Probing 10 kV and 100 A :

Challenges and Solutions for High Voltage / High Current Wafer Testing

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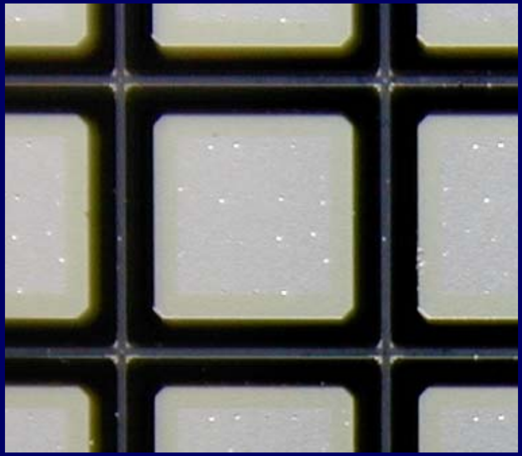
Overview

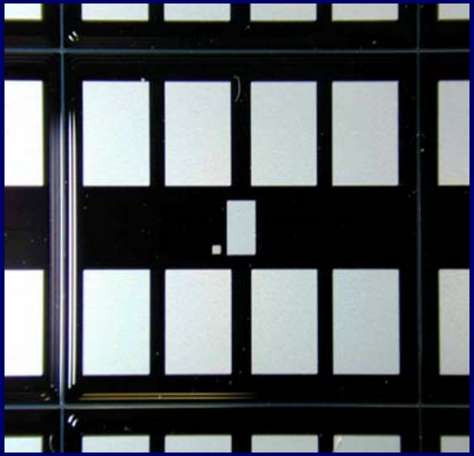
- The D.U.T.: power semiconductors
- High voltage probing: effects going together with high voltage, solutions
- High current probecards: concepts, melting phenomena and causes
- Probe Tip Shape: T.I.P.S. "Probe Refresher"
- "SmartClamp": protection of probes using active current limiting

The D.U.T.

- **MosFETs, IGBTs, Diodes** with
  - breakthrough voltages up to 6.5 kV
  - forward currents up to 100 A



Power Diode, anode pad



IGBT, source and gate pads

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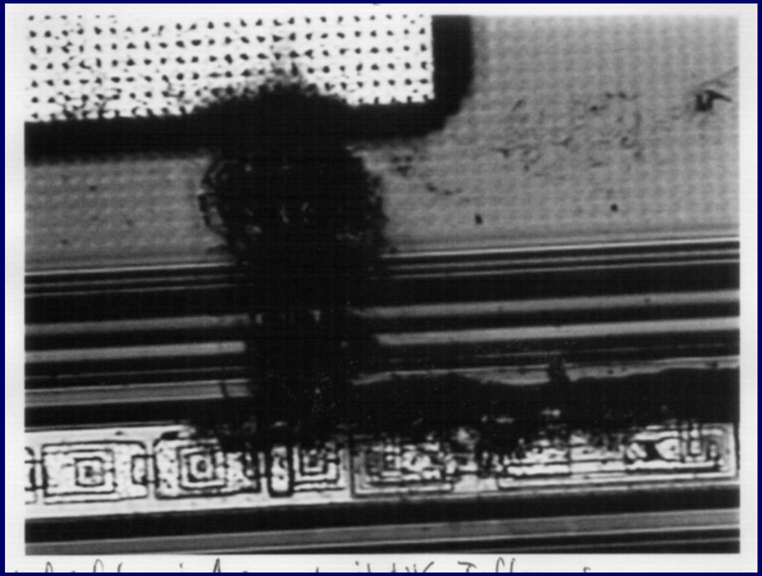
High Voltage Testing (1)

- applied in probing breakthrough voltage of DUT
- challenges: **sparking, flashovers** on wafer surface and from probes to wafer



Damage on wafer surface (IGBT) due to flashover between source-pad and dicing frame structure

High Voltage Testing (2)

- rule of thumb: for **electrical field strength**

  E > 2 kV/mm

  flashovers may occur.

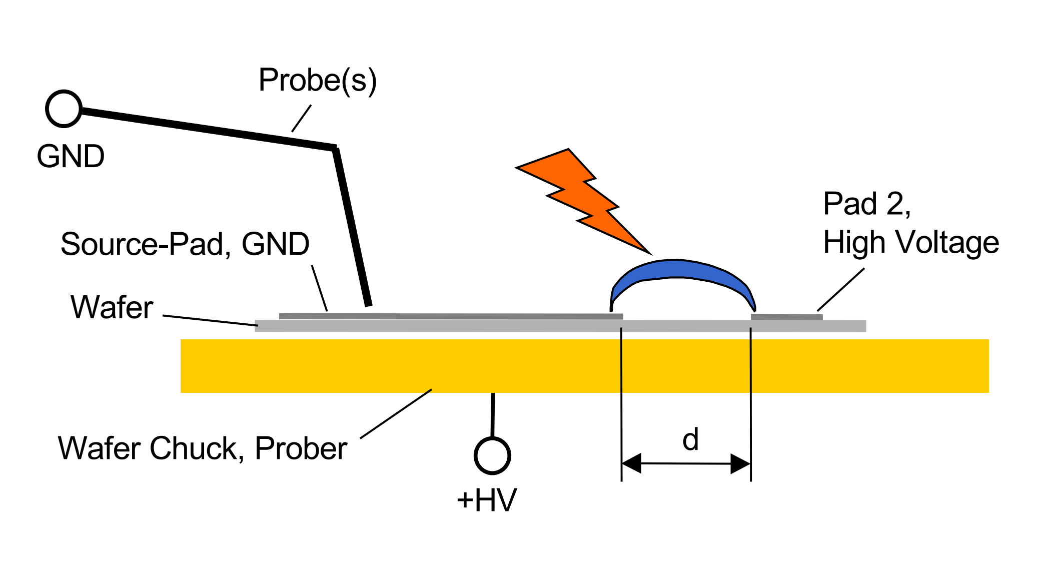


Fig. 2: high voltage test setup

E = U/d
E ... field strenght
U ... maximum test voltage
d ... minimum distance between high voltage pads

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High Voltage Testing (3)

- Theory: Physics of **gas discharges**
  - Flashover voltage as a function of gas pressure and electrodes distance is described in "Paschen" curves.

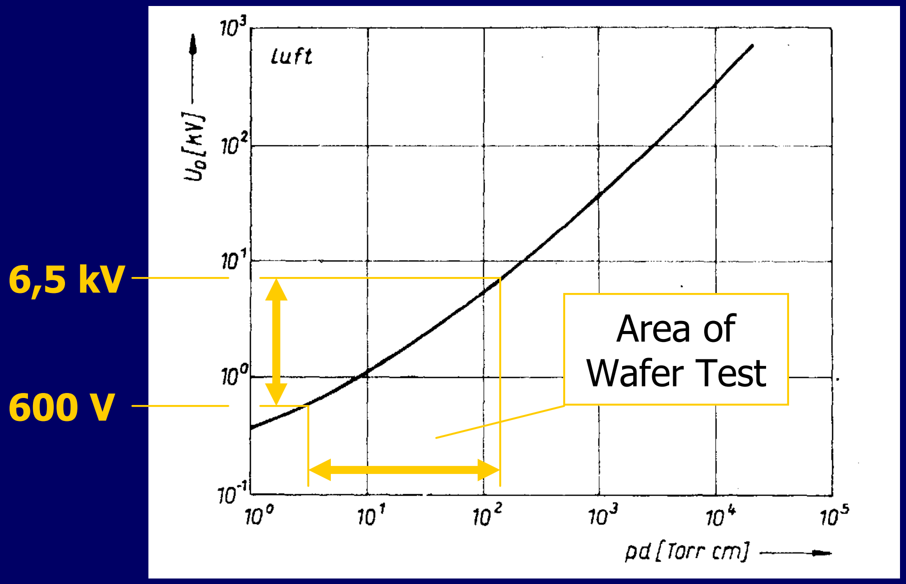

Fig. 3: Paschen-curve for air [1]

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Avoiding flashovers (1)

- **Chip design**: avoid small pad distances
  - + easy to test, feasible in some new designs
  - - not applicable for existing designs, chip area
- **Gas atmosphere** with high dielectric strength (e.g. SF_6, CH_2Cl_2, CCl_4....) [2]
  - + simple test setup
  - - gases are envrionmentally hazardous, very restricted use, expensive

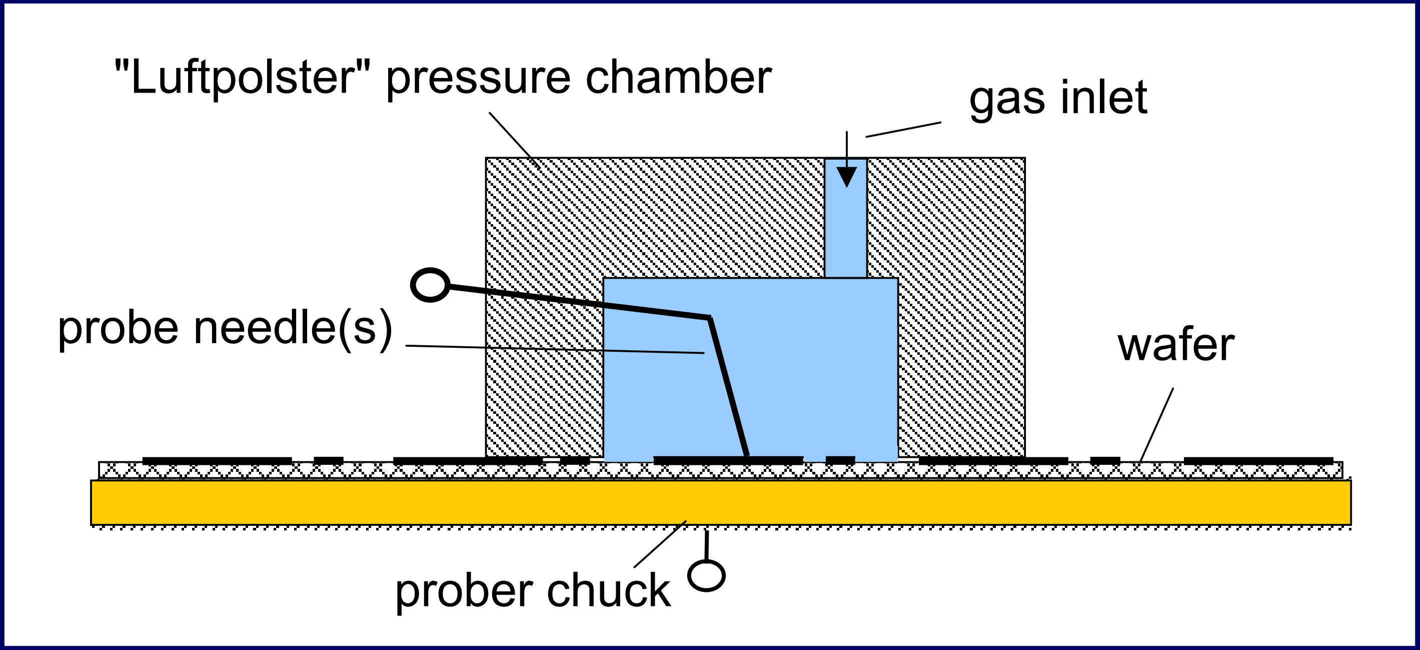
Avoiding flashovers (2)

- **Testing in Liquid** with high dielectric strength
  - ? Wet testing process ?

- **High Vacuum:** ionization length longer than critical dimensions on chip -> no gas discharge possible
  - ? vacuum wafer test ?

"Luftpolster" concept

- **Compressed Air:** breakthrough voltage in gases increase with gas pressure.
  - Basic idea: device is tested under compressed air



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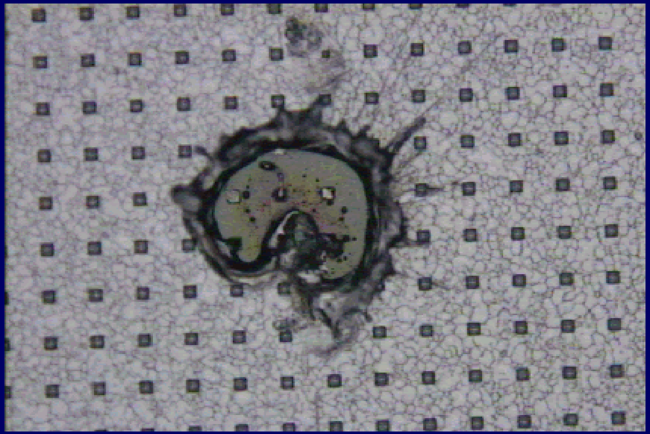
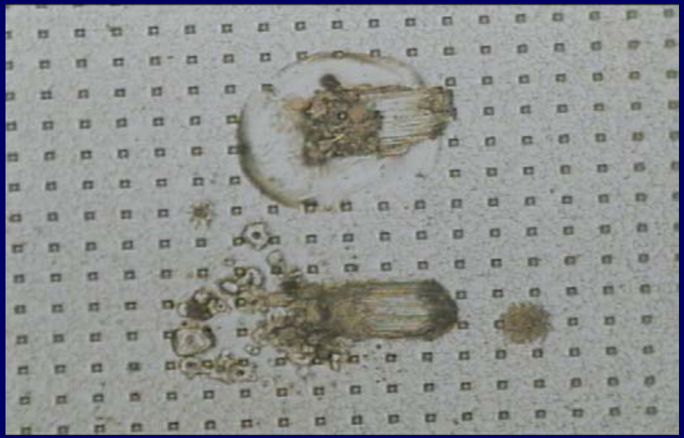
"Luftpolster" Probecard

2 kV / 100 A probecard with "Luftpolster" setup

High Current Testing

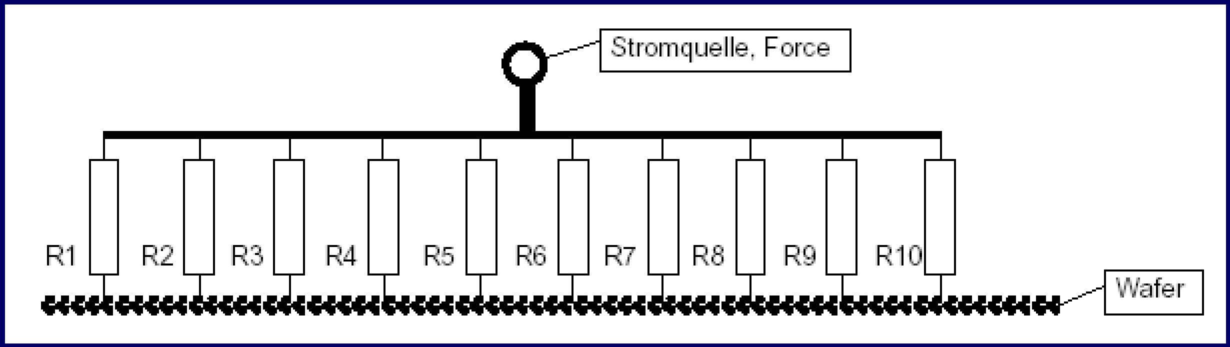
- Applied in probing forward voltage V_f of power diodes / on resistance R_{on} of IGBTs, MOSFETs
- challenges: **thermal damage, melting** of
  - probe tips, probe needles
  - bond pads beneath and around contact area





High Current Probecard (1)

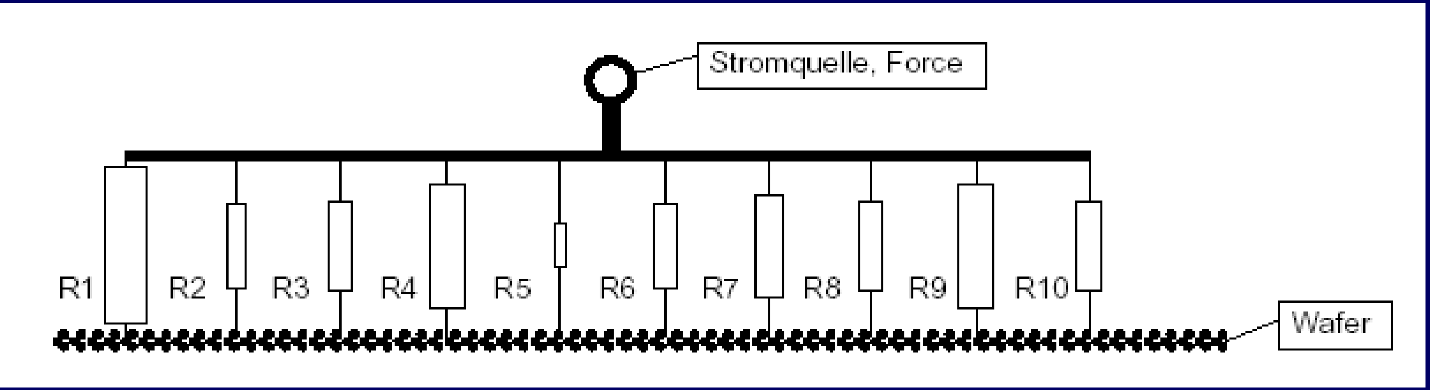
- current is distributed to **multiple probes connected in parallel**
- ideal situation: contact and lead resistances are equal: **currents are balanced**



Electrical model of ideal high power probecard,
10 probes connected in parallel

High Current Probecard (2)

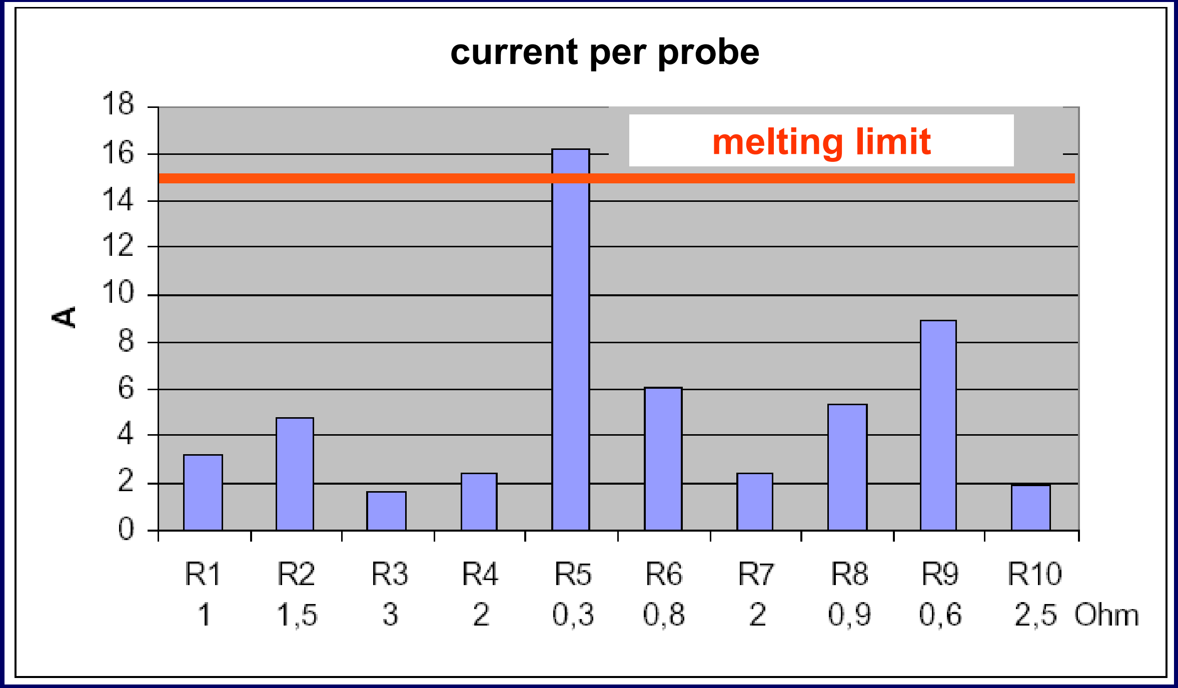
- melting phenomena (probes, bond pad):
  - due to excessive currents in single probes (> 15 A) much higher than the design current per probe
  - cause: imbalanced currents in probes that arise from variations in contact resistance



Electrical model of real high power probecard, unequal contact resistances of probes

High Current Probecard (3)

- Current distribution that might occur in a real high current probecard:



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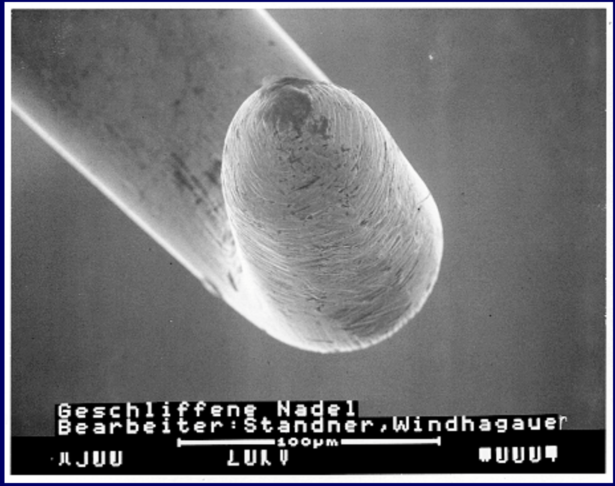
Probe Tip Shape (1)

- "Passive" method: **keep radius probe tip shape** during lifetime of probecard for **low contact resistance**:

  "Probe Refresher": mechanical grinding of tip shape during probecard maintenance

flattened probe tip



... after grinding

Probe Tip Shape (2)

T.I.P.S. "Probe Refresher" machine

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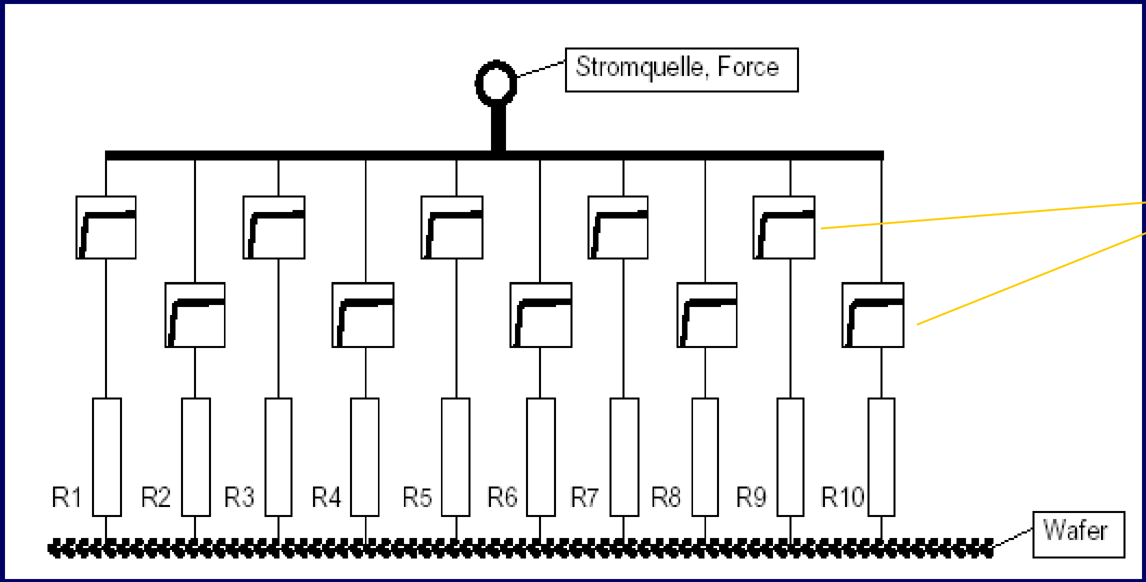
Probe Current Limiting (1)

- "Active" method: **"SmartClamp" -** electronic circuitry in the lead to each probe individually limits current in each trace, has low resistance at nominal current



SmartClamp modules

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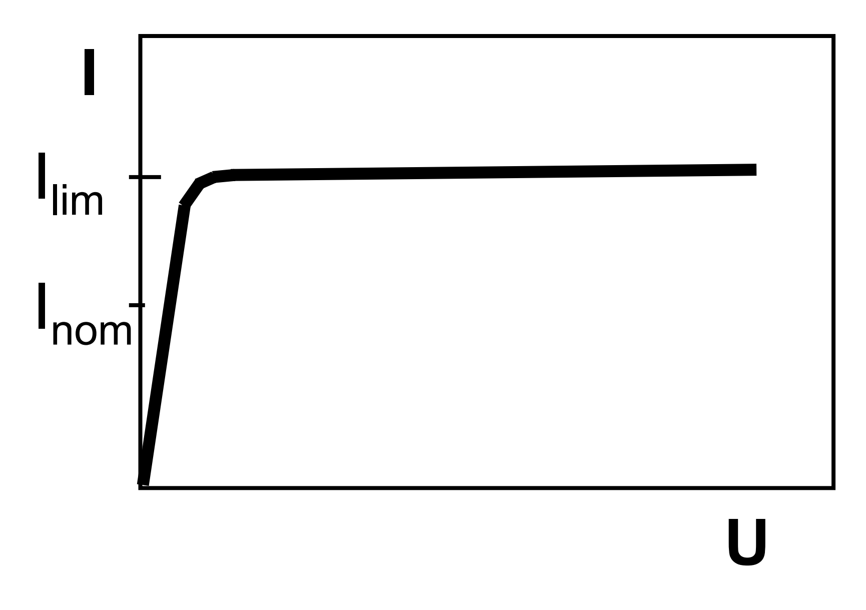
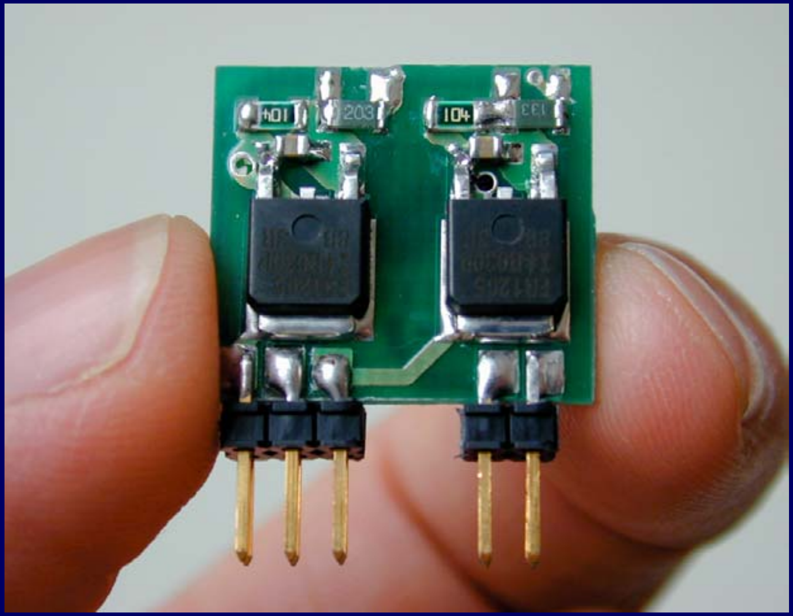
Probe Current Limiting (2)



Electrical characteristics of "SmartClamp" module



"SmartClamp" module

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"SmartClamp" Probecard

100 A Probecard with 20 on-board SmartClamp modules

Acknowledgements

Infineon Technologies Austria AG

Franz Reinwald et al.

- References

[1] Der elektrische Durchschlag in Gasen, H.Hess, 1976

[2] Hochspannungsisolierstoffe, A. Imhof, 1957