SILVER SINTER MATERIAL DISPENSE OPTIMIZATION: ELIMINATION OF SINTERING VOIDS DEFECT FORMATION IN GALLIUM NITRIDE DIE ATTACH

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ABSTRACT

The shift from LDMOS to GaN in RF power packaging faces challenges, primarily due to difficulties in the assembly process, particularly the die attach process. These issues lead to voids affecting product quality, causing yield losses and reliability risks. Efficient thermal management is crucial for GaN die technology to address concerns like thermal dissipation and high-temperature stability for high-reliability and high-temperature applications.
Die attach voids in GaN devices were initially detected during process control monitoring using scanning acoustic tomography (SCAT). These voids, appearing as black and white anomalies, range from 1% to 3% and can reach 5% cumulatively. They negatively impact device efficiency, cause temperature-related electrical property issues, and potentially compromise long-term reliability and product lifespan.
To address this issue, a thorough root cause analysis was launched and identified the most probable root cause leading to the resolution of the problem. Preliminary investigations suggest that the formation of "canals" along the dispense path of the silver epoxy material causes the formation of voids in the GaN device. These canals disrupt the uniformity of the material dispense and contribute to the observed die attach voids during SCAT. The focus now is on understanding the factors leading to the formation of these canals and implementing corrective actions to eliminate this issue and improve overall product quality.

1. 0 INTRODUCTION

GaN in RF power packaging has encountered difficulties, mainly due to assembly process setbacks, particularly in the die attach process. These challenges have led to issues like voids affecting product quality, resulting in yield losses and reliability risks. GaN die technology demands efficient thermal management to address the thermal dissipation and high-temperature stability concerns associated with high-reliability and high-temperature applications. Overcoming these challenges is crucial for the successful implementation and performance of GaN devices in various applications.

Void issues, along with delamination, emphasize the necessity for a systematic approach to attain low defect PPM rates. Initial qualification lots have shown a 25% yield loss predominantly due to die attach voids, using silver sinter. Black and white voids in GaN devices, as observed during scanning acoustic tomography (SCAT) in the carrier device (Fig. 1), do not meet the stringent single void requirement of less than 1%. With measured voids ranging from 1% to 3%, and cumulative voids reaching 5%, these defects can negatively impact device efficiency, lead to temperature-related electrical property issues, and potentially threaten long-term reliability and product lifespan.

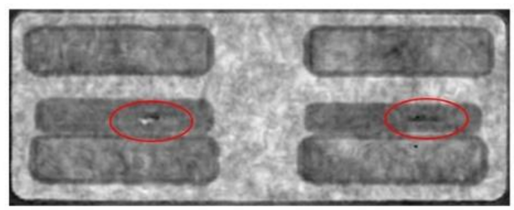

Fig.1 Anomaly detected during SCAT.

Die attach voids in the GaN device were initially detected as SCAT anomalies during process control monitoring, a predetermined screening control for identifying die attach performance issues in GaN products. Thru-SCAN analysis revealed non-homogeneous material microstructures appearing as black and white voids, which were later confirmed through failure analysis and cross-section examinations on representative units. Black voids are found between the Au BSM and Ag-sinter epoxy layer, while white voids are within the Ag-sinter layer (Fig.2). The void signature rejection rate is approximately 25%, with some lots experiencing 0% yield. These localized voids were observed across multiple lots from the qualification lots.

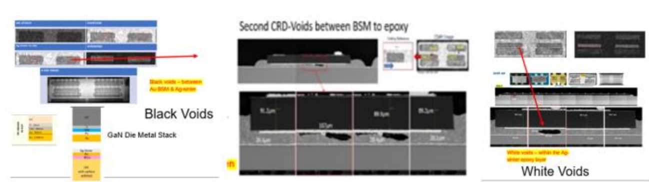

Fig 2. Ion-mill cross section of internal anomaly confirming die attach void on unit with black and white signature during SCAT.

The silver epoxy canals, which appear as gaps between the solder dispense path, seem to coincide with the void locations, likely disrupt the uniformity of the material dispense and contribute to the observed die attach voids as seen during SCAT (Fig 3.). Guided with the failure mechanism, the focus on understanding the factors leading to the formation of these canals and implementing corrective actions to eliminate this issue and improve overall product quality was underlined.

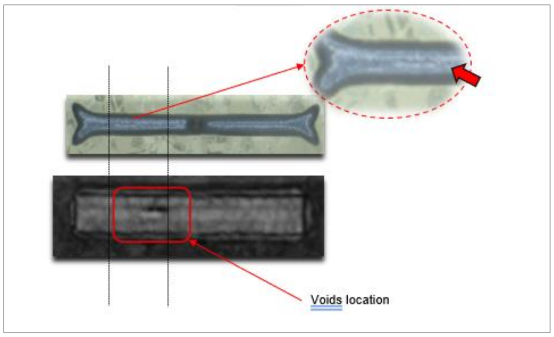

Fig 3. Voids location coincides with the formation of "crater" or "canal" on dispense path

2. 0 REVIEW OF RELATED WORK

1. Void defects are a critical concern for large-area sintered silver attachment using the pressure-less sintering. Void defects must be controlled before sintering, especially during mounting devices. To minimize the void defects, some researchers designed and optimized the dispensing or stencil-print pattern of silver pastes and patterns during the dispensing process. The air bubbles of the dispensing material during the mounting can be squeezed out. However, the pattern should be optimized to prevent the excess insufficient and overflowing of the dispense material. Moreover, the mounting accurate pressure and position should be controlled.
2. A virtually void free die attach was successfully achieved using a fixed but critical volume of Ag sinter material by a process of pressure-less sintering on a multi-axis cartesian style bonder, retrofitted with a high-speed jetting dispenser. While this process potentially offered an ideal combination of cost-effectiveness, control and speed, it required the development of additional software protocols to secure the level of performance demanded of the dispenser to meet exacting technical requirements. effective manner.

The absence of voids was verified through industry standard non-destructive analysis utilizing C-mode scanning acoustic microscope (CSAM).

3.0 METHODOLOGY

To identify the primary cause of deviation in the silver epoxy dispense performance, a systematic approach called Fishbone Analysis was employed. This method involves analyzing various potential root causes related to the failure mechanism, such as die attach tooling set-up, dispense writing sequence, dispense writing orientation, and dispense parameters. By reviewing each factor that could influence the silver epoxy dispense performance, a likelihood table was established to determine the most probable root cause. This structured approach helps in understanding the interrelationships among different factors and pinpoints the main cause of the issue, enabling targeted improvements and enhancing the overall performance of the silver epoxy dispense process.
To confirm the hypothesis derived from the Fishbone Analysis and find the best dispense parameters to avoid the dispense gap, an on-off validation was conducted. Design of Experiment (DOE) engineering tools were employed to evaluate the interactions between various dispense parameters. By systematically varying these parameters and analyzing their effects on the dispense failure mechanism, the most suitable parameter settings were identified. This process ensures that the selected parameters will minimize the occurrence of dispense gaps, thus improving the overall performance and reliability of the silver epoxy dispense process.

4.0 RESULTS AND DISCUSSION

To further refine the solution and eliminate the trapped air issue in the die attach material, a fractional factorial design of experiment (DOE) was employed. This optimization approach focused on controlling factors like dispense pattern, dispense pressure, and dispense feed rate to achieve a non-homogenous dispense of silver sinter material on the header during die attachment. By considering the interactions among these parameters, an optimal die attach condition was determined, effectively addressing the homogeneity problem encountered during product qualification. See table below which outlines the controllable input that has influence to the dispense gap in silver epoxy.

Table 1. DOE Matrix for Dispense Parameter Optimization

DOE Matrix

Fractional Factorial Design

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Factors:  4   Base Design:        4, 8   Resolution:  IV
Runs:     9   Replicates:            1   Fraction:   1/2
Blocks:   1   Center pts (total):    1
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StdOrder	RunOrder	CenterPt	Blocks	Dispense Height	Pattern Movement Speed	Dispense Lead Time	Dispense Pre Disable Time
1	1	1	1	0.15	5	0	0
7	2	1	1	0.15	15	100	0
9	3	0	1	0.1675	10	50	25
3	4	1	1	0.15	15	0	50
2	5	1	1	0.185	5	0	50
5	6	1	1	0.15	5	100	50
4	7	1	1	0.185	15	0	0
6	8	1	1	0.185	5	100	0
8	9	1	1	0.185	15	100	50

❑ Use 30pcs per leg for 9 runs, with 1 lot (30pcs) as Control lot

The established optimum parameters were applied consistently to both active and passive dies, using the previously released baseline dispensed parameters as a reference. The results from the contour plot analysis (Fig 4.) were crucial during the DOE runs, ensuring that all requirements, such as SCAT yield at 100%, bond line thickness, and die tilt, were met. As a result, the validated parameters led to successful outcomes for both active and passive dies, maintaining high product quality and meeting all the necessary performance criteria.

Fig 4. DOE Result Contour Plot

The controlled experiment on the die attach material dispense parameters has had a substantial impact on resolving voids in GaN die silver sinter die attach. Several key observations have contributed to the improvement of die attach voids:

1. The contour plot analysis from the DOE results, with a fixed feed rate, provided the necessary settings and parameter tolerances for both active and passive dies. This allowed for a more consistent and effective die attach process.
2. Following the implementation of the corrective actions derived from the experiment, no black and white voids were observed in any of the units tested. This indicates a significant reduction in void formation during the die attach process.
3. The SCAT (Semi-Automated Test) yield for GaN die improved to 100%, demonstrating a substantial enhancement in the overall quality and reliability of the die attach process.

These observations collectively demonstrate the effectiveness of the controlled experiment in addressing the void issues in the GaN die silver sinter die attach. The improvements achieved will contribute to better product performance and customer satisfaction.

5.0 CONCLUSION

Early detection of abnormalities in process control monitoring played a crucial role in identifying issues related to GaN product qualification. While it initially posed challenges, this detection proved vital in determining the appropriate die attach dispense parameters for GaN in silver sinter. To effectively distinguish between abnormalities and noise in monitoring, it is essential to maintain a keen focus during early development and production ramp-up stages.
Incorporating the dispense pattern parameter alongside other critical process parameters is vital for the successful development of GaN die attach in silver sinter. This optimization led to the elimination of black and white voids in the GaN die attach process, significantly reducing void occurrences from 25% to 0%. Consequently, the total yield of gallium nitride products improved, resulting in enhanced financial performance and increased customer satisfaction with regards to delivery and quality.
The positive impact of these improvements was not limited to the initial device type; it was expanded to cover other gallium nitride products under development. To ensure future reference and continuity, relevant documents such as the Control Plan, FMEA, and parameter settings were updated. With the elimination of voids, there is an opportunity to achieve 100% SCAT, further enhancing the overall product quality and performance.

6.0 RECOMMENDATIONS

Addressing the root cause, which is primarily an operational and detectability gap during package qualification, can be improved by implementing a structured Design for Manufacturing (DFM) review. This review should be a product of a thorough technical risk assessment to ensure all critical processes and packaging requirements are considered, even those that might have been overlooked during predevelopment and initial assembly trials.
In addition to the DFM review, deploying a standardized method for differentiating visual non-conformities compared to a reference "golden sample" is essential. This approach should be communicated and implemented across all stakeholders involved in the process. By doing so, potential issues can be effectively identified and addressed early on, preventing any failure from occurring.
The implementation of these measures will not only help in capturing critical aspects that may have been missed earlier but also contribute to a more robust and efficient manufacturing process. This will ultimately lead to improved product quality, customer satisfaction, and a stronger position in the market.

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10.0 APPENDIX