the attached functions library for detail and expamples)


waferID
BSIanneal
FSIenergy
angle
dose
structure
wafer data
structure
.measured
vectors
.t
.tus
.vc
.ic
function
sw_read_wafer
(reads ASCII (.csv)
waveforms data file
exported from scope)
structure
.values
vectors
.Toff
.Eoff
.didt
Vpeak
function
sw_eval_wafer
(analyses waveforms
and returns values)


waferID
BSIanneal
FSIenergy
angle
dose
structure
wafers values
cell vector
.BV
vectors
Waf1
[die1, die2, ...]
Waf2
[die1, die2, ...]
Waf3
[die1, die2, ...]
cell vector
.Toff
vectors
Waf1
[die1, die2, ...]
Waf2
[die1, die2, ...]
function
sw_fill_columns
(fills several wafers
computed values
into one structure)
plotting / exporting

5 Measurements Results

[3]

5.1 Switching

- time intervals defined according to Figure 2 and Figure 3
- sandwich DC link - $V_{peak,off}$ reduced to $\approx$ 50V (previously $\approx 120V$)
- fast SiC freewheeling diode - $i_{peak,on}$ reduced significantly

[3] needs to be completed

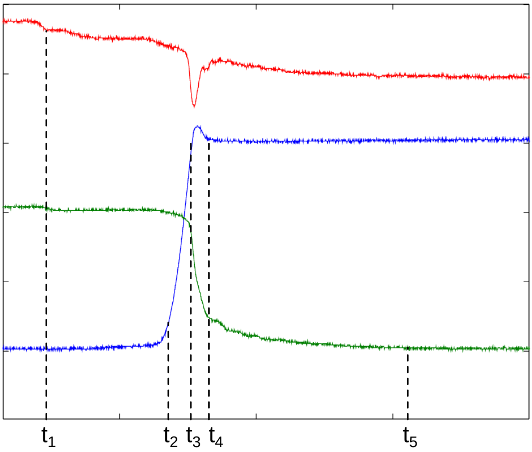


Figure 2: Definition of time intervals during turn-off action.

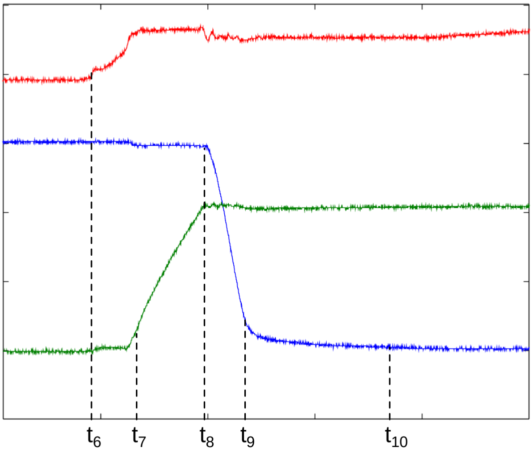


Figure 3: Definition of time intervals during turn-on action.

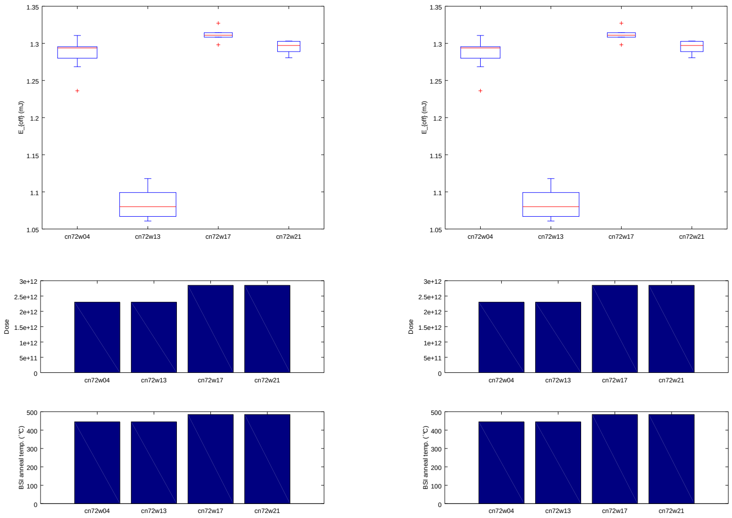


Figure 4: 600V, 40A, 25°C

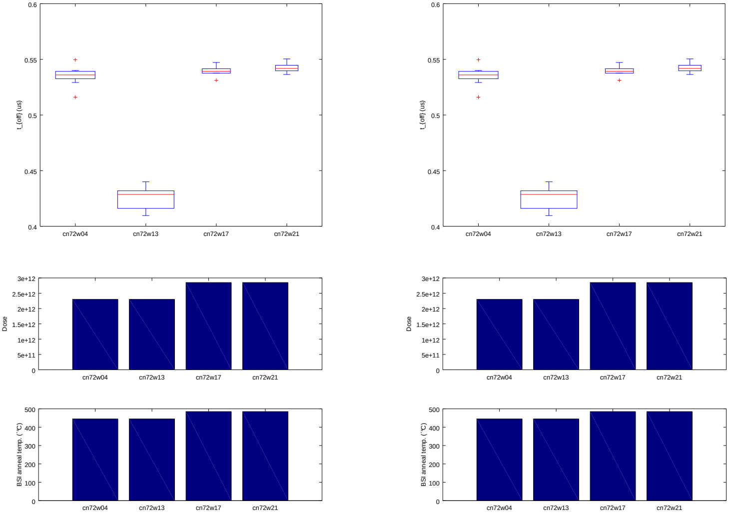


Figure 5: 600 V, 40 A, 25 °C

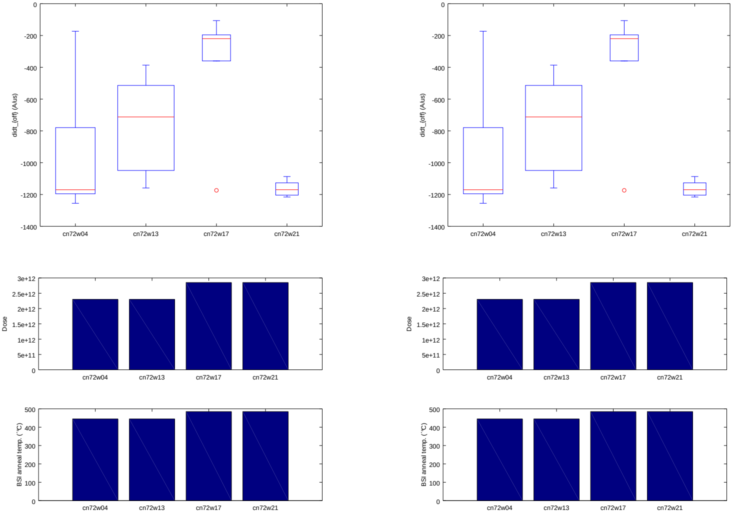


Figure 6: 600 V, 40 A, 25 °C

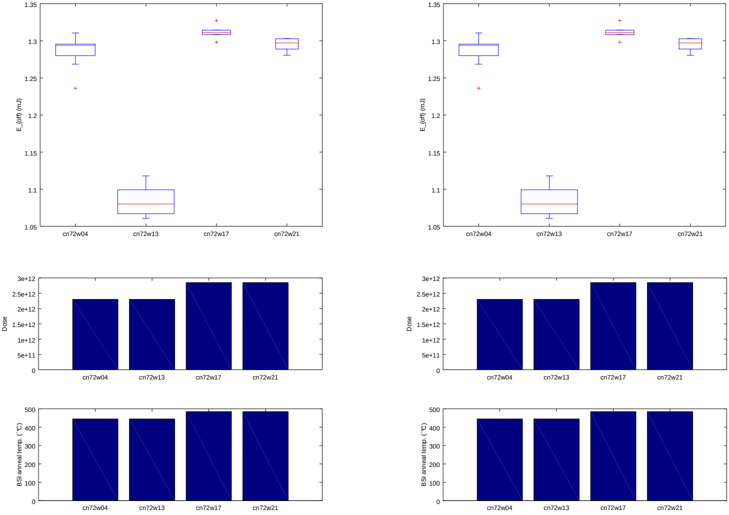


Figure 7: 600 V, 40 A, 25 °C

Appendix

A Current Transformer Design Guidelines (double-pulse)

- Current transformer is unable to transfer continuous current, nor will be optimal for universal use, however the correct design yields an excellent yet inexpensive current sensor for *high frequency* double-pulse test

- **Task**:
    - sum of on-times: $T_{max} = T_{on,1} + T_{on_2}$
    - max. current: $I_{max} = i(T_{max})$
    - DC-bus voltage: V_{DC}
    - ferrite core cross-sectional area: A
    - max. flux density (ferrite core): B_{max}
    - secondary turns: $N_2 =?$

Magnetic flux linkage:

$$\Psi_2(t) = \overbrace{\Psi_0}^{=0} + \int v_2(t)\,\mathrm{d}t \tag{1}$$

$$\Psi_2 = N_2 B A \tag{2}$$

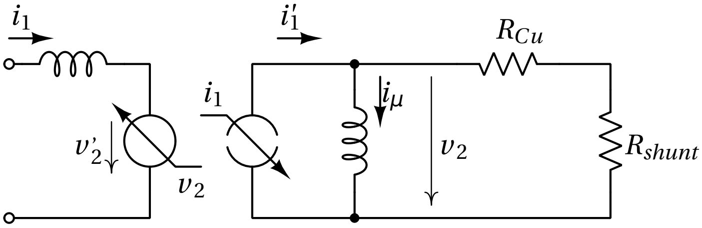


Figure 8: Current transformer equivalent circuit.

$$v_2(t) = \overbrace{R_2}^{R_{Cu}+R_{shunt}} \cdot i_2(t) = R_2 \cdot \frac{V_{DC}}{L_{coil}} \cdot t \tag{3}$$

L_{coil} - double-pulse tester load coil.

Substituting (3) into (1) and combining with (2) yields:

$$\Psi_{2,max} = \frac{R_2 V_{DC} T_{max}^2}{2 L_{coil} B_{max} N_2} = N_2 B_{max} A \tag{4}$$

$$\boxed{N_2 \geq \sqrt{\frac{V_{DC} T_{max}^2 R_2}{2 L_{coil} B_{max} A}}} \tag{5}$$

note:

- $R_2 ++ \rightarrow$ limited by B_{max}
- $R_2 -- \rightarrow$ limited by shunt parasitic inductance impact

Resulting transformation ratio:

$$v_{out} = R_{shunt} \cdot \frac{i_1}{N_2} \implies \boxed{\frac{v_{out}}{i_1} \left[\frac{V}{A}\right] = \frac{R_{shunt}}{N_2}} \tag{6}$$