Exploring Failure Distribution Plots for Predictive Lifetime Analysis in the Qualification of Silver Sinter Die Attach Material in Air Cavity Package

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ABSTRACT

The fast-paced technology makes semiconductor industries have a very tight competition to deliver high performing products with undeniable reliability in a very short period. Qualification process alone with all the required reliability life and product tests will require a considerable time (ranging from 3 months to a year). Exploring predictive lifetime analysis in qualifying the silver sinter die attach material on air cavity package were able to establish the following: 1) failure rate or time to fail based on the monitored failure mechanism (thermal resistance in lieu of delamination amount); and 2) can be used in calculating through extrapolation or interpolation its compliance to mission profile or customer requirement.

Silver sintering technology has been known for its improved thermal and mechanical properties. This study aims to assess the product lifetime of silver (Ag) sinter die attach material with respect to its thermal behavior. It is known that an increase of thermal resistance (Rth) on the product may signify degradation on the die attach material properties or due to delamination or voids.

In this study, the qualification of the high-power RF transistor product with Ag sinter die attach material samples were subjected to DC power cycling test to evaluate if the die attach material can sustain its thermal properties based on customer application (requirement: 10,000 cycles). The Rth shift along read points were monitored in this study as an input in the predictive analysis of the material using Weibull Analysis. Based on the reliability test data gathered and plotted data, 1% of the total samples will fail (have an Rth shift >10%) at 10,050 cycles using the Lognormal distribution plot. By doing some extrapolation to predict 50% failure rate from the total population, it resulted in 18,197 cycles. The analysis on the degradation of thermal properties will be dealt with in a separate study. The calculated predictive lifetime or Weibull can be used as reference for the succeeding qualifications of the air cavity package using the same bill of material to save qualification time and resources.

1.0 INTRODUCTION

The semiconductor industry nowadays has been gearing towards to a more environment-friendly components to achieve a renewable and more efficient approach. The product's capability to sustain and prolong its lifetime depends on the materials used, like the die attach material.

The silver sinter material is considered as one of the most reliable die attach materials in the semiconductor industry given its best in terms of thermal conductivity, high melting temperature and giving high durability during applications.

Product lifetime analysis and predictability has been one of the considerations in any product or material qualification. As this will be able to determine or predict the wear and tear of the product given the reliability test data or failure rate.

To analyze the lifetime of the silver sinter die attach material, this study aims to determine and estimate the product lifetime of the silver sinter using Weibull Analysis based on the reliability data and failure mechanisms gathered.

There are various product lifetime analysis tools that can be used in determining the time to fail of a certain product. These are applied to analyze the physics of failure. On this study, the Supersmith Weibull software was utilized to create the failure distribution plot. This software produces Weibull, LogNormal, Gumbel (both upper and lower) distribution, and normal probability-plots to analyze data used for making reliability improvements (SuperSMITH software | Weibull analysis software | Download demo).

2.0 REVIEW OF RELATED WORK

New technologies are now emerging to a lead-free die attach technology in which the silver sinter becomes one of the alternative solutions in semiconductors. This material is considered the best option for semiconductor products with high power application and high temperature requirements.

The Silver sinter material is commonly used for the bonding and interconnection of power electronic devices, such as gallium nitride (GaN) and silicon carbide (SiC) power modules. The lifetime or the time a product wears out is usually predicted through failure distribution analysis.

Previous studies have noted how different failure mechanisms affect the lifetime of the material in a product. The experimental results of the silver sintered samples allow us to formulate lifetime prediction models or plots by correlating the failure mechanisms of the samples to the graph. Different lifetime prediction model was also used to determine in the experiment (P. Paret, et al., 2021).

The primary advantage of the Weibull analysis is the ability to provide reasonably accurate failure analysis and failure forecasts with extremely small samples (Abernethy, R., 2004).

In using the Weibull plot, sometimes the data points are not aligned or do not fall in a straight line. Identifying the best distribution would help in distributional analysis. The slope of the Weibull plot, beta, β, is indicative of the following class failures (Abernethy, R., 2004):

- $\beta < 1.0$ → early fails
- $\beta = 1.0$ → random fails
- $\beta > 1.0$ but < 4.0 → early wear out fails
- $\beta > 4.0$ → old age wear out

Abernethy, R. (The New Weibull Handbook, 2004) described the different failure distribution plots below:

The Weibayes distribution plot is a Weibull analysis that is used for small samples and zero failures given a reasonable estimate of beta. It helps treat the data sets with and without failures.

The Maximum Likelihood Estimation (MLE) has excellent statistical characteristics for large data sets. However, this type of distribution plot is complex because it requires a computer and an iterative solution for beta. This plot is not recommended for small samples as the results will be optimistically biased.

Lastly, the LogNormal distribution models a process of progressive deterioration of a product. It also has many applications such as materials properties and delamination. Lastly, it is used to predict time to failure (TTF) of the product.

3.0 METHODOLOGY

In this study, seven samples assembled using Ag sinter material were subjected to DC power cycling test (DC PCT). This test is to ensure the reliability of the RF power transistor focusing on the Ag sinter die attach material under application. The test data monitored per read point are its: test performance with Rth parameter being monitored and SCAT analysis for delamination/void check.

Table 1 shows the power cycling test plan for this study.

Table 1. Power Cycling Test Plan

Reliability Test	Req'd read point
DC Power Cycling Test	10,000 cycles

DC-PCT is based on JESD22-A105C

The Rth shift percentage of the silver sinter material was analyzed per readpoint, and predictive lifetime was established using Weibull analysis. The failure criteria of Rth shift >10% per reliability read point were interpolated to get the estimated value that the sample will fail.

The computed data points were plotted on the Weibull software to determine the estimated lifetime of the silver sinter material.

4.0 RESULTS AND DISCUSSION

To understand the failure mechanism that occurred in the Ag sinter material, the failed Rth shift percentage test data points (passing criteria is </=10% shift) were interpolated to determine the failing read point of the samples to be plotted in the Supersmith software.

Table 2. Interpolated test data point (Rth shift %) of silver sinter in air cavity package

	Read point						
	4320cyc	5000cyc	10000cyc	interpolated rdpt	12960cyc	interpolated rdpt	25920cyc
Unit #	1D	1.16D	2.31D		3D		6D
1	-0.06	3.09	3.08		6.24	16921.76	18.54
2	0.68	1.80	1.93		3.68	24611.1	10.71
3	-0.69	2.43	2.3		4.79	19766.61	14.71
4	0.62	3.52	3.64		7.12	15641.38	21.04
5	-0.19	3.11	3.07		6.2	16902.99	18.69
6	0.06	1.66	1.67		3.33	25998.19	9.96
7	3.09	6.10	6.69	11674.8	12.54		12.54

Table 2 shows the electrical test parameter data (Rth shift %) and interpolated based on the defined failure criterion. The highlighted interpolated data points were plotted in the Weibull graph using Lognormal distribution. The LogNormal distribution is the best choice in determining the silver sinter material deterioration as all the plotted data points are well-fit. It is also best fit for delamination growth with high stress because thermomechanical stress increases progressively as the delamination increases. The Weibull plot will require more samples.

Figure 1 shows the failure distribution plot, using Supersmith software, of the samples tested.

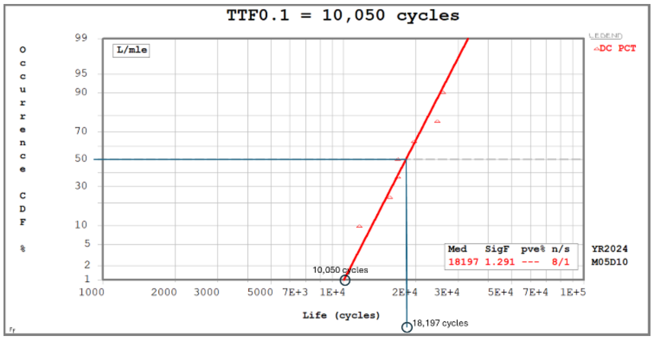

Figure 1. Failure distribution plot of silver sinter die attach in air cavity package using Lognormal distribution plot

In this graph, the Time to Failure (TTF0.1) was determined at 10,050 cycles, meeting the requirement of 10,000 cycles.

By doing some extrapolation to predict 50% failure rate from the total population, it resulted in 18,197 cycles.

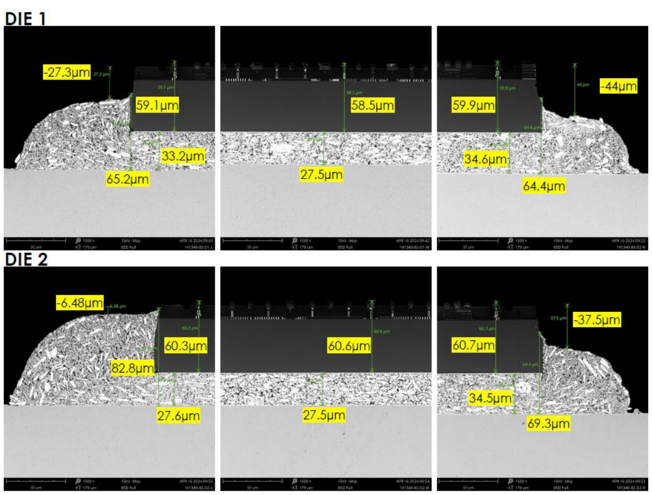

Figure 2. Cross section of silver sinter die attach in air cavity package after 25,920 cycles DC-PCT

Failure analysis on samples with >10% Rth after 25,920 cycles showed no die attach delamination. This shows that the increase of Rth is not related to delamination or voids and must be addressed in a separate study. This is to fully understand what new failure mechanism in the silver sinter structure has caused high Rth shift.

5.0 CONCLUSION

The silver sinter die attach in air cavity package can meet the customer requirement of 10,000 cycles based on lifetime predictability plot in Lognormal distribution using Supersmith software. Through this plot, the 1% failure rate of >10% Rth will reach 10,050 cycles. This also guarantees that the product will have optimum thermal performance.

6.0 RECOMMENDATIONS

It is recommended to study further the cause of thermal resistance degradation on the analyzed samples with silver sinter as it does not correlate with delamination or voids. It is required to do another experimentation and failure distribution plot for new failure mechanism. These results can be further analyzed with actual reliability testing and larger sample size.

7.0 ACKNOWLEDGMENT

The authors would like to acknowledge the contribution of

- Roelof van der Berg (Senior Principal Quality Engineer) for giving inputs in this study and analysis of the failure modes and assisting on the Weibull analysis for development projects.
- Mario de Vaan (Sr. Director, AMP Manufacturing and Global Quality)
- Reliability and Failure Analysis team in Nijmegen, Netherlands and Philippines for the support

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