Design, manufacturing and reliability tests of a large AlSi fully hermetic package for space application

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Session THA6 "Packaging Technologies"

Outline

- Motivations of the work
- Overview of existing materials for hermetic packaging
- Some details about AlSi material
- Preliminary experience
- Mechanical design of the package
- Manufacturing
- Application of the technology to a Ku/Ka up-converter
- Some technological results
- Reliability test-plan and status
- Conclusion

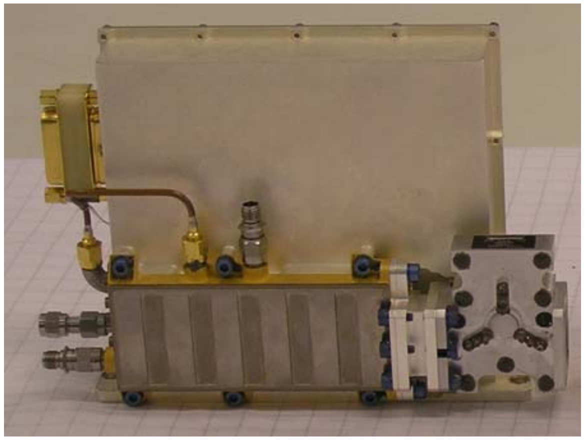
Motivations of the work 1/2

Typical microwave products for space application developed at THALES ALENIA SPACE

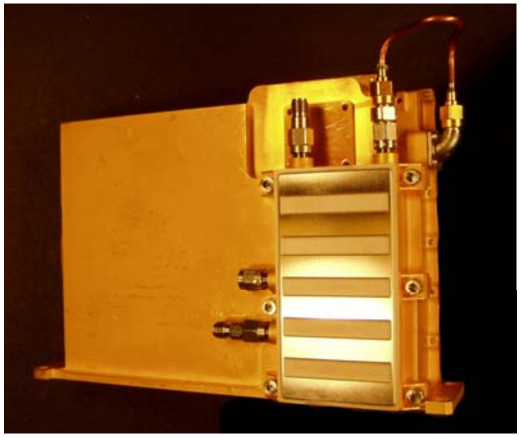
- from C to Ka-band receivers
- from C to Ka -band low noise amplifiers
- down/up-converters
- …

Can be designed for stand-alone or assembly applications

More and more functionalities and thus their complexity is increasing



Ku-band receiver



30/20GHz down-converter

Motivations of the work 2/2

Current technology & qualified solution for the package

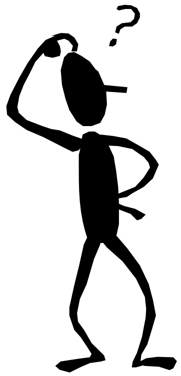
- **macro-hybrid technology** based on a monolithic metallic body with glass sealed feedthroughs for both LF and RF in/outs
- qualified for small to medium packages (62mm x 93mm) and under extension of qualification for larger packages (about 90mm x 90mm)
- material : **Kovar**® (matched to active GaAs devices and alumina substrates, encapsulation by seam welding process)

Increasing complexity is synonym to very large package and to higher power dissipated

Limitations of Kovar®

- high **density** (8.3g/cm^3), compared to Aluminium (2.8g/cm^3)
- poor **thermal conductivity** (17W/m°K)

Strong need for an enhanced package material



Overview of some existing materials
Fully metallic approach

Aluminium

- very interesting candidate for the following characteristics
  - very lightweight material ($2.8 g/cm^3$)
  - high thermal conductivity (238W/mK)
  - easy machining and plating
  - well known in hybrid technology
- but
  - **CTE (24ppm/°C) is not matched** to GaAs dice and alumina substrate
  - specific solution for glass feed-throughs process
  - encapsulation by laser welding (standard for Al) not a preferred internal process

Titanium

- low density ($4.5 g/cm^3$), but **thermal conductivity too low (15W/mK)**

Copper Tungsten

- high thermal conductivity (230W/mK, for Cu/W-10), but **very high density ($17.3 g/cm^3$)**

Principle

- microscopic mixing of several materials.
- matrix (= structure) + binder (= fibers or particles)
- results cumulate advantages of both its matrix and binder : good compromise between thermal conductivity, CTE and density

Manufacturing process

- hot isostatic pressing (AlBe)
- spray forming (AlSi) : mixing of powders and densification by pressure
- high pressure infiltrating casting (AlSiC) : infiltration of molten Al alloy on a SiC preform

Solutions on Al matrix

- Al/Graphite : hermeticity non proven for space program
- AlBe : high constraint for machining due to toxicity
- AlSi and AlSiC

AlSiC versus AlSi

Advantages Drawbacks	AlSiC	AlSi
☺☺	TEC matched to dice and substrates low density	TEC matched to dice and substrates material machinable from the block low density
☺	high thermal conductivity	high thermal conductivity
😐	Kovar ring to be brazed on top of AlSiC walls	Kovar ring to be brazed on top of AlSi walls
☹	very abrasive material limited machining plating variation from lot to lot	fragile material
☹☹	mainly limited to base-plate	

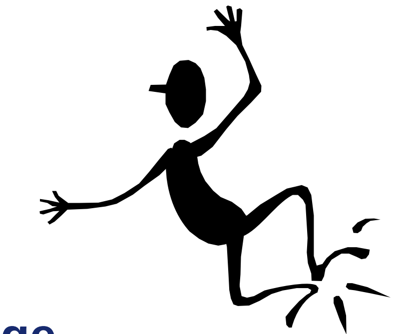
AlSi : a good candidate

Material supplier

- Sandvik Osprey from a patented and proprietary Osprey CE Alloys process - produced in the form of billets by gas-atomisation, rapid solidification and spray-forming technologies

Compliant to main characterictics

- very lightweight material (<2.5g/cm^3)
- high thermal conductivity (120-180W/mK)
- tunable CTE (5-20ppm/K)



No technical unfeasibility for the design of a complex package

Material machinable from the block = monolithic package

Experiences for THALES from BRITE/EURAM EU projects ("LOCOMO" and "MMC packages")

CE Alloy designation	Alloy composition	CTE, ppm/°C, 25-100°C	Density, g/cm^3	Thermal Conductivity at 25°C W/mK	Bend Strength, MPa	Yield Strength, MPa	Elastic Modulus, GPa
CE20	Al - 12%Si	20.0	2.70				
CE17	Al - 27%Si	16.0	2.60	177	210	183	92
CE17M	Al - 27%Si*	16.0	2.60	147			92
CE13	Al- 42%Si	12.8	2.55	160	213	155	107
CE11	Si - 50%Al	11.0	2.50	149	172	125	121
CE9	Si - 40%Al	9.0	2.45	129	140	134	124
CE7	Si - 30%Al	7.4	2.40	120	143	100	129

*CE17M also contains minor additions of Fe, Mg and Mn

from OSPREY website

Solution proposed : CE9 grade

Compliant to main characteristics

- very lightweight material (2.45g/cm^3)
- high thermal conductivity (130W/mK)
- CTE : 9ppm/K – measured at 7.4ppm/K for [-60°C, +20°C] and 9.3ppm/K fro [+20°C, +150°C]
- no major constraint of shapes for machining

Package manufacturer : HCC AEGIS

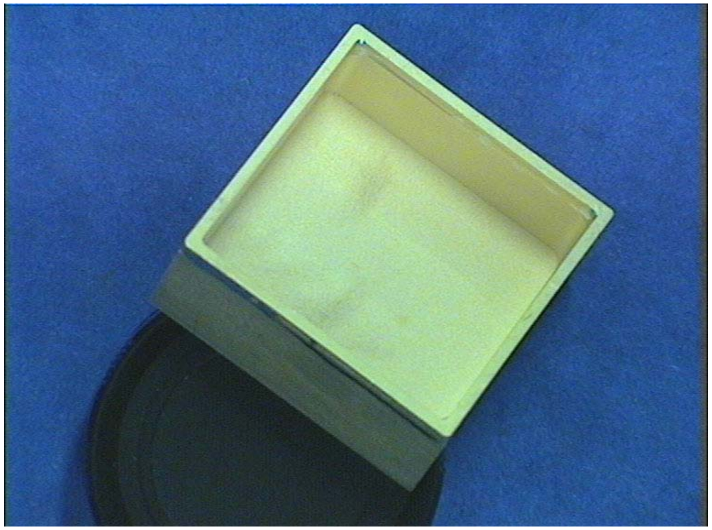
- acknowledged to aerospace quality requirements
- excellent capability for new developments

Preliminary experience 1/3

Design of small AlSi packages (28mm x 28mm) to validate

- at AEGIS level
  - machining of AlSi
  - plating of AlSi
  - Kovar ring assembly
  - validation of the hermiticity (open package)

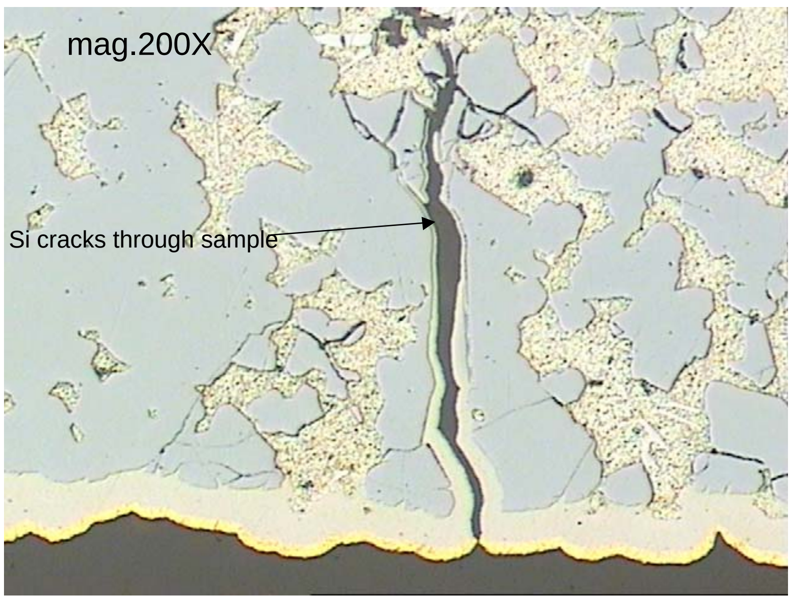
- at THALES level
  - metallisation adhesion to AlSi material
  - seam welding with Kovar ring
  - hermiticity test
  - thermal conductivity characterisation of AlSi material



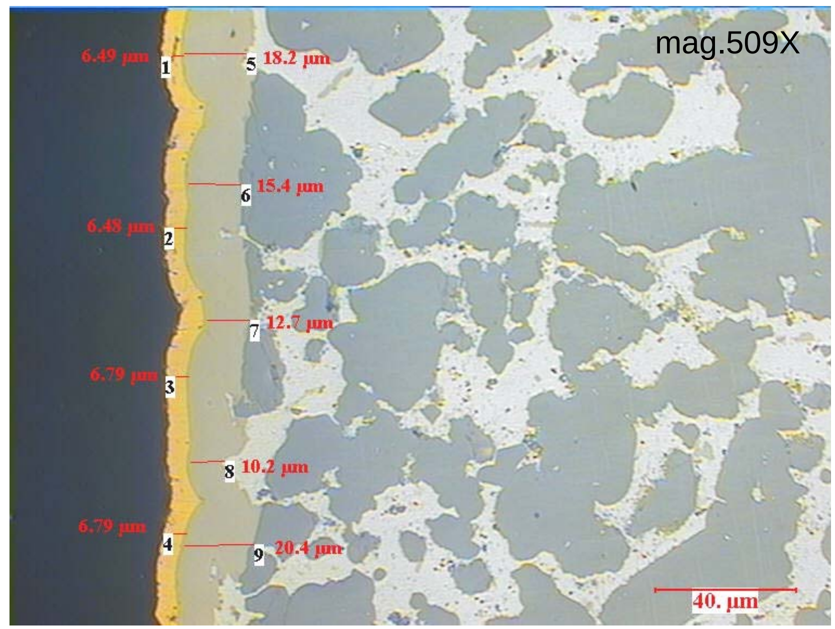
Preliminary experience 2/3

Results at AEGIS level

- care must be taken to ensure that the Si is not damaged (with micro-cracks) during the final machining operation particularly with CE9
- electroless Ni (>5µm) and electrolytic pure Au (>1.27µm) with initial thin Zn coating
- hermeticity proven (test open package)



CE9 alloy with bad final machining



CE9 alloy with good final machining

Results at THALES level

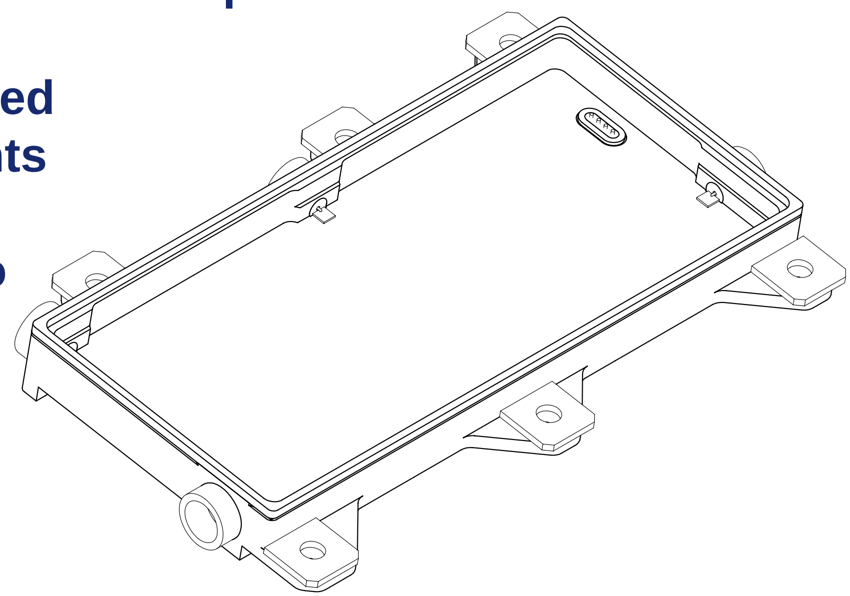
- hermetic after sealing (fine & gross leak) proven
- still hermetic after 10 ambient pressure/vacuum cycles
- still hermetic after 10 thermal shocks [-55°C, +125°C]
- RGA test
  - hermetic (99.9% N_2)
  - very low level of H_2 detected (advantage compared to fully Kovar® package)

ECHANTILLON		VT1	VT2	
PRESSION	torr	352	379	
AZOTE	%	99.9	99.9	
OXYGENE	ppm	<100	<100	
ARGON	ppm	<100	<100	
CO2	ppm	<100	<100	
HUMIDITE	ppm	410	453	
HYDROGENE	ppm	<100	156	
HELIUM	ppm	ND	ND	
FLUOROCARBONS	ppm	ND	ND	
Hydrocarbon	ppm	ND	<100	

AEGIS™
THALES

Mechanical design of the package

- A fully machined AlSi body, Nickel/Gold plated
- Very large package : 99.2mm x 60.0mm
- Four K connectors designed for applications up to 30GHz with alumina substrates directly connected to the microwave pin
- One DC connector based on 4 pins required for the biasing of the active components
- Six mechanical interfaces for assembly to the next level
- A dedicated ring is brazed on top of the peripheral AlSi walls to allow the seam welding process



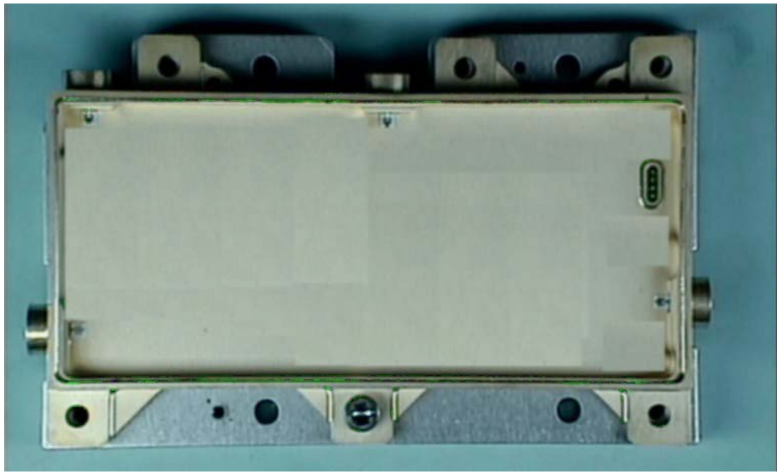
Manufacturing of the package

Two lots of 10 packages manufactured by HCC AEGIS with success

Break-out have been identified on the edges of some packages after machining

- occurred when it is necessary to move the package from one axe to another
- located at non critical area

Special care was applied on the plating and on the braze volume to attach the RF connector as close as possible to the thin film substrate



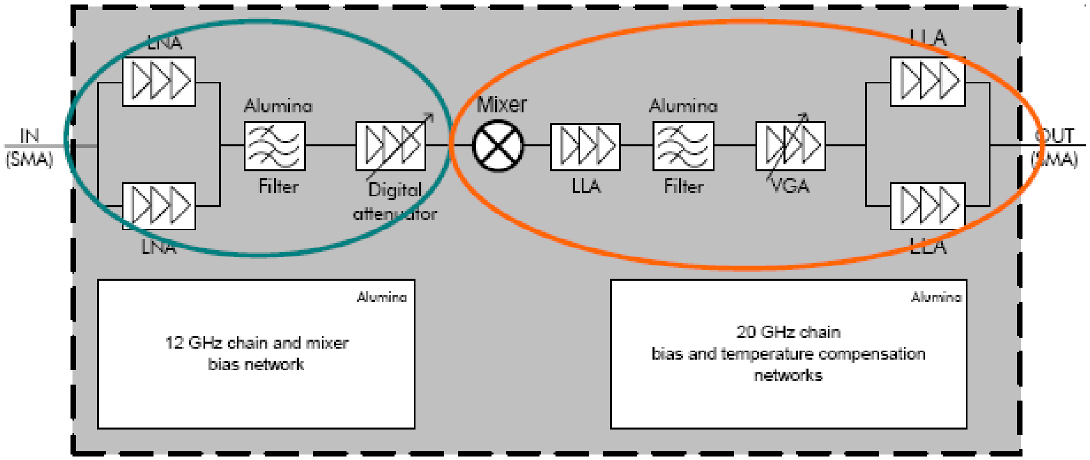
All these very large packages (99.2mm x 60.0mm) have been finally tested fully hermetic after assembly and plating

Ku/Ka (12/20GHz) up-converter for telecom applications

The module contains

- several MMIC devices (LNA, digital attenuator, LLA, VGA)
- thin-film alumina substrates for microwave functions (such as filters),
- thick-film alumina substrates for bias networks & temperature compensation

All the packages manufactured have been tested also fully hermetic and compliant to the electrical specifications

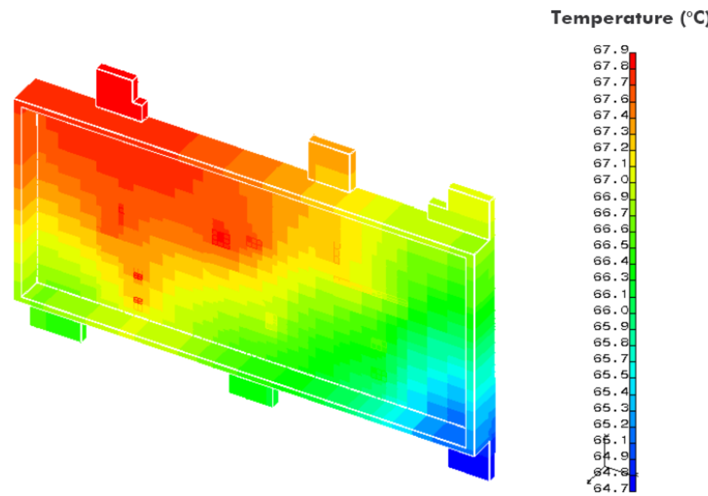


Weight

- only 32g for the full package (with connectors)
- around the half versus a standard Kovar® package

Thermal analysis based on UPCON Ku/Ka design

- very <u>homogeneous repartition of the heat</u> though the module
- only 3.2°C thermal gradient within the AlSi package
- more than 20°C for a Kovar® based version
- for the most critical active components
  - <u>more than 10°C margin</u> (in term of junction temperature) on the AlSi package
  - no margin on a Kovar® version



Standard mechanical analysis of the full equipment inside Telecom Repeater

- based on finite element method
- equipment <u>compliant with sine/random vibrations and generic mechanical shocks</u>.

Reliability test-plan 1/2

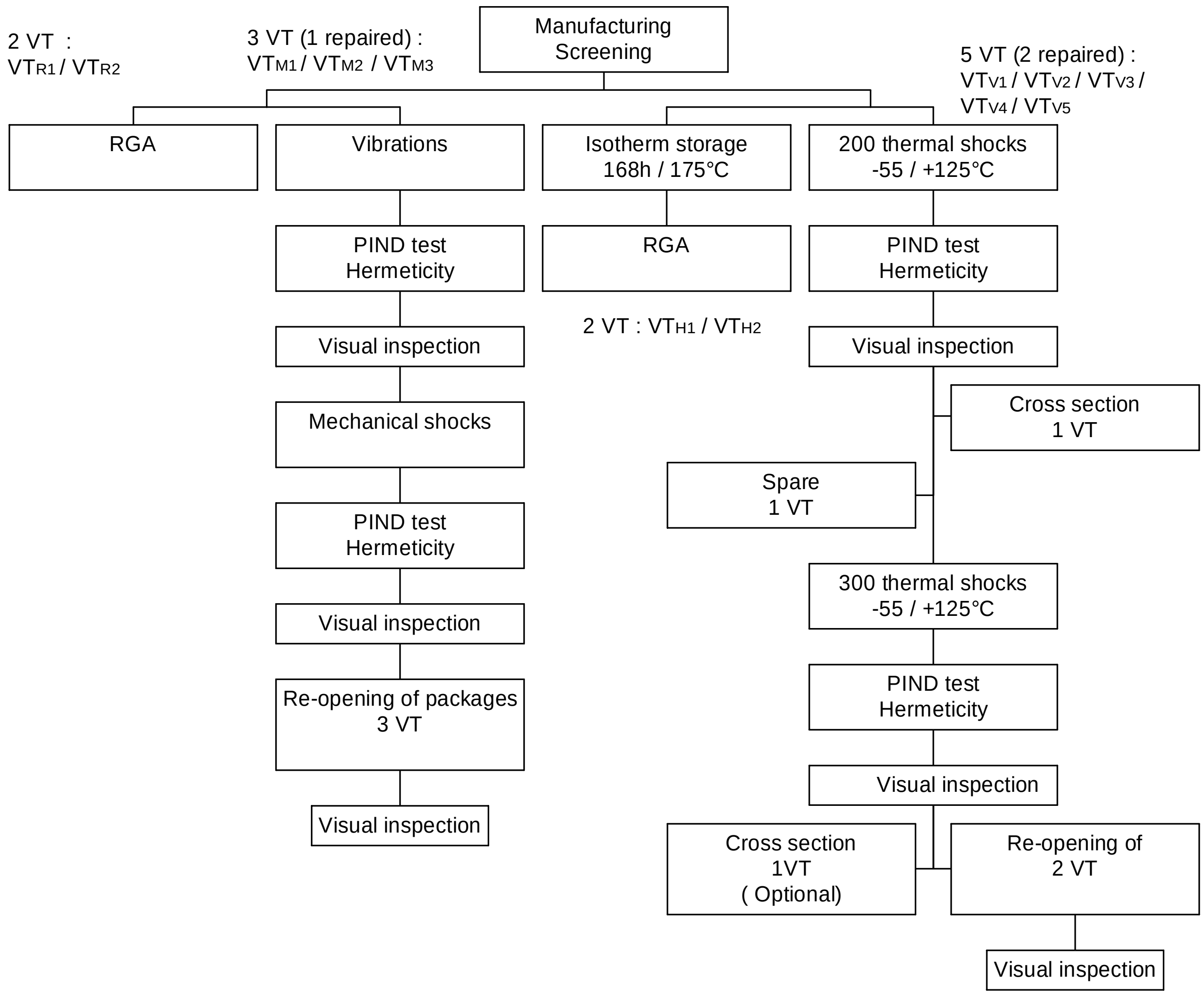
A reliability test-plan has been established to evaluate the ability of this technology towards space requirements

- RGA test : standard Residual Gas Analysis after sealing and screening to complete a fully hermetic package (primary concern for this technology)
- isotherm storage : this test consists to a storage at 175°C for one week with a RGA test after storage (screening step included)
- mechanical tests : packages will be stressed to the combination of vibrations and mechanical shocks (according to MIL Std 883 Method 2002)
- thermal cycles : to evaluate the CTE mismatch between the AlSi material and the devices. The definition is 500 cycles in the [-55°C, +125°C] temperature range with intermediate steps at 200 cycles

Twelve packages have been fully assembled for these qualification tests

Standard manufacturing and screening processes prior to the tests

Reliability test-plan 2/2



RGA test : 2/2 packages succeeded

isotherm storage : 2/2 packages succeeded

mechanical tests : on-going

thermal cycles : 4 packages still hermetic after 200 thermal shocks and RGA test compliant on 1 package

Conclusion

A new generation of very large metallic packages based on AlSi CE9 reference has been designed and manufactured for space application

This material is compatible with stringent requirement such as ability to machining and plating, lightweight, high thermal conductivity and moreover hermeticity

Solution compatible with a vertical stand alone configuration

A Ku/Ka down-converter has also been described

A reliability test-plan has been proposed and preliminary results are hopeful to replace standard Kovar® packages when required

Acknowledgement

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and

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