Hermetic Packaging for Multichip Modules

Hermetic packaging is a requirement for all applications where electronic components must be protected from corrosive environments to ensure acceptable service life. Extremely high reliability is required for space electronics, often utilising hermetic packages. Metal packages with glass to metal seals are the common solution for low to medium power levels. Due to poor thermal conductivity and limited electric conductivity of metals used in standard hermetic packages, direct bond copper solutions have been developed. **Jürgen Schulz-Harder and Andreas Meyer, ELECTROVAC CURAMIK, Regensburg, Germany**

Hermetic packaging can be solved by different technologies, depending on application requirements and environmental conditions as temperature, outside gas pressure and outside gases. Electronic plastic packages can survive 20 years in clean environments at lower temperatures and the same can fail in a few days in corroding atmosphere at higher temperatures or higher pressure. Important for the protection of encapsulated electronics is the permittivity for gases of the materials used for packaging. The difference of gas permittivity span over orders of magnitude for plastics on side and glass/ceramic and metals on the other side. This fact is background, that metal packages with glass or ceramic isolated feedthroughs or multilayer ceramic packages with integrated feedthroughs are used for high reliable packages. A second reason for leakage in packages are different thermal expansions of the conductive feedthroughs and the packages material. Under temperature cycling conditions paths for moisture diffusion are opened and the lifetime is reduced due to corrosion. Therefore thermal match of materials used in packages has to be considered. Besides hermetic requirements, heat dissipation and isolation are becoming important aspects for the package design.

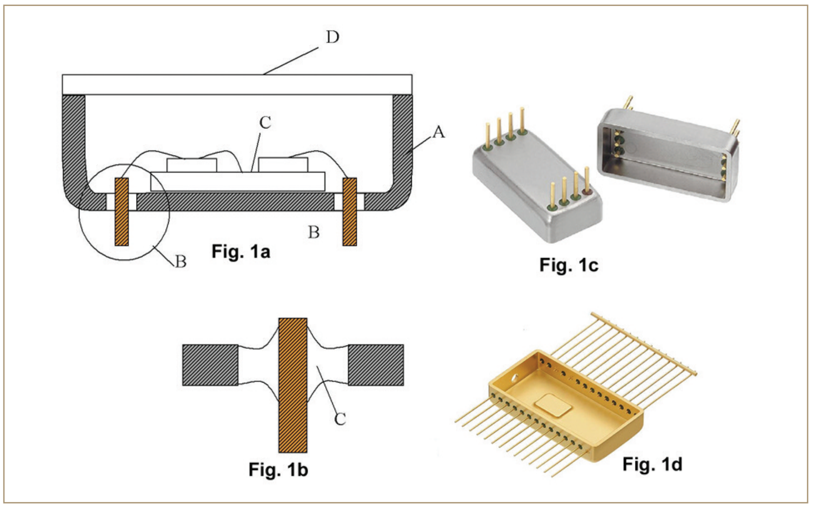


Figure 1: **Metal packaging solutions**

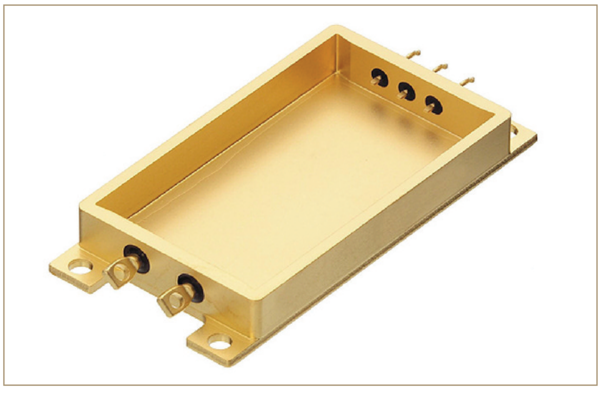


Figure 2: **Glass to metal sealed package with feedthroughs at the side wall**

Table 1: **CTEs of available glass materials are in the range 4 to 10ppm, limiting the number of usable pin materials**

Pin material	TEC [1/K] *10^{-6}	Spec. Resistivity Ohm mm²/m
Kovar	5.1	0,49
NiFe 47	10.0	0,44
CF 25	11.1	0,07
NiFE(Cu Core)	10.0	0,12
Mo	5.6	0,056

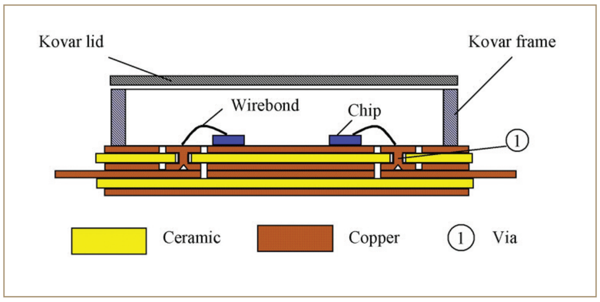


Figure 3: Hermetic DBC sandwich package

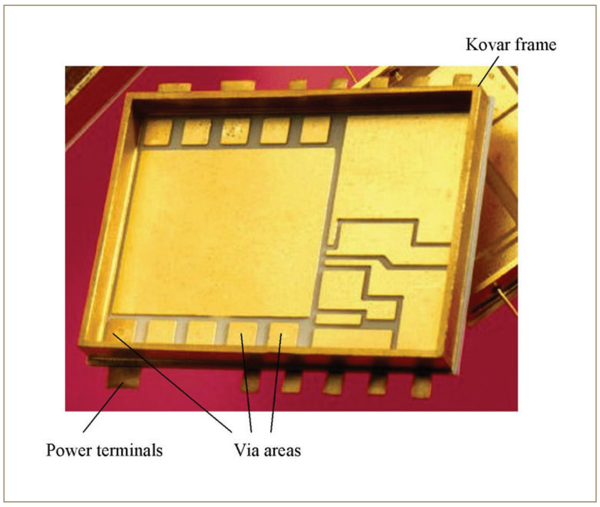


Figure 4: DBC sandwich package

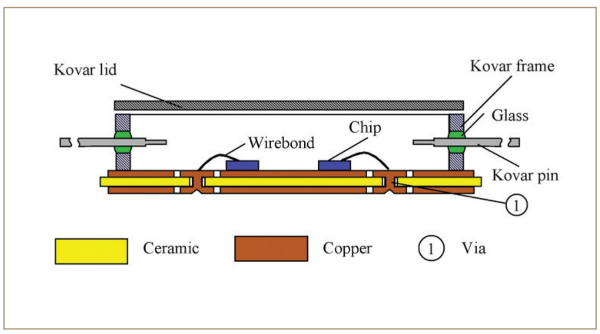


Figure 5: Single-layer DBC package with glass to metal sealed Kovar pins

Glass to metal seals

The simplest metal package solution (Figure 1) consists of a metal case (a). The bottom and the walls are cold formed from the same material. At the bottom feedthroughs (b) isolated by glass are applied. A ceramic based substrate is soldered or glued on to the bottom and the circuitry is connected to the pins by wire bonds. At the top a lid (d) closes the package. The joint between lid and the body is achieved by welding or soldering.

Figure 2 shows a package where the bottom and the sidewalls are manufactured independently and finally brazed together. This allows the use of different materials for bottom and sidewalls due to thermal requirements, e.g. if the bottom requires higher thermal conductivity and the side wall has to have a matched CTE to the glass material. To avoid crack under thermal cycling conditions the thermal expansion of the pins, the glass and the body has to be selected from thermal expansion behaviour to get an optimised match. The CTEs of available glass materials are in the range 4 to 10ppm. This is limiting the number of usable pin materials listed in Table 1.

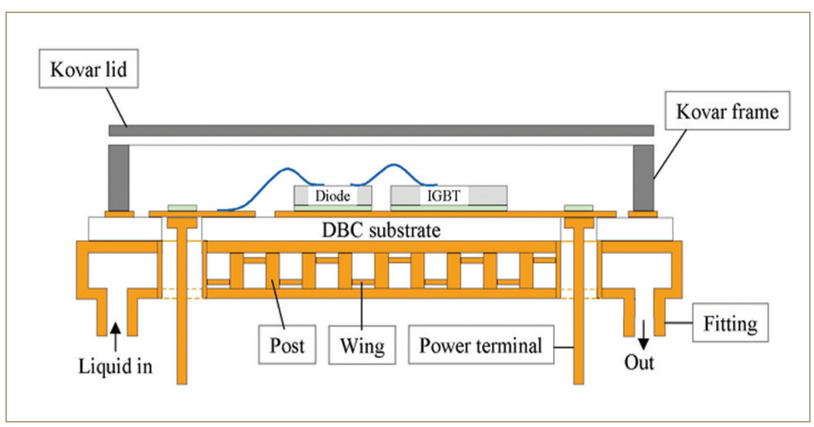
Unfortunately, the available materials are having a low electric conductivity. This leads to a limited current carrying capability of hermetic metal packages. Due to not ideal TEC matching, the pin diameter is limited to approximately 1 to 1.5mm for typically 1 to 1.5mm thick side walls or bottoms.

DBC based hermetic packages

To overcome metal package limitations, hermetic solutions based on direct bonding copper technology has been proposed and introduced especially for space and military power electronic applications. Figure 3 shows the general design of a DBC sandwich package. Two DBC substrates are bonded together and the power terminals are realised by massive copper vias and copper conductors between the two DBC substrates.

An industrial solution is shown in Figure 4. The copper power terminals are 0.3mm thick and have a width of 5mm, corresponding to a diameter of 1.4mm. A maximum current of 28A can be carried by this type of terminals. Connecting several vias and terminals in parallel the current carrying capability can be multiplied. The typical resistance of 1 via is 50 to 80 x $10^{-6}\Omega$. As this sandwich package has two ceramic layers with relatively low thermal conductivity, the thermal performance of this type of package can be too low for some applications. A better performance shows a package type depicted in Figure 5 where the power terminals are realised only by 1 layer and top to bottom vias. The glass to metal sealed feedthroughs in the Kovar frame are for low power signal connections.

Figure 6: Hermetically sealed liquid cooled device



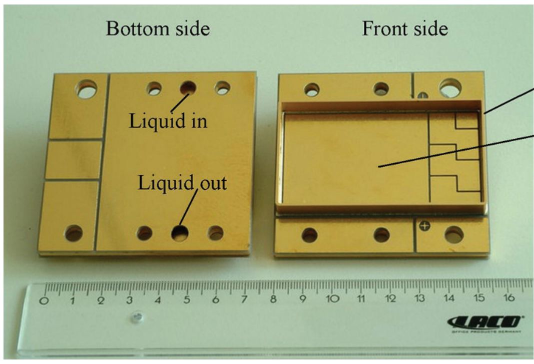


Figure 7: Prototype of a hermetically sealed liquid cooled DBC package

For very high power applications with the demand of high heat dissipation, direct liquid cooling of DBC substrates by micro-channel networks has been developed [1]. The principle assembly of a hermetically sealed liquid cooled DBC substrate is depicted in Figure 6, a prototype of a hermetically sealed liquid cooled DBC package in Figure 7. The power terminals are conducted from the backside of the top copper layer through a hole in the ceramic and the cooler to the outside.

Heat spreading is another effective method for cooling hot spots. Generally, the heat spreader should be placed directly beneath the heat generating device. This needs space and material with high thermal conductivity and matched CTE. Unfortunately such materials as Cu-diamond are expensive. Additionally, the heat spreader needs a larger area around chip, that increases the package size.

Effective heat spreading can be achieved by heat pipes. The virtual heat conductivity of heat pipes can go up to several 1000W/mK depending on the materials used to designed a heat pipe.

Flat heat pipes integrated in a DBC sandwich has been proposed recently and investigated for hermetic power packages. Figure 8 depicts the principle of a flat DBC sandwich heat pipe. The measured virtual thermal conductivity of this sandwich was >800W/mK. The main barrier is the alumina used for this sandwich. The main obstacle for commerzilation of this type of substrate is the fact, that the filling and closing of the heat pipe has to be made after die attach by soldering, as the liquid inside the heatpipe (normally water) will burst the assembly at solder temperatures.

Conclusion

The limits of hermetic metal packages are the pin materials. Metal packages with high thermal conductivity bottoms are comparable with DBC solutions. DBC solutions are offering the application for high current carrying hermetic packages. Direct liquid cooled hermetic packages shows the best thermal performance. Hot spots can be effectively dissipated by thermal electric coolers or by integrated heat pipes.

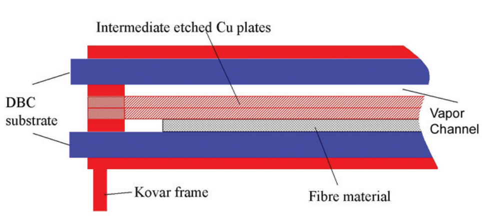


Figure 8: Structure of a DBC heat pipe

Literature

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