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Baseplates in metallic matrix composites for power and microwave applications

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Baseplates for microelectronic devices in fields where transform environments are encountered, such as automotive or airborne must have some fundamental characteristics such as:

High thermal conductivity, low density, good mechanical properties and a coefficient of thermal expansion (CTE) nearly equal to the microelectronic substrates and the components installed on the baseplates. Metallic matrix composites are very good candidates because they perfectly answer to those requirements. In this presentation, with some examples of electronic devices in power and microwave applications we will show the big interest to use this kind of material.

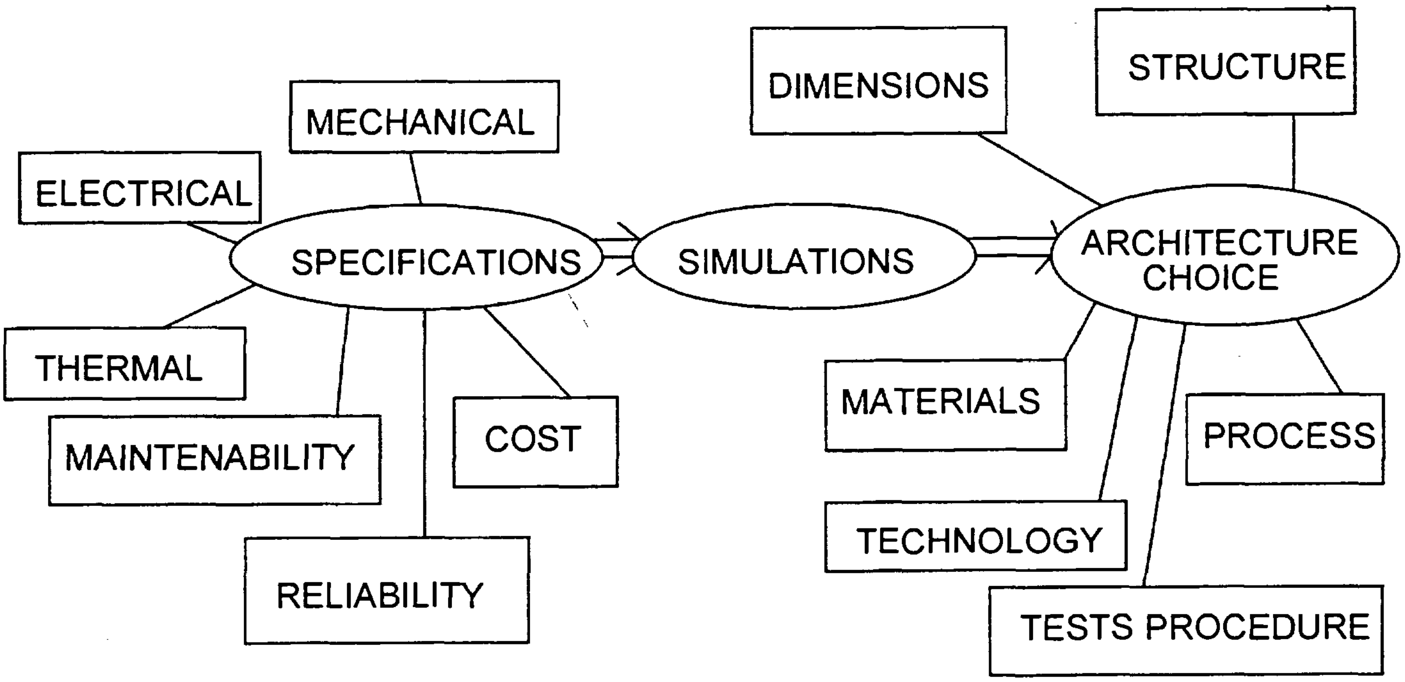
THOMSON-CSF
MICROELECTRONIQUE

BASEPLATES IN METALLIC MATRIX COMPOSITES FOR POWER AND MICROWAVE APPLICATIONS

I/ HYBBRID MICROELECTRONIC ALLOWS

- HYGHLY MINIATURISED SOLUTIONS
- VERY HIGH DENSITY INTERCONNECT SOLUTIONS
- OPTIMISED ELECTRICAL PERFORMANCES
- ADAPTATION TO SEVERE ENVIRONMENTAL CONDITIONS (thermal, mechanical, electromagnetical,...)
- PACKAGING SOLUTION FOR EACH APPLICATION
- RELIABILITY IMPROVEMENT

II/ HYBRID MICROELECTRONIC PRODUCT DESIGN



MECHANICAL
ELECTRICAL
SPECIFICATIONS
THERMAL
MAINTENABILITY
COST
RELIABILITY
SIMULATIONS
DIMENSIONS
STRUCTURE
ARCHITECTURE CHOICE
MATERIALS
PROCESS
TECHNOLOGY
TESTS PROCEDURE

III/ THERMO-MECANICAL PROPERTIES NEEDED FOR MICROELECTRONIC MATERIAL

III.1/ POWER DEVICE APPLICATIONS

- GOOD THERMAL CONDUCTIVITY
- HIGH MECHANICAL RIGIDITY
- EXPANSION COEFFICIENT IN GOOD ACCORDANCE WITH SUBSTRATE UP TO LARGE DIMENSIONS
- GOOD APTITUDE TO BE METTALIZED

III.2/ HIGH FREQUENCY DEVICE APPLICATIONS

- HIGH MECHANICAL RIGIDITY
- EXPANSION COEFFICIENT IN GOOD ACCORDANCE WITH SUBSTRATE UP TO LARGE DIMENSIONS
- GOOD APTITUDE TO BE METALLIZED
- LOW LOSSES
- LOW WEIGHT FOR AVIONIC APPLICATIONS
- GOOD THERMAL CONDUCTIVITY IF POWER APPLICATION

IV/ MATERIALS USED FOR PACKAGING IN THOMSON-CSF HYBRID MICROELECTRONIC APPLICATIONS

- COMPARAISON OF MECHANICAL AND THERMAL PROPERTIES:

MATERIALS	MOLYBDENIUM	ALUMINIUM (AG4AC)	TITANIUM (T40)	KOVAR (Fe/Ni/Co)	Cu/Mo/Cu (20/60/20)	Al/SiC (70 %)
Density (g/cm3)	10,02	2,7	4,51	8,3	9,6	3,04
Dilatation (ppm/°C)	4,9	23,6	8,5	6	6,5	6,8
Thermal Conductivity (W/m°K)	143	125	17	17	230	170
Young Modulus (GPa)	350	55	108	125	240	228
Melting Point (°C)	2610	610	1675	1450	-	500

=> KOVAR FOR LOW FREQUENCY AND MICROWAVE DEVICES

=> TITANIUM FOR LOW FREQUENCY AND MICROWAVE DEVICES IN PARTICULARY FOR AVIONIC APPLICATIONS

=> ALUMINUM FOR POWER AND MICROWAVE DEVICES

=> COPPER, COPPER TUNGSTEN, OR COPPER MOLYBDENUM FOR POWER AND MICROWAVE DEVICES

=> ALUMINA FOR LOW FREQUENCY AND MICROWAVE DEVICES

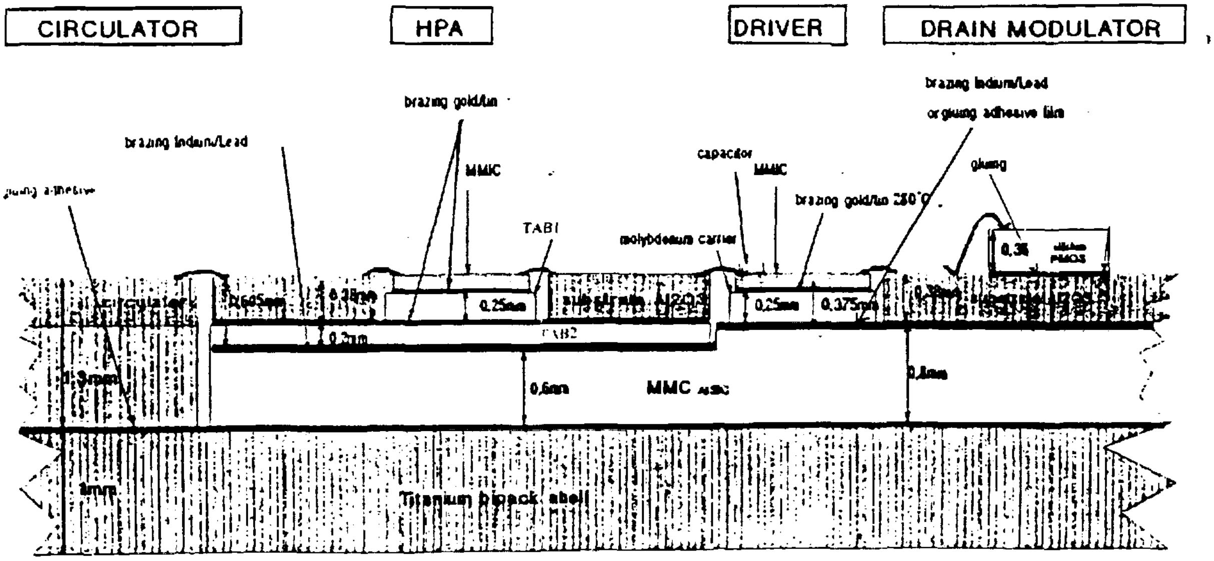
=> MMC (ALUMINIUM AND SILICON CARBIDE) FOR SPECIFIC APPLICATIONS (T/R MODULES ...)

V/ POWER ASSEMBLY WITH ALUMINUM / SILICON CARBIDE BASEPLATE FOR HIGH FREQUENCY DEVICE

V.1/ HIGH FREQUENCY AMPLIFIER SPECIFICATION FOR T/R MODULE APPLICATION :

- X BAND FREQUENCY
- PULSE: WIDTH < 0.3 to 50 μs
  DUTY CYCLE < 10 %
- OUTPUT POWER : 5 W PEAK
- RECEIVER GAIN : 22 dB
  (10% BAND)
- OPERATING BAND WIDTH ~ 20 %
- DIMENSIONS : 12 X 50 mm
- TEMPERATURE RANGE : +10°C/+60°C
- STORAGE TEMPERATURE : - 40°C / + 85°C
- MAXIMUM JUNCTION TEMPERATURE :110°C

V.2/ AMPLIFIER ARCHITECTURE



V.3/ Al / SiC MATERIAL CHARACTERISTICS FOR RUNNING PROGRAMS

- ALUMINIUM MATRIX (70 %) WITH SiC FIBERS OR WISKERS
- Ni / Au METALLIZATION
- OBTENTION BY LIQUID PROCESS
- THERMAL CONDUCTIVITY ~ 170 W/m.K
- THERMAL EXPANSION : 6,8 x 10-6 / °C (IN GOOD ACCORDANCE WITH ALUMINA SUBSTRATE)
- LOW DENSITY : 3,04 g/cm3
- DIFFICULTIES FOR MACHINING (YOUNG MODULUS : 228 GPa)
- LOW MELTING POINT ~ 500 °C

V.4/ MAIN Al / SiC IMPROVEMENT FOR SUCH POWER ASSEMBLY

V.4.1/ THERMAL RESISTIVITY

- 3 D THERMAL SIMULATIONS WITH PROMETHEE SOFTWARE :

=> IN TRANSITORY CONDITIONS FOR MMIC COMPONENTS
=> IN PERMANENT CONDITIONS FOR COMPLETE AMPLIFIER
(because bigger time constant)

- STUDIED PARAMETERS :

=> PACKAGING MATERIAL NATURE
=> TAB MATERIAL NATURE
=> INSERTION OF AN Al/SiC BASEPLATE
=> EXCHANGE AREA WITH COOLING JIG

- SIMULATION RESULTS :

PACKAGING	TAB 1	TAB 2	COOLING GIG AREA	Al/SiC	R j-c (°C/W)	Rj-f (°C/W)
Titanium	CuMoCu	Mo	S	No	7,5	23
Titanium	CuMoCu	CuMoCu	S	No	7,5	21,7
Titanium	CuMoCu	CuMoCu	S	Yes	7,5	19,5
Titanium	CuMoCu	CuMoCu	1.5xS	Yes	7,5	17,3
Titanium	Mo	Mo	1.5xS	Yes	7,5	18,6
Al/SiC	CuMoCu	CuMoCu	1.5xS	No	7,5	16,5

R j-c : Jonction / Component base Thermal Resistivity
R j-f : Jonction / Fluid Thermal Resistivity

=> THERMAL RESISTIVITY 6% BETTER WHEN THE TWO "TAB" ARE IN CuMoCu
=> THERMAL RESISTIVITY 15% BETTER WHEN PRESENCE OF AN Al/SiC BASEPLATE
=> THERMAL RESISTIVITY 25% BETTER WHEN COOLING JIG AREA IS 50 % BIGGER
=> 43 % OF THERMAL RESISTIVITY THROUGH THE COMPONENT FOR THE BEST CONFIGURATION

- ADOPTED CONFIGURATION :

=> TAB IN MOLYBDENIUM (because easier to manufacture than CuMoCu)
=> USING OF AN Al/SiC BASEPLATE
=> PACKAGING IN TITANIUM

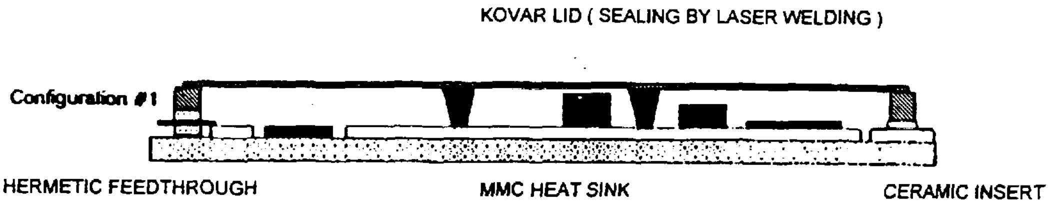
V.4.2/ OTHER MECHANICAL AND PHYSICAL CHARACTERISTICS

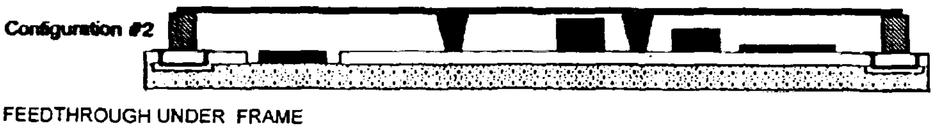
- WEIGHT REDUCTION : - 16 % COMPARED TO TITANIUM MATERIAL
- GOOD FLATESS AFTER ASSEMBLY < 100 µm (NO SIZE LIMITATION)
- GOOD APTITUDE FOR BRAZING / SOLDERING (EASY TO SET UP)
- AMPLIFIER IN ACCORDANCE TO ELECTRICAL AND THERMAL SPECIFICATIONS

VI/ OTHER APPLICATIONS OF METALIC MATRIX COMPOSITES IN MICROELECTRONIC DEVICES

VI.1 / HIGH FREQUENCY DEVICE

MULTILAYER ON METALLIC MATRIX COMPOSITE BASEPLATE

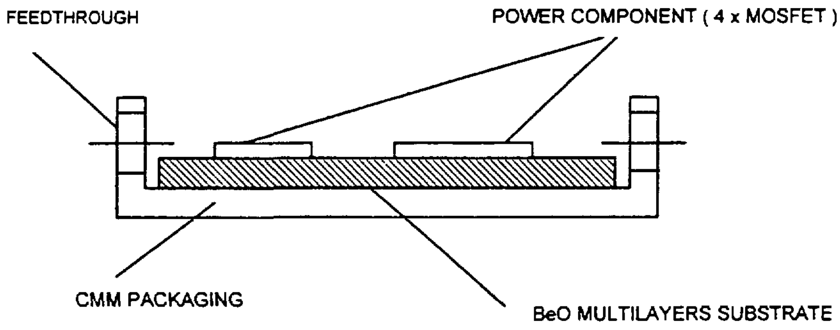




TIME SCHEDULE NEEDS : DEMONSTRATORS ~ 10 MODULES / 1997
PROTOTYPES ~ 200 MODULES / 1998
SERIES ~ 600 MODULES / 2000
MASS PRODUCTION ~ 1000/ MONTH / 2002

VI.2/ POWER DEVICE

BeO SUBSTRATE BRAZED IN A METALLIC MATRIX COMPOSITE PACKAGING



MAXIMUM POWER DELIVERED : 400 W
ELECTRICAL YIELD : 90 %
FREQUENCY : 125 KHz

VI.3/ METALLIC MATRIX COMPOSITES COMPOSITION

TODAY TWO VERY INTERESTING COMPOSITIONS :

- Al/SiC BUT DIFFICULTIES TO MANUFACTURE COMPLEX SHAPES BECAUSE NOT EASY TO MACHINE
- Cu/C BECAUSE VERY GOOD THERMAL PROPORTIES (300 W/mK COMPARED TO 160 W/mK OF Al/SiC) AND EASIER MACHINING

IN A BRITE-EURAM PROJECT REGROUPING 8 EUROPEAN PARTNERS ELECTRICAL DEMONSTRATORS INTEGRATING Cu/C WILL BE MANUFACTURED(END OF THE PROJECT IN 1999)

VI/ CONCLUSION

- GOOD THERMAL RESULTS ON A HIGH FREQUENCY AMPLIFIER USING AN Al/SiC BASEPLATE

- TODAY 300 AMPLIFIERS MANUFACTURED IN ACCORDANCE WITH THERMAL AND ELECTRICAL SPECIFICATION

- BIG INTEREST TO USE METALLIC MATRIX COMPOSITES ESPECIALLY Al/SIC AND VERY SOON Cu/C FOR THEIR GOOD THERMAL PROPORTIES AND GOOD APTITUDE TO MICROELECTRONIC PROCESSING

- POSSIBLE MANUFACTURING OF COMPLETE PACKAGE IN METALLIC MATRIX COMPOSITES