Application Note

Handling Gallium Arsenide Die

Rev 2

INTRODUCTION

Gallium arsenide die have physical properties that require special care in assembly to ensure high yields and good reliability. A few simple precautions in the die mounting and wire bonding operations will result in a smooth prototype or production flow. This note discusses handling, assembly procedures, visual inspection criteria, and electrostatic discharge precautions. The recommendations given in this document are meant as references and may vary depending on specific equipment and application.

DIE MOUNTING

ANADIGICS microwave integrated circuits are manufactured on GaAs substrates that are susceptible to chipping and cracking during the die attach process. ANADIGICS bare die may be purchased in a variety of presentations including waffle or gel pacs for manual operations and on adhesive films attached to film-frames or grip-rings for automated equipment. Regardless of the presentation, a soft silicon/rubber tip die pick-up tool is recommended for the die pick step of the die attach cycle, although tweezers may be used with extreme care for manual die attach. If a rubber tip pick-up tool is used, care should also be taken to keep the tip clean of debris and epoxy. Picking up at the edge of a die or a contaminated die can leave debris or epoxy on the tip of the pick-up tool which could be transferred and damage subsequent die. If a pyramidal die collet is used for die placement and die are presented on an adhesive film, the following interim step is recommended: Remove the GaAs die from the adhesive film using a rubber tip pick-up tool and then transfer it to the die collet to limit die cracking.

A few ANADIGICS die types do not incorporate an outer passivation layer; on these die there is no protection of the air bridge structures incorporated in the die design. The circuitry on these dies will be very malleable and susceptible to physical damage from tweezers, pick-up tools and forces applied during die pick which can result in damaged circuits.

On automatic die attach equipment care must also be taken to ensure the ejector pins are not damaged and have a tip radius sufficient to prevent damage to the die underside. Chips or divots made to the die under-side during the die pick can propagate into cracks on the die upper surface in subsequent operations and present a long term reliability concern. ANADIGICS recommends an inspection for ejector pin damage to the die under-side be made at set-up and periodically during production to ensure die are not damaged during pick from tape. When large die with severe aspect ratio's are to be die attached, we suggest a multi-tip ejector pin set-up be employed to limit die cracking during removal from the adhesive film.

ANADIGICS MESFET and pHEMT die have no back metalization and must be epoxy mounted. Although ANADIGICS HBT die are back metalized to facilitate via contact between the topside circuitry and ground, we suggest these also be die attached using conductive epoxy. A good thermally conductive, low electrical resistance, silver-filled epoxy is recommended. It is also important that this epoxy have good mechanical characteristics at temperatures as high as 260^{o}C. Epoxy application to the substrate prior to die placement is also a critical step of the die attach sequence. If the epoxy is applied by stamping, it is recommended the epoxy be scrubbed to minimize voiding between the die and substrate. Whether the epoxy is applied through stamping or dispensing, it is important to ensure it covers the entire die underside with a uniform bond-line thickness and exhibits a minimum 90% coverage along the die periphery. It is also critical the epoxy kerf creep does not extend more than ½ of the die thickness. Insufficient epoxy coverage can result in not only reduced electrical performance but also in damage to the die during wire bond should a bond be made over an unsupported edge of the die. Excessive epoxy extension up the side of the die can cause immediate electrical problems or long term reliability issues.

On those die that are not passivated, it is critical that only the lightest pressure possible is applied during die placement portion of the die attach operation. Too much pressure can crush or tear the air bridges. Slight deformation of the air bridge is allowable, but seriously deformed or broken air bridges should be screened at post die mounting visual inspection. Therefore, it is recommended that unpassivated GaAs die be pressed into mounting epoxy by the sides of the die, and not by applying pressure on the top surface of the die. Should a pyramidal collet be used, care should be taken to ensure the die collet matches the die size and the die and die collet are accurately aligned before picking. A misaligned pyramidal collet will cause the die to chip, crack, or possibly shatter. Also, care must be taken when using a die collet to ensure the edges of the collet do not contact the epoxy; this may not only disturb the die placement but may also cause epoxy contamination on the top subsequent die.

Equipment maintenance is important to any die attach operation. Excessive use of oil on moving parts could lead to oil flowing into the collet air line, causing oil to be deposited on the die. This oil can cause several problems later, from poor bond adhesion to package sealing problems. Worn or damaged ejector pins, die collets and pick-up tips can cause damage to underside, edges and top circuitry of a die. It is also critical to ensure optimized tooling and die attach conditions have been selected to prevent die damage and ensure a high-quality die attach.

PLASMA CLEANING

A rigorous plasma clean between die attach and wire-bond is necessary to produce reliable bonds at the die surface. (Reference ANADIGICS specification 60022-014). In addition, ANADIGICS also recommends a “Ball Lift Test” per this specification be implemented to check wire bond adhesion to die bond pads as a process control monitor. The use of a Ball Shear Test in-place of a “Ball Lift Test” is discouraged.

WIRE BONDING

Ball bonding is recommended at a stage temperature of 150^{o}C with either 0.001" or 0.0013" bond wire, but wedge bonding can also be used. Power, time, pressure, and temperature settings are dependent upon the type and manufacture of the wire bonder. Care should be taken to characterize the wire bonder and setup using optimum parameters. Due to the brittle nature of GaAs, the substrate is subject to damage under the bonding pad. This can cause bond pad failure if too much force or too much ultrasonic energy is used during bonding.

A good combination of force and ultrasonics will make the bond in the shape of a Hershey’s Kiss or a raindrop. If too much force is used, the bond will be large and flat; if too little is used, the bond will be small and drawn up. After the force is set, adjust the ultrasonics to the point where the bond does not stick. Then increase the ultrasonic energy up slowly until the bond sticks well for your application. When building hybrids with both Si and GaAs die, it is recommended to bond the die with the first bond. This will simplify your setup since the first bond is the easiest one to control. ANADIGICS also suggests utilizing lower velocities when transiting from die to substrate to minimize bond pad damage during loop formation.

Care should be taken when setting up the desired connections to the die so as not to contact the exposed air bridges, which may cause shorts. If using wedge bonding, ensure that the first bond tail does not touch any circuit traces. If a second bond is used to make connection to the die ensure that the tear cycle does cause the wedge to cut across circuit traces. This may tear air bridges or otherwise damage the circuitry.

THERMAL CONSIDERATIONS

It is good practice to provide a good thermal path for any semiconductor device. This includes using a thermally conductive epoxy and a good thermally conductive mounting surface, such as alumina or metal. It is important that the thermal coefficient of expansion of the mounting surface does not differ greatly from that of GaAs (TCE value of approx. **x10**$^{-6}$ K^{-1}). Ceramics such as alumna or beryllium oxide are good, and some metal alloys such as kovar or alloy 42 are acceptable.

VISUAL INSPECTION

Visual inspection of the die is recommended upon receipt of a die shipment and after wire-bonding. A stereo microscope at 30X is recommended. At this magnification, shipping or assembly related defects could be detected. Inspection at higher magnification is performed by ANADIGICS to detect any process related defects that could result in reduced reliability or electrical performance.

Parts should be inspected for foreign matter, bent or broken air bridges, scratches and chips or cracks in the active area of the die. Foreign matter that cannot be easily cleaned may cause shorts between air bridge lines on unpassivated die. Broken air bridges usually suggest open circuits. Bent or otherwise disfigured air bridges can be allowed in most applications.

Because of the brittle nature of GaAs, some chipping of the edges of the die is normal. If these chips are confined to the edge of the die and do not touch active element of the device, they are acceptable. Chips may be caused by the die separation process, abnormally rough shipping, or almost any assembly procedure, particularly when handling with tweezers. Cracks that lie in the active region of the die may propagate with time and cause a failure. Exceptions can be made for chips or cracks that touch a bond pad. Reliability testing at ANADIGICS has shown cracks of this type do not cause reduced MTTF (Mean Time to Failure).

Scratches in metalization traces may suggest poor handling procedures and may disqualify a die for extremely high reliability level, but may not affect the electrical performance of the device. Scratches on the edge of a capacitor are of some concern, since this may cause the capacitor top plate to short against the bottom plate. The bond pads will have scratches caused by circuit testing. These scratches are normal and are not cause for rejection.

After mounting and bonding, parts should be inspected to ensure good epoxy fillets around the edge of the die. Large voids in the epoxy should be deterred as well as die that do not sit reasonably flat in the package. Wire bond sites should be inspected for short circuits and damage to traces or air bridges. Bond heels should also be inspected for proper deformation.

STATIC SENSITIVITY

All semiconductor devices are sensitive to electrostatic discharge. Often static induced failures are latent in nature, and sometimes the only indication of damage is just poor yields. Therefore, it is prudent to assume that all integrated circuits, including GaAs integrated circuits, require static controlled work stations. Operators should wear dissipative wrist straps and work over dissipative table mats. Finished work should be kept in dissipative packaging.

It is worth repeating that static failures are often not obvious. Semiconductor devices can be repeatedly handled without causing immediate failures. It should be noted that many kilovolts can be delivered with a simple touch causing a failure that may not show up for months. Therefore it is good practice to take all possible precautions during handling and assembly.

SUMMARY

Handling GaAs die encompasses many of the same concerns as most semiconductor devices. General cleanliness and static protection practices are applicable as required by the desired screening level. A few allowances must be made to compensate for the brittleness of the material and the exposed air bridges. Often it helps to reduce the cycle speed of automated equipment. It also is important to pay close attention to the forces of die mounting and wire bonding, as well as the energy level of the ultrasonics during wire bonding. Inspections are necessary in keeping qualified processes from shifting and keeping quality levels high. Once these conditions are met, GaAs integrated circuits can be assembled with high yield and reliability.

ANADIGICS, Inc.
141 Mount Bethel Road
Warren, New Jersey 07059, U.S.A.
Tel: +1 (908) 668-5000
Fax: +1 (908) 668-5132

URL: http://www.anadigics.com
E-mail: Mktg@anadigics.com