Excerpt – Direct Bonded Copper

Presented by

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Courtesy of Curamic Electronics

Authors thank

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for providing information and photos

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DCB Process

- Oxygen reduces the melting point of Cu from 1083°C to 1065°C (Eutectic melting temperature).
- Oxidation of copper foils or injection of oxygen during high temperature annealing (1065°C and 1080°C) forms thin layer of eutectic melt.
- Melt reacts with the Alumina by forming a very thin Copper-Aluminum-Spinel layer.
- Copper to copper is fused the same way.
- Copper-Aluminum-Nitride (AlN) DBC is possible. The AlN-Surface must be transformed to Alumina by high temperature oxidation.

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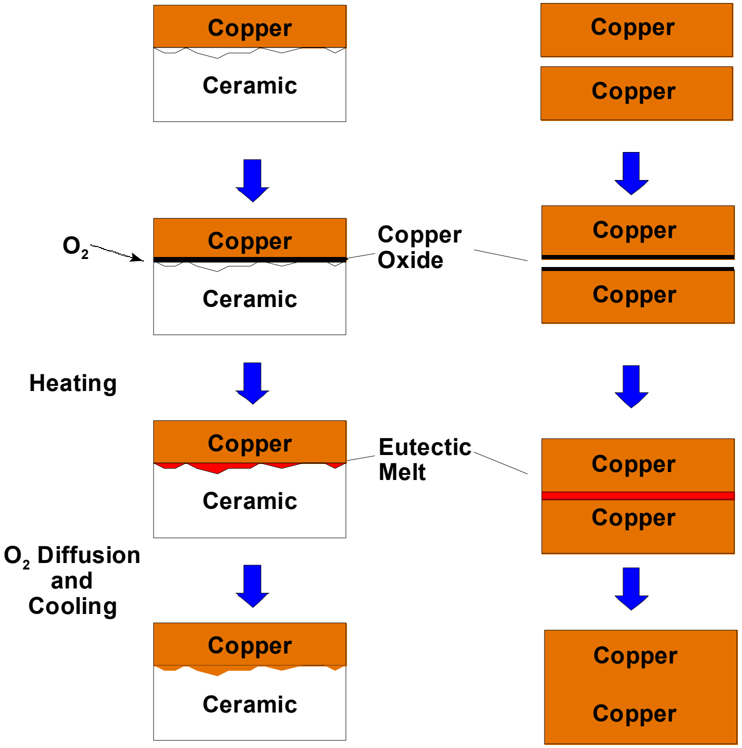
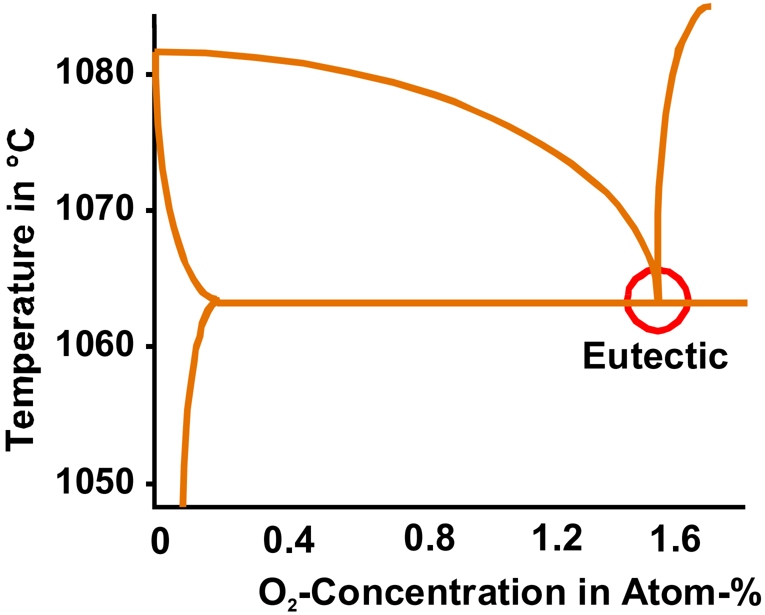
DBC Process





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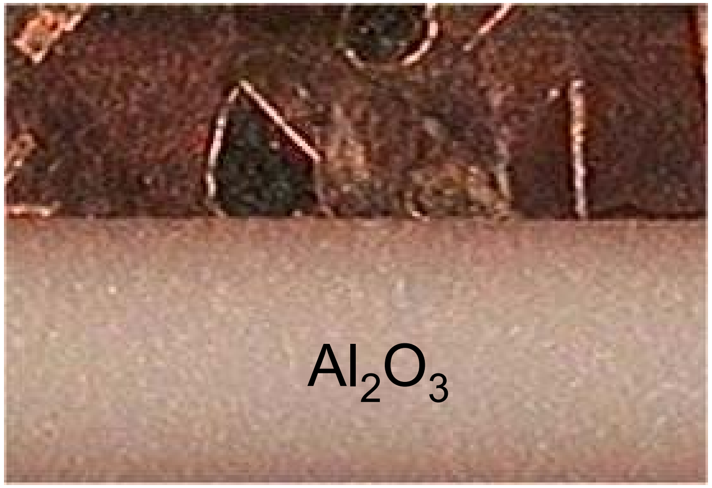
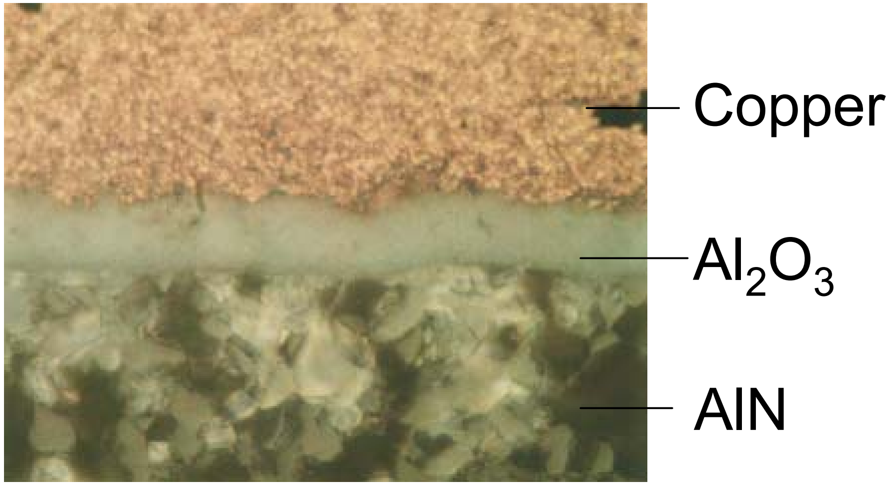
DBC - Interfaces





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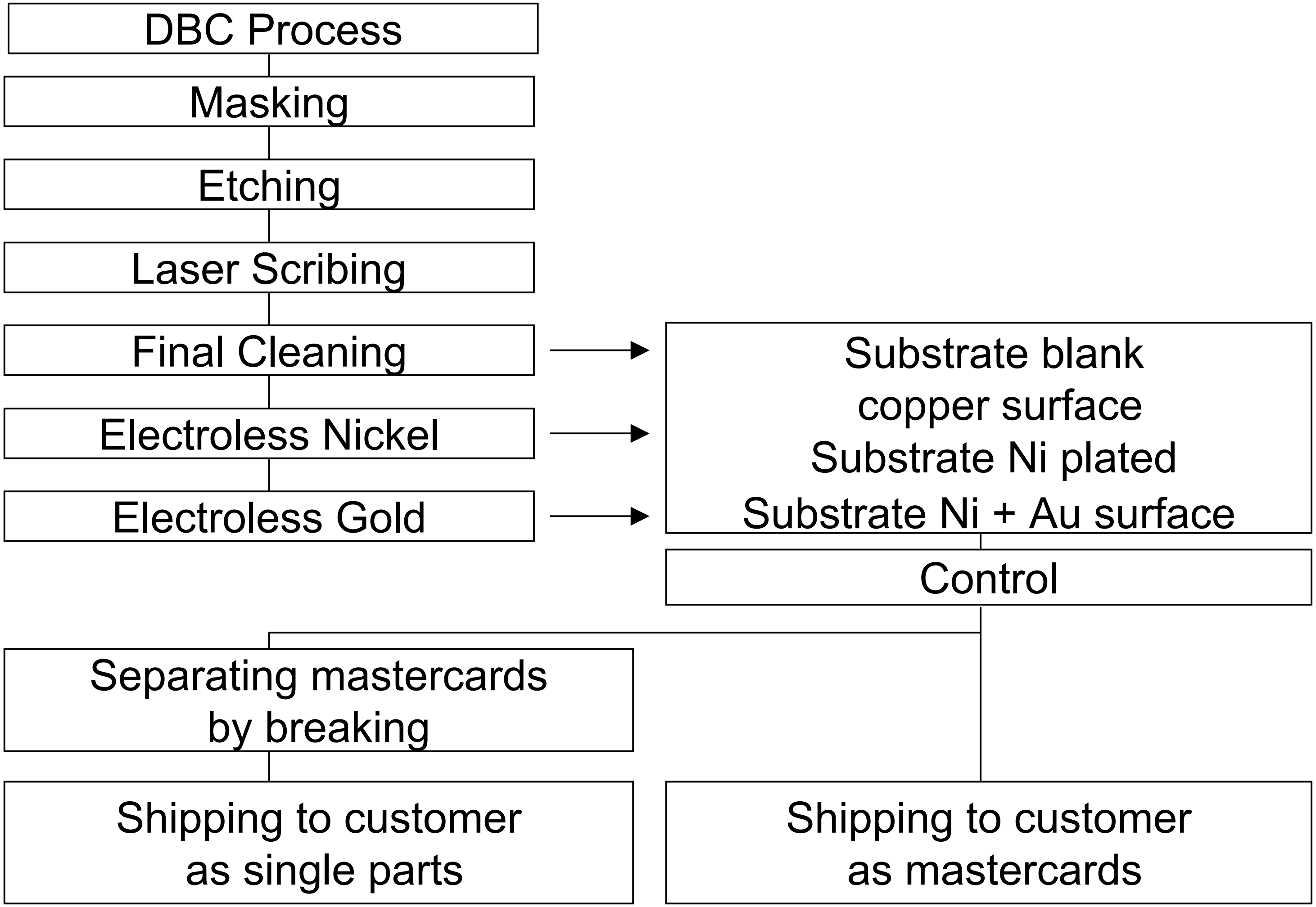
Flow Chart of DBC Processing



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Masking

- High precision screen printers for high volume
- Semiautomatic and fully automatic with pattern recognition
- Redundant equipment
- Photomasking for high density circuits
- Air conditioned clean rooms

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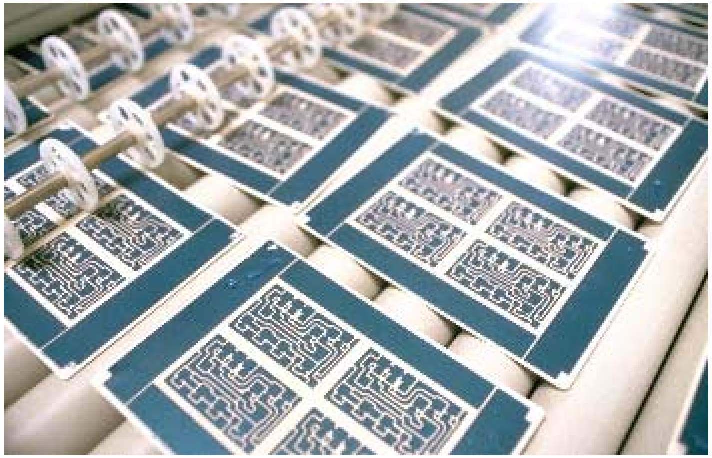
Etching

- Specially designed precision etchers for thick copper layers
- Automatic chemistry control
- Mask stripping integrated
- 3 separate high volume lines in operation
- Controlled by SPC



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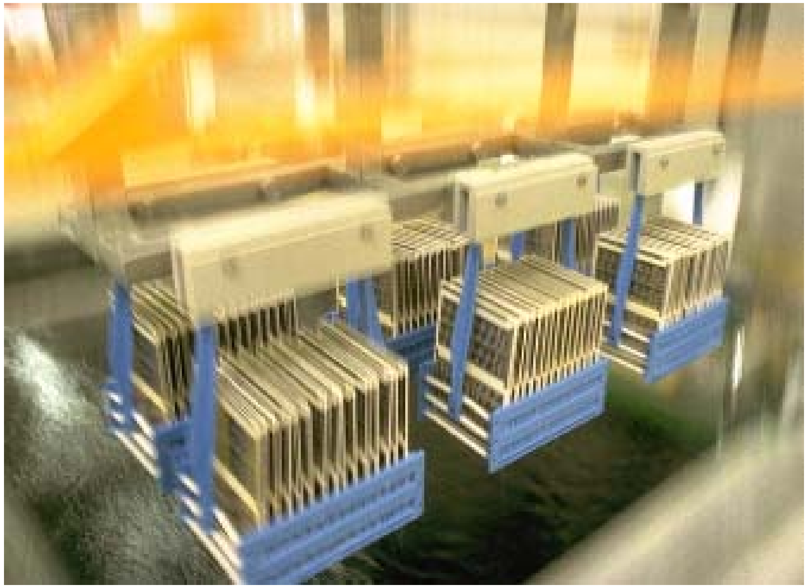
Plating / Final Cleaning

- Fully automatic high volume plating line for electroless Ni + Au
- Controlled by SPC
- Final cleaning for Cu integrated
- Parallel backup lines
- Solderability and wire bond testing



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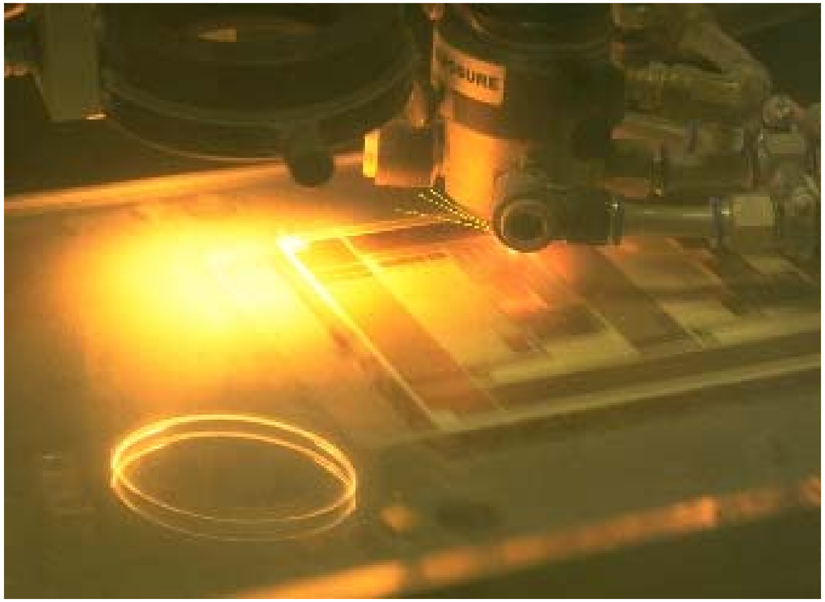
Laser Machining

- Fully automatic high precision CO_2 lasers with pattern recognition
- Designed for high volume throughput
- Scribing and drilling
- Multiple equipment
- Controlled by SPC



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Features of DBC Substrates

- Low thermal coefficient of expansion despite relatively thick copper layers
  (TCE = 7.2 - 7.4 - 10-6 at 0.3mm / 12mil copper)
- High current carrying capability with thick copper
  (Copper width 1mm / 40mil, height 0.3mm / 12mil, continuous flow 100amps = temp rise of 14 - 17 °C)
- High peel strength of copper to Al2O3 $\geq$ 60N/cm; AlN $\geq$ 45N/cm at 50mm/min peel speed
- High thermal conductivity
  (Al2O3 = 24W/mK; AlN =170 W/mK)
- Low capacitance between front- and backside copper
  (Appr. 18pF/cm2 for 0.63mm ceramic thickness)

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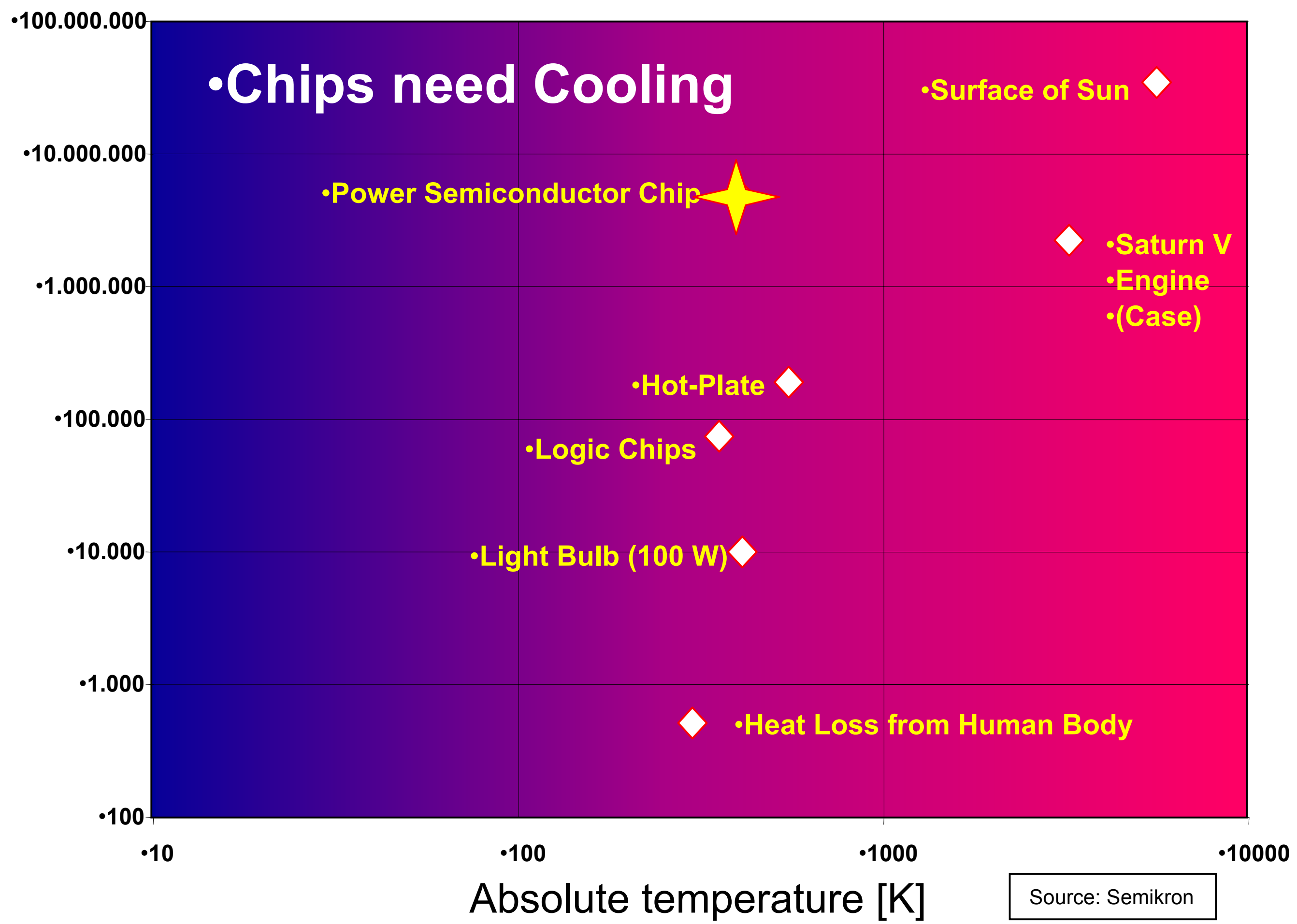
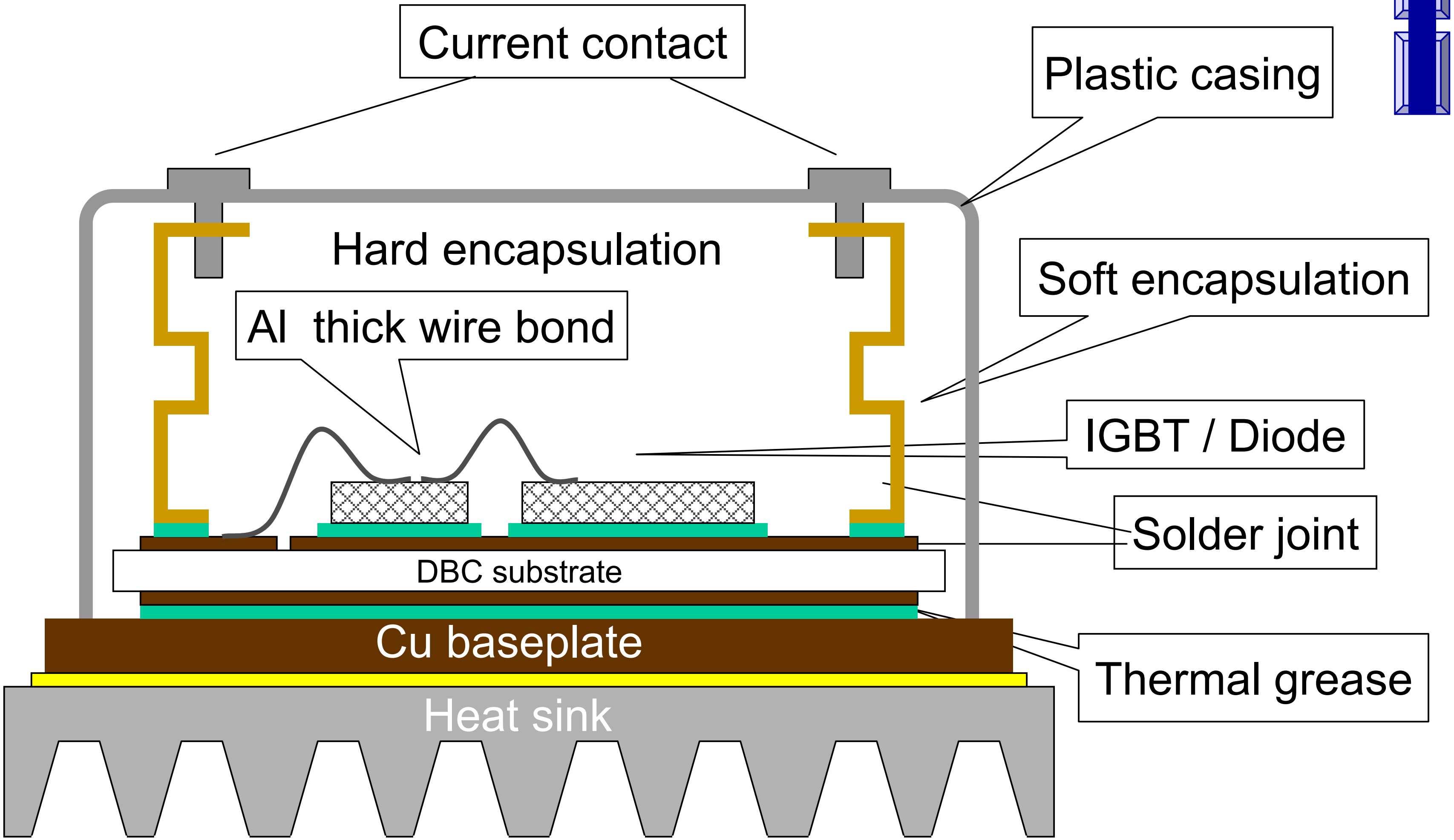
Relative Heat Flux (W/sqm)



Source: Semikron

Courtesy of Curamic Electronics

Principal Design of IGBT Power Module



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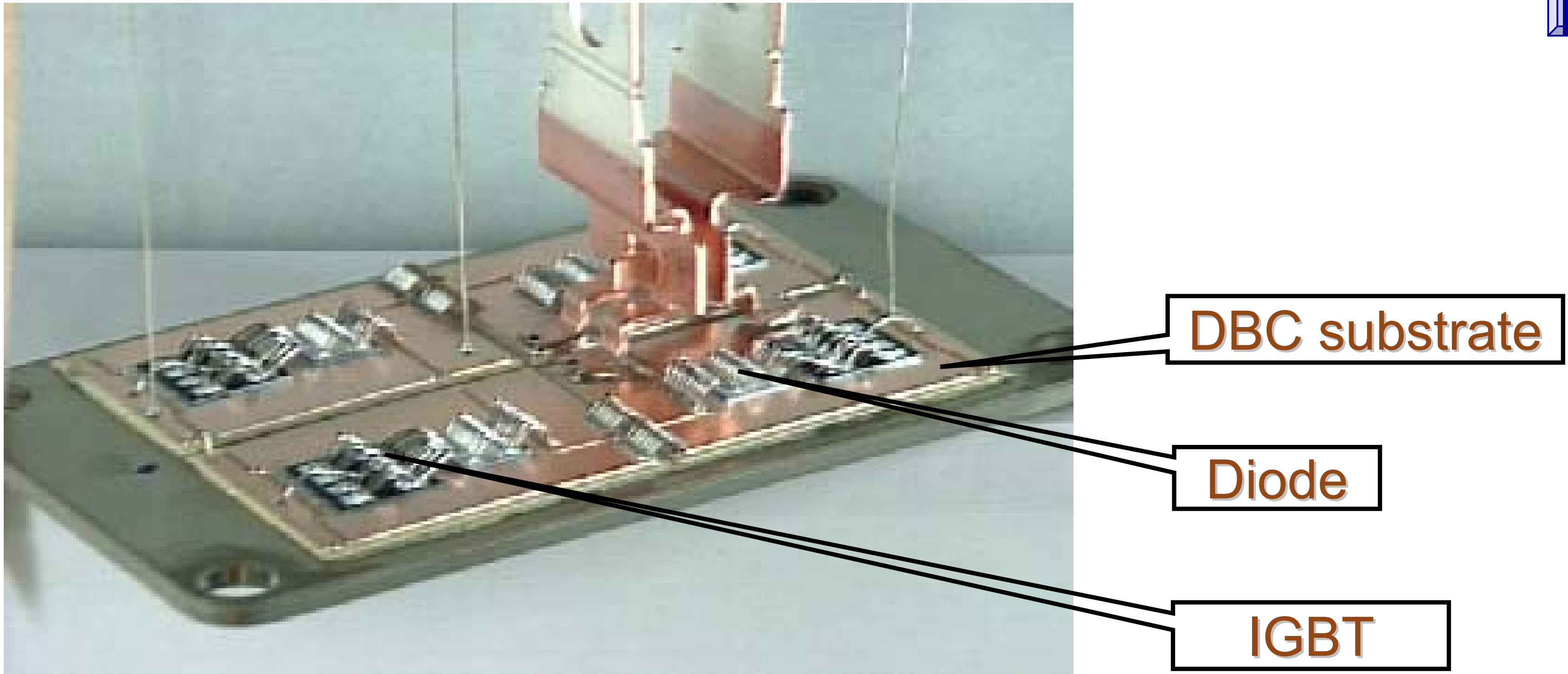
Single Switch Module

4 Substrates, 4 IGBT‘s and 4 Diodes



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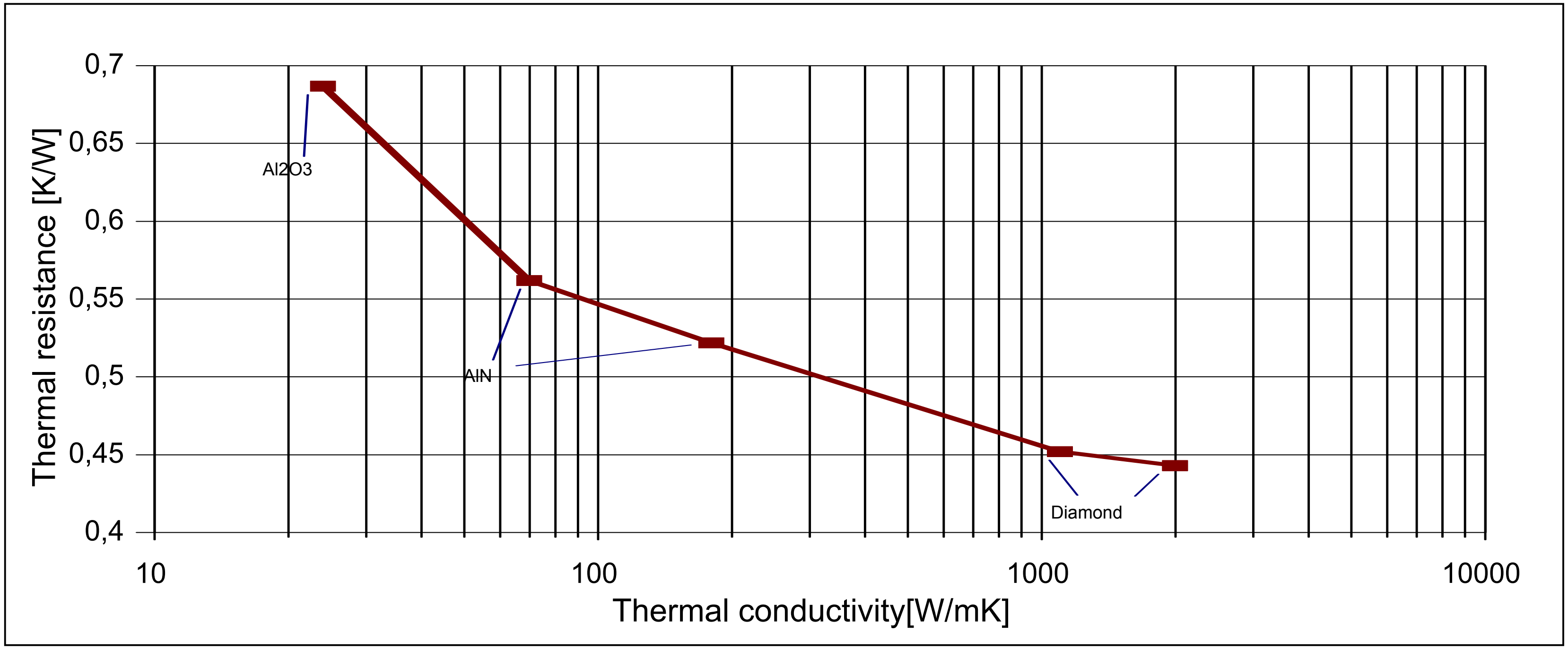
Power Module – Thermal Resistance

Thermal Resistance
as a function of
Substrate Thermal Conductivity



Chip area = 100mm^2; ceramic thickness; 0,635mm; copper baseplate 3mm; power dissipation 100W; solder 0,070mm

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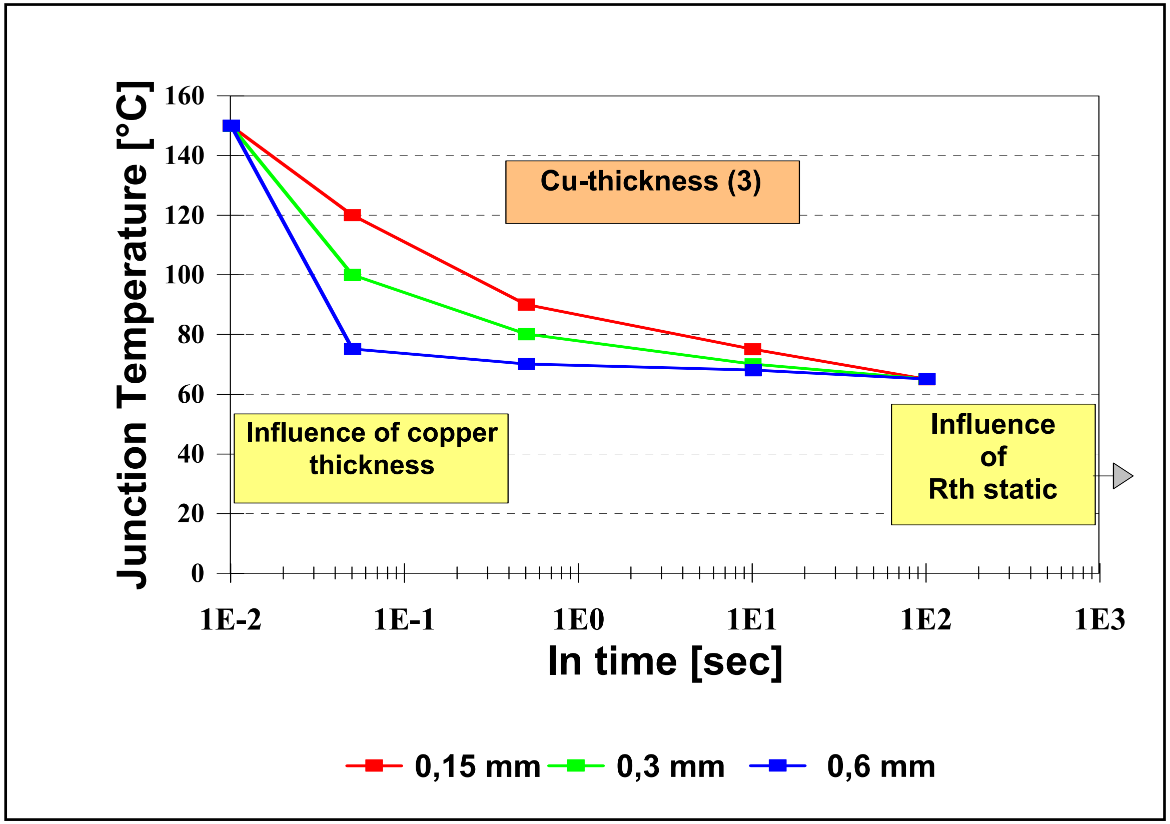
Thermal Mass



Junction temperature as function of the dynamic thermal resistance

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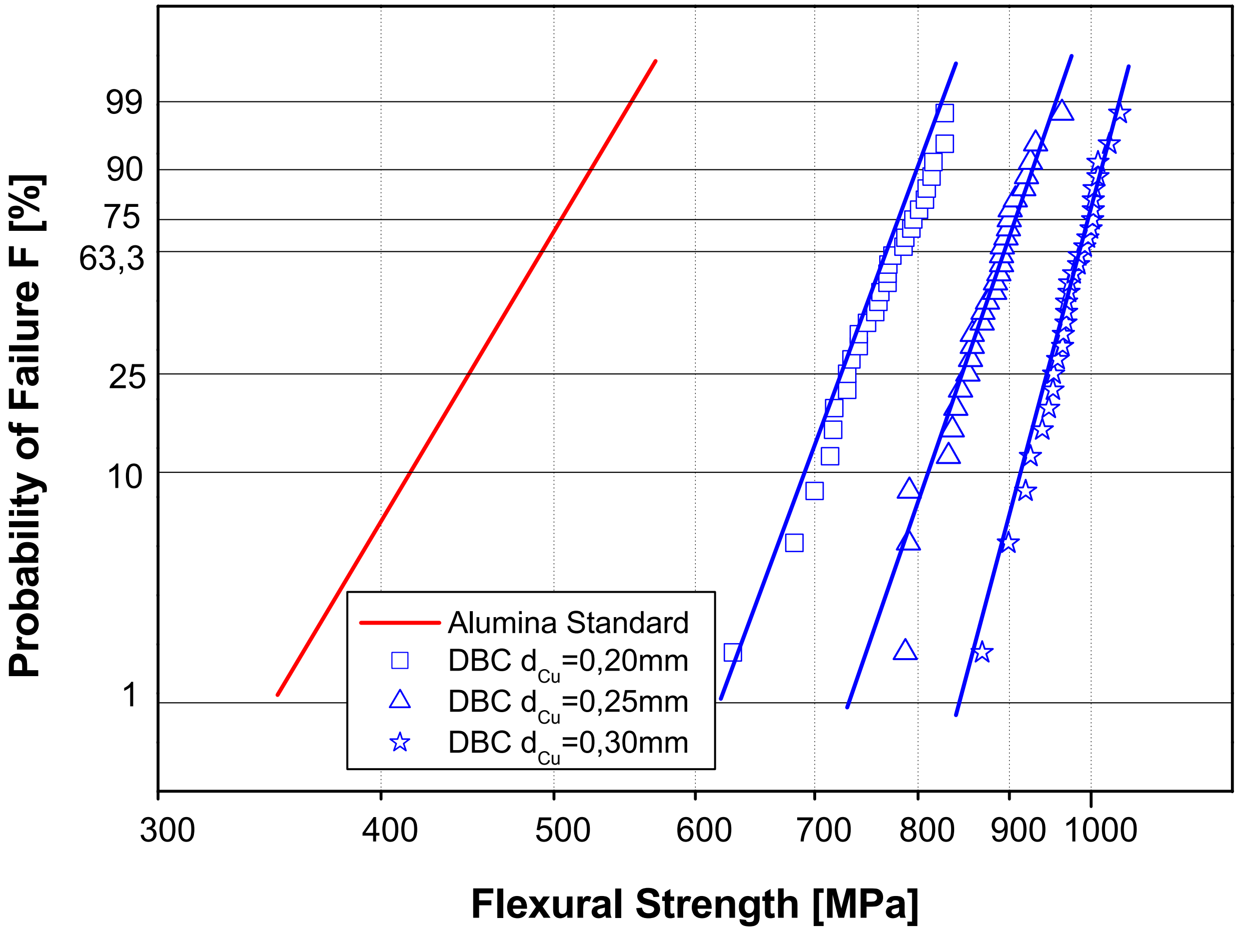
Flexural Strength of DBC

as a function of copper thickness



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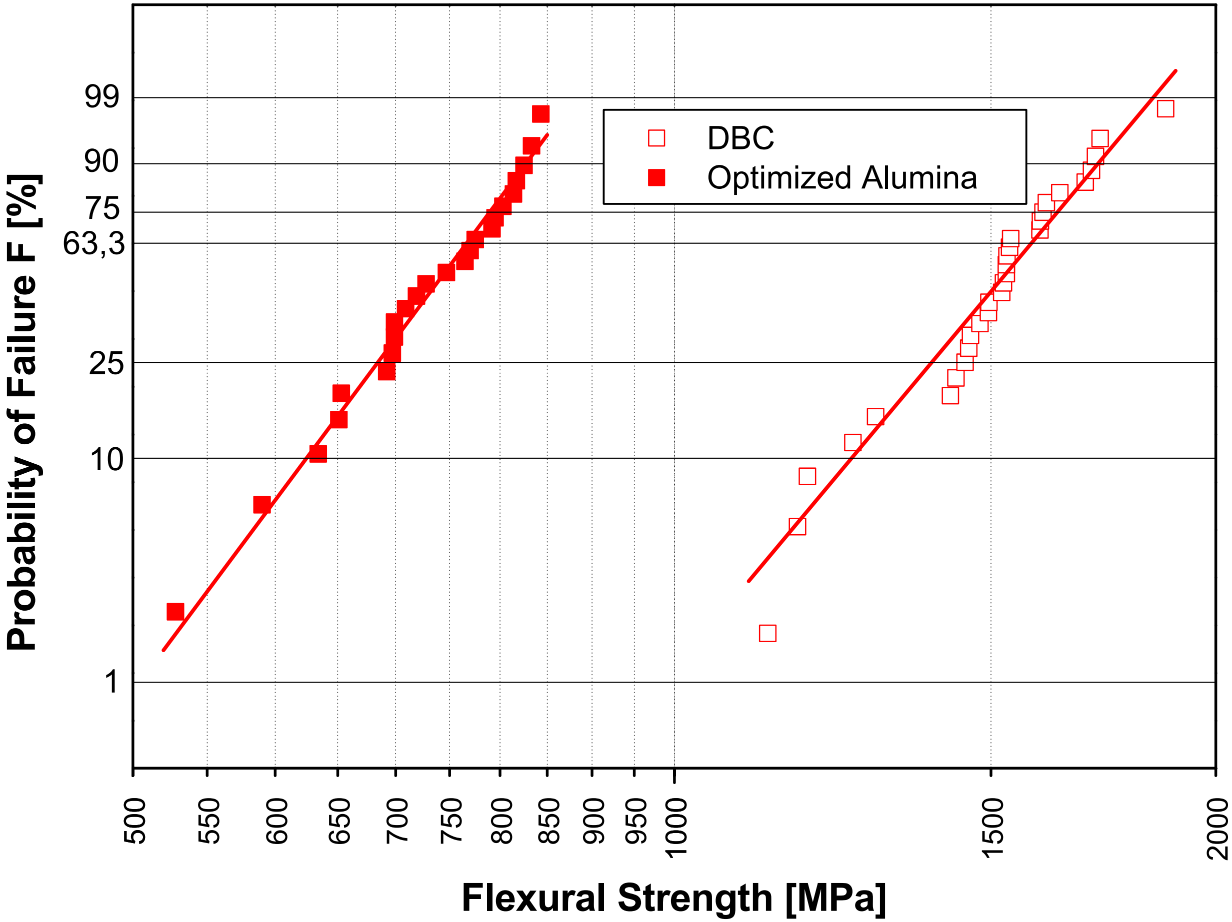
Flexural Strength of HPS DBC

Compared with Blank HPS (optimized Alumina) Ceramic



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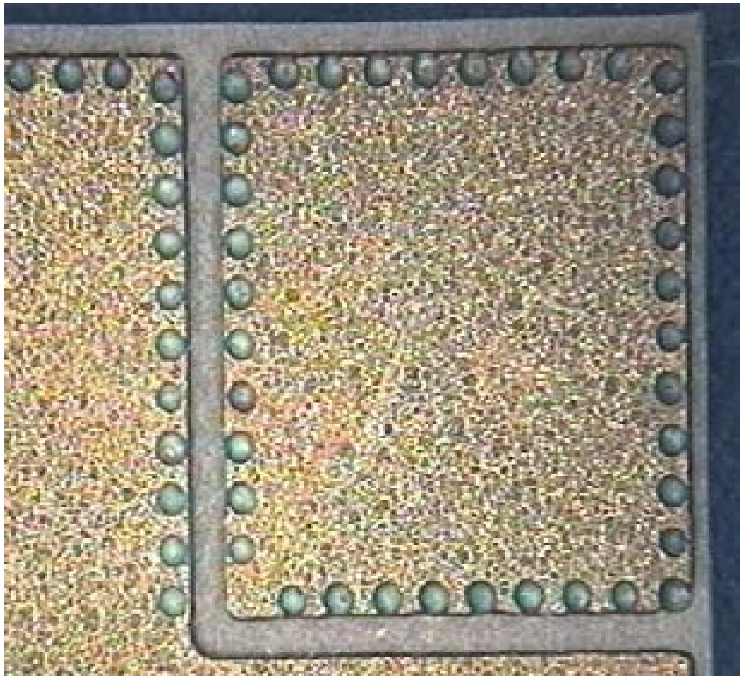
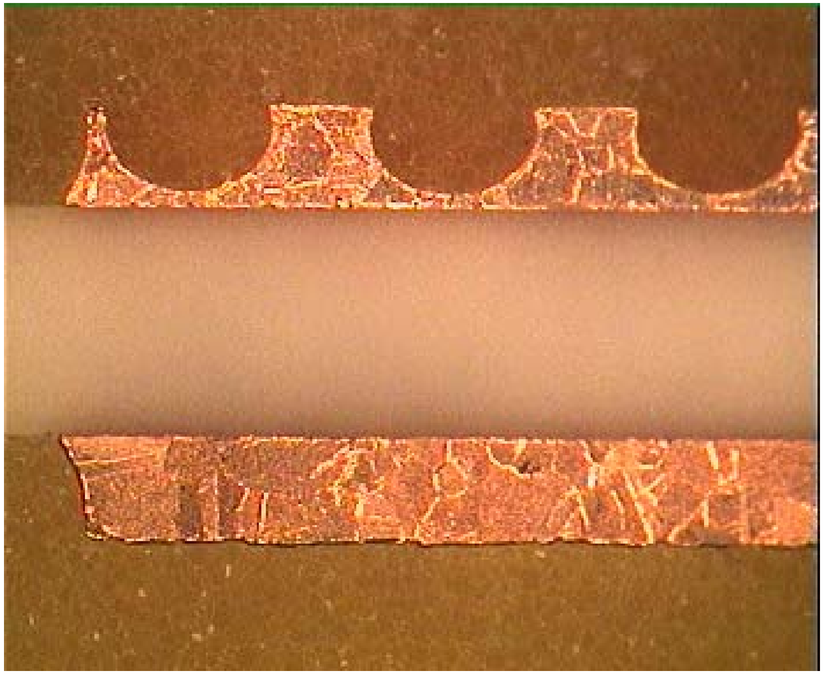
Dimple Design



Top view



Cross section

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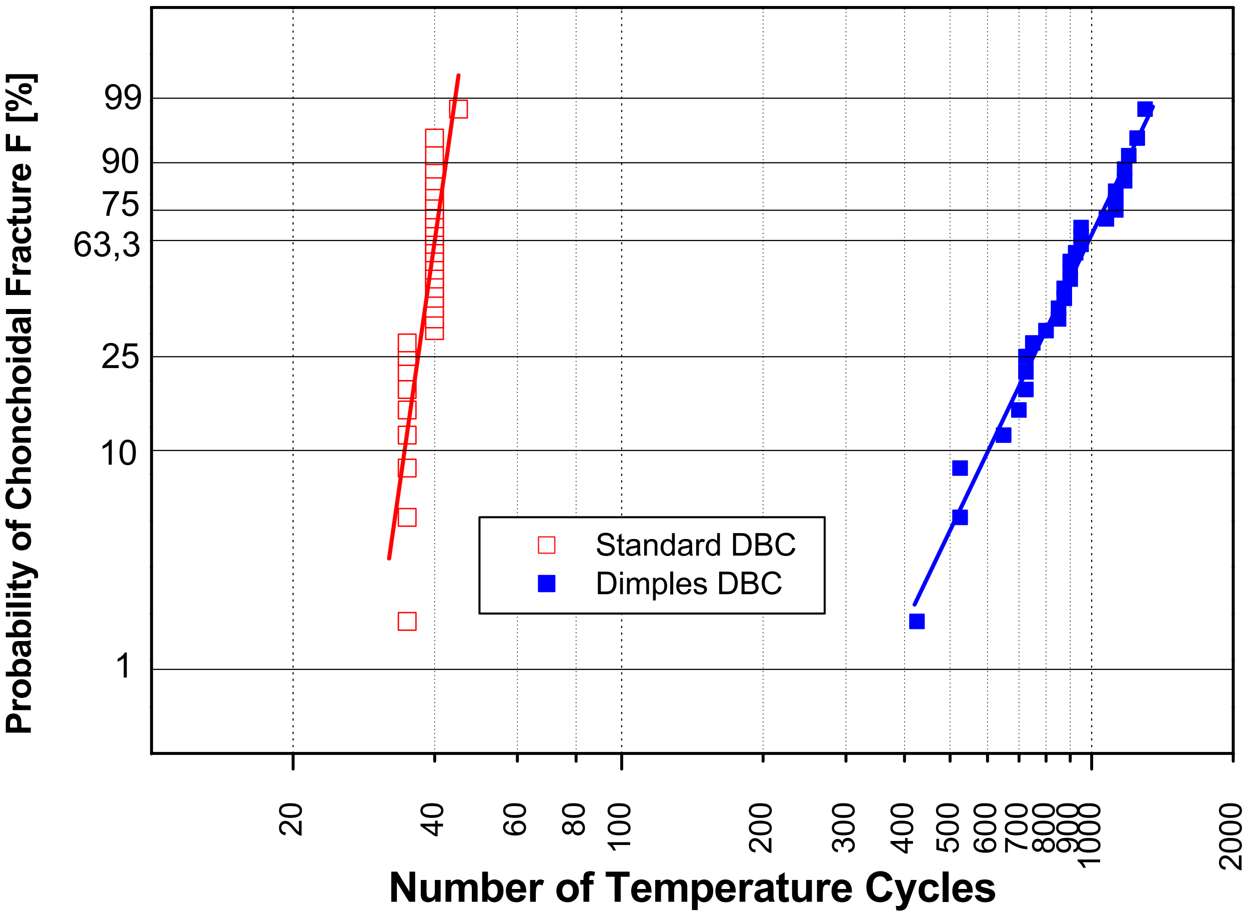
Thermal Cycling Reliability

Standard Alumina DBC with and w/o Dimples



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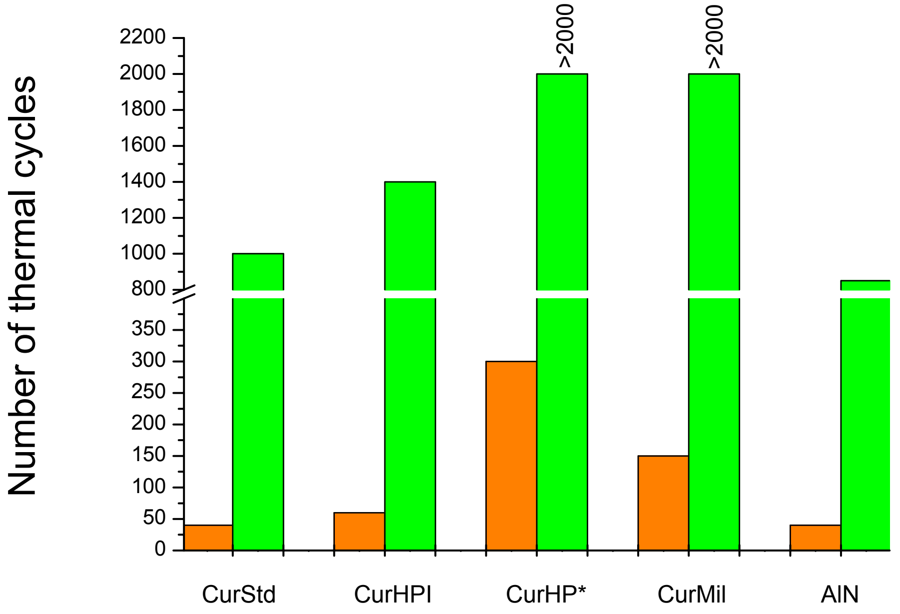
Average Life N0 – (Weibull)



🟧 without Dimples

🟩 with Dimples (Copper pattern design for thermal stress relief)

*$d_{(ceramic)} = 25$ mil, $d_{(Cu)} = 12$ mil -55°C / 150°C / 15 min.

$d_{(ceramic)} = 15$ mil, $d_{(Cu)} = 8$ mil -55°C / 150°C / 15 min.

Courtesy of Curamic Electronics

Special Substrates

- Active Metal Brazed (AMB)
- Refractory Metallization
- Substrates with vias
- Substrates with lead offs
- 3-Dimensional substrates
- DBC Packages
- Water cooled substrates

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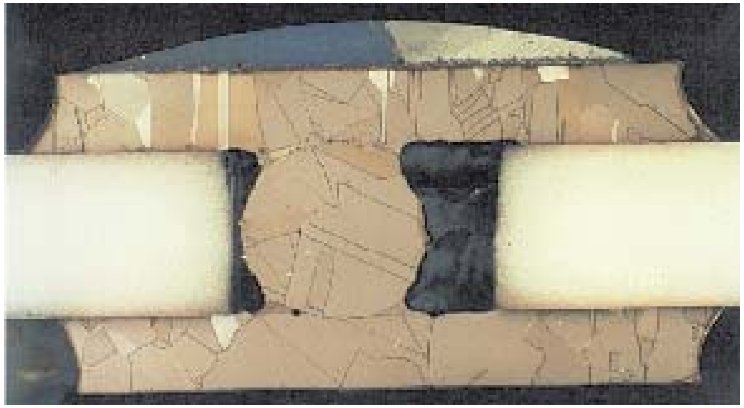
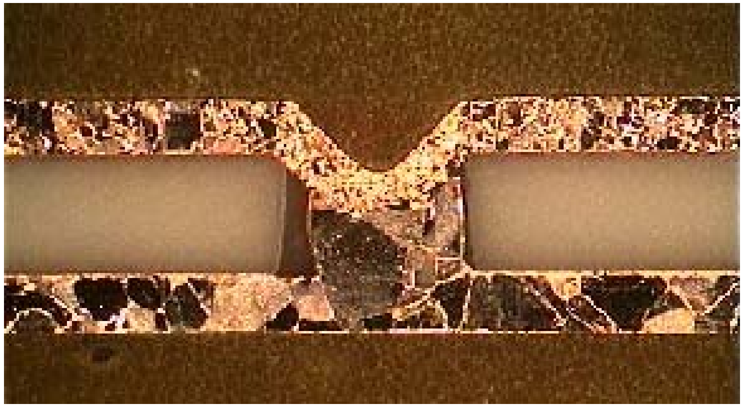
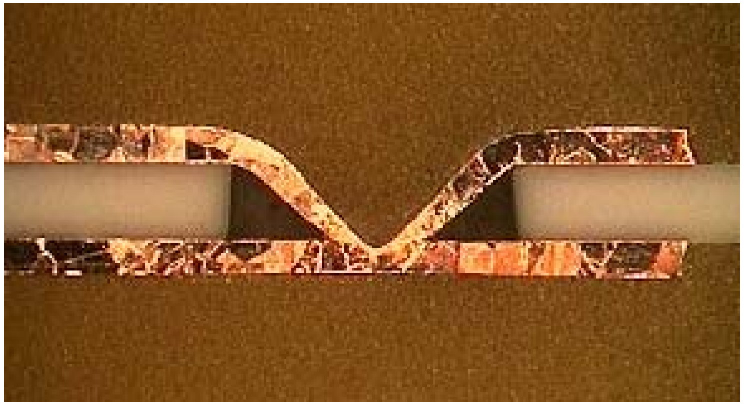
Via Technology



Both sides flat surface. Ceramic hole diameter min. 1.0mm R<100μΩ



One side flat surface. Ceramic hole diameter min. 1.0mm R<100μΩ

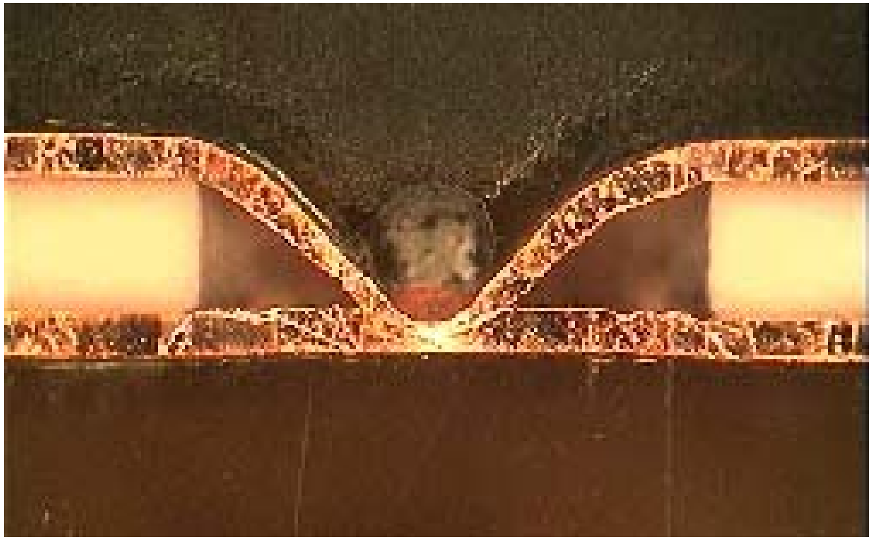


One side flat surface low cost. Ceramic hole diameter 2.5mm (0.3mm copper layer) R<100μΩ

Courtesy of Curamic Electronics

Vias in DBC Substrates

- High current front to back feed-through
  - 100 A current
  - 100 μOhm
- For backside ground-plane or shield
- Both hermetic
- Version 1 can be used as thermal path also



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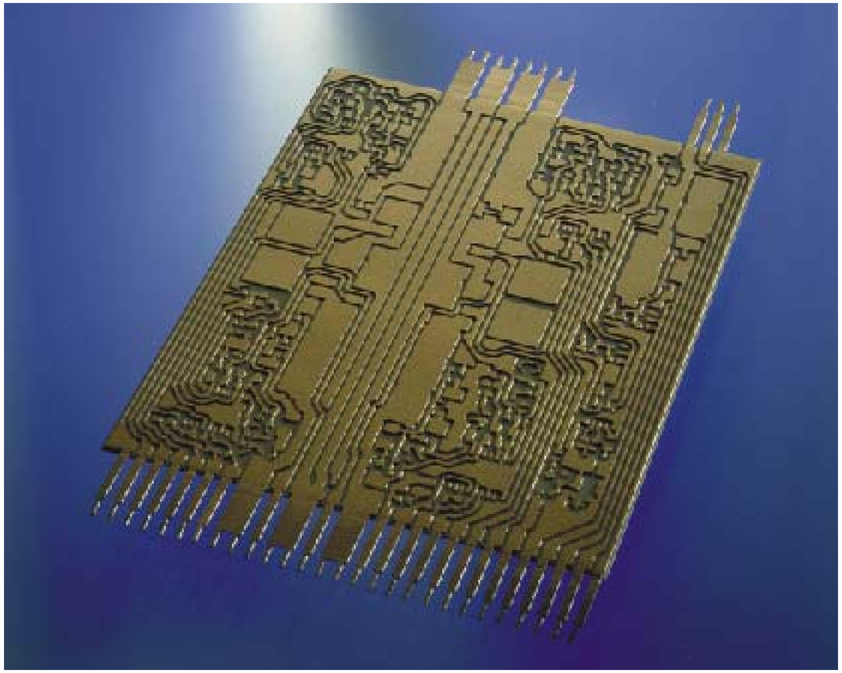
Integral Terminals

- Terminals made of same copper sheet as circuit
- High electrical conductivity due to solid metal without interface resistance
- Very high reliability



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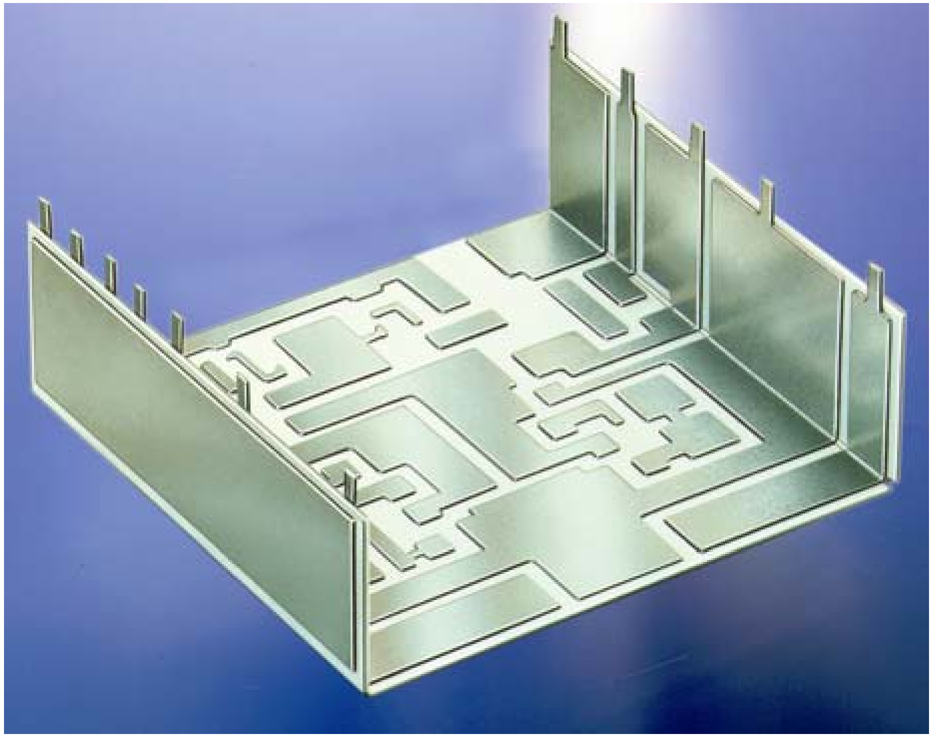
3-Dimensional DBC

- For very high density circuits
- Extremely reliable due to integral connectors
- Base for power
- Sidewalls for non-power components
- Assembled flat and bend up



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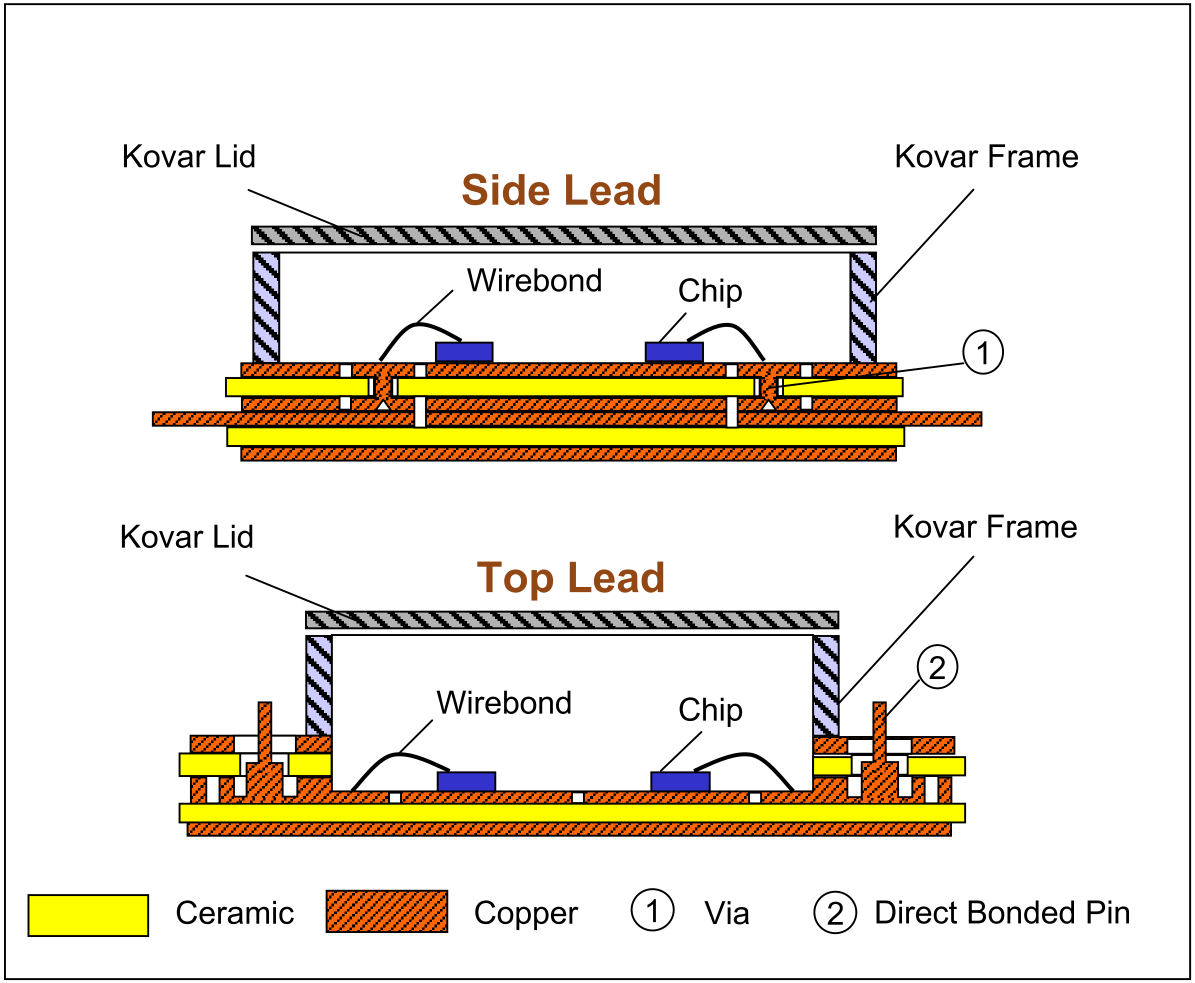
Package Types



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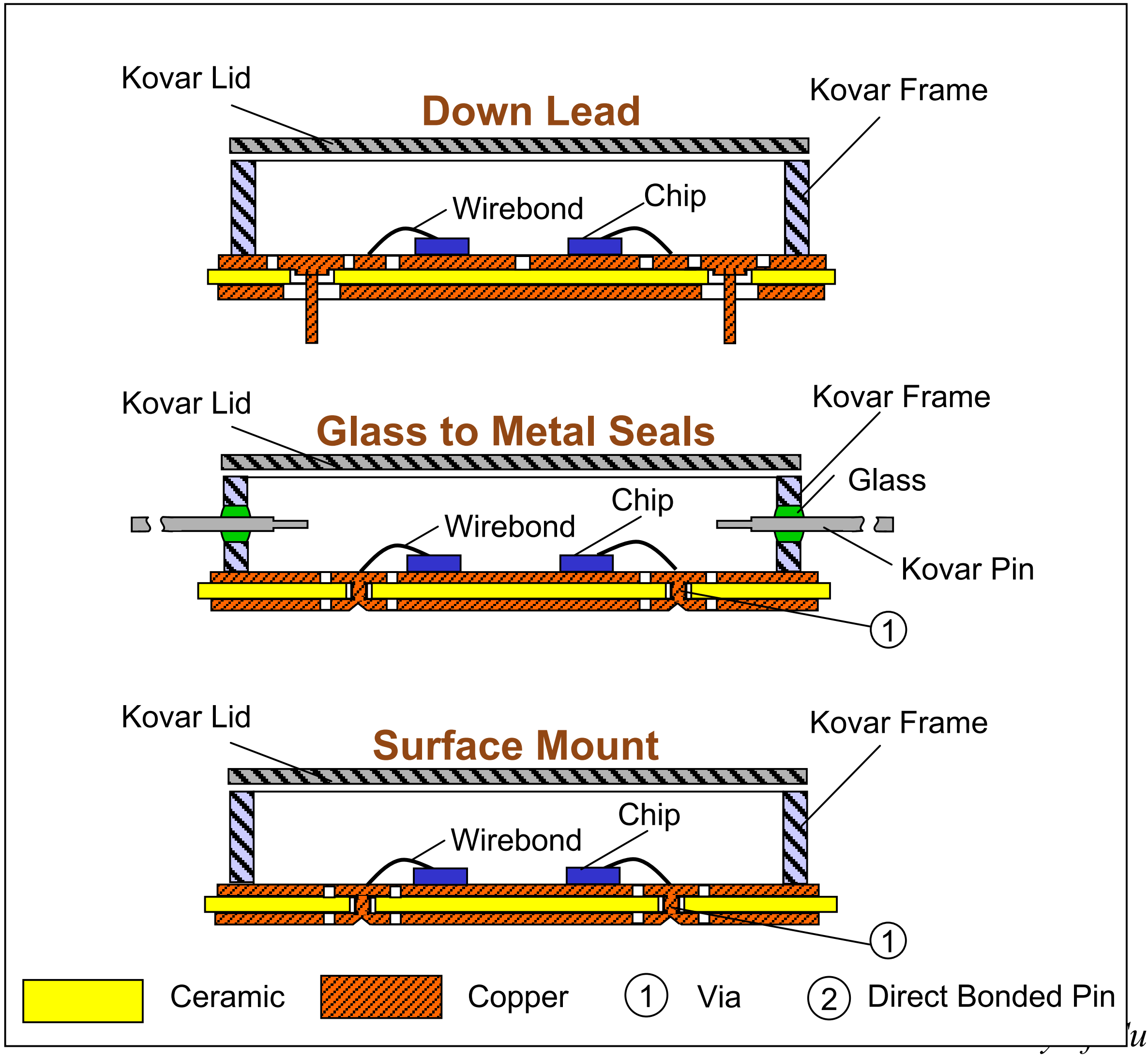
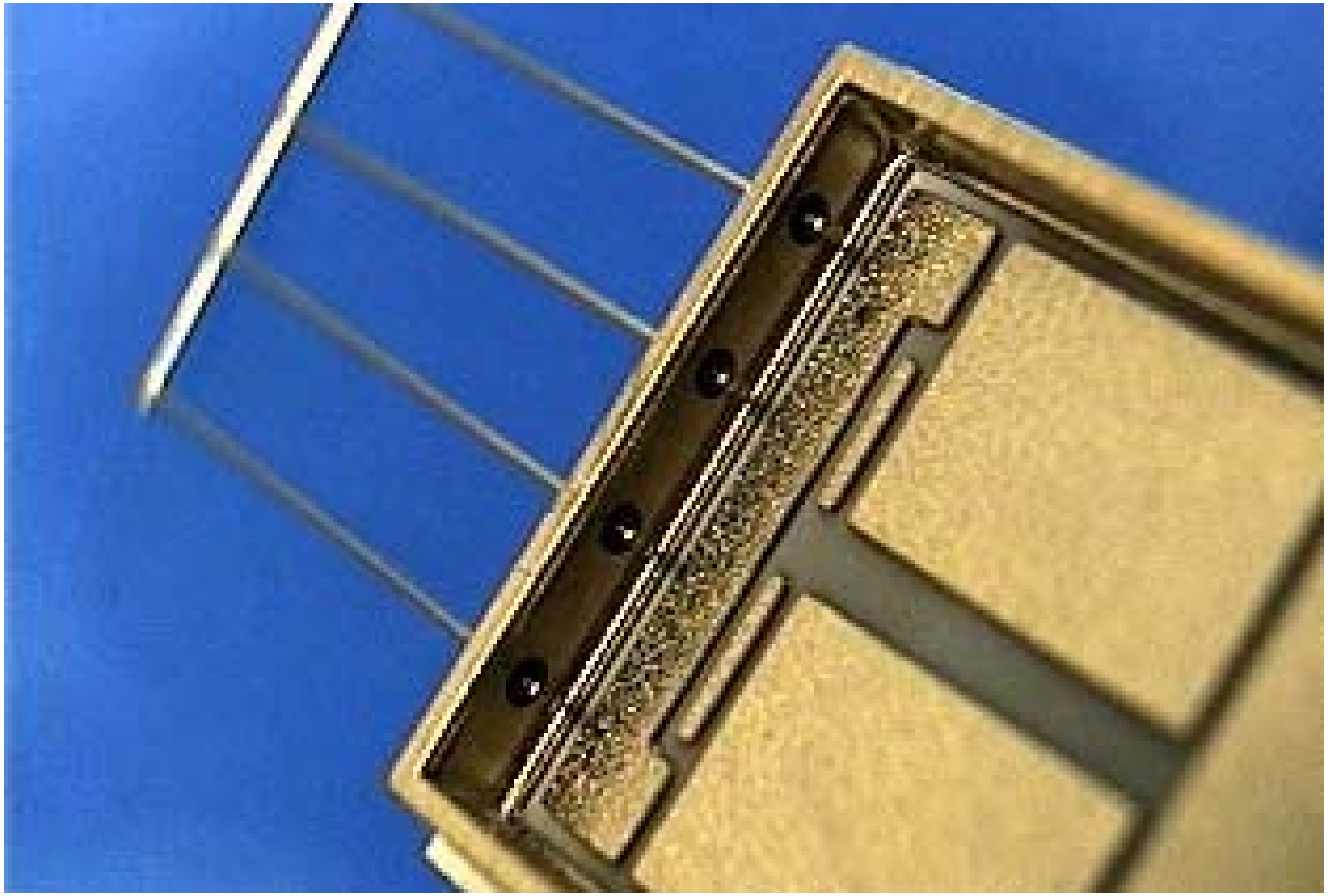


Kovar Frame Brazed on DBC Substrate

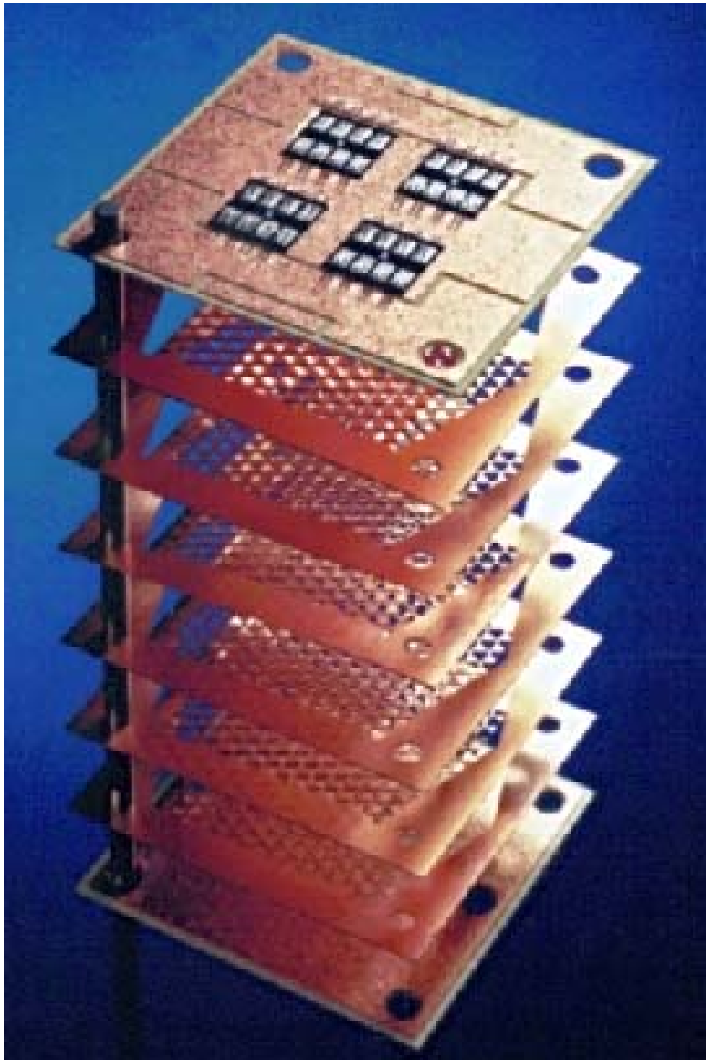
Glass Sealed Feed-Through



Courtesy of Curamic Electronics

Fluid Cooled DBC

- Lowest thermal resistance of all available solutions for COB
- Rth ranging from 0.08 to 0.02 K/W using Al2O3 or AlN
- Power dissipation up to 3 kW on 2” x 2”
- Extremely compact design
- Modular system assembly



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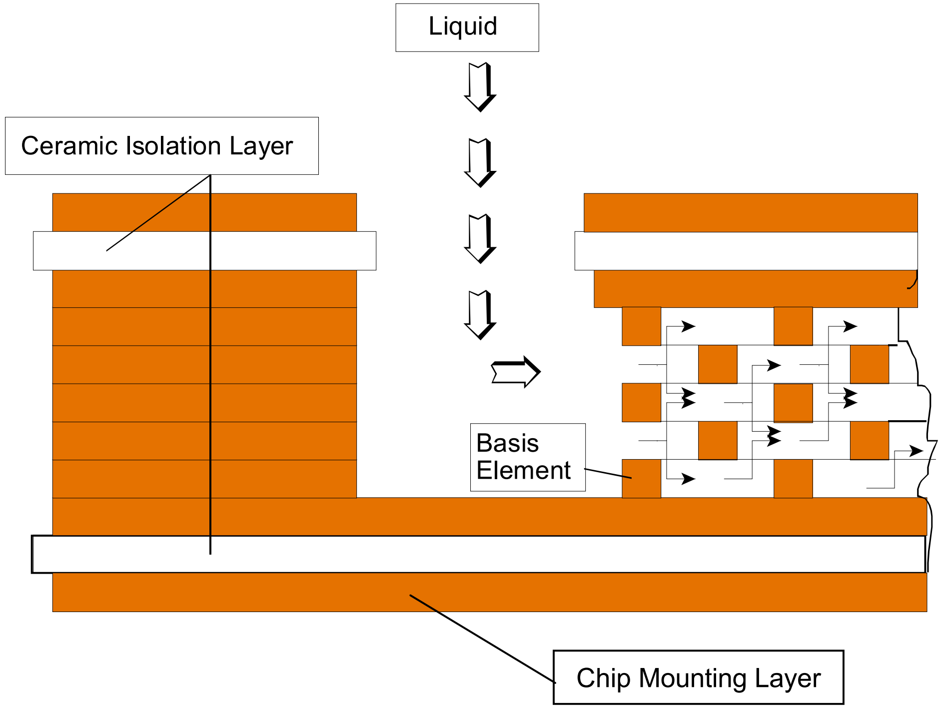
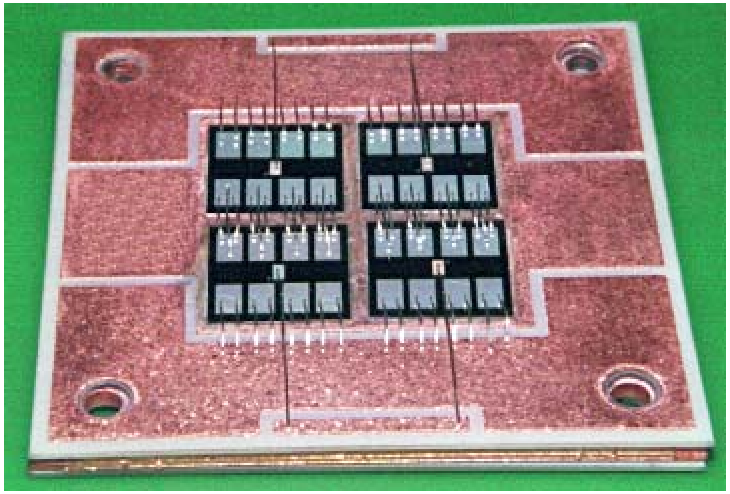
Liquid flow-through micro channels





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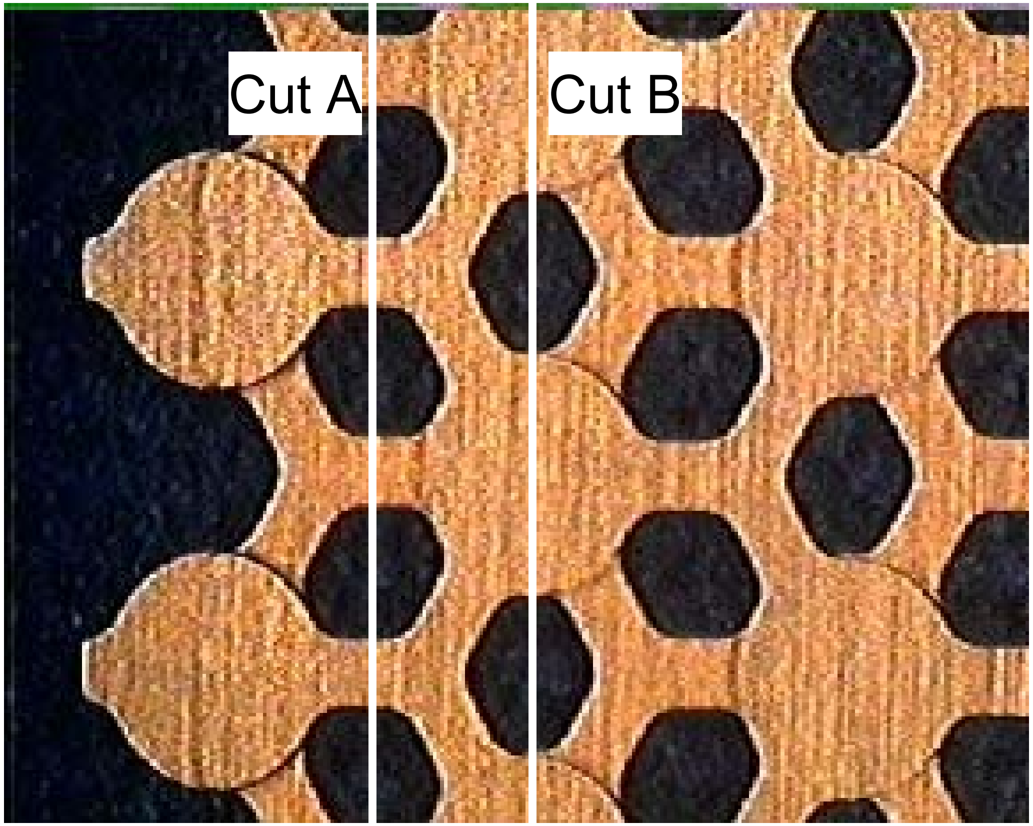
Micro Channels



Courtesy of Curamic Electronics

Micro Channel Water Cooled Module

Half bridge

- 6 IGBT
- 12 Diodes
- 62 mm Standard module size
- 450 A
- Cooling water temperature up to 80°C possible

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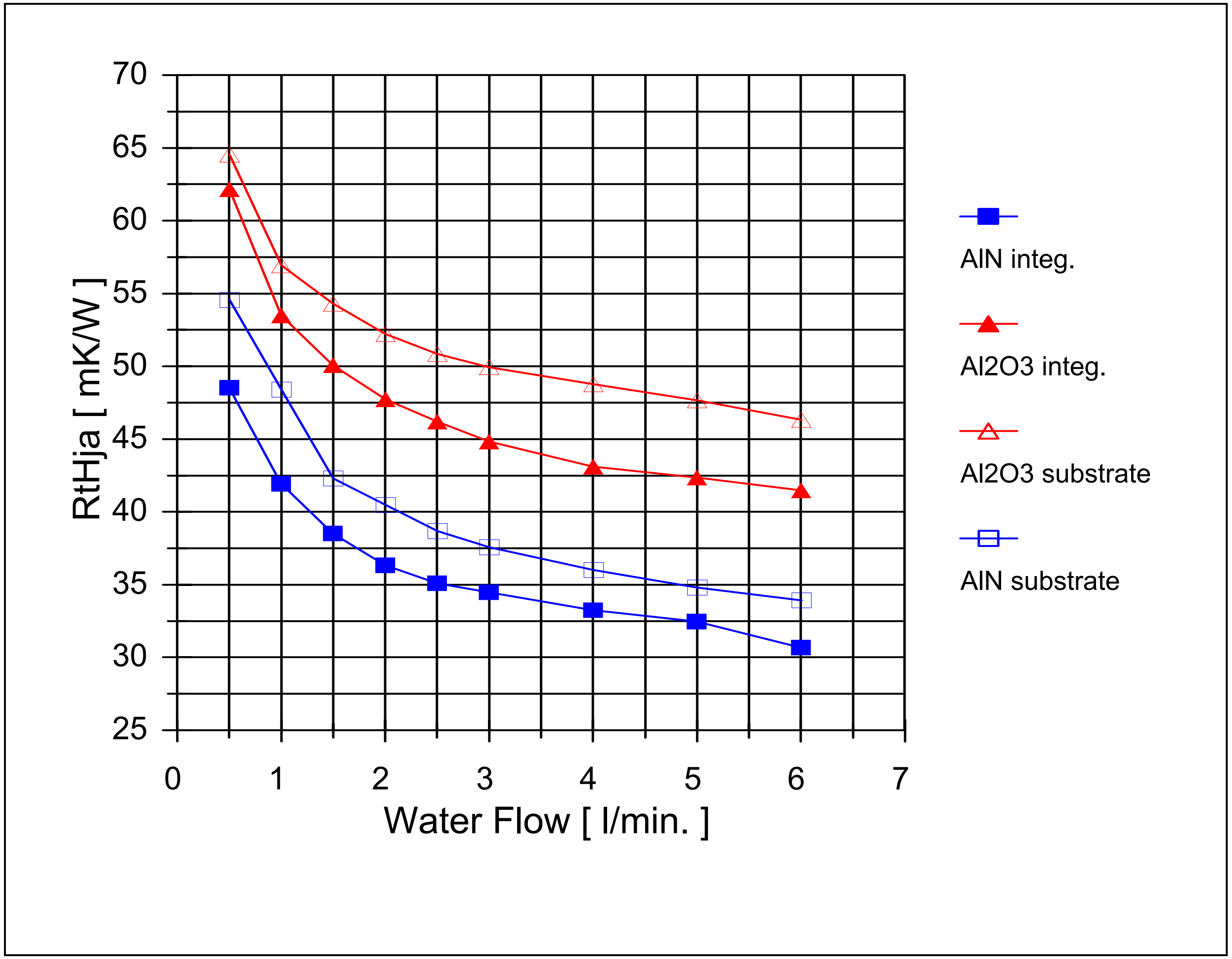
R_{thja} as a Function of Water Flow



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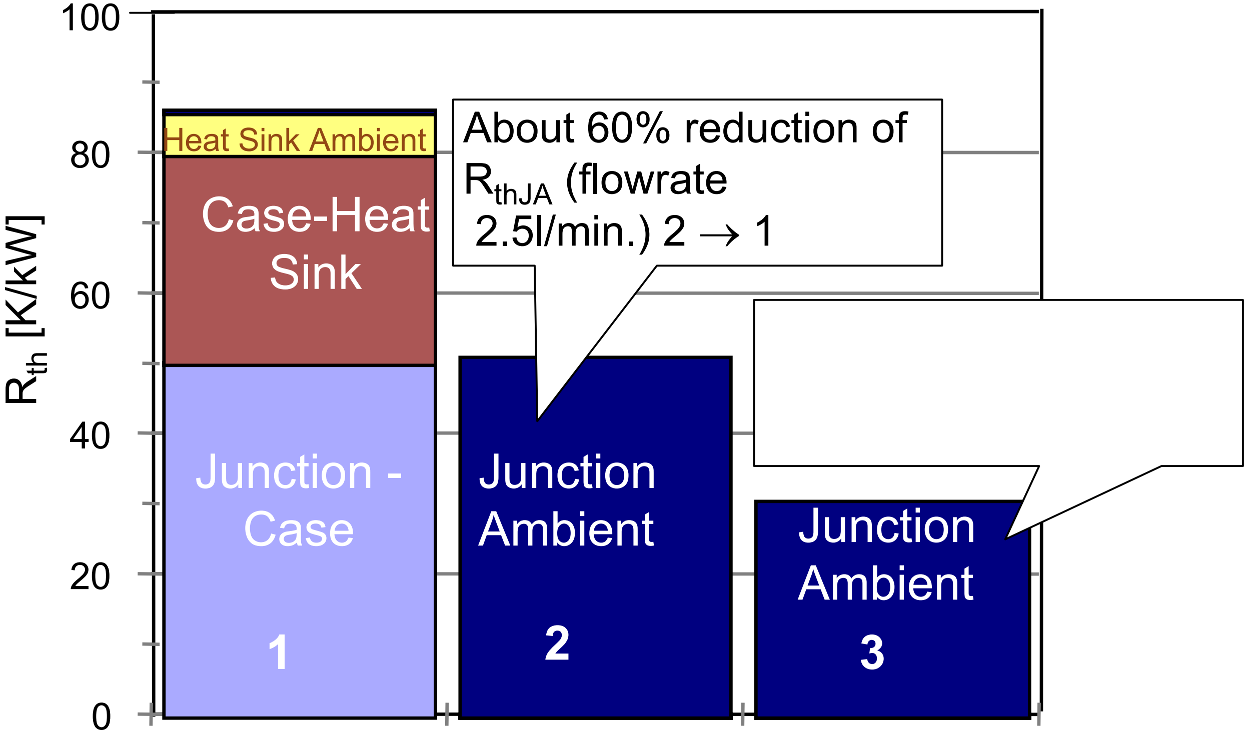
Module comparison

Conventional v. Integrated water cooling



About 60% reduction of R_{thJA} (flowrate 2.5l/min.) 2 → 1

1 →Standard module on closed cooling system (calculation)
2 →Module with integrated cooling system
(measurement: soldered Al_2O_3 ceramics)
3 →Module with integrated AlN substrate

Courtesy of Curamic Electronics