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Addressing Tape Delamination on Complex QFN through Tape Supplier Collaboration

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Abstract**—** *Very thin Fine Pitch Dual Flat Package No Leads (VFDFPN) is an IC used smartphones or displays. STMicroelectronics (ST) manufactures this device in Calamba on an existing Quad Flat No lead (QFN) line.*

VFDFPN12 leads is one of its sub-packages introduced having a thicker wire diameter of 33um against normal wire of 20um requiring higher bond force. Also the bonding layout requires several leads with triple stitch bonding resulting to higher pressure applied on lead causing the tape to delaminate from the lead. After mold this results to moldflash and tape residue specific to the affected leads.

This technical paper will cover all engineering efforts collectively done starting with the most effective containment to the best cost effective solution available. Understanding the phenomenon of tape delamination with respect to wirebond process and material was clearly defined. With the collaboration of our leadframe tape supplier, we co-develop a tape which can withstand underlying factors and end up with a product with no moldflash and tape residue.

Keywords**—** *QFN Tape delamination, Residue.*

I. INTRODUCTION

STMicroelectronics predicts its new SOI-based STOD13AS power chip under package VFDFPN12 could be used in nearly every new smartphone or small electronic device that has an AMOLED display

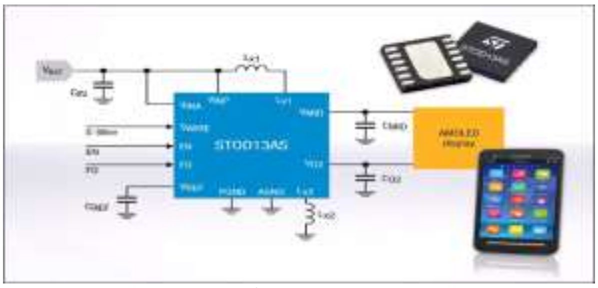


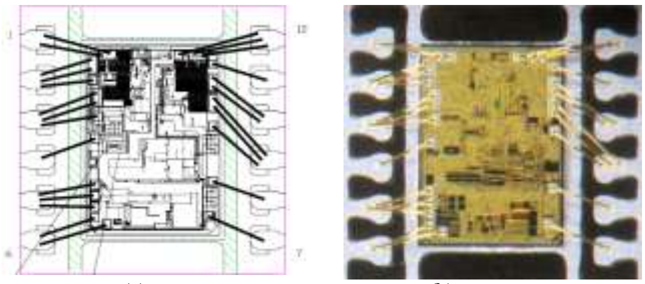
Figure 1. Schematic diagram of the STOD13AS device on a VFDFPN12 package

The STOD13AS is a high efficiency dual DC-DC converter which integrates a step-up and inverting power stage suitable for supplying AMOLED panels. Thanks to the high level of integration it needs only 6 external components to operate and it achieves very high efficiency using a synchronous rectification technique for each of the two DC-DC converters.

However this high potential volume product comes with a manufacturing challenge due to tape residue and moldflash which can lead to solderability failure during device mounting on PCB.

1.1 Understanding Device Construction

STOD13AS device on a VFDFPN12 package with pin no. 3, 8, 11 and 12 having single wires, 1, 6 & 9 with two wires and 2,4,5, 7 and 10 having triple wires. All wires has a diameter of 33um as compared to normal wire diameter of 20um. Device carrier is a pre-taped etched full PPF NiPdAu leadframe base.



(a) (b)

Figure 2. (a) Wirebonding layout configuration and (b) actual bonding appearance of device STOD13ASTPURSV1 on a VFDFPN12 package

1.1.1 Defect signature

As per defect signature, combination of tape residue and moldflash on leads was seen after detape process on molded strips.

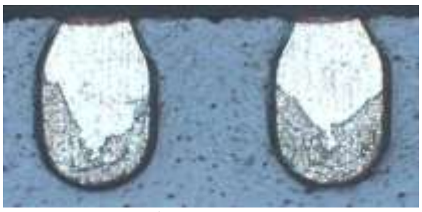


Figure 3. Actual picture of leads with tape residue and moldflash

1.1.2 Process mapping

As per defect mapping tape residue and moldflash was seen on all units localized on specific pins 1,2,4,5,6,7,9 and 10.

The same pins showed tape delamination after wirebond process which is not existent prior wirebond as shown on figure 4 below. It should be noted that this affected pins has 2 or 3 wires on leads as compared to 1 wire for lead without delamination

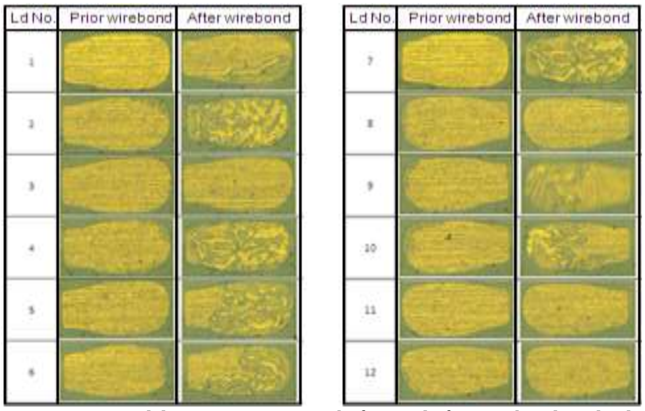


Figure 4. Tape delamination mapping before and after wirebond per lead

1.1.3 Defect failure mechanism

With this mapping, defect failure mechanism was established wherein the force exerted by 2 or 3 wires on the same lead exceeds the adhesion strength of the tape as compared to a single wire on lead.

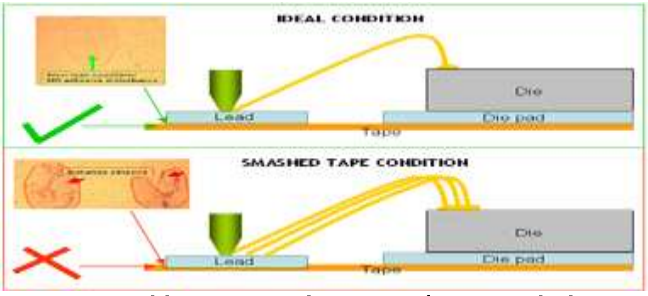


Figure 5. Tape delamination visual comparison for 1 wire on lead against 3 wires on lead

II. Review of Related Literature

2.1 Taped Leadframes for Semiconductors Packaging

Evolution of the taped leadframes as conceptualized under patent 6130473 aims to support miniaturization of IC packages which is progressing rapidly with the increasing demand for mobile electronic equipment. In particular, the demand for the QFN (quad flat non-leaded package), a lead frame type CSP, is increasing now. The productivity of the QFN assembly process can become much higher by using the MAP (molded array packaging) technology. This enables the thickness of conventional frames to shrink significantly to result in a thinner packages for improved heat dissipation and shorter geometries for improved electrical performance.

In that technology, QFN support tape is a key material. It needs not only to attach well to the backside of the lead frame to avoid flash burrs in molding, but also to be removed easily from the lead frame and the molding resin with no residue after molding.

2.2 Understanding the Tape Manufacturing Process

Based from the abstract of patent 6478999 entitled ”Process of making tape adhesive” by Ishizawa, a manufacturing method of adhesive tape, by preparing a raw material of a biaxially or non-drawn, film or sheet on the back surface of which a release agent has been applied and to which an adhesive agent has been applied, and subjecting the raw material to uniaxial drawing under heated conditions without deteriorating releasing and adhesive performance of the raw material, thus producing an adhesive tape having high strength and low elongation.

2.2.1 Current tape technical data sheet (TDS)

As per supplier technical data sheet, the current leadframe tape used is an acrylic high temperature masking tape designed for protecting surface exposed to high temperature where easy, residue-free, silicone-free removal is required. In particular, this tape has been designed for clean removal from typical electronic packaging substrates and typical semiconductor passivation layers.

Product construction consist of backing made of polyimide, adhesive made of acrylic material and liner made of polyester.

2.2.2 Tape adhesion strength

Based from the Article from 3M, strength can be readily matched to the substrate and stress characteristics to which the bond will be subjected. Most adhesives and tapes perform better when the primary stress is tensile or shear. In most industrial applications, however, a combination of stresses are involved that may include cleavage and peel.

Tensile is pull exerted equally over the entire joint. Pull direction is straight and away from the adhesive bond.

Shear is pull directed across the adhesive, forcing the substrates to slide over each other.

Cleavage is pull concentrated at one edge of the joint, exerting a prying force on the bond. The other edge of the joint is theoretically under zero stress.

Peel is concentrated along a thin line at the edge of the bond where one substrate is flexible. The line is the exact point where an adhesive would separate if the flexible surface were peeled away from its mating surface. Once peeling has begun, the stress line stays out in front of the advancing bond separation.

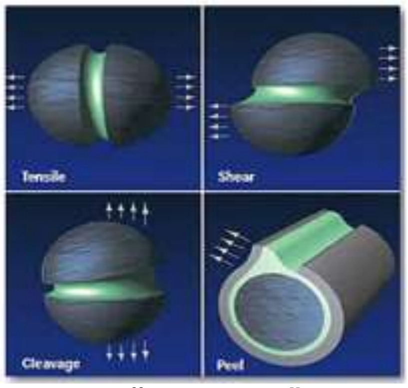


Figure 6. Different tape stress illustration

2.2.3 Factors affecting tape strength

Different substrates exhibit very different properties under changes in operating conditions such as temperature, humidity or exposure to U/V light. As general guidelines however, designers need to consider three main factors; surface characteristics surface energy, and potential expansion / contraction associated with temperature change.

With regards to surface characteristics: it's important to know if the surface(s) are rough or smooth as it will influence the choice of adhesive tape. Surface energy is the 'excess' energy at the surface of a material and is important for any adhesive technology because the surface energy of a substrate influences the ability of an adhesive to 'wet-out' i.e. spread out evenly on the surface. If wetting is inhibited by a low surface energy then it is only possible for a weak bond – if any – to be formed. Expansion and contraction at temperature is another factor. Solids expand or contract as temperature varies, with this change in dimension occurring in all directions. However as they don't all expand and contract at the same rate, then depending on the difference, increased stress can be placed on an adhesive bond. This means that the type of carrier must then be taken into account when choosing a tape.

III. Experimental Section

3.1 Materials

Our experiments utilizes etched full PPF NiPdAu leadframe pre-taped using current and modified version from existing tape supplier while maintaining all other materials intact including the 33um diameter gold wire and using same wirebond machine platform.

The first part of the design of experiment aims to look for an optimized 2nd bond parameter on current materials set and check if tape delamination can be eliminated without affecting wirebond quality specifically non-stick on lead ppm. Sample size per run is 48units.

The alternative experiment if no bond parameter would satisfy the output response requirements is to explore other leadframe tape or technology such as in-house taping. However this would may require investment or increase material cost. Collaboration with tape supplier to formulate a tape that would possibly eliminate tape residue with the current condition of high parameter setting brought about by the 33um wire diameter and 3 stitch wire configuration on leads was pursued.

3.2 Procedure

In order not to disrupt supply chain, the first focus of activities was to have an effective containment while working on the best possible solution to solve the tape delamination issue. As a result of brainstorming several potential solution was identified and was rank through a set of criteria with lowest score being the best solution. Selection of the most effective containment was also identified. This are shown on the table below.

Table 1. Solution selection matrix for tape delamination

Possible Solutions	Selection Criteria					SCORE
	Process Cycle time	Qualification Timeline	Cost Impact	Project Approval gates	Project Risk	
Tape development	1	3	1	2	2	12
Qualify other tape supplier	1	3	4	4	2	60
Process Optimization	1	3	3	3	4	108
In-house taping	3	4	3	4	3	432
100% Laser Deflash	4	2	3	1	2	48
Manual rework	4	2	4	2	3	192

Note: Lowest score is the best solution

3.2.1 Moldflash / Tape residue removal (containment)

In selection of the containment action first criteria to satisfy is qualification timeline wherein 100% laser deflash and manual rework both having a score of 2. However for the other criteria 100% laser deflash is much lower since machine is already available and the risk of inconsistency is high due to manual operation for rework.

Laser deflash machine needs to be reprogram from selective laser deflash which marks on a per unit to 100% laser deflash which will mark the entire panel. With this the vision camera needs to be disabled for scanning of moldflash. Mark layout also needs to adopt to this change with consideration of marking time.

3.2.2 Moldflash /Tape residue DOE

The design of the experiment is divided into 6 runs with the two critical factors identified as 2nd bond parameter and leadframe tape type. For the 2nd bond parameter it is splitted to low, mid and high settings for parameters force, power and time. While for leadframe tape type, tape A is the current tape while tape B is the modified tape.

Table 2. Summary of experimental combinations

Expt	2nd bond parameter	LF Tape Type
1	L-L-L	Tape A
2	M-M-M	Tape A
3	H-H-H	Tape A
4	L-L-L	Tape B
5	M-M-M	Tape B
6	H-H-H	Tape B

For tape B development, wirebonded and molded samples was provided to tape supplier for analysis that will aid them to identify the weakness of the tape and provide appropriate action as represented by runs 4, 5 and 6. Based from this samples provided, it was decided to improve the anchor strength between the adhesive and polyimide backing. PSA (adhesive) layer was made thinner by 2.5um as disclosed by the tape supplier was the significant changes made.

The test method on lab scale will check responses of adhesion on copper and molding resin. Tape residue will also be verified for both interface conditions.

For adhesion on copper and residue below were the test conditions:

- Test piece: 10mm width x 100mm length
- Substrate: Copper panel C1100P
- Bonding condition: 2kg roller, 300mm/min, 2 times
- Heating: During 20~40min after bonding, place the sample in 210degC oven for 45mins
- Measurement: After heating, place the sample in room temperature for 1 hr. Measure 180deg peel force with 300mm/min rate
- Residue: After adhesion measurement, inspect surface of cu panel by visual and finger

For adhesion on molding resin and residue below were the test conditions:

- Test Piece: 50mm x 100mm, heat treatment in 190degC x 10min after liner move
- Molding: put the molding resin block on PSA side of tape and press with 185degC x 100sec

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- Measurement: place the sample in room temperature for 1hr. Cut the tape down with measurement width and remove unnecessary tape. Measure 180deg peel force with 300mm/min rate
- Residue: After adhesion measurement, inspect surface of molding resin by visual and finger

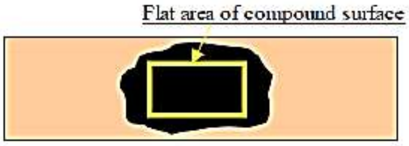

Figure 7. Illustration of flat area of compound surface

IV. Results and Discussion

4.1 100% Laser deflash

Laser deflash marking layout was change from spiral type for individual unit to an interlace horizontal lines across the unit covering the whole panel. This marking layout was the best option in terms of cycle time wherein if we retain a per unit marking this will consume much time as marking delay due to layout indexes per unit. This is shown in the layout below.

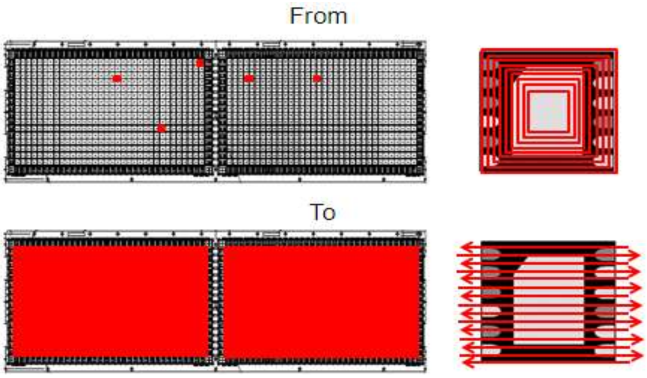

Figure 8. Laser deflash mark layout comparison

Also performed quality checks such as solderability test, delamination via SCAT, electrical test and quick reliability check which all passed. Below is the actual 100%laser deflash visual which takes 8 minutes to process per strip.

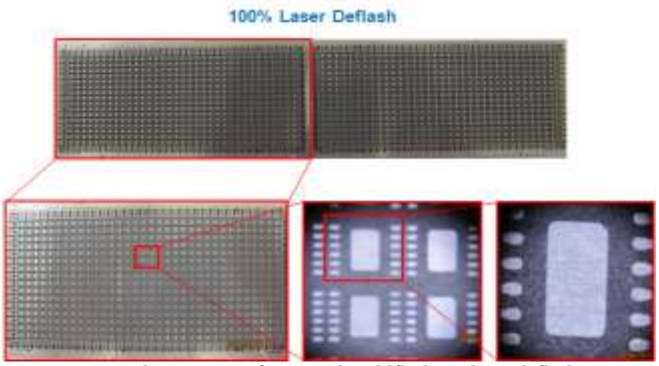

Figure 9. Actual apperance of removed moldflash via laser deflash process

4.2 Design of Experiment

4.2.1 2nd Bond parameter response to tape residue and moldflash current tape

Based from the result, no parameter was able to address moldflash/tape residue. Tape residue was improved but not zeroed out as we lower down the parameters. However the non-stick on lead defect is relatively high at this low setting.

Table 3. DOE different wirebond parameters to tape residue/ moldflash and non-stick on leads

LOWER PARAMETER COMBINATION @175°C VERSUS DEFINE PARAMETER RANGE								
Parameter Combination	Time	Power	Force	Samples	NSOL PPM	After WB Photo	After Mold Photo	Remarks
LOW Bond parameter @ 175°C	10	20	150	40 Units	104,166.67			With Tape Residue
MID Bond parameter @ 175°C	13	30	160	40 Units	0			With Tape Residue
HIGH Bond parameter @ 175°C	15	40	170	40 Units	0			With Tape Residue

4.2.2 Modified tape laboratory result

Based from the data provided by supplier, tape B showed better response to tape residue for both cu and mold compound. Anchor strength was measured to be higher for tape B than current tape A. This was the decision point to arrive at a large scale evaluation.

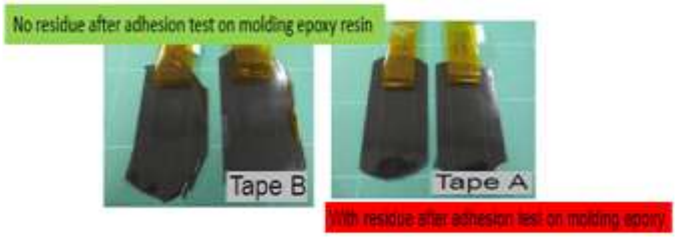

Figure 10. Laboratory test result by tape supplier

4.2.2.1 Modified tape manufacturing results

As per result of the modified tape B, tape delamination was significantly reduced after wirebond and mold which resulted to a small tape residue on the edge of the lead after mold detape on same lead location with 3 stitch wires. This however was eventually removed after chemical deflash process. Note that modified tape B did not undergo 100% laser deflash step.

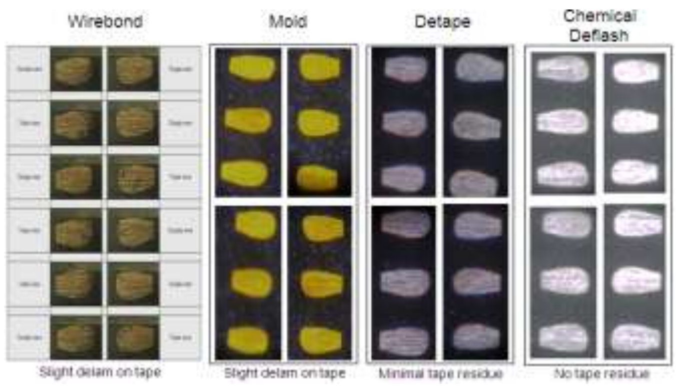

Figure 11. Lead visual after each assembly step

Additional quality check such as solderability and final test showed passing results. Inspection of test contactor tips was showed no deposit of contamination build up due to the product.

4.3 Tape Improvement

To improve anchor strength between the adhesive and polyimide layer that can withstand the force applied to the lead by the 2nd bond parameter thinner adhesive is one of the critical factor. This has better anchor strength to withstand triple wire-bonding. It was decided to reduce the adhesive layer from 5.0um to 2.5um.

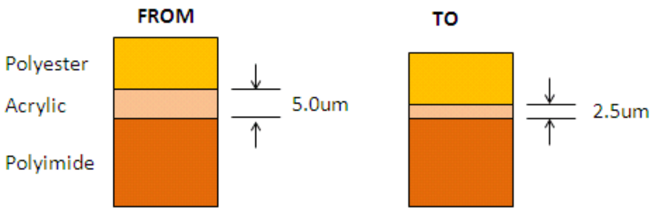

Figure 12. Illustration of the layer difference between the current and modified tape

It was confirmed by tape and leadframe supplier that this tape development would not result to the increase in overall leadframe cost as compared to other alternative solution which would entail increase in material cost or requires investment.

V. Conclusion

We conclude that tape delamination leading to tape residue and moldflash on leads with triple stitch bond can be cost effectively address by improving the tape material through reduction of the adhesive layer thickness from 5.0um to 2.5um.

Also laser deflash is an effective process in recovering moldflash and tape residue of this nature with consideration of process cost and cycle time.

VI. Recommendations

It is recommended to check fan-out possibility of the modified tape to other taped QFN packages and future devices.

With the result, it is also advised to remove 100% laser deflash for this package and revert to normal selective laser deflash to improve cycle time and cost.

Acknowledgment

We are thankful first and foremost to GOD who gave as the strength and knowledge to make this possible.

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