II. Die Attachment

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How the GaAs MMIC is attached to the package (die attach) is a general technology applicable to all of the package configurations to be discussed in this section. Die attachment performs several critical functions. It must provide a good thermal path between the MMIC and the package base, which is itself usually attached to a heat sink to remove the heat generated by the MMIC. It must provide a good electrical contact between the backside metal of the MMIC, or its ground plane, and the package base that usually serves as the ground plane for the microwave interconnect lines within the package. Lastly, it must perform these two critical roles over the lifetime of the MMIC and through the environmental conditions required for the mission.

The stability and reliability of the die attach is largely determined by the ability of the structure to withstand the thermomechanical stresses created by the difference in the CTE between the GaAs and the package base material. These stresses are concentrated at the interface between the MMIC ground plane and the die-attach material and the interface between the die-attach material and the package. GaAs has a CTE of 5.8 ppm/K and most packages have a slightly higher CTE (6 to 10 ppm/K [1]); this puts the GaAs MMIC in compression as shown in Figure 9-8. An expression has been developed to relate the number of thermal cycles a die attachment can withstand before failure to the properties of the system [2]. This expression, the Coffin–Manson relation [2], is

$$Nf \propto \gamma^m \left(\frac{2 * t}{L * \Delta CTE * \Delta T} \right)$$

where

$$\begin{aligned} \gamma &= \text{shear strain for failure} \\ m &= \text{constant dependent on the material} \\ L &= \text{diagonal length of the die} \\ t &= \text{die-attach material thickness} \end{aligned}$$

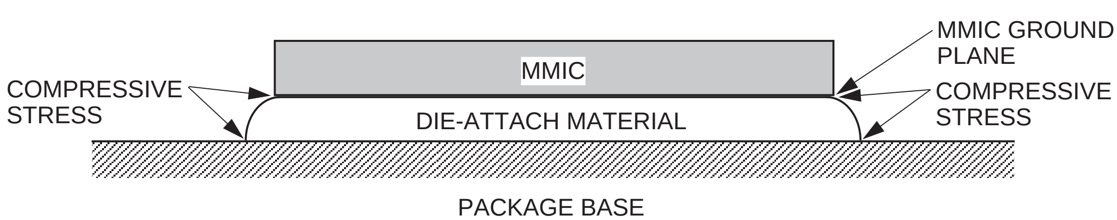

Figure 9-8. GaAs MMIC in compression.

The number of thermal cycles before failure can be significantly reduced by the presence of voids in the die-attach material as shown in Figure 9-9, since voids cause areas of concentrated localized stress concentration that can lead to premature die delamination. The void density tends to increase as the package assembly is thermally cycled. Also, voids cause localized heating of the MMIC, since the void is not a good thermal conductor. Therefore, the thermal resistance of the die-attach material increases as the system is thermally cycled [3]. To minimize these effects, the CTE of the GaAs MMIC and the package base material should be matched as closely as possible, the die-attach material should have a high shear strain before failure, and the presence of voids in the die-attach material must be avoided. This is best accomplished by cleaning the GaAs MMIC and the package before assembly, the removal of all oxides from the two surfaces to be attached, performing a dehydration bake before die attach, and storage of the parts in an inert atmosphere before die attach.

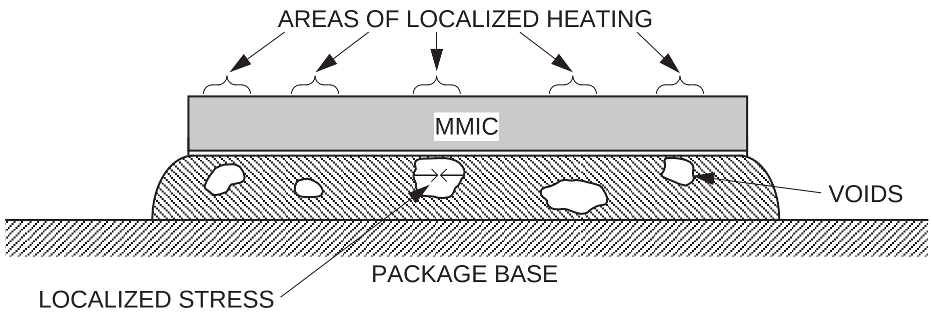

Figure 9-9. The presence of voids in the die-attach material.

Another potential failure mechanism is created if the die-attach material fills any unfilled via holes of the MMIC since the CTE of the die-attach material probably will not match the CTE of the GaAs. During thermal cycling, the die-attach material will expand at a different rate than the GaAs and cause cracks in the via holes [4]. This can be avoided by proper visual inspection of the backside metallization of the MMIC before packaging to reject any MMICs having unfilled via holes, although the same problem can occur from a CTE mismatch between the plated Au in the via hole and the GaAs substrate.

Presently, microwave packages use either hard solders, soft adhesives, or epoxies for die attach. Each method has advantages and disadvantages that affect MMIC reliability. Consider first the solders. Typically, a Au-Sn (80/20) solder is used for GaAs MMICs since it works with the Au ground plane of the MMIC and the package base material to form a Au-Sn eutectic when the assembly is heated to approximately 250°C in the presence of forming gas. Thus, a single, rigid assembled part with low thermal and electrical resistances between the MMIC and the package base is fabricated. Furthermore, these desirable characteristics are stable when the packaged MMIC is thermally cycled [5]. Since the solder die attach is rigid, it is even more critical that the CTE of the MMIC and the package be matched since the solder cannot absorb stresses created by thermal cycling or the die-attach process, and die cracking can result. Regardless of the solder used, flux, a commonly used soldering agent to assure the two surfaces to be bonded are clean and wettable, should not be used for GaAs MMIC since flux degrades the MMIC reliability [1].

Adhesives and epoxies are comprised of a bonding material filled with metal flakes, as shown in Figure 9-10. Typically, Ag flakes are used as the metal filler since it has good electrical conductivity and has been shown not to migrate through the die-attach material [6,7], even under thermal stress. The advantages of these die-attach materials are the lower processing temperature, between 100 and 200°C, required to cure the material, their ease of application, and a lower built-in stress from the assembly process as compared to solder attachment. Furthermore, since the die attach does not create a rigid assembly, shear stresses caused by thermal cycling and mechanical forces are relieved to some extent [2,4]. This characteristic of the die-attach material also leads to crack formation and delamination during temperature cycling [2]. Before a catastrophic die-delamination failure, the MMIC will probably fail parametrically, since the thermal resistance of the die attach increases as voids and cracks are formed. Increases in R_T of a factor of 6 after 1000 temperature cycles are possible [2]. The rate of change in R_T vs the number of temperature cycles is dependent on the contact materials and how well they match the CTE of the GaAs [2,5]. Other disadvantages of the soft die-attach materials are a significantly higher electrical resistivity, which is 10 to 50 times greater than solder, and thermal resistivity, which is 5 to 10 times greater than solder. Therefore, solder is probably required for power amplifiers because of the need for low thermal contacts. Lastly, humidity has been shown to increase the aging process of the die-attach material [7].

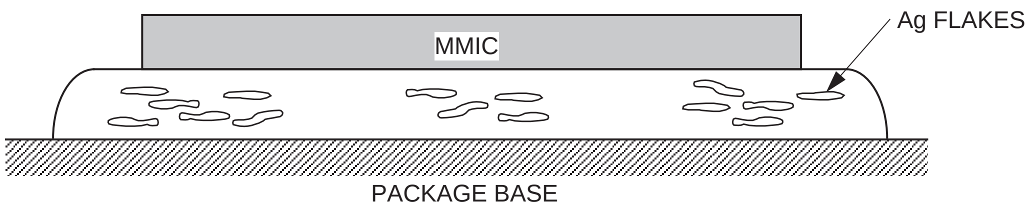

Figure 9-10. Bonding material.

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