ThalesAlenia Space
A Thales / Finmeccanica Company

PCMC (Pure Copper Metallised Ceramic) package for high power application

S. Libon

THALES

Thales Alenia Space ETCA

Ref : MF-SL/070024
Date : 22/05/07

PCMC technologies

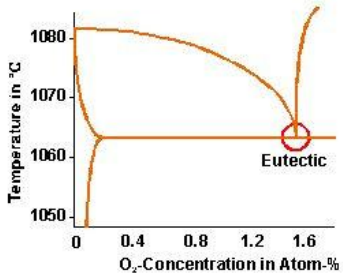
PCMC technology

Ceramic to Cu joint

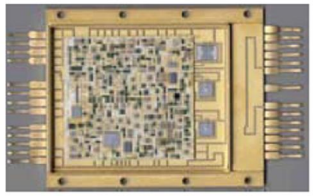
Interconnection (upper-lower level)

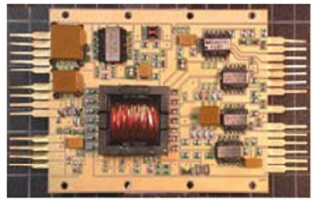
PCMC packages

Curamik
DBC (Direct Bonded Copper)



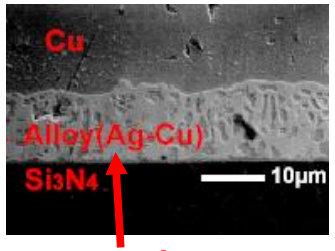
Spinell reaction of eutectic with alumina: $CuO + Al_2O_3 = CuAl_2O_4$



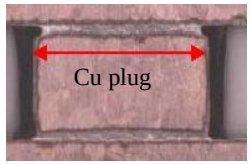


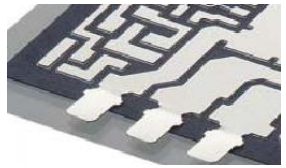
Supplier: Sagem electronics

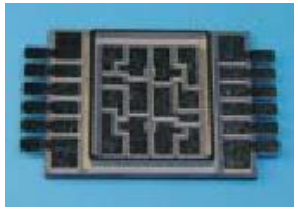
Kyocera
AMB (Active Metal Brazing)

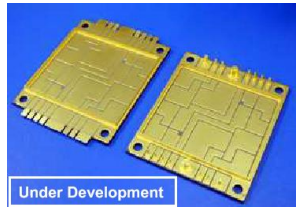


Ti compound



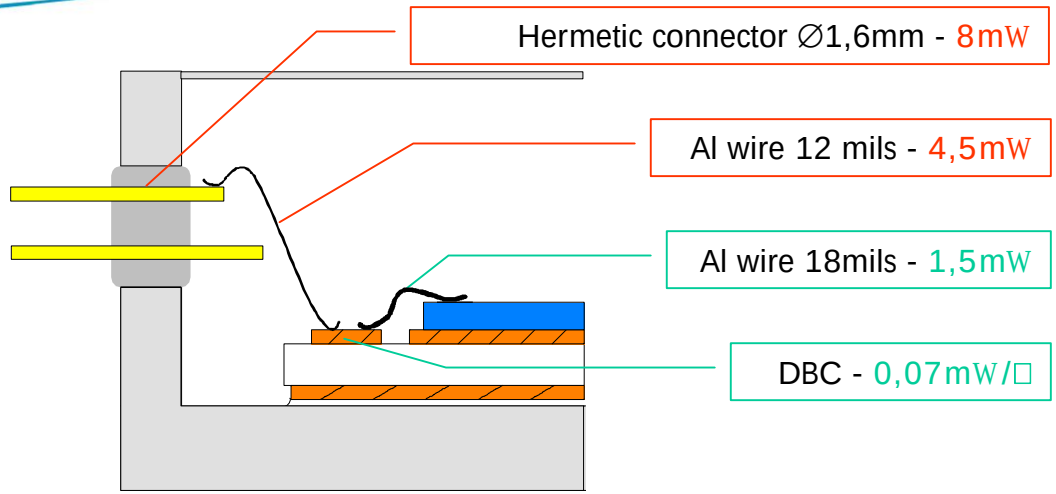


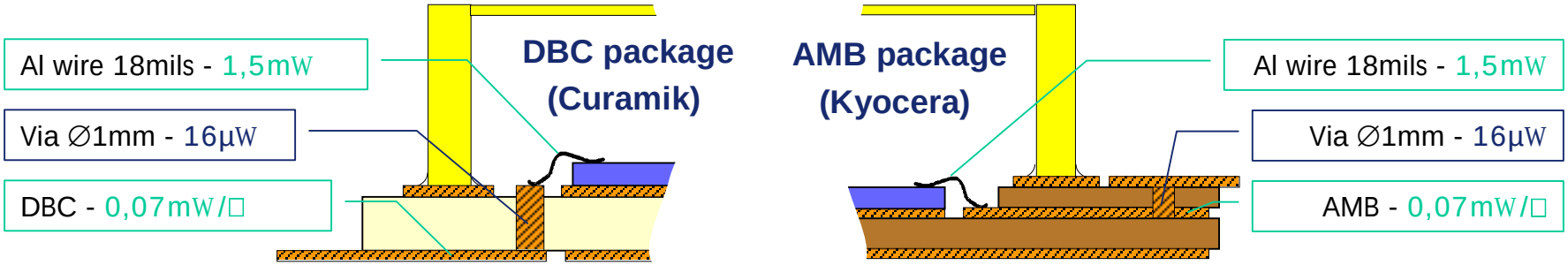




PCMC packages studied

Actual solution
(Homemade MCPH)

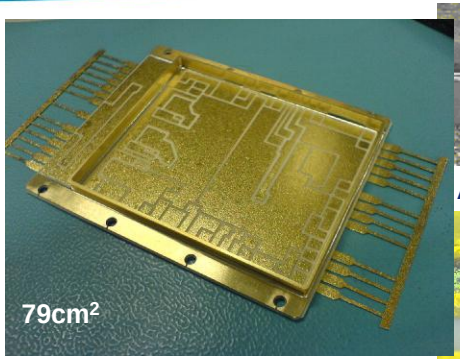


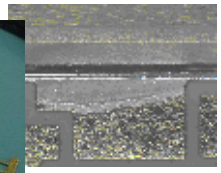


Reduction of serial resistance by a factor of 5

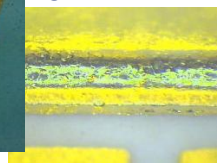
Material	Thermal conductivity (W/mK)	Flexural strength (MPa)	TCE (ppm/K)
Al_2O_3	30	275	7,1
Si_3N_4	60	850	2,7

Incoming



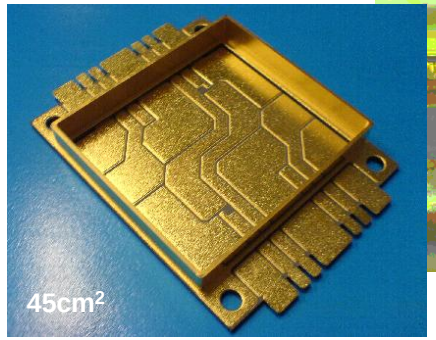


AgCu under the frame => Bleeding

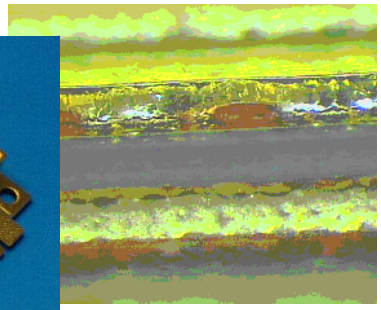


AuSn under the frame => No pbs.

DBC AuSn: Planarity <150µm
DBC AgCu: Planarity <300µm

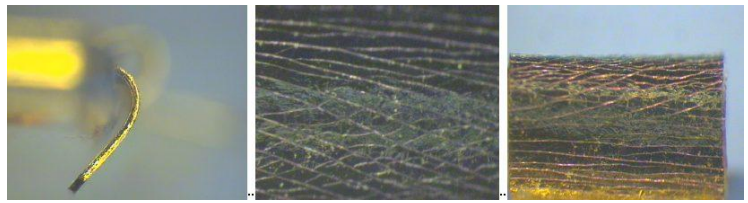


AMB AgCu: Planarity <150µm



AgCu under the frame
=> Cavities

1. Planarity will be a central issue
2. Better brazing capability with Curamik AuSn



Similar performances on

3. Ni/Au treatment resilience to bending
4. Wire bonding capability (1 mil unsafe)

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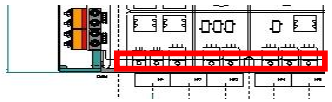
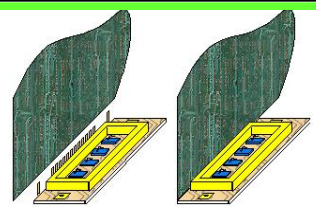
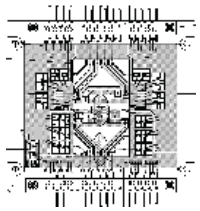
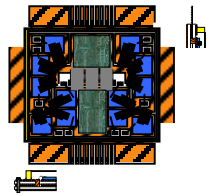
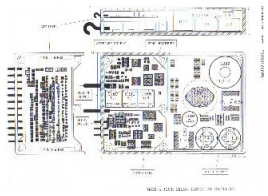
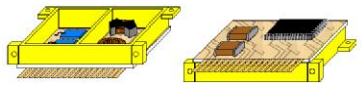
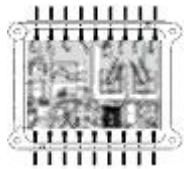
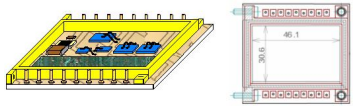
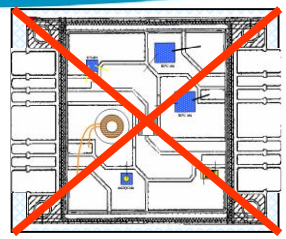
Case Studies

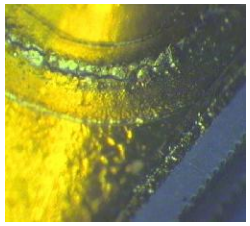
Application	Characteristics	Actual design	New design	Improvements
PCU	2,25kW transmitted 90W 17W/die diss. 100V 22,5A			• Trench height: & width • Volume: 7% • Weight: 40 to 50% • Cost: 8% • Electrical: 8W
HPPU inverter	3kW transmitted 36,8W 3W/die diss. (extreme: 15W/die) 1000V 45A			• Double Power capacity • Volume: 80% • Weight: 20% • Cost: 80% • Electrical: 24W
MPLC DC-DC converter	210W transmitted 15W 4W/die diss. 100V 18A			• Base plate real estate: 50% • Volume: 15% • Weight: >0 • Cost: 15% • Electrical: 10,5W
EPC SMART	500W transmitted 13W 4,4W/die diss. 200V 8A			• Double sided • Volume: 20% • Weight: 5% • Cost: 23% • Electrical: 0,6W

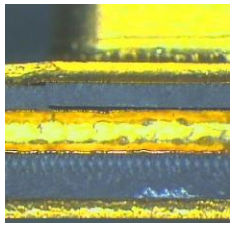
1 sided solution

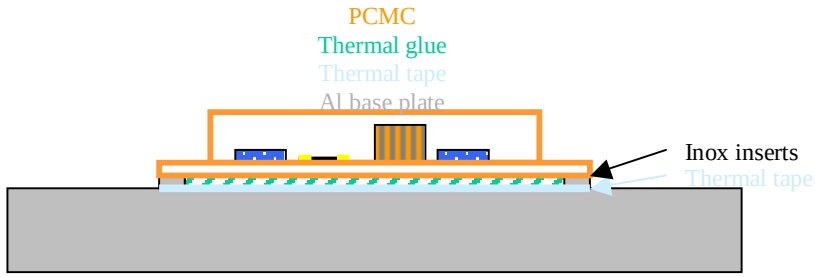
2 sided solution

Mounting: 1 sided

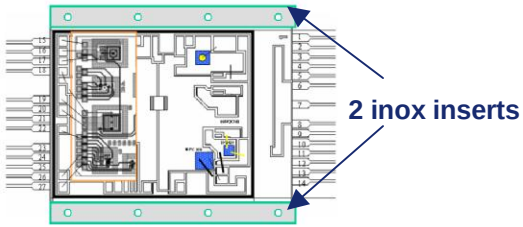


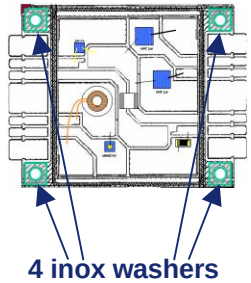


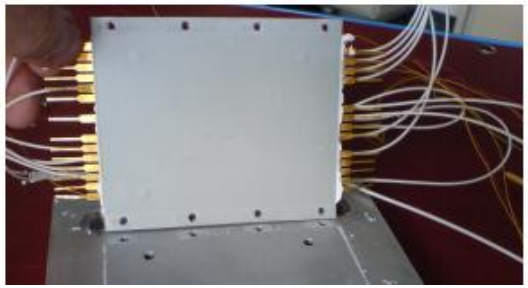


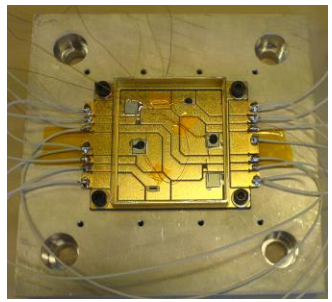


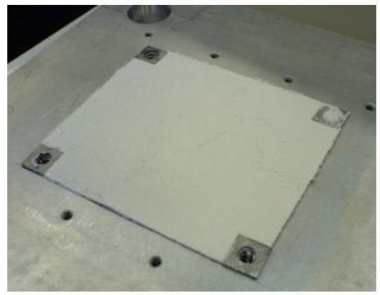
Mounting flat on a tape Þ Cracks under the frame (AMB) Þ Thermal glue with inox inserts





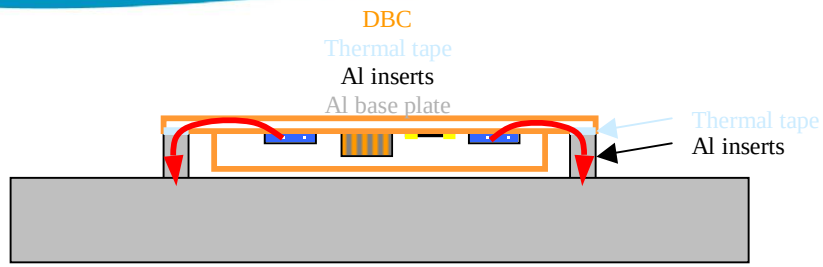


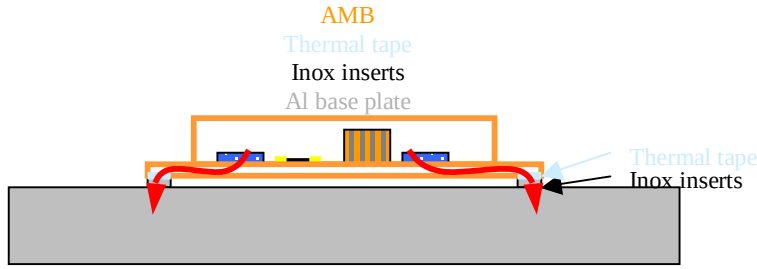




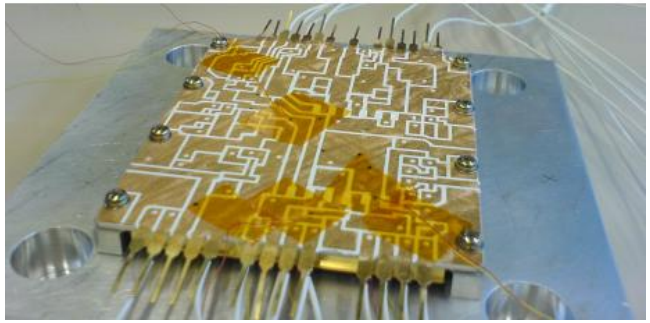
Reworkable; Base plate ready; Planarity in manufacturing (TBD)

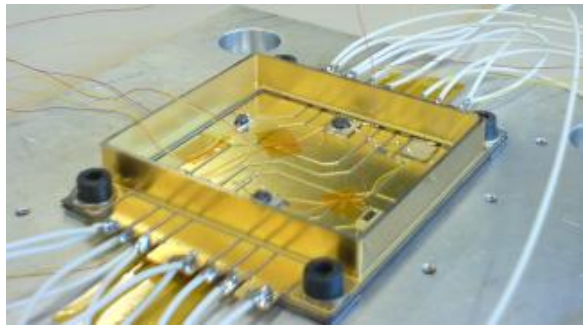
Mounting: 2 sided



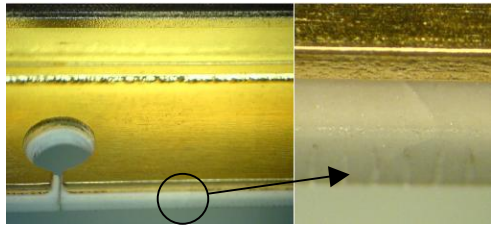


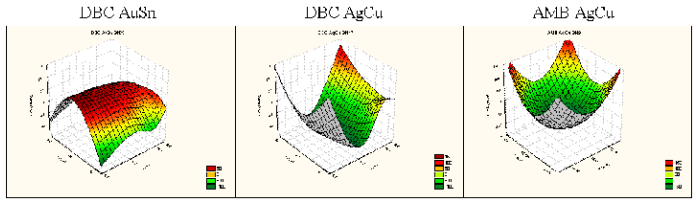
Thermal path trough mechanical structure





Inserts to represent the 2 sided fixture

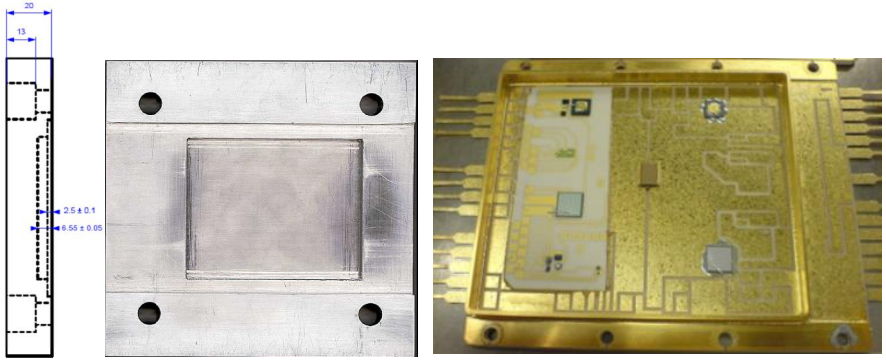




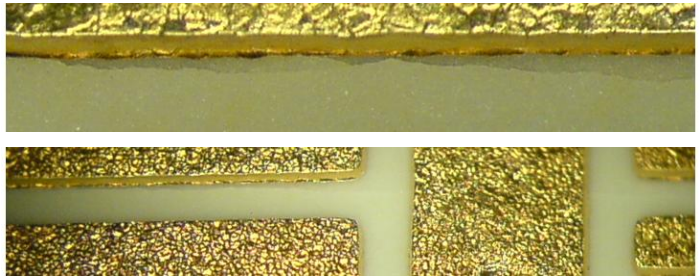
Stress at fixture points (DBC)

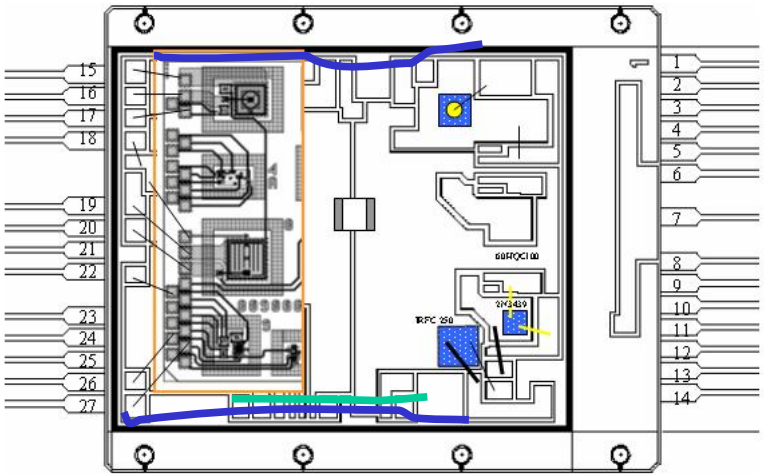
Cost to obtain co-planarity of fixture points

Shocks: DBC



Perpendicular shocks fractures:



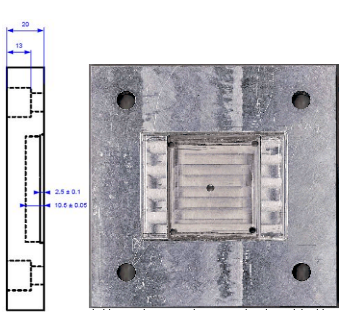


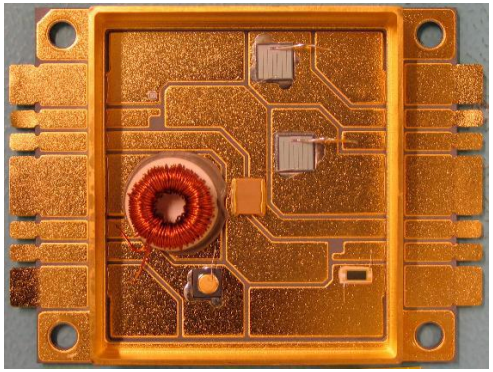
2000g AgCu

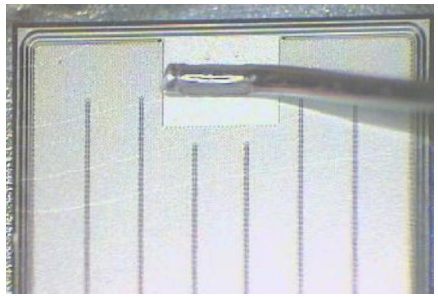
3000g AuSn

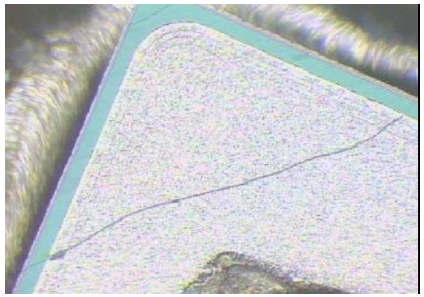
No problems with brazed components

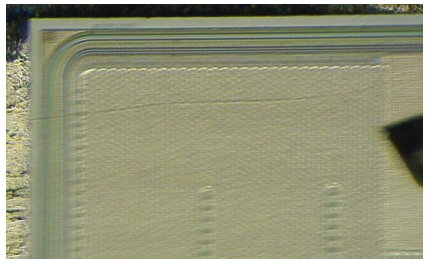
Shocks: AMB

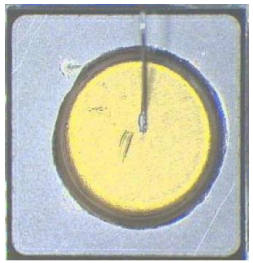




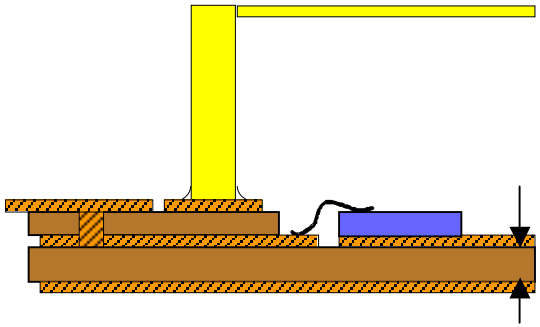








Cracks on brazed components starting at 1500g perpendicular to package



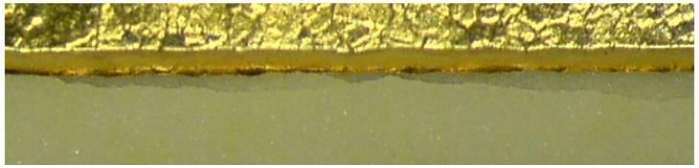
625µm of Si_3N_4

No problems on glued components or lateral chocks up to 2500G

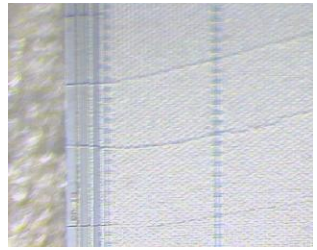
Shocks: interpretation

Ceramic materials characteristics (from Kyocera)

		Thermal Conductivity (W/m·k)	Flexural Strength (MPa)	Fracture Toughness (MPa 1/2)	CTE (ppm/degree-C)	Young modulus (GPa)	PCMC Thickness (µm)
DBC	96%Al_2O_3	20	274	3.7	7.1	@ 350	1000
AMB	Si_3N_4	60	700	6.5	2.7	@ 250	635



DBC AgCu @ 2000g
DBC AuSn @ 3000g
AMB pass 2500g



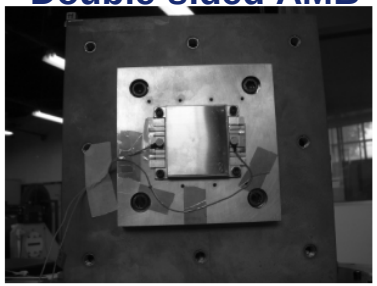
AMB @ 1500g
DBC AgCu pass 2000g

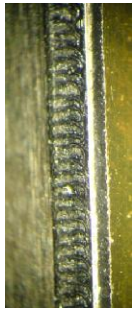
Conclusions:

- 625µm Si3N4 unfit for brazed components Þ back reinforcement
  Þ brazed components not possible on 2-sided AMB packages
- Al2O3 is intrinsically more fragile

Vibrations

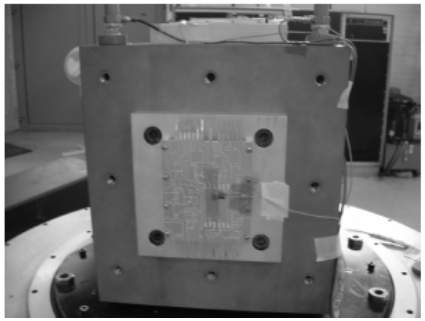
Double-sided AMB



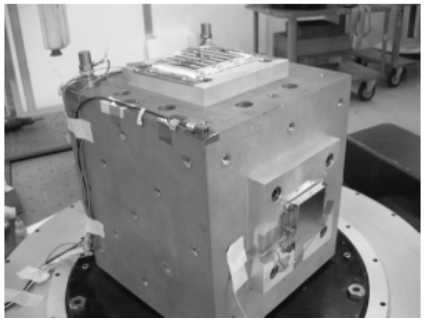


SN8 cover fracture during Y random vibrations due to a cover design error
=> Once repaired, no problem

DBC 2-sided



DBC 1-sided



No problems, DBC 2-sided pushed up to 1.5 g^2/Hz

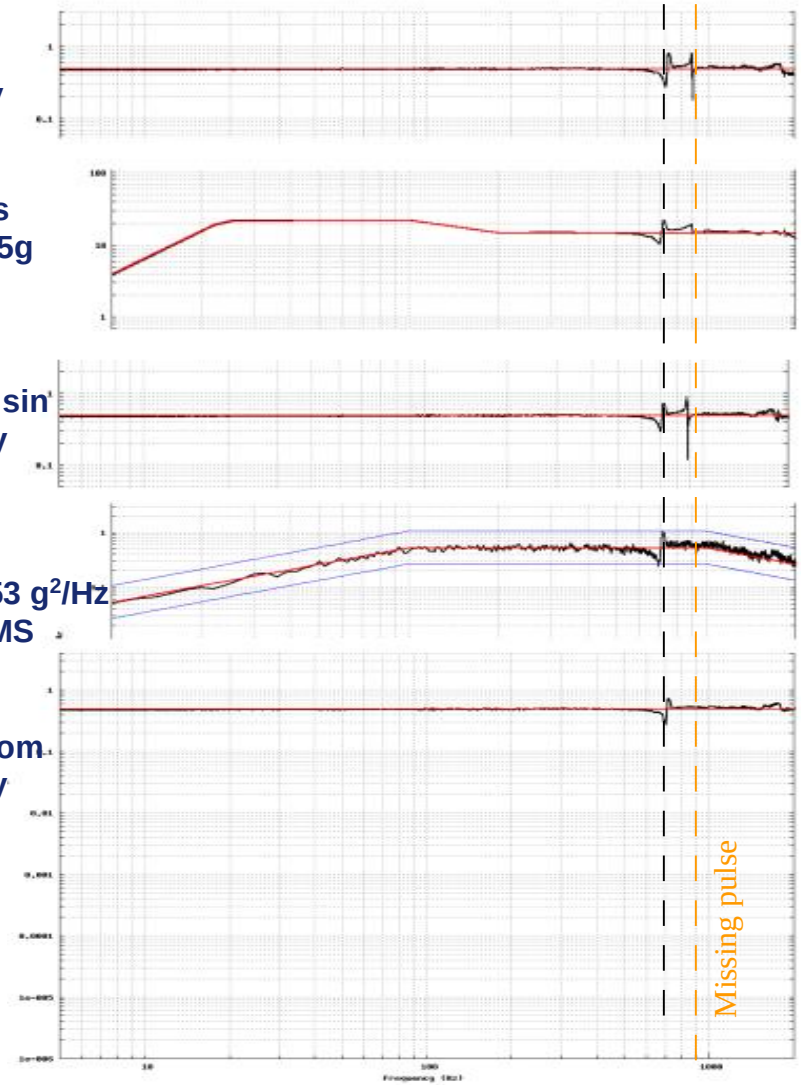
Reference sin survey

High sinus Peak@22.5g 1 oct/min

Post-high sin Sin survey

Random peak @0.53 g^2/Hz 29.53 g RMS 10 min

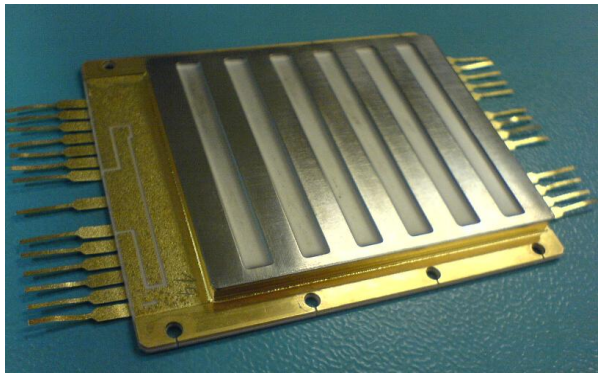
Post-random Sin survey



Thermal cycling

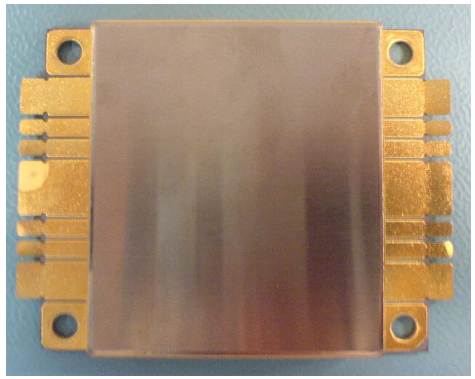
Thermal cycle:-55/+125°C in less than a minute

DBC



OK up to 500 cycles

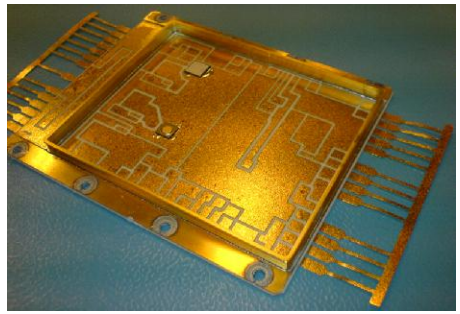
AMB

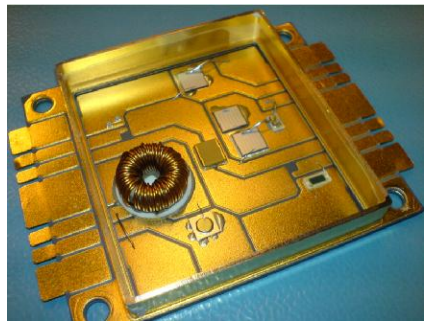


OK up to 500 cycles

RGA & Parylene deposition

	DBC SN14	AMB SN8	units
Pressure	652	721	torr
Nitrogen	79,2	79,9	%
Oxygen	4099	ND	ppm
Argon	336	<100	ppm
CO2	484	774	ppm
Moisture	6922	1349	ppm
Hydrogen	337	277	ppm
Helium	19,6	19,8	%
Fluorocarbon	<100	119	ppm
Hydrocarbon	<100	<100	ppm
O2/Ar	12,2		

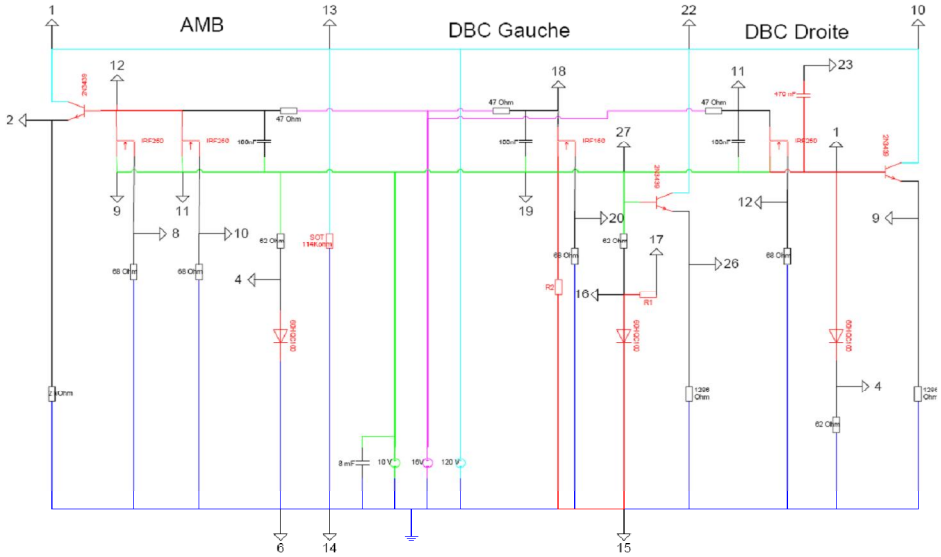




Parylene deposition shows no problem

RGA Air trapped inside DBC:
Due to a processing error (air entrapment)

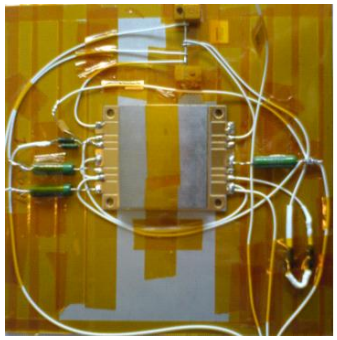
Endurance

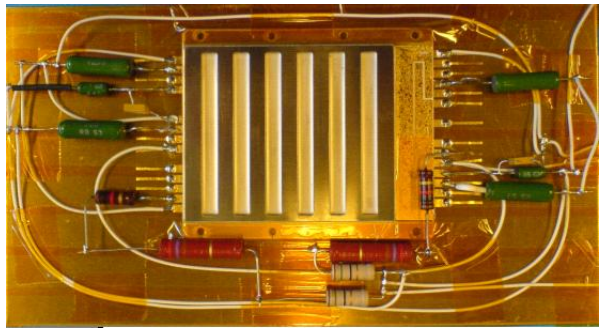


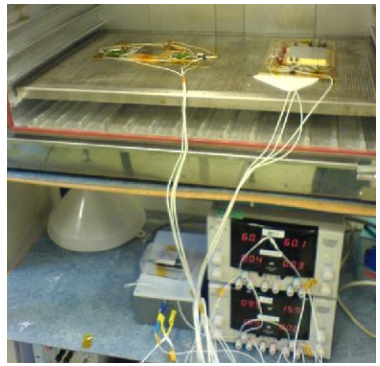
Following ESCC component specifications: 2000h 125°C

No significant change on:

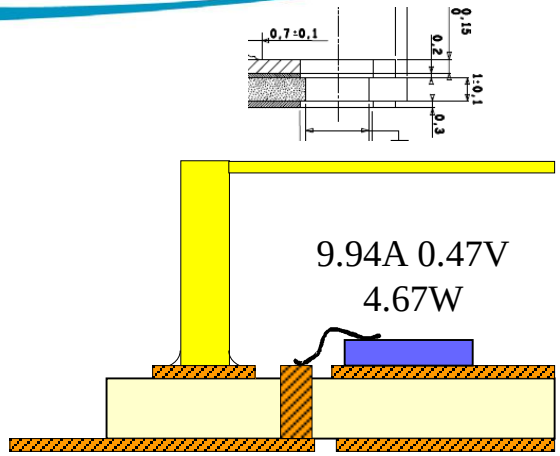
- **-IRFC150**
- **-IRFC250**
- **-2N3439**
- **-60HQC100**
- **-ceramic capacitor**
- **-thick film resistors**
- **-Cu interconnections (for magnetics)**



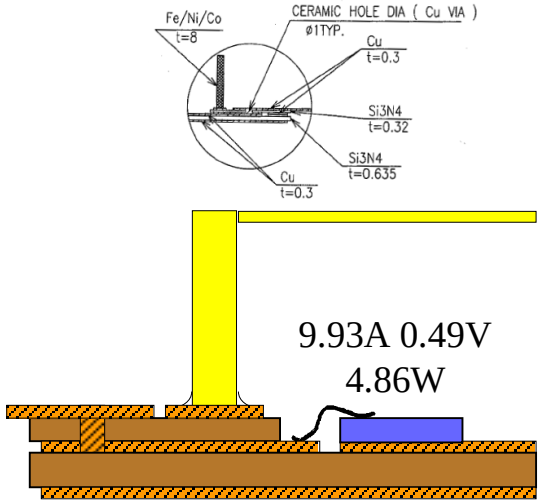




Thermal resistance



	K_{th}	Surface	Thickness	ΔT°
Si	150	$(6528\mu m)^2$	500µm	0.35°
AuSn	253	$(6528\mu m)^2$	30µm	0.01°
Cu	397	$(6528\mu m)^2$	200µm	0.05°
Al_2O_3	30	$(6528\mu m)^2$	1000µm	3.54°
Cu	397	$(6528\mu m)^2$	300µm	0.08°
Total				4.04°
Measured				3.5°



	K_{th}	Surface	Thickness	ΔT°
Si	150	$(6528\mu m)^2$	500µm	0.37°
AuSn	253	$(6528\mu m)^2$	30µm	0.01°
Cu	397	$(6528\mu m)^2$	300µm	0.08°
Si_3N_4	60	$(6528\mu m)^2$	635µm	1.17°
Cu	397	$(6528\mu m)^2$	300µm	0.08°
Total				1.72°
Measured				2°

Uniaxial Results close to theoretical values
Cu tracks DT° neglectable vs ceramic

Decision matrix

Problems encountered	AMB AgCu	DBC AgCu	DBC AuSn	Criticity
Cavities in brazing joint	3/10 opposing cavities			Aspect
Ni/Au craks during lead bending	Always	Always	Always	Aspect
Planarity	<150µm (45cm^2)	<300µm (80cm^2)	<150µm (80cm^2)	Fabricability
Substrate flexibility	OK up to 45cm^2 No brazed component allowed >1000g	OK up to 80cm^2 Brazed components	OK up to 80cm^2 No brazed component	Capability
Chock resilience	>2500g	>1500g	>2500g	Yield
Thermal transfer	60 W/mK	30 W/mK	30 W/mK	Capability

Final choice:
-Limited risk
-Large substrates
-No brazed components