AN0001

UMS User guide for bare dies GaAs & GaN MMIC

Storage, pick & place, die attach and wire bonding

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1. Introduction

This document provides information and recommendation related to UMS GaAs and GaN bare dies products for storage, handling, mounting and bonding.

2. MMIC storage

Depending on the customer requirements, storage duration, pick & place method and equipment, MMIC can be shipped in different conditionings:

- GEL-PAK® trays
- Wafflepacks
- UV Film on rings

GEL-PAK, Waffle-pack trays, and on-film wafers should be placed in a temperature and humidity controlled area, preferentially under a nitrogen flux.

2.1. GEL-PAK® trays

This is the standard UMS storage method. GEL-PAK® Vacuum Release Trays are membrane base trays that hold dies in place during shipping and handling, and release them only when required.
Note that there is no constraint for positioning the dies on the tray. It is therefore possible for UMS to align precisely the dies on the tray when using an automatic pick & place equipment.

Standard GEL-PAK® trays used by UMS are black conductive.

Although the GEL-PAK® tray is the UMS standard storage method, it is not recommended for long-term chip storage.

2.2. Wafflepack trays

These trays contain several cavities matched to the die dimensions. The wafflepack is custom designed for each die type, moreover there is additional space provided for die insertion and removal, depending on the pick & place tool. Therefore this space allows the dies to move during shipment and also during Wafflepacks handling. This may induce damages to the dies.

Standard wafflepack trays used by UMS are black conductive (see ESD chapter).

There is no limitation for long term storage in Wafflepacks.

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2.3. UV Films (Adwill D-877H) on ring

These adhesive plastic films are used at the dicing process level and allow keeping a mechanical alignment of the dies during and after the process.

In order to save time and cost, UMS can ship wafers on film rather than dies on trays. In such a case, the standard UMS way of shipping is diced wafers on 8" rings, using an UV type film.

This film offers a highest adhesive strength until it is exposed to an UV lamp. The picking of the largest dies is in this case easier.

3. Electrostatic discharge protection

High frequency GaAs and GaN devices are usually not equipped with on-chip ESD (Electrostatic Discharge) protection circuitry as the overall performance is degraded by additional parasitic effects. To address higher operating frequency, the gate length and the gate periphery are decreasing. MMICs are thus more and more sensitive to ESD degradation or failure. Depending on the port characteristics, circuits can be damaged by ESD voltages in the 100-1000 volts range, classifying these products in Class 0. However, observing the same standard rules as the ones used for silicon devices handling, proves to be efficient to protect GaAs devices from ESD degradation.

3.1. Material classification

Regarding ESD, materials can be classified in four families:

- Conductive
- Electrostatic dissipative
- Electrostatic low charging (formerly astatic or antistatic)
- Insulating

3.2. Basic principles for preventing ESD

The main basic principles for preventing ESD are:

- Avoid charge sources
- Eliminate surface charge
- Eliminate volume charge
- Neutralize residual charge
- Control humidity level
- Identify ESD sensible products, areas and equipments
- Develop and maintain an ESD Control Program

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These principles should be applied to infrastructures (floor, furnitures), personnel, equipment, tooling, and packing.

4. MMIC handling and pick & place

Pick & Place refers to the operation of transferring the die from a tray or film to a package, module or board before die attach. This process can be done manually or by means of automatic equipment. In both cases, due to the fragility of bare dies, it is important to note the following key points:

4.1. Cleanliness

Chip and wafer containers must not be opened and exposed outside of dedicated mounting areas. Dies and wafer must be handled in a clean environment:

- Clean room ISO 7 or better
- Temperature 21 +/- 2°C,
- Hygrometry 50 +/- 10%,
- Under dry Nitrogen

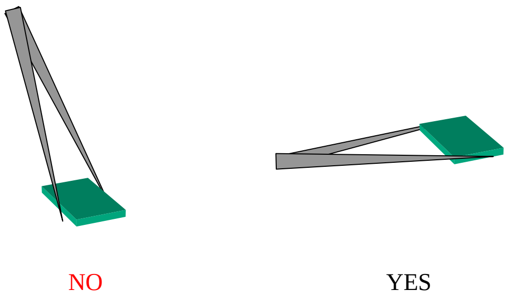
4.2. Electrostatic discharge protection

See chapter 3

4.3. Handling

For prototyping and small production, dies can be picked up and placed manually whereas for high volumes, automatic pick & place machines achieve a better placement accuracy and productivity.

<u>Manual handling</u>: Chips can be handled using clean stainless tweezers. To avoid mechanical degradations to the chip upper edge, it is preferable to pick the chip as indicated hereafter.



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Vacuum probes: Instead of using tweezers, vacuum pick-up tools can be used with appropriate non ESD tips materials adapted to the die periphery and design.

Air bridges:
Applicable to GaAs and GaN bare die
Most of UMS chips are using air-bridge technology. To protect the chip surface during pick & place operations, 4 to 6 support areas are systematically implements at the periphery of the chip. These support areas are constituted by stacking all the metal and dielectric layers. This insures that the pick-up tools will contact the support areas first, providing that the tip size is adapted to the chip periphery.

Automatic pick & place: Automatic pick & place machines can pick-up directly the chips from GEL-PAK® trays, Waffle-packs or adhesive films. The body of the pick-up tools (the shank) is specific to each equipment while the tip is adapted to the chip geometry and the chip conditioning:

- Conical tips
- Rectangular tips
- Peripheral tips (to minimize the contact area with the tool)
- Pyramid die collets (no contact with the top of the chip)
- Materials (metal, plastic, composite)

In the case of die picked directly from wafers, the chip is simultaneously pushed up through the adhesive film by a specific die ejector pin.

4.4. Transients

Voltage surges and transients coming out from power supplies and instrumentation hardware should be prevented. Galvanic insulation of hardware through transformers also protects chips from main spikes. A particular attention should be paid to avoid ground loops that could result in a ground floating effect of volts to tens of volts. All parts of hardware close to sensitive devices should be carefully checked to be at 0V referred to ground (AC and DC) during all working phases of these equipments. All electrically powered equipments or tools should be powered through a grounded type AC plug.

5. Die attach

5.1. General recommendations

To attach the chips to their external environment, a substrate or a metal base, two methods are generally indicated, depending mainly on the thermal dissipation and outgassing requirements, on the adaptation to their carrier mechanical characteristics:

- Epoxy die attach for low power devices
- Eutectic die attach for medium and power devices.

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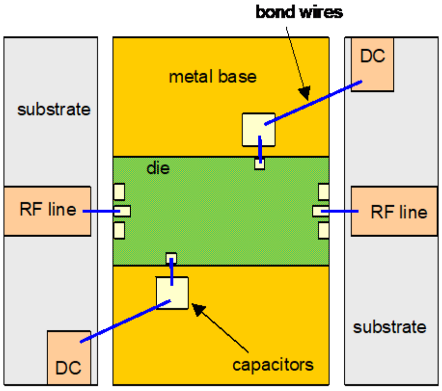
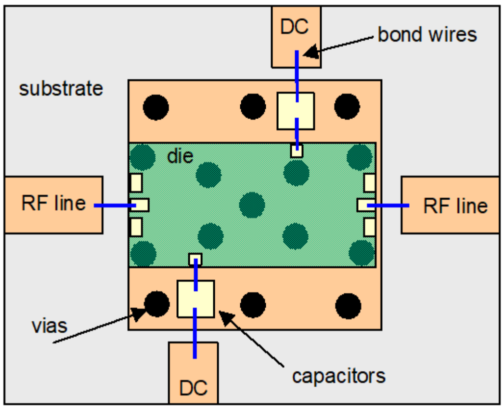
These methods are compliant with the UMS chip backside technology (4µm gold plating) which is common to most of the UMS processes.

Die attach on a metal base: This is the recommended best solution to achieve at the same time a good RF grounding and thermal heatsinking. (See picture below). The base plate should be preferentially gold plated copper composite, Molybdenum or other CTE compatible material. The die can be attached by epoxy glue, eutectic brazing or silver sintering.



Die attach on a substrate: Reserved to low power devices this option should include via holes through the substrate and under the chip to provide a low RF ground inductance and avoid undesirable non TEM propagation modes and spurious oscillations (see picture below).



5.2. Epoxy glue die attach

This is one of the industry standard die attach method. It is based on a Van der Waals interaction rather than atomic or molecular. An adhesive paste composed of two components, silver grains filled epoxy and a hardener, is deposited in liquid form on a clean gold plated surface, which may be a metal or an insulating substrate. For proper grounding in RF applications, the epoxy should be electrically conductive and generally the chip should be attached directly on the carrier which can be a metal or a ground pad connected to the base plate with via holes through the substrate. If the chip requires small thermal dissipation, the

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epoxy glue should also have good thermal performances even if eutectic or silver sintering die attach is preferable in this case.

It is possible to use automatic dispensing equipment. Many pick & place machines have the capability to dispense epoxy glue, with the advantages of accuracy, control and repeatability of the epoxy drops.

The curing process is necessary to polymerize the epoxy glue and stabilize the die attach. This can be done in standalone conventional ovens. Curing cycle time is dependent on the epoxy glue used and is described in the epoxy manufacturer instruction guide.

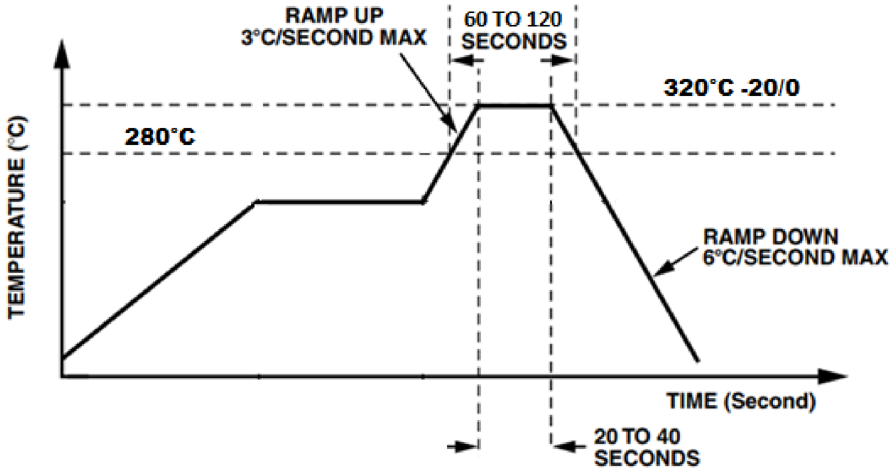
5.3. Eutectic die attach

This process, recommended for power devices is however more difficult to control than the classical epoxy attach. This is really a soldering joining process involving intermetallic interaction. As already mentioned, most of UMS chips have a 4µm gold backside compatible with the eutectic attach.

UMS recommended process is 80/20 Au/Sn under dry nitrogen or a 90/10 nitrogen/hydrogen or formic acid flow to prevent oxide formation. It can be used on gold plated carriers like molybdenum, copper composite, etc. Any kind of flux shall not be used.

It is recommended to minimize the duration of the reflow temperature. The duration above 280°C (melting point of the eutectic Au80Sn20 solder) should not exceed 1-2 minutes and not exceed 40s above 300°C with a maximum peak temperature never exceeding 320°C.

The graph below gives an example of temperature profile which can be applied with eutectic Au80Sn20 soldering in vacuum oven. This temperature profile is just given for indication and is extremely dependant of the oven and of the thermal mass of the carriers on which is soldered the die.



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5.4. Other die attach processes

Another existing process designed for devices requiring high thermal and electrical conductivity is the silver sintering die attach.

Silver sintering pastes are mainly composed of silver (>80%) and resin. A curing process is necessary for compacting and forming a solid mass of material without melting it to the point of liquefaction. This can be done in standalone conventional ovens. Curing cycle time is dependent on the silver sintering paste used and is described in the manufacturer instruction guide. Curing temperature is generally around 200°C for few hours.

5.5. EPOXY & Eutectic die attach control

The die attach process can be considered as successful if the following criteria are met:

- The solid alloy is bright.
- An alloy fillet is visible at least under three of the four sides of the die.
- There is no risk of backside to front side short-circuit resulting from an excessive alloy thickness.

Main common problems in eutectic die attach are linked to a contamination of the chip carrier, the preform or the die backside caused by an improper cleaning or a non-clean environment.

A regular test of die shear strength should be completed to validate the die attach process control versus time. It should be also completed after any important modification of the process or change in the hardware. This testing is described in MIL-STD-883 method 2019.5.
Note that UMS performs a die shear test to check the wafer backside quality on a sampling basis.

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6. Wire bonding

Even if flip-chip bonding is doing considerable progress, wire bonding is still a standard way to interconnect dies with the external environment, package or substrate. Automatic wire bonders have an accuracy and repeatability compatible with millimeter-wave requirements.

6.1. Bond pads

Die bond pads are fully compatible with manual and automatic gold wire bonders. The bond pads are metalized with 3.5µm electroplated pure gold. To prevent from stress effect possibly induced by the bonding process, UMS chip design rules specify a 25µm prohibited area for circuit layout close to the bond pads and an additional 25µm area authorized for non-sensible components.
Dimensions of the pads depend of various parameters:

- Maxi current
- Bonding constraints
- Use of BCB protection

For GaAs MMIC

DC PADS

GaAs	Without BCB	with BCB
	(Level EL)	*(Level BCB)*
PAD	100/100µm	86/83µm

RF PADS

GaAs	Without BCB	with BCB
	(Level EL)	*(Level BCB)*
INOUTV2_MSM_72	122/72µm	105/58µm
INOUTV2_MSM_100	122/100µm	105/72µm

For GaN MMIC:

DC PADS

GaN Standard DC PADS	Without BCB	with BCB
	(Level PO)	*(Level BCB)*
PAD	90/90µm	100/100µm

RF PADS

GaN Standard RF PADS	Without BCB	with BCB
	(Level PO)	*(Level BCB)*
INOUTV2_MSM_66	116/64µm	116/64µm
INOUTV2_MSM_100	94/94µm	100/190µm
INOUTV2_MSM_200	94/194µm	100/190µm

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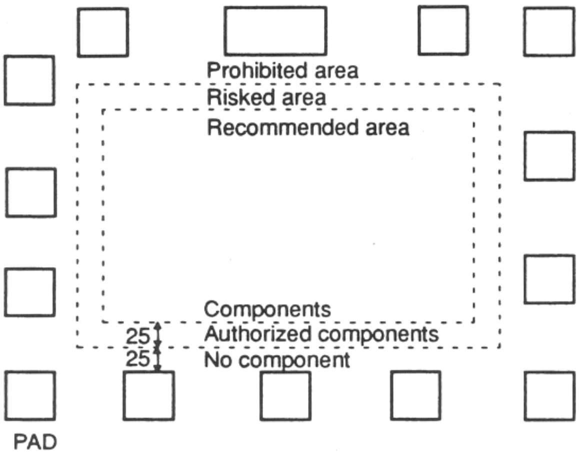

Prohibited area	: No component must be drawn here except EL connections.
Risked area	: Components must be drawn here, only if it is not possible to place them in the *recommended area*.
Recommended area	: components must be drawn here.

6.2. Bond wires

Among the wide choice of bonding wires or ribbons to connect MMICs to substrates, the most commonly used are pure gold with 25µm diameter. This is a quasi standard and most of the designs are taking into account the inductance effect of the bonding wires in the final chip performance.
During the chip design phase, unless otherwise stated in the product data-sheets, it is assumed that the device RF ports are connected to the external environment by a pure inductor with a typical value of 0.10 to 0.15nH. For a single 25µm wire, this is equivalent to a typical length of 0.12 to 0.19mm. It is therefore recommended to avoid longer bonding wires to save the chip performance.

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6.3. Bonding process

Ultrasonic thermocompression wire bonding process is the standard method in the industry

Ultrasonic thermocompression wedge bonding: The wire is pressed on the bond pad with a controlled force (generally around 15 to 30 grams). This process requires a precise adjustment of the tool force, work stage temperature (generally between 100 and 150°C) and ultrasonic power.

The advantages of the wedge bonding are:

- Small footprint (~2 times the wire diameter in width but ~4 times the wire diameter in length)
- Shortest bonds between the die pad and the external substrate, even if short wires can be performed with an automatic ball bonding equipments.
- Capability to bond small diameter wires (18µm)

The disadvantages of the wedge bonding are:

- Unidirectional motion in case of manual process. Omnidirectional bonding is possible with automatic equipments only
- The tool overall dimension which is larger compare to the ball bonding capillary. It sometime imposes the wiring direction when the connections are not performed on the same plan.
- BCB coating on top of dies can be damaged by the tool or by the wire itself (wire angle, wire tail …)

Ultrasonic thermocompression ball bonding: Most commonly used due to its high rate production capability. The wire is fed through a capillary and the component is heated to around 100-150°C. The recommended ball bonding force is 20 to 50 grams and depends on many parameters. Ultrasonic power is also a critical parameter for this type of wire bonding which is equipment, tool and component carrier characteristics dependant.
The bond pad size must be adapted to the gold ball size which is around 2 to 3 times the wire diameter.

The advantages of the ball bonding are:

- Omnidirectional motion of the bonding tool after the first bond
- Performing complex loop shape if necessary
- Fast bonding method because the bonding wire is fed directly under the tool end
- Process easier to control
- length can be controlled with automatic equipments

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The disadvantages of the ball bonding are:

- The ball diameter which often imposes larger bond pad size compared to the wedge bonding
- The wire length which can be a bit longer compare to the wedge bonding process due to the wire shape. This can be an important parameter for high frequency applications.

6.4. Bonding process control

A regular control of bonding process should be completed to validate the die attach process.
This testing is described in MIL-STD-883 method 2011 (destructive pull test) and MIL-STD-883 method 2023 (non-destructive pull test)
Note that UMS performs a bond pull test to check the front side bond pads quality on a sampling basis.

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Recommended environmental management

UMS products are compliant with the regulation in particular with the directives RoHS N°2011/65 and REACh N°1907/2006. More environmental data are available in the application note AN0019 also available at https://www.ums-rf.com/.

Recommended ESD management

Refer to the application note AN0020 available at https://www.ums-rf.com/ for ESD sensitivity and handling recommendations for the UMS package products.

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