"Vertical Goes Power":

Multi-Site Wafer Probing of Automotive ICs

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Overview

- The D.U.T.: Power/Logic devices for automotive applications
- Cantilever Probes
- Vertical Probes ?
- Thermal Modelling of Interposer, Probes, Bond Pad
- Probes Protection / Current Limiting
- Example Probecard
- Conclusion

The D.U.T.

- Automotive ICs can be characterized by:
  - Logic circuitry combined with power outputs
  - Pulsed current on high power outputs: 3-15 A,1 ms, multiple outputs on one IC
  - Pincount: approx. 50-200 pins, pad pitch: 100 µm and more
  - Sometimes irregular pad layouts with inner lying pads
- Wafer testing by now:
  - Cantilever probecards mostly in single die Configuration, varying tip diameters to adapt to high Current demands

Cantilever Probe Card

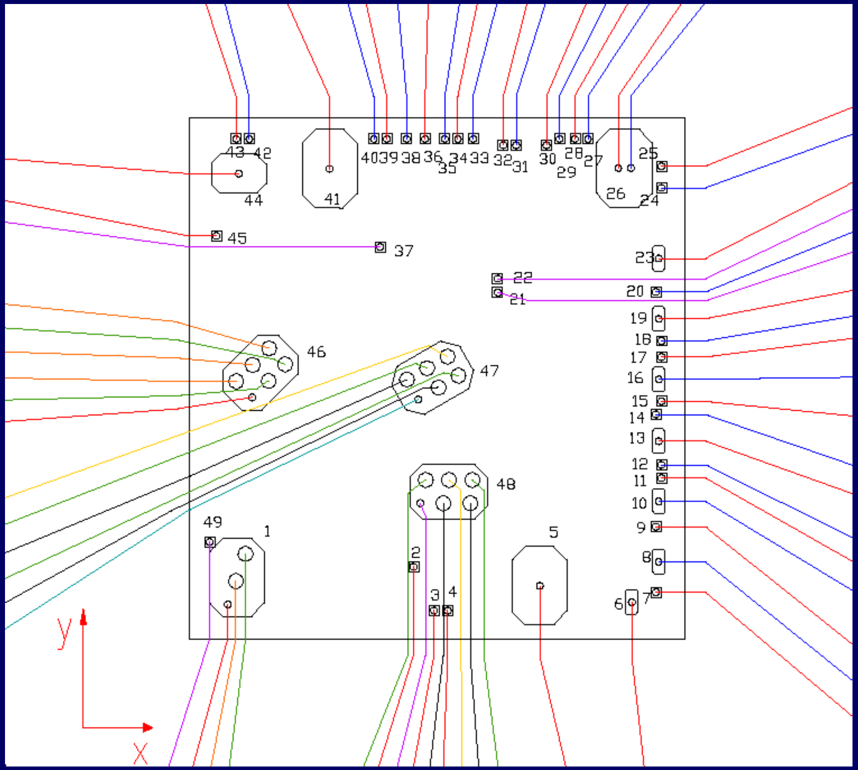


Fig. 1: Example of pad and cantilever probes layout for Automotive IC: 14 different probes types, 2 different tip diameters

- **Multi-die testing ???**

Vertical Probe Card ?

- Common idea: vertical buckling beam cards are not suitable for high power applications, but....
  - Same probe materials used for cantilever and vertical probes...
  - Contact areas and conducting areas comparable to cantilever configuration
- ...so why not ?

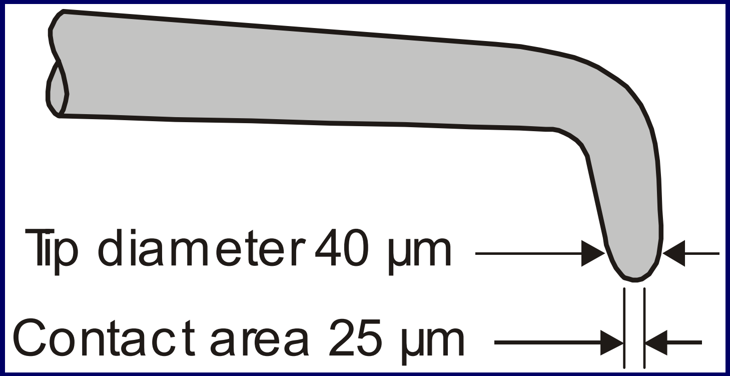
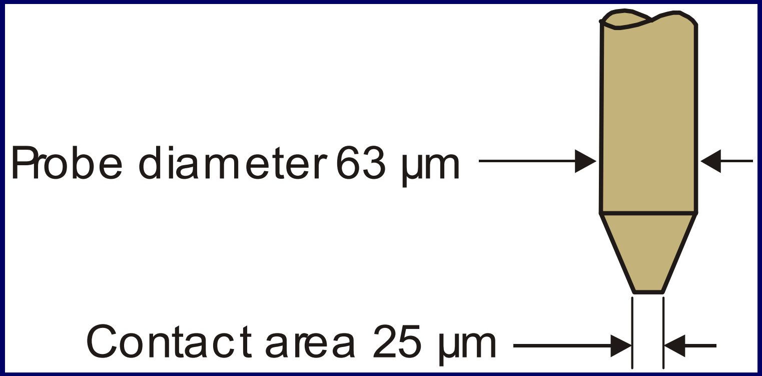


Fig. 2a: typical cantilever probe



b) vertical probe

Thermal Modelling (1)

- High Current paths: Where is the "fuse"?
  - Probe Beam ?, Probe Tip ?, Interposer ?
- Analytical model of probe and interposer trace: calculate electrical heating during a short pulse (< 1 ms) to determine maximum current and pulse duration :

$$\Delta T = \frac{j^2 \cdot \rho_{el}}{c \cdot \rho_m} \cdot t$$

ΔT...temperature / K
j ... current density / A/m^2
ρ_{el} ... resistivity / $\Omega \cdot m$
ρ_m ... density / kg/m^2
c ... specific heat / $J/(kg \cdot K)$
t ... pulse duration

Trace / Probe Heating
for 1,5 A / 1 ms pulse
trace heating [K]
1,76
probe heating [K]
4,4
probe tip heating [K]
177

Equ. 1: formula and calculation results for electrical probe and interposer trace heating

Thermal Modelling (2)

- Model of bond pad - electrical heating:

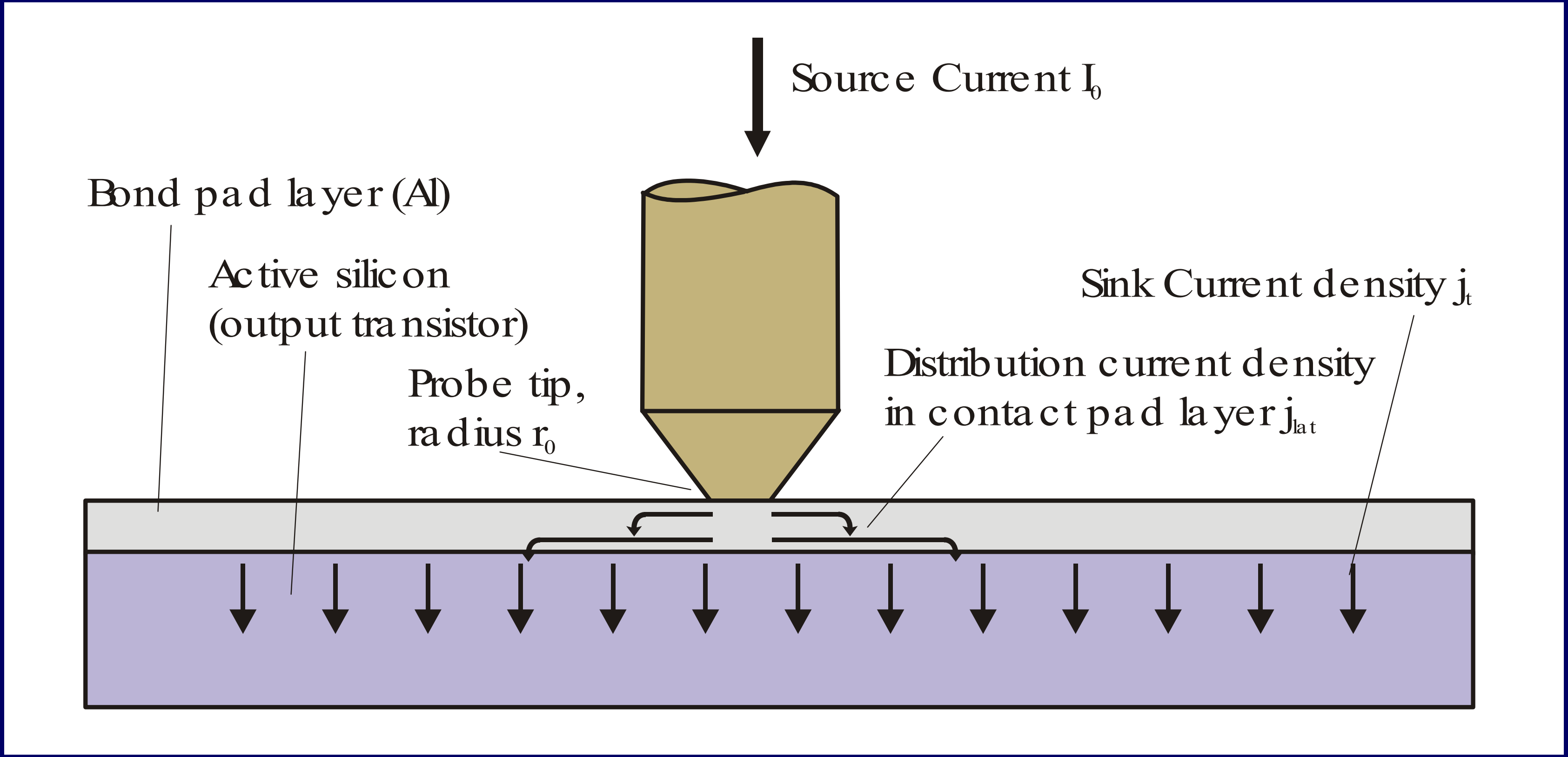


Fig. 3: model of current flow in probe and bond pad

Thermal Modelling (3)

- From analytical model: derive equations for current densities in bond pad

$$j_D(r) = \frac{I_0}{2d}\left(\frac{1}{\pi \cdot r} - \frac{r}{A}\right);\; r > r_0$$

$$j_D(r) = \frac{I_0}{2d}\left(\frac{r}{\pi \cdot r_0^2} - \frac{r}{A}\right);\; r < r_0$$

j_D ... *distribution current density*
I_0 ... *source current*
d ... *bond pad thickness*
A ... *bond pad area*
r_0 ... *probe tip radius*
r ... *radius from center*

Equ. 2: distribution current density in bond pad layer

Thermal Modelling (4)

- Numerical calculation of electrical heating of bond pad

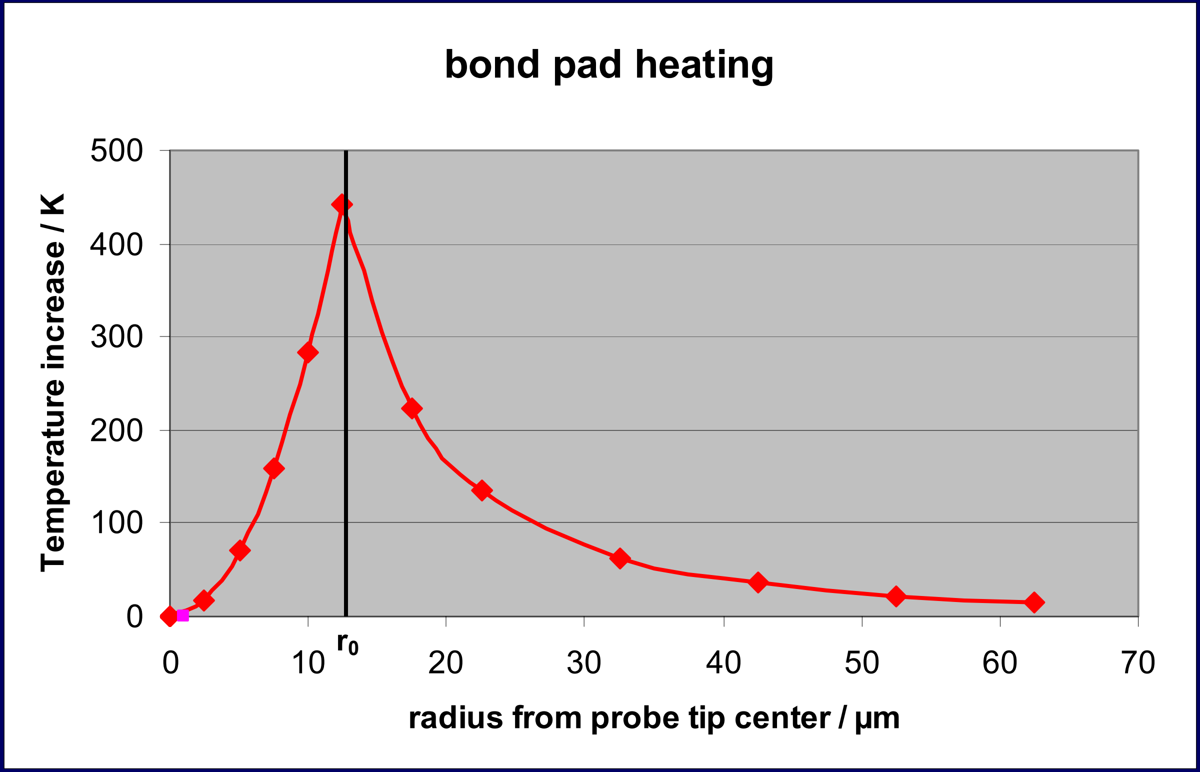


Fig. 4: graph of temperature distribution in bond pad

Conclusions from Thermal Modelling

- Limiting factor for short current pulses is not the probe, but the heating of the bond pad
- Vertical probe card design: interposer traces stay cooler than probes, in case of continuous (DC overload), the probe will burn, not the interposer
- Short overcurrent pulses will not damage probes initially, but cause the bond pads to melt around the circumference of the probe tip -> overcurrent protection needed

"Experimental" verification

- Melting phenomena on high current probe contacts (cantilever probes)

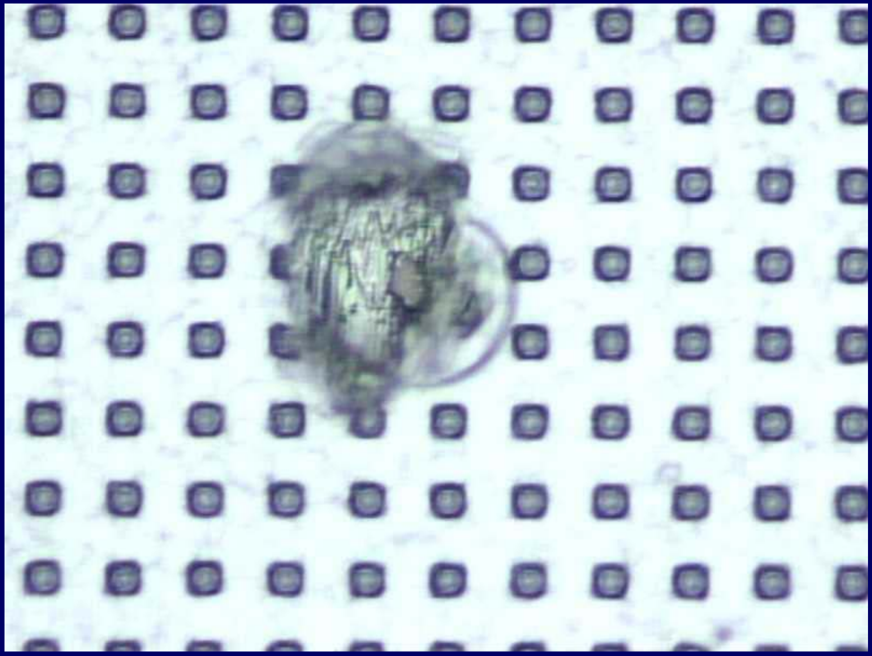


Fig. 5: molten bond pad due to overcurrent spike, probes still O.K. !

Probe Current Limiting (1)

- "Boundary Conditions":
  - "Transparent" to Tester
  - No influence on test results within probing range of currents
- this implies:
  - Low resistance of clamping circuitry withing nominal test currents, high resistance only when clamping
  - Electrically "floating" with respect to tester current supplies

Probe Current Limiting (2)

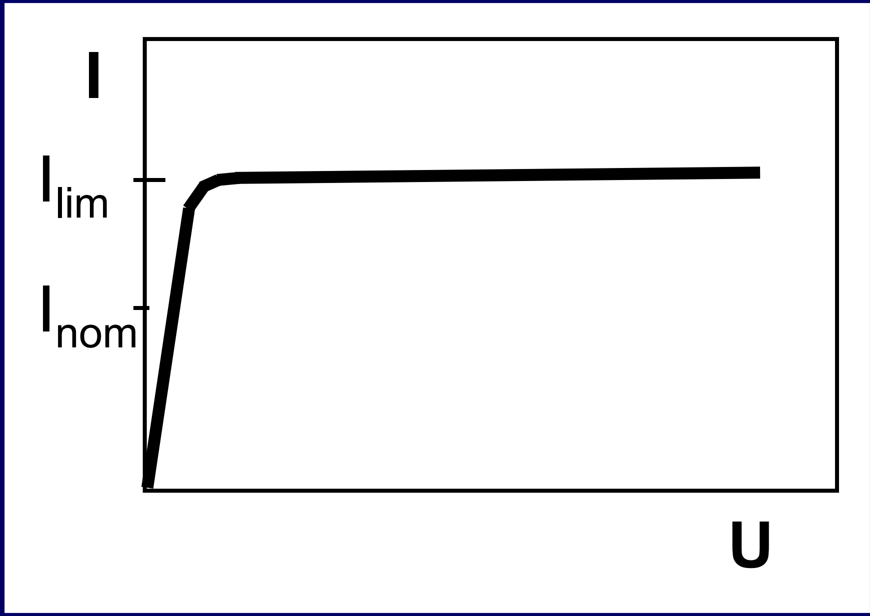


Fig. 6: Electrical characteristics of "SmartClamp" module

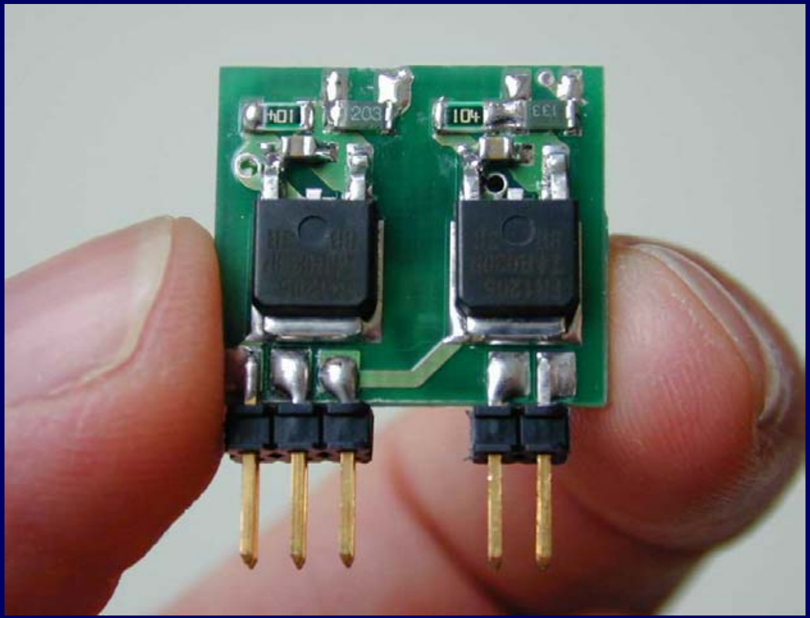


Fig. 7: "SmartClamp" module

The Test Vehicle (1)

- Infineon airbag controller:
  - 8 power outputs (3 A), 16 power pads
  - dual die configuration
  - 96 A total current on power pads
  - 32 electrically independent clamping circuits on probecard
  - 172 probes
  - Cantilever probecard available for comparison

The Test Vehicle (2)

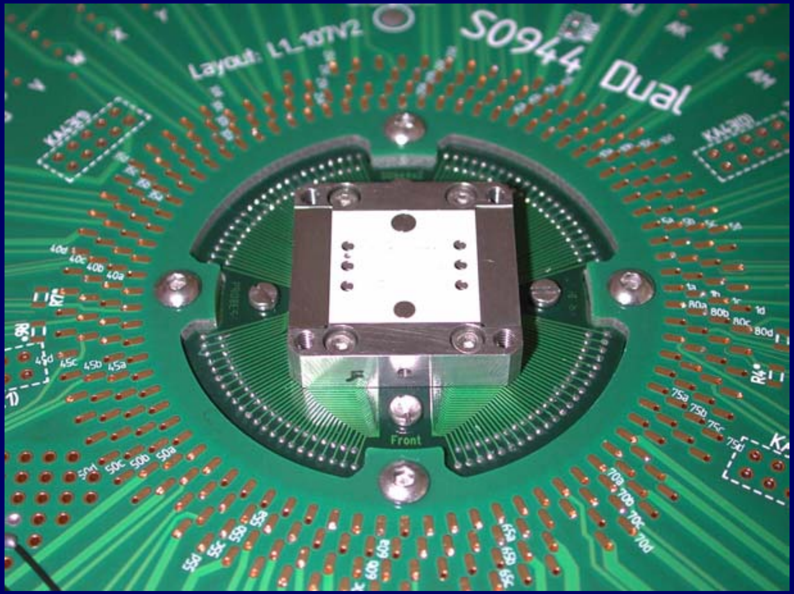


Fig. 8a: probe head and high current MLO interposer

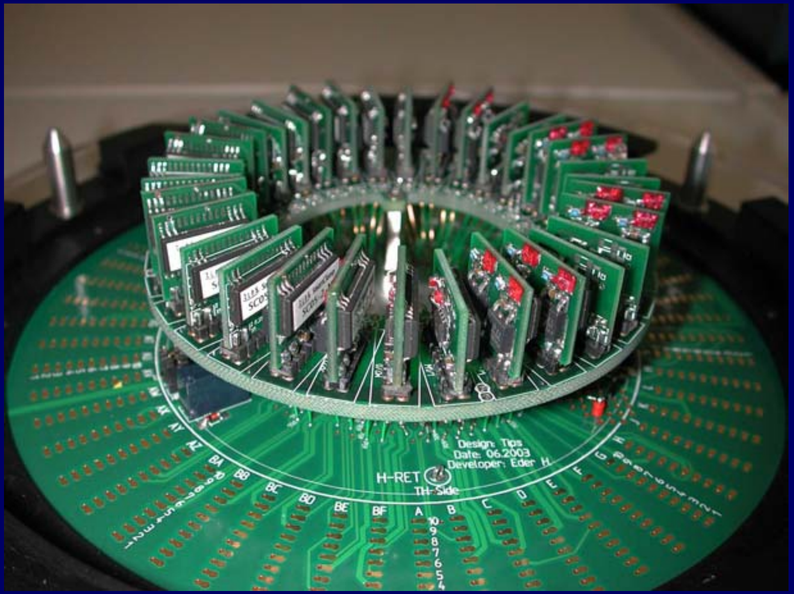


Fig. 8b: SmartClamp overcurrent protection on top of probecard PCB

Conclusions

- Vertical probing for power devices is feasible and shows at least equal results compared to cantilever probecards
- In pulsed high current applications the limiting factor is not the probe itself but the bond pad area around the probe impact
- Clamping unwanted current spikes by use of SmartClamp circuitry effectively protects bond pads and probes from thermal damage

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