REDUCING ELECTRICAL TEST OUTLIERS THROUGH SILVER SINTERING DIE ATTACH METHOD OPTIMIZATION

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ABSTRACT

Silver Sintering is one of the goes to die attach material in high power semiconductor application. Better thermal and electrical conductivity is the main advantage of using this epoxy especially in Silicon Carbide Die-Volt which currently the fast-growing package that Fastech offerings.

During the beginning stage of silver sintering technology in Fastech manufacturing, several challenges occurred one of those is encountering electrical test outliers due to epoxy voids in die to lead frame interface.

This paper tackles on how Process Engineering evaluate and address the issue in epoxy voids by optimizing the die attach method for Silver Sintering Application.

1. 0 INTRODUCTION

1.1 Yield Performance

During the early stage of silver sintering epoxy in production manufacturing. Electrical test performance of affected device encountered few outliers of deference in on-state voltage of the body drain diode, in MOSFET device or also known as Delta Voltage Source-Drain (DVSD).

Figure 1.0, shows the Delta Voltage Source-Drain (DVSD). distribution of first production lot that availed silver sintering epoxy as die attach material.
Based on the graph, it shows few units with Delta Voltage Source-Drain (DVSD). reading above 110 millivolts. This units are outliers with respect to the majority of units which only has between 60 to 90 millivolts readings.

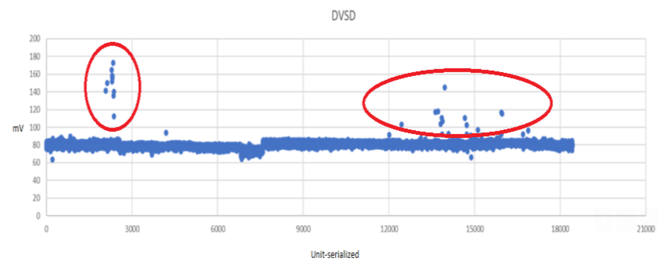

Figure 1.0 DVSD Distribution of First Production Lot

1.2 Defects Identification

Delta Voltage Source-Drain (DVSD). outlier samples were sent to failure analysis to determine/identify the cause of this high DVSD reading.
Based on the failure analysis conducted, as shown in figure 2.0, Voids reading of units with higher than 110mV DVSD reading, fourteen-unit sample with DVSD reading of higher than 110mV are subjected to X-ray inspection to measure the epoxy coverage of die to lead frame interface. Thirteen out of fourteen samples submitted are failing to the maximum void's requirements. Failed in voids are having more than five percent of maximum single voids and more than ten percent of maximum cumulative voids.


Voids reading

Unit #	DVSD reading	Die to Leadframe		Remarks
		Single	Cumulative	
1	>110mV	21.1%	34.9%	Failed
2	>110mV	20.7%	35.0%	Failed
3	>110mV	18.7%	40.6%	Failed
4	>110mV	18.1%	27.61%	Failed
5	>110mV	19.1%	33.1%	Failed
6	>110mV	15.4%	23.1%	Failed
7	>110mV	12.8%	24.6%	Failed
8	>110mV	13.0%	23.8%	Failed
9	>110mV	10.5%	12.5%	Failed
10	>110mV	15.8%	16.1%	Failed
11	>110mV	0.7%	1.9%	Passed
12	>110mV	18.9%	34.9%	Failed
13	>110mV	10.4%	11.4%	Failed
14	>110mV	10.5%	12.1%	Failed

Remarks: 13/14 above the voids monitoring requirement
Voids requirement on die: 5% max single voids / 10% max cumulative voids
Failure Analysis/Reliability

Figure 2.0 Voids reading of units with higher than 110mV DVSD reading

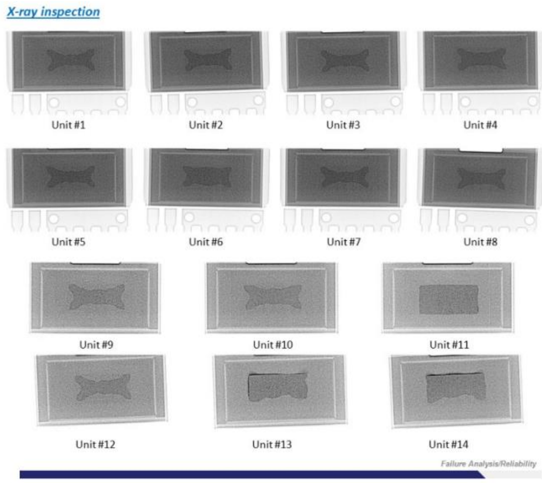

Figure 3.0 Voids signature of units with higher than 110mV DVSD reading

1.3 DVSD reading and Epoxy Voiding Correlation

Figure 4.0, shows the correlation of DVSD reading and its corresponding epoxy voiding. Based on the given data, DVSD reading that falls above 115 mV will have most likely have epoxy voids underneath. Sample unit 1 to 14 except unit number 11 fell above 115 mV and have void reading above 10%. While unit number 11 has 113 mV DVSD reading and only has 1.9% epoxy voids readings.

Unit #	DVSD Reading (mV)	Void Reading				Remarks
		Single	Cumulative	Voids limit	DVSD limit	
1	174.6870279	21.1	34.9	10	115	failed
2	156.3248336	20.7	35	10	115	failed
3	152.6812464	18.7	40.6	10	115	failed
4	142.4172074	18.1	27.61	10	115	failed
5	141.5753812	19.1	33.1	10	115	failed
6	161.955744	15.4	23.1	10	115	failed
7	164.3073857	12.8	24.6	10	115	failed
8	141.0438418	13	23.8	10	115	failed
9	135.0022852	10.5	12.5	10	115	failed
10	159.8627269	15.8	16.1	10	115	failed
11	113.3975089	0.7	1.9	10	115	passed
12	159.3040675	18.9	34.9	10	115	failed
13	121.7075735	10.4	11.4	10	115	failed
14	118.7583357	10.5	12.1	10	115	failed

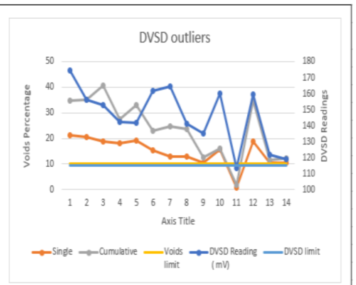

Figure 4.0 DVSD reading and Epoxy Voiding Correlation

To further validate that the cause of DVSD outlier is the epoxy voiding in Die to lead frame interface and the cause of voiding is due to insufficient volume of epoxy. Bond line thickness was measured on unit's sample number 1 with highest DVSD reading of 174mV with epoxy voids of 34.9% and unit sample number 11 with 113 mV DVSD reading and 1.9% epoxy voids.

Bond line measurement of unit sample number 1 is 1.79 mils while unit sample number 11 has a BLT of 2.5 mils as shown in figure 5.0, Decapsulated sample unit, its clearly see that there is insufficient epoxy observed.

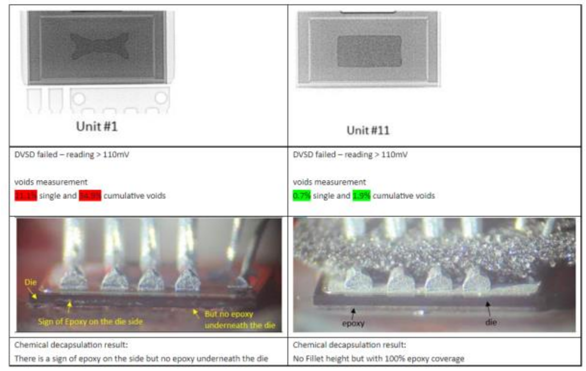

Figure 5.0. DVSD Outlier Decapsulated Samples

1.4 Statement of the Problem

Seeing electrical test outliers on processed lot using silver sintering epoxy clearly indicates that there is a quality concerns, that needs to address or capture in real-time during die attach process and should not go all the way up to electrical testing. Prevention or early detection of insufficient epoxy that causing epoxy voiding should be address to eliminate the electrical test outlier.

1.5 Objective of the Project

The main objective of this project is to establish a prevention and early detection of insufficient epoxy that causing epoxy voiding should be address to eliminate the electrical test outlier.

2.0 METHODOLOGY

2.1 Project Conceptualization

The concept of this project is to focus on improvement of two major part of die attach method which is the machine and process. These two parts of die attach method is important and works hand by hand with each other, improvement for this two will lead to a solution and improve and solve the insufficient epoxy that causing epoxy voiding should be address to eliminate the electrical test outlier.

Shown in Figure 6.0 is the illustration of phases of methodology to achieve our objective. There are three major phases: the first phase is the machine improvement; this phase will focus on all actions that can be done at the machine that can help to detect any insufficient epoxy as real time as possible.

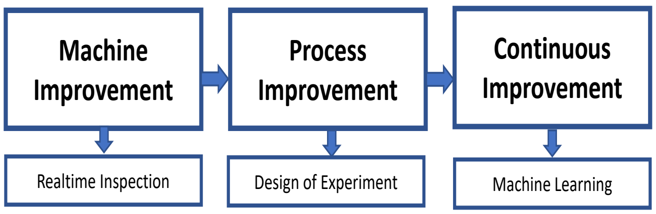

Figure 6.0. Methodology of the Project Phases

The second phase is the process improvement, this phase will focus on method of die attach that will prevent and improve the epoxy coverage during die attach process. The third phase is the continuous improvement, this phase is focus on any other factors that may help to continually improve the silver sintering die attach process to produce high quality and reliable product.

3.0 RESULTS AND ANALYSIS

3.1 Machine Improvement

3.1.1 Realtime Inspection

Since epoxy die attach machine use for silver sintering epoxy has a feature or capability of pre-bond (prior die placement) inspection. Process Engineering took advantage of this feature to automatically inspect the dispensed epoxy pattern in Realtime on every single unit.

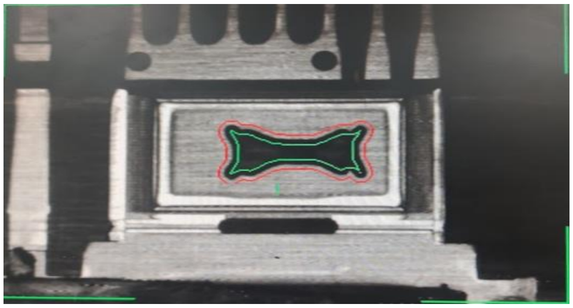

Figure 7.0. Epoxy Inspection Control window

As show in Figure 7.0, Epoxy inspection was controlled using epoxy area coverage. Red Markings corresponds to the maximum epoxy area. Green Markings for minimum epoxy area. Any epoxy dispense that will fall outside this minimum or maximum limit, the machine will automatically stop and alert the operator to skip the die placement process on affected unit.

Minimum and maximum control limit was defined by correlating to actual visual appearance of unit after die placement. As seen in Figure 8.0, Epoxy dispense that fell outside the maximum control will exhibits too much epoxy. Epoxy fillet height will go beyond more than 75% of thickness of the die. Less than 75% epoxy fillet height is the required fillet height for silver sintering epoxy, if epoxy will go more than 75% fillet height silver flakes can cause shorting if this will go on top of the die. Electrical Test shorting will most likely exhibit. Then epoxy dispense that fell under the minimum control limit, insufficient epoxy will be the output. This is known to have DVSD failure if proceeded at assembly.

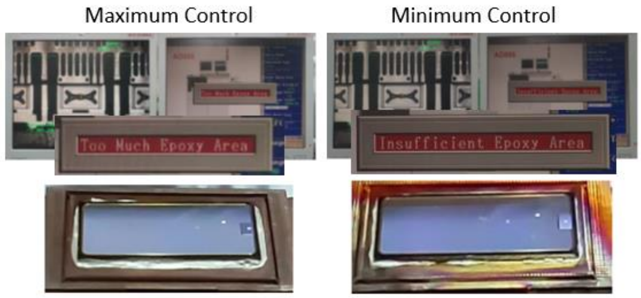

Figure 8.0 . Epoxy Inspection Control Window Validation

With this Realtime Epoxy Inspection, Epoxy dispense made each and every unit process will be automatically inspected by the machine to check the quality of the epoxy dispense pattern. Using this machine feature is a great addition on quality improvement of product produce.

3.2 Process Improvement

3.2.1 Design of Experiment

In the process improvement phase, Design of Experiment was conducted to establish the best combination that will produce 100% epoxy coverage. Three factor was considered and determine, these are epoxy dispense pattern, epoxy dispense needle size and scrubbing during die placement.

As shown in Figure 9.0, fishbone, British flag and double fishbone was use for epoxy dispense pattern. 8, 10 and 12 mils for dispensing needle sizes and with or without scrubbing during die placement was the combination use to build 12 run DOE experiment.

Factor			fishbone	british flag	double fish bone
	Epoxy Dispense Pattern				
	Needle Size		8	10	12
	Scrubbing		yes	no	-

Run	Pattern	ss	Needle Size	Scrubbing	Result
1	fishbone	20	8	no	failed in 100% epoxy coverage
2	british flag	20	8	no	failed in 100% epoxy coverage
3	double fishbone	20	8	no	failed in 100% epoxy coverage
4	fishbone	20	8	yes	failed in 100% epoxy coverage
5	british flag	20	8	yes	failed in 100% epoxy coverage
6	**double fishbone**	**20**	**8**	**yes**	**100% epoxy coverage**
7	fishbone	20	10	no	too much epoxy more than 75% epoxy fillet height
8	british flag	20	10	no	
9	double fishbone	20	10	no	
10	fishbone	20	12	no	
11	british flag	20	12	no	
12	double fishbone	20	12	no	

Figure 9.0 . Process Improvement Design of Experiment

As the result of this DOE, run 7 up to 12 exhibits too much epoxy due to large size of epoxy dispense needle of 10 and 12 mils. While Run 1 up to 6 are done using 8 mils epoxy needle size, only the run 6 which is using double fishbone epoxy dispense pattern with combination of scrubbing during die placement achieved 100% epoxy coverage for all 20-sample size conducted. Run 3 which almost same as run 6 but doesn’t have scrubbing during die placement achieved 100% epoxy coverage but only for 16 units our of 20 units sample conducted. With these results, its clearly says that using double fishbone epoxy dispense pattern on 8 mils dispensing needle with combination of scrubbing during die placement can achieved 100% epoxy coverage repeatedly and consistently.

Figure 10.0 shows the epoxy dispense pattern used in run 6 and its sample actual epoxy dispensed.

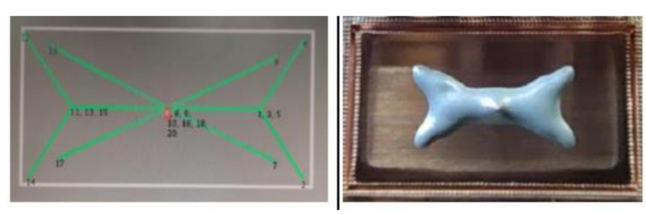

Figure 10.0 . Double Fishbone Epoxy Dispense Pattern

3.2.1 DOE Result Validation

To validate this result of using double fishbone epoxy dispense pattern on 8 mils dispensing needle with combination of scrubbing during die placement. This was implements on all the lots being process from December 2021 up to this day. and continually monitoring the electrical test performance especially the DVSD reading.

As shown in Figure 8.0, DVSD outliers was monitored from August 2021 up to today. It's clearly seen that after the implementation of double fishbone epoxy dispense pattern on 8 mils dispensing needle with combination of scrubbing during die placement. DVSD outliers was lessen in fact zero out.

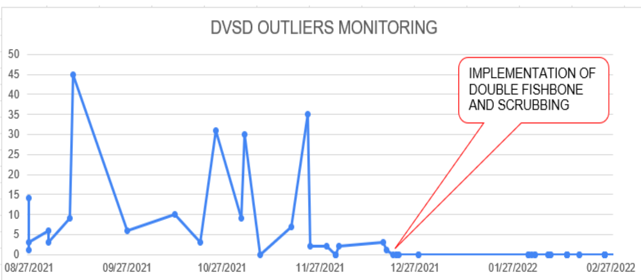

Figure 8.0 . DVSD Outliers Monitoring

3.2 <u>Continuous Improvement</u>

3.3.3 Machine Learning

As part of continuous improvement, machine learning will be explored. Since machine learning has a capability of prediction. Electrical test result prediction of each and every lot can be explored. Data gathering of assembly data on die attached will be explore and pursue. Data on Realtime inspection can be acquire as well the post bond inspection of machine can also use if possible.

This machine learning experiment for silver sintering epoxy will be tackle in detail on the continuation of this project.

4.0 CONCLUSION

Based on the results and actions taken to achieve the team's objective, we concluded the following:

1. 100% silver epoxy coverage can be achieved using double fishbone pattern together with die scrubbing during placement of die.
2. Insufficient Epoxy as well as too much epoxy can be monitor/inspect in real-time using Epoxy Inspection Feature of Die Attach Machine.

5.0 RECOMMENDATIONS

Process Engineering Team Strongly recommends to continue this project for more robust and reliable process.

6.0 ACKNOWLEDGMENT

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2. Rio Haldos- Engineering Manager, who participated and contributed towards the development and continuation of this project.

7.0 ABOUT THE AUTHORS

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