Radiation Hard Glass and Sapphire-based Miniature Hermetic Packages for Space Applications

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Electronics to be used in space are routinely subjected to harshest environmental conditions imaginable, but at the same time require a very long lifetime. Thus, hermetic packaging of electronics has been not a choice but a requirement for space applications. The limited space available in space applications points to miniaturized solutions instead of using conventional hermetic sealing options which are often bulky. A novel technique to hermetically seal optical components was tested and proven for reliability in space relevant atmospheres.

Extremely harsh environments to which components in space applications need to endure, like high-g acceleration, extreme levels of vacuum, exposure to chemicals and various gases and vapors, dust particles, large temperature gradients and variations, large variations in humidity as well as rough mechanical shocks asks for a rugged electronics packaging. Therefore, hermetic packaging of electronics is not a choice but a requirement for space applications. When the electronic component to be sealed is an optoelectronic device with a primary function of transmitting or receiving light, the lid should be transparent. The need for a transparent lid like glass reduces the choices for sealing to adhesive bonding, which gives only a near hermetic seal. Other conventional hermetic sealing methods could be used with a more complicated lid made by brazing of a glass lid on to a metal frame for example. These methods can hardly be miniaturized and are restricted to specific metals due to thermal expansion mismatch concerns. Specifically some of these metals can also cause hydrogen pollution in the package cavity, which leads to high radiation sensitivity of the component.

A novel low temperature laser based hermetic sealing technique using glass and sapphire was tested in this project. This sealing technique was used to hermetically seal a Vertical Cavity Emitting Laser (VCSEL) array and a micro-lens array, which are aligned to each other. This system is intended to be used in an optical transceiver application. The micro-lens array was used either to collimate or focus the light beam to the desired spot size for subsequent coupling to an optical fiber

Four different designs options, covering 3 different transparent materials for the housing and 3 different light handling options were selected for manufacturing. One design is with a stack of 2 parts bonded together and the other three designs are made with a stack of 3 parts bonded together (Figure 1).

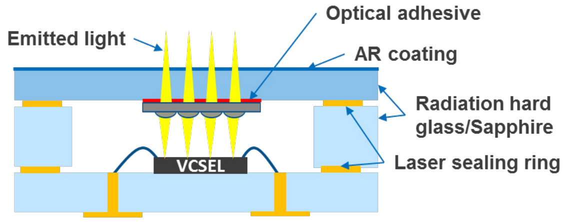

Figure 1: Schematic of one of the 3 stack designs.

The laser sealing process was developed for all the 4 designs to achieve a hermeticity level of less than 10^{-10} mbar*l/s and a shear strength of greater than 190 MPa for sapphire and more than 93 MPa for the glass packages. A total number of 36 samples were manufactured according to the geometries in Figure 2 and screened for hermeticity and functionality. The samples were also subjected to accelerated thermal shock tests to screen for any infant failures before the actual reliability tests.

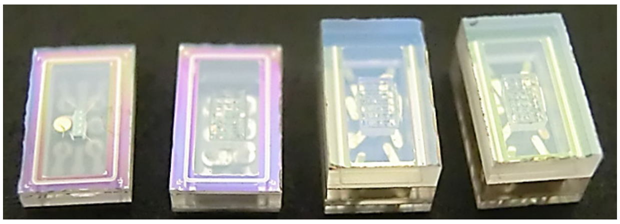

Figure 2: Manufactured samples of 4 different designs.

The parts were subjected to stringent reliability tests like resistance to glass cracking as listed in Table 1. The maximum temperatures of the tests were less than the maximum allowed operating temperature of the VCSEL to avoid any possible degradation of the VCSEL performance.

Table 1: Reliability tests conducted and the standards used.

Reliability Test name	Test standard reference	Test parameters
Vibration	MIL-STD-750 method 2056	20 Hz - 2g$_N$ 80/1000 / 2000 Hz - 20g$_N$ 4 minutes/axis/sweep dir.
Mechanical shock	MIL-STD-750 method 2016	100x 1000g, Tau< 1ms
Moisture resistance	MIL-STD-750 method 1021	10 cycles with 3h dwell time
Temperature cycling	MIL-STD-750 method 1051	Condition B (-40°C+100°C), 1000 cycles
Resistance to glass cracking	MIL-STD-750 method 1057	10x dipping in boiling & cold (0°C) water
High temperature storage	JEDEC-JESD22-A103D	100°C for 1000 hours.

After reliability testing, the parts were inspected for hermeticity using helium bombing tests and for VCSEL electro-optical functionality. The hermeticity tests showed a very good yield for all the parts (< 1×10^{-9} mbar*l/s). The optical output power of the samples did not show any measurable change before and after the reliability as can be seen in Figure 3.

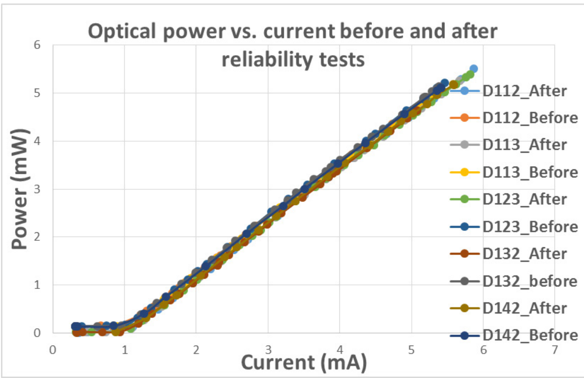

Figure 3: optical output power vs. current for one of the designs.

As a result, the technology has achieved a technology readiness level of 4 for space applications and is generally suitable for a wide range of applications in harsh environments.

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