United Monolithic
Semiconductors

AN0026

Application note for GaN on SiC Transistor

Handling and Assembly guidelines

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1. GaN Power bar presentation

GH50 and GH25 are respectively 0.5µm and 0.25µm gate length HEMT GaN on SiC technology.

These technologies offer high power density, typically 4 to 6W/mm, associated to high PAE up to C-band (GH50) and Ku-band (GH25).
This power bar technology enables to design high power hybrid products or chip on board products where impedance matching can be realized by the customer on their preferred substrate at their convenience.

Table 1 gives the main information regarding GaN on SiC power bar interconnect.

Interface	Value / Spec.
Die thickness	100µm +/-10%
Die sawing tolerance	+6/ -50µm
Back side platting	Gold (Au)
Back side pull back for die edge	Nominal: 50µm (sawing spreads not included)
Top side bond pads platting	gold (Au)
Top side air bridges	Yes
Die passivation	SiN
Transistor source connection	Through SiC via holes (gold plating)

Table 1: GaN on SiC Power bar interconnect

Figure 1 gives an example of mechanical interface drawing for a GH50 power.

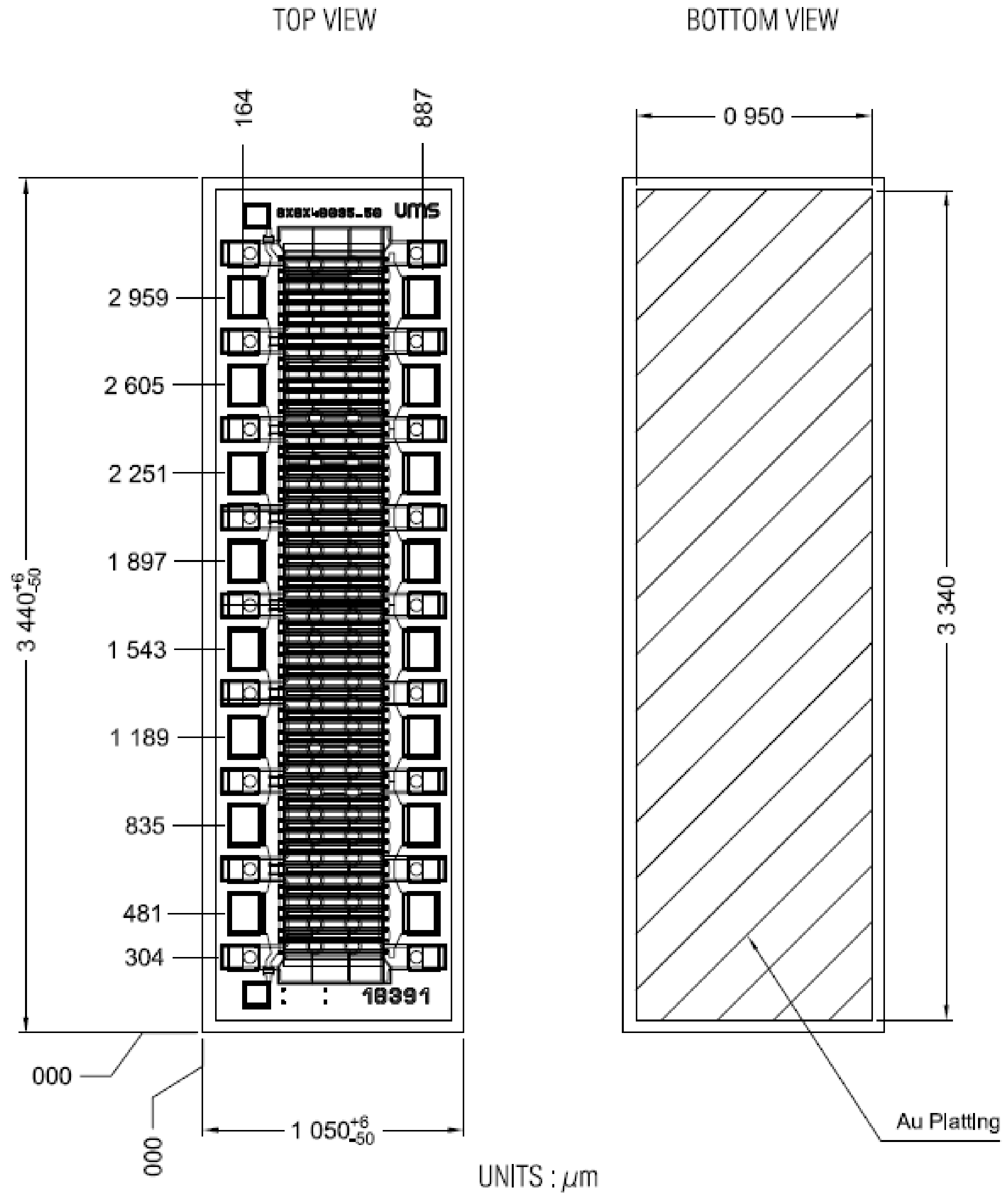

Figure 1: Example of GH50 power bar mechanical interface drawing

2. Recommendations for pick & place

Usually UMS GaN bare dies are delivered in GelPack box. However other packing options as waffle pack box or sawn wafer on UV tape may be available upon special request.

Automatic or manual pick and place processes can be both considered for die picking from GelPack. Even if GaN on SiC is less brittle than GaAs, a special care for picking process parameters definition and picking tool selection has to be paid to avoid damaging the die.

Prior to any picking operation from the GelPack box, the adhesion of the die to the gel has to be decreased by applying vacuum on the GelPack tray. Then the adhesion of the dies drops down near zero and the dies can be released from the film with minimum risks of braking.

In case of automatic picking process, a pyramidal die collet tool is recommended in order to avoid any contact with the centre part of the dies where are located the transistors with their air bridges connecting the transistor sources together. The pyramidal tool will enable to ensure a good contact at the 4 edges of the dies while centre area is fully avoided. A ring of 100µm surrounding the die can be considered as safe area for direct contact between the die and the picking tool.
An example suitable pyramidal tool is given at Figure 2.

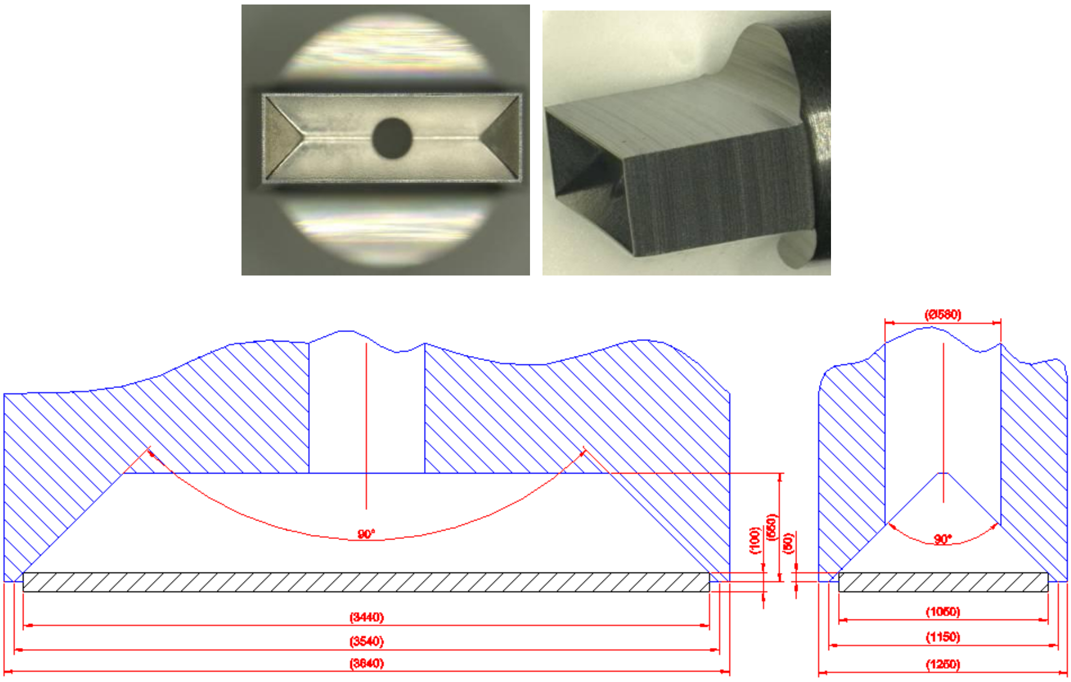

Figure 2: Example of tungsten carbide die collet tool recommended for GaN power bar picking (indicative dimensions)

When the die collet comes in contact with the die, the mechanical force applied on the die should not exceed 40g. When the contact between the die and the die collet tool is got, vacuum can be applied to maintain the die on the die collet tool.

In case of manual handling process, the die can be removed from the gel of the GelPack box by using a tweezer. It’s recommended to use ESD plastic tweezers to avoid damaging the die edges. However metallic tweezer can be used as well if preferred by the operator. In both cases, the cleanliness of the tweezer is very important to avoid any pollution of the die.

During die placement, the mechanical pressure applied on the die for positioning should not exceed 40g.

During handling operation, it’s highly recommended to avoid any contact with a tool or a surface which may have been polluted by organic materials, especially when soldering die attach process is foreseen. In case of the die has to be transferred from the GelPack box to any other temporary carrier before placement in its destination module, this carrier should be cleaned before in order to remove any organic residue at its surface.

In case of doubt about a pollution generated during the manipulations, the dies can be cleaned by argon plasma, acetone rinsing or by a formic acid atmosphere at 280°C for few minutes. Then it’s recommended that the die attach operation should not be delayed more than 1 to 2 hours following the cleaning.

3. Recommendations for die attach

Several methods can be considered to attach the GaN power bar to its substrate. The die attach process can be selected considering three main constraints which are related to the application:

- Cost
- Dissipated power
- Mechanical mismatch between the die and the carrier where the die is attached (CTE mismatch)

The main methods are listed in the following table.

Die attach process	Die attach material	Pros	Cons
Gluing with a dispensor	Silver filled epoxies	Low cost Low Young modulus	Limited thermal conductivity (<20W/m.K)
	Sintered epoxies (pressure less sintering materials are mandatory)	Excellent thermal conductivity (from 50 to more than 100 W/m.K) Low Young modulus	Medium cost (material cost is higher than thermal epoxies) Quite new materials
Soldering in a vacuum oven	Eutectic $Au_{80}Sn_{20}$ solder performs	Very mature technology Void rate can be excellent (close to 0%) when vacuum oven process is well defined See Figure 3.	Medium thermal conductivity (~60W/m°K) Expensive High Young modulus
Soldering with scrubbing	Eutectic $Au_{80}Sn_{20}$ solder performs	Very mature technology Fast process Medium cost process	Medium thermal conductivity (~60W/m°K) High Young modulus Solder join reliability (higher risks of voids, inter-metallic more difficult to control)

Table 2: Methods for die attach

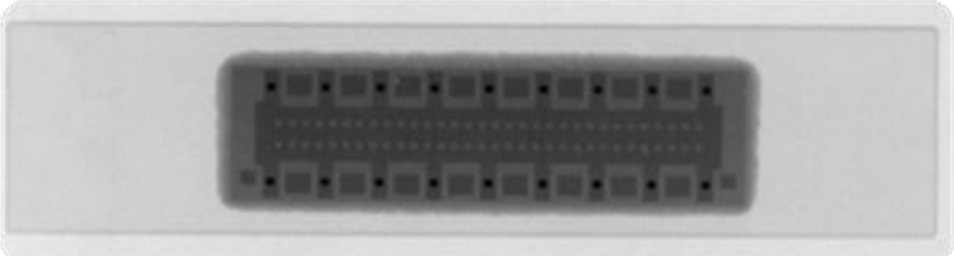

Figure 3: Xray view of a GH50 power bar soldered (eutectic $Au_{80}Sn_{20}$) in vacuum oven.

The selection of the substrate on which the die will be attached is also highly important regarding the final performances (thermal management and mechanical reliability).

The choice of the process and the material for the attachment of the die has to be done considering two main properties of the substrate:

- The CTE of the substrate.
    - The die attach material needs to absorb the CTE mismatch between the die (SiC CTE~2.5ppm/°C) and the selected substrate (Cu CTE~17ppm/°C, Mo CTE~5.1ppm/°C).
- The plating type and quality of the substrate.

- Depending on the platting of the substrate, the results obtained in die shear test can be completely different. The plating can also strongly influence the voiding rate in the die attach.

UMS recommends to use substrate materials with a limited CTE (but always slightly above SiC CTE, ideally between 5 to 7ppm/°C) in order to avoid too much mechanical stress in the die attach.
In case of substrate with a high CTE (>11ppm/°C), gluing processes might be preferred due to lower Young modulus of the epoxy based materials in comparison with the solders.

In case of soldering process, a gold plating of the substrate (typically more than 4µm of gold) is necessary to achieve a good inter-metallic interface.
In case of gluing there is more latitude to select the plating process of the substrate. However, gold and silver plating remain in most of the cases very good solutions.

As an example, a good attachment of the GaN/SiC power bars has been achieved in production with eutectic $Au_{80}Sn_{20}$ soldering (35µm thick solder performs) of 5x1mm² power bars on a substrate offering a CTE in the range of 10ppm/°C. The graph below gives an example of temperature profile which can be applied with eutectic $Au_{80}Sn_{20}$ 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 package on which is soldered the die.

It is recommended to minimize the duration of the reflow temperature. The duration above 280°C (melting point of the eutectic $Au_{80}Sn_{20}$ solder) should not exceed 1minute with a maximum peak temperature never exceeding 300-320°C.

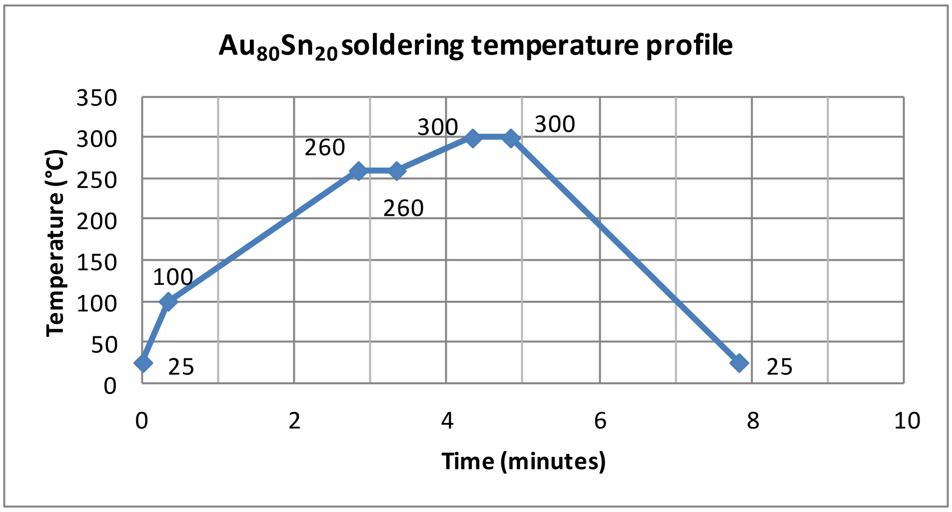

Figure 4: Example of temperature profile for $Au_{80}Sn_{20}$ eutectic soldering.

4. Recommendations for wire bonding

UMS GaN power bars are compatible with micro-bonding with Gold wires.
Ball-wedge and wedge-wedge processes can be used. UMS recommends using thermo-sonic bonding process in order to enhance the adhesion of the wires on the pads.

Bond pad opening is generally not smaller than 200µmx100µm in order to comply with wire size from typically 1mils to 2 mils.

Some examples of thermo-sonic bonding parameters are given below for a 1mil Gold (Au) wire:

	Ball-wedge bonding (both ball and stitch)	**Wedge-wedge bonding (both stitches)**
Chuck temperature	125°C	125°C
Force	15g	15g
Ultra-sonic	230mW	230mW
Time	250ms	250ms

Table 3: Examples of wire bonding thermo-sonic welding parameters

This setup is dedicated to a certain kind of equipment and might be different in case of others wire bonders being used.

If necessary a thermo compression process can also be used. It is recommended to limit the mechanical force to 25g maximum.

5. General considerations for thermal management

Considering that power management is one of the most critical issue with power devices, a special attention has to be paid to the following topics:

- **Decrease as much as possible the thermal resistance of the die attach** by reducing the voiding rate and the thickness of the die attach.
    - With eutectic soldering a near to 0% voiding process can be defined. Vacuum ovens enable to get very low void rate not bigger than 5% in production (see Figure 3). 25µm thickness solder preforms are recommended in order to avoid too much thermal resistance. However thicker solder preforms (35µm) could be beneficial for higher CTE mismatch.
    - Epoxy cure conditions with silver filled epoxies or sintered epoxies have to be defined carefully in order to enable to decrease the void rate significantly. 0% voiding rate is also achievable with these materials.

- **Increase the thermal conductivity of the substrate** on which is attached the die.
  - However, very often the increase of thermal conductivity of a metallic substrate generally leads also to increase its CTE. A trade-off between thermal conductivity and CTE has to be defined carefully in order to comply with the recommendations given above (see paragraph about die attach).

Table 4 gives the correspondence between the thermal conductivity and the CTE of several materials which can be considered as potential substrates for the attachment of the GaN power bars.

Materials	Kth (W/m.K) @ 25°C	CTE (ppm/°C) @ 25°C
Mo	138	5.1
$Cu_{15}Mo_{85}$	184	6.6
$Cu_{15}W_{85}$	185	7.8
$Cu_{40}Mo_{60}$	230	9.1
$Cu_{25}W_{75}$	230	9.5
CPC (1:1:1)	260	9.5
CMC (2:1:2)	285	10
Cu	390	17
Diamond Cu matrix	550	6
Diamond CVD	1000	1
SiC (for reference)	240	2.5

Table 4: Thermal properties of some substrates for GaN die assembly.

6. Glossary

CTE:	Coefficient of thermal expansion
SiC:	Silicon Carbide
Mo:	Molybdenum
Cu:	Copper
C:	Carbide
W:	Tungsten
CMC (2:1:2)*:	Laminated material (Cu:Mo:Cu)
CPC (1:1:1)*:	Laminated material (Cu:CuMo:Cu)

**(x:x:x): each x stands for the relative thickness of each layer of the laminate.*

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