

Bonding, Handling, and Mounting Procedures for Millimeterwave PHEMT MMIC's

M/A-COM Products
Rev. V4

Discussion

Millimeterwave MMIC's are becoming more common in commercial applications. Their small size and potentially lower cost has made them valuable in the growing market of millimeterwave systems. Their size and delicate nature also makes them fragile. The following information is provided to help die users handle, mount, and bond MMIC chips.

It should be noted that MMIC's usually require specialized equipment for die attachment and bonding. These operations require a clean environment and special handling equipment such as vacuum pickups, hot gas bonders and/or thermal compression and/or thermo-sonic bonding equipment.

M/A-COM Tech offers a family of GaAs MMIC amplifiers above 15 GHz. This note addresses:

GaAs MMIC Devices

- Low Noise Amplifiers
- Power Amplifiers
- Gain Blocks
- Driver Amplifiers

Handling and Assembling of Chips and Circuits

The challenges of handling and assembling chips into packages can be best separated into two areas: putting the chip into the circuit (die down) and making top contact to the chip (top bonding).

Permanent damage to the MMIC may occur if the precautions are not followed. The MMIC's should be handled in a clean room type of environment. All devices are static sensitive, so handling equipment and personnel should comply with DOD-STD-1686 Class I. Avoid instrument and power supply transients while bias is connected to the MMIC. Use shielded signal and bias cables to minimize inductive pick-up. In general, DO NOT touch the surface of the die. It is recommended that the MMIC die be handled with vacuum pick-up tools with rubber or soft material or handled along the long side with tweezers.

Chip Bonding Methods

A recommendation for improved bonding is to plasma clean the carrier before any eutectic is used. The MMIC should be plasma cleaned before wire bonding.

A risk in using MMIC's is the possible damage incurred when assembling chips into circuits. In general, the value of the MMIC circuits exceeds the cost of the MMIC chip itself. When packaged MMIC's are used, the critical

die attach and top contact operations are performed by M/A-COM Tech and all devices are RF tested after assembly into the packages. When the circuit fabricator performs the die attach and wire bonding operation on a complex substrate, he/she runs the risk of losing or damaging a chip during the bonding operation which can result in the loss of the whole circuit or in an expensive rework cycle.

The most common issues that arise when bonding MMIC's to the circuit are: the introduction of excessive series resistance, especially under forward bias conditions due to the improper bonding of the chip to the ground plane; poor reliability due to the entrapment of contaminants under the bond; and mechanical failure of the bond under thermal shock or temperature cycling. All three conditions are the result of improper wetting of the die to the ground plane and are usually caused by inadequate cleanliness or inadequate bonding conditions.

Table 1 provides helpful information in the selection of die down techniques.

Chip Die Down Bonding Techniques

Eutectic Bonding of Chips - Power Amps

The eutectic bonder is one of the most convenient ways of bonding chips onto a metal ground plane or circuit. Both silicon and GaAs chips may be bonded using similar techniques.

GaAs power die are back metallized with Ti/Au metallization. The use of gold tin solder perform (80% Au, 20% Sn) with an eutectic melting point of $295 \pm 5^\circ\text{C}$ is recommended. A clean, flat, gold plated surface is required to insure good wetting. The preform should be large enough to insure that the die fits within the areas shown, should be ~1 mil thick, and should be 10% smaller than the die itself. During the attaching process, the die collet should be "scrubbed," rubbed into the eutectic, to ensure a good die attach. The carrier of package temperature and collet temperature should be $295 \pm 5^\circ\text{C}$. There should be a 90/10 nitrogen/hydrogen gas applied to the bonding surface. When the forming gas is applied ensure that the bonding surface temperature does not fall below the recommended temperature. This should be done only for the die. All other components - 50W lines, caps, resistors - should be done with electrically conductive epoxy. DO NOT expose the die to a temperature greater than 320°C for more than 20 seconds.

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Die Down Method	Resultant Thermal Resistance	Temperature Required	High Temperature Capabilities	Power Handling Capability	Ease of Operation	Special Equipment Required	Potential Problems
Conductive Epoxy	Good with proper technique	Room temp to 150°C	Good	Low to medium power	Easiest to apply	Little to none	High series or thermal resistance
Soft solder i.e., Pb-Sn-Ag (90,5,5) Pb-Sn (60,40)	Good to very good	200 - 280°C 180 - 200°C	Good	Good to very good for low or high power	Simple application	Heated stage hot gas bonder or gas curtain and furnace	Flux is usually required with lead solders. Cleaning of flux must be done carefully
Eutectic Solder Au-Sn (80,20) Sn-Sb (97,3)	Very good	Approx. 300°C Approx. 230°C	Good	Very good	Simple application	Heated stage or hot gas bonder	Needs clean reducing atmosphere

Table 1. Selection Guide for Die Down Bonding Techniques

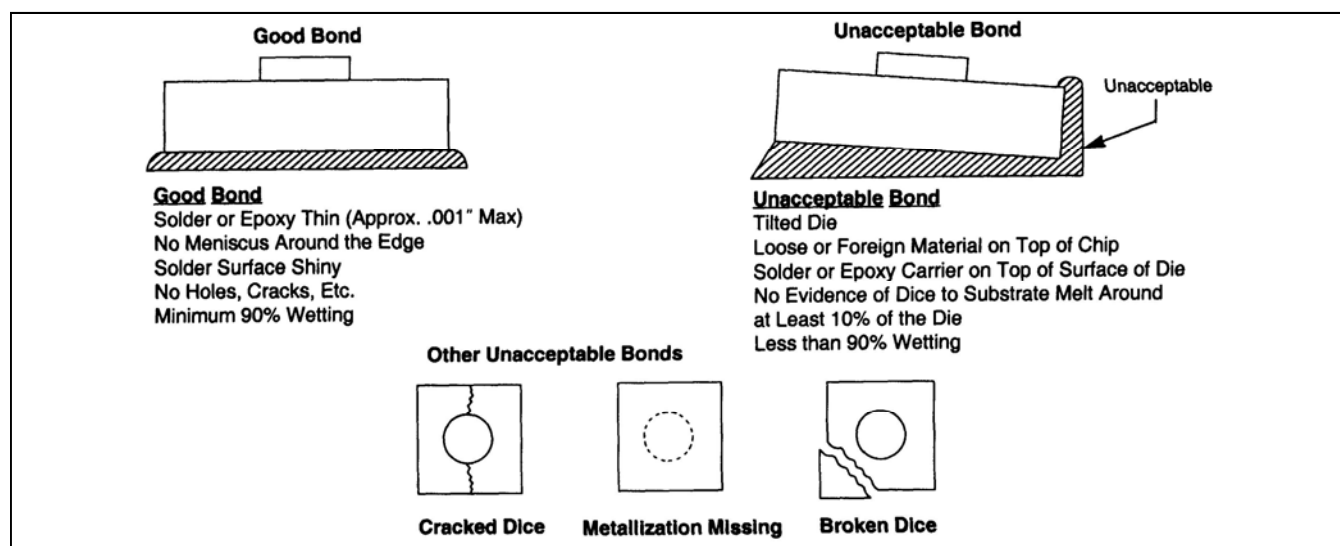


Figure 1. Die Bonding Criteria

Die Bonding with Conductive Epoxies - LNAs

Although satisfactory die down bonds may be obtained using these epoxies, the power amplifiers may not perform to specification. The low noise amplifiers work well when epoxies are used. The following precautions should be observed to obtain consistently strong bonds.

The low noise die are back metallized with Pd/Ni/Au (100/ 1,000 / 30,000Å) metallization. Thermally and electrically conductive epoxy is recommended for die-mounting the low noise die, although Au/Sn eutectic preforms can be used.

The attachment surface should be clean and flat. Electrically conductive epoxy is required and must be within the warranty shelf and/or pot life. It is advisable to use half the listed pot life. Silver conductive epoxies should not be used where they will come into contact with lead tin solders or high tin solder. There can be an anodic reaction which may cause failure of the bond. Epotek H2OE or Ablestick 84-1LMI is recommended.

A minimum amount of epoxy should be applied, then the die should be placed into position. **Figure 1** shows good and unacceptable bonds.

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Curing of the epoxy should follow the manufacturer's recommended schedule. They epoxy must be cured in air or oxidizing atmosphere since the reaction requires oxygen. The epoxy oven should be clean and have good air flow. The epoxy will not cure well if there are other solvent fumes in the atmosphere.

The carrier fluid must not be allowed to flow on the top of the chip. Not only will it make the chip un-bondable, it will be almost impossible to detect under normal bonding procedure. If a vacuum tip is used to put the chip in place, remove the vacuum when the chip is 10 mils from the epoxy. Static charge will hold the chip to the tip. If the vacuum tip touches the epoxy, it will become coated with the epoxy carrier fluid and contaminate the next chip. This same problem may occur with the use of tweezers. The tweezers should be cleaned before picking up another chip if they touch the epoxy.

The shear bond strength of a good epoxy joint can approach that of solder 50-100 kgms/cm². The thickness of the conductive epoxy should be kept at 0.001" or less.

The shear bond strength should be about:
 40-60 grams for 0.010 x 0.010 inch chip
 150-250 grams for 0.020 x 0.020 inch chip
 350-500 grams for 0.030 x 0.030 inch chip

In general, the epoxy will shear before the chip breaks. Weak bonds are usually caused by the use of old epoxy, bonds that are too thick, or lack of cleanliness.

Visual Inspection

Die down bonds should be checked with a 5-15X microscope and should meet the visual criteria shown in **Table 2**.

Top Contacting Methods

The usual criteria for choosing a specific top bonding technique are the size of the top contact of the chip, the type of chip, the sensitivity of the chip to temperature and pressure, the type of circuit board, and the equipment available. Usually, the simplest contacts are a gold 0.0007 to 0.001 inch diameter wedge bonded gold wire. The inductance of a 1 mil diameter wire will be ~0.5 nH for a 0.20 inch long lead. This inductance can be reduced considerably by using multiple contact wires.

It is very difficult to give definite parameter values of force pressure time and temperature for an optimum bonding schedule. Different wire, bonding surfaces, or die characteristics require different bonding conditions. GaAs is very brittle and extra care should be taken when wire bonding. In general, the bonding parameters should be adjusted to maximize reproducibility at a high bond pull strength.

Die Down Method	Visual (Good Bond Criteria)	Typical Bond Strength (In Stress)	Extra RS1 From Die Down (0.020" Chip)
Conductive Epoxy	Flat, maximum epoxy thickness approx. 0.001 inch 90% min. wetting	Approx. 50-100 kgms/cm ²	Less than 0.1 ohms
Soft Solder	Flat, maximum epoxy thickness approx. 0.001 inch 90% min. wetting	Approx. 70-100 kgms/cm ²	Less than 0.1 ohms
Gold-tin Eutectic Solder	Flat, maximum epoxy thickness approx. 0.001 inch 90% min. wetting	Approx. 100-150 kgms/cm ²	Less than 0.1 ohms

1. This is the approximate extra RF series resistance from an ideal lossless bond of a 0.020" x 0.020" chip.

Table 2. Visual Inspection for Good Die-Down Bonds (Using a 5-15x Microscope)

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Wedge bond with 1.0 mil diameter gold wire or 3.0 mil x 0.0005 mil ribbon and a force of 18 to 22 grams. Bonds should be started on the die and terminated on the package, if possible. For RF connections, two wires are recommended. Most bonding pads are 4.0 x 4.0 mils and most input and output pads are 4.0 x 4.0 mils.

Most problems are caused by improper bonding machine and tool settings as well as improper maintenance and cleanliness. It is important to control the movement of the part being bonded, alignment of tools, tool height, angle, and tool condition.

In general, the die will crack or "crater" if too hard a wire or excessive pressure is used. Too little pressure results in small, weak bonds. A good wire bond should be stronger than the wire and should also be two or three times the wire diameter. When wire bonding, the deformed width of the wire should be about 1.3 to 1.8 times the wire thickness. If the deformed width is too small, the bond will tend to lift off. If it is too large (greater than 1.8 times the wire diameter) the wire tends to weaken and break. Figure 2 shows the relationship between the pull strength and the deformed width of the ultrasonic bonded wire.

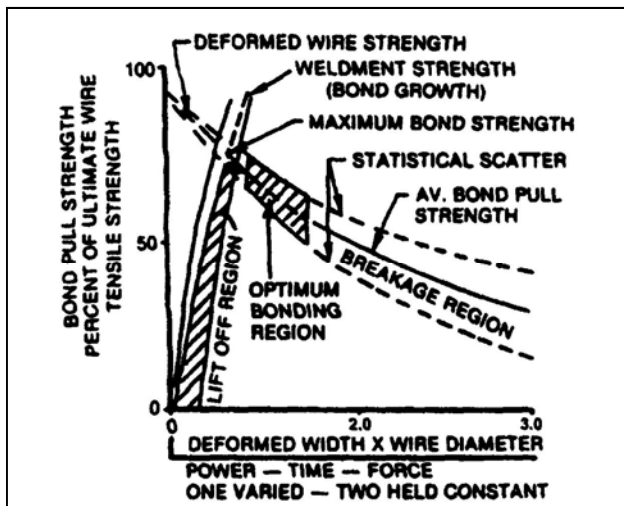


Figure 2. Pull Strength vs. Deformation for a Wirebond

Acceptable Bonds

- Wire does not separate when tested
- No fractures in bond
- No separation of metallization
- Wire breaks before bond

Unacceptable Bonds

- Wire separates from bond
- Bond fractures at weld
- Separation of metallization from dice

Wire or Ribbon Size (inches)	Minimum Pull Strength (grams)
0.0007 wire diameter	1.5
0.001 wire diameter	3.0
0.002 wire diameter	9.0

Table 3. Bond Strength Criteria (Gold Wire or Strap)

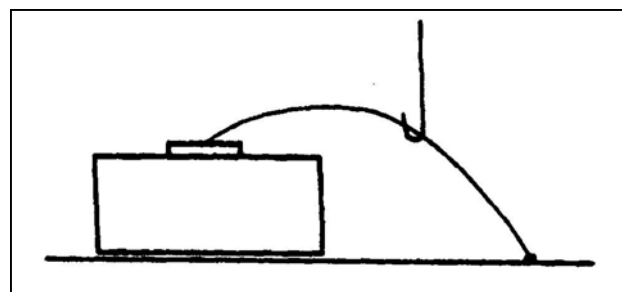


Figure 3.

Bond Strength Pull Test

It is extremely important to maintain good quality control procedures in order to ensure good bonding. Figure 3 and Table 3 illustrate criteria for visual inspection and for testing on bond strength.

Capacitors and Resistors

It is recommended that capacitors and resistors are selected that meet at least the same temperature ranges as the MMICs. The following are recommended devices to use.

Capacitors

- Dielectric Laboratories
- 100 pF P/n D30BH101K5PK or equivalent
- 1000 pF P/n D35BV102KPX or equivalent

Resistors

- Mini-Systems, Inc.
- 10 WP/n MSTF-2ST-10R00J-G or equivalent