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Residual stress brazing process induced in hybrid package for ISP applications

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ABSTRACT

One of the most used components in the RF transmission devices mounted on satellite antennas are the ISP modules. They are designed by exploiting hybrid materials technology to improve their operative characteristics. In particular they are made up of a metallic carrier, a ceramic substrate, a metallic frame and a metallic cover. Inside the ceramic substrate metallic circuits and vias they are allocated to connect microelectronic components fixed on the external surface of the substrate of RF transmission modules. Metallic cover is one of the most delicate elements of the package because it must provide for the tightness of the assembly. The cover is welded to the frame by seam-welding technique. In order to assembly ceramic substrate and metallic frame a brazing process must be carried out. This brazing process introduces residual stresses at the end of the welding process. These residual stresses induced by the thermal cycles could cause crack growth and eventually a component fracture during the operating life of the satellite. In order to foresee their criticality, qualification tests, based on MIL standard, are mandatory. This MIL procedure establishes that the package must be thermally cycled with 500 cycles in the range of $223\,K \leq 398\,K$. On account of this, thermal loads, associated to thermal cycles, may cause fractures in ceramic substrate and the failure of electronic components. In this paper a numerical approach able to simulate all the brazing process and to evaluate numerically all the stresses inside the ISP module will be proposed. Parametric studies on thermal loadings and on geometrical characteristics of the brazing subcomponents such as the metallic carrier, the ceramic substrate, the metallic frame and the metallic cover in order to evaluate maximum and critical stresses will be also presented. To perform such numerical analysis laboratory tests such as DMA have been carried out and detailed in the paper. The aim of these tests is to characterize the mechanical and thermal properties of all the material employed for the numerical simulations. Finally a comparison between numerical analysis relevant to a broken ISP module will be presented in order to validate the used approach.

1. Introduction

This work wants to evaluate the real stresses field and the residual stresses distribution induced by the manufacturing process into hybrid packages used for electronic application in space environment. In order to evaluate possible critical situations during the manufacturing a complete numerical simulations of the packaging construction will be here performed and analyzed.

The scope of packaging design for electronic device is to assure protection from a possible physical damage, caused by mechanical load and from contamination caused by the operative environment conditions. For

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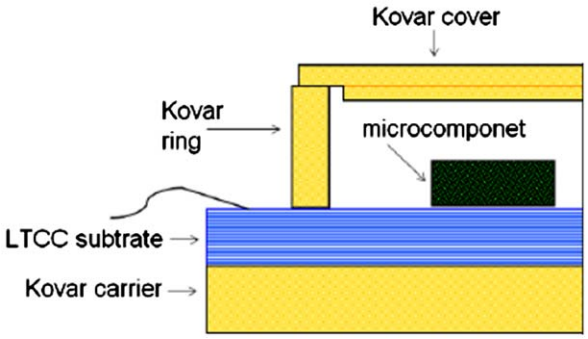

Fig. 1. Layout of the package structure.

space packaging the used materials, the wire connections and the power technologies require the most possible efficiency and reliability to take structural and thermal load induced by the operative life into account.

Many studies are performed to reach high integrated electronic devices used for a communication system mainly concerning the optimization of weight. The multilayer ceramic technologies can give an answer to this request with multiple integrated circuits embedded into layers with thin gold tracks for electrical interconnections.

Alcatel Alenia Space Italia has developed many advanced configurations for electronic packages with Integrated Substrate Packaging (ISP) solutions applied in many space applications [1]. The ISP construction allows to include different circuits into the ceramic substrate in order to obtain a very compact device with good mechanical properties and low electrical losses. The ISP package is made up of a metallic carrier, a ceramic substrate, a metallic ring and a metallic cover as shown in Fig. 1.

The carrier, the ceramic substrate and the metallic frame are brazed together, whereas the metallic cover is welded later by the seam-welding technique to create a hermetic cavity in order to protect the components from the aggressive space environment.

The thermal cycling load applied to simulate the operating environmental space conditions causes some stress concentrations in the brittle ceramics. Eventually these stresses may induce cracks or damages and the package loss its hermetic cavity. The most stressed points of the package are positioned at the corners of the device where there is the sum of the mismatch of thermal expansion coefficients and shear stresses caused by the inherent geometric design of the package.

The other critical thermal process involved in the package manufacturing is the seam welding technique to join the Kovar® ring with the cover to create the hermetic cavity.

2. Packaging issues

In order to assure physical protection to the integrated microelectronic components and to the electrical connections, high performances material and high technology solutions must be considered. Many other parameters such as the structural and the thermal parameters like power, data transmissions and I/O interfaces are necessary to improve the ISP applications.

The electronic packages for space applications involve the use of particular materials and high technological solutions in order to assure physical protection to high density integrated microelectronic components. For this scope a complex structural, thermal and power design must be used [2].

The ISP design must consider the microwave operating length that is comparable with physical dimension in order to obtain the full operating regime.

If a large number of passive components are embedded into the board, the length of the wiring necessary to connect these components must be reduced, so that improved characteristics can be achieved such as making the board itself smaller and consequently lighter.

In order to assure functionality, efficiency and high performances electro-thermo-mechanical properties must be compliant with standard requirements during the design to obtain a high signal speed, small dimensions and a high performance. ISP must provide also a correct electro-magnetic impedance, assuring a hermetic environment and a thermal, shock and vibrations loads strength.

To satisfy these requirements a new ISP technology must be thought where the following items must be looked up:

- low dielectric coefficient for insulation materials;
- high density and low electrical strength conductors to reduce thermal generation and low voltage losses;
- Kovar®, ceramic substrate and circuit coefficient of thermal expansion must be similar;
- substrate mechanical strength must provide to external thermo-mechanical stresses resistance.

2.1. The ceramic substrate

A lot of ceramic materials are used for electronic applications and LTCC (low temperature co-fired ceramic) multilayer is an important technology to miniaturize these devices. The LTCC substrates are better than logic card as far as concerns the response to high frequencies, the thermal stability and the high integration capability. The LTCC manufacturing process involves many high thermal cycles to create the assembly and mechanical stress caused by the punching necessary to create the electrical and thermal vias. By virtue of the above procedure some defects can arise inside the multilayer structure which eventually can produce failures during the operative life of the substrate and therefore of the whole assembly.

The LTCC substrate is used for its packaging density of passive components and a metal ring and a metal cover are used to create a hermetic cavity to protect the electric parts mounted on the free surface.