Die Sticking Quality Issue of Tape-and-Reel Packaging for WLCSP

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Abstract

Various factors could deteriorate the quality of Tape-and-Reel (TnR) packaging for Wafer-level Chip Scale Package (WLCSP) devices, of which "*die sticking onto cover tape*" issue found during die pick-up from the pocket or carrier tape during the Surface-mount Technology (SMT) process is a serious real-world challenge. If TnR packaging process is not carefully designed and monitored, such die sticking events would significantly slow down die pick-up throughput, and millions of units could be placed on hold by end customer, with serious financial ramifications. A series of design of experiments (DOEs) were carried out, as a collaboration between ADI and UTAC, to explore this die sticking phenomenon. Based on lessons learned from production runs of WLCSP devices, along with the results of the DOEs as presented in this paper, new and improved Tape-and-Reel packaging design guidelines were formulated for preventing the occurrence of die sticking issue.

Background of Tape-and-Reel Packaging

Generally, WLCSP devices are packed in Tape-and-Reel, which is the preferred packing material for transportation and storage. WLCSP devices have become thinner and smaller in size, along the x-, y-, z-dimensions, and hence become more challenging to make sure die units are protected during shipment, storage, handling, and pick-and-place. During pick-and-place process, or during automated component placement by surface-mount SMT machine, the machine is running thousands of components per hour with a very high degree of accuracy. Anytime there is unit missing in the TnR pocket, due to die sticking on cover tape or fly die event, the machine would stop, and manual intervention required to restart the SMT manufacturing flow. Therefore, throughout the whole process of TnR packaging flow, new design improvements and better practices are required for packing the finished reels.

In the tape and reel packaging, the components are placed in specifically designed pockets that are embossed in a *carrier tape*. And the *cover tape* is used to seal the pockets by either heat-seal or pressure-seal mechanism, where the die units are kept in place within these pockets. A row of sprocket holes along one side of the carrier tape are in place as to facilitate the indexing as to move the tape. The sealed tape is then wound onto a rigid plastic reel (usually 7-inch or 13-inch in size) that provides mechanical protection during transport, handling and storage.

The tape and reel specifications of Analog Devices are in conformance with the EIA-481 Industry Standard [1]. Among other quality issues, *die sticking onto cover tape* is the most critical issue faced by the end customers, having high number of customer-return cases. By simply complying to EIA-481 Industry Standard is not enough to prevent these serious quality issues, and further guidelines are required.

Tape and reel material suppliers are aware of this die sticking quality concern and they have several innovative solutions through the packing material (both carrier tape and cover tape) design upgrades to combat this issue. However, this paper will not focus on these advanced TnR packing material, and instead focus on design guidelines and improved practices for utilizing the traditional TnR material available in the market.

Description of the Design of Experiments and Results

Packing media such as pocket tape reels of Tape-and-Reel process are designed to protect the devices from electrical, chemical and mechanical damages during transportation and storage. To better understand contributing factors, several DOEs were conducted. Direct discussions with several top Tape-and-Reel material suppliers were engaged to gain better insights. Based on DOE results, along with feedbacks from TnR suppliers, design guidelines were formulated as to prevent the issue.

An example of DOEs carried out with various factors that could influence the quality of Tape-and-Reel Packaging is listed in Table 1. Critical process parameters are evaluated such as tape sealing temperature, carrier tape depth (*Ko*), simulated pressure winding of the reel, type of dicing tape, dicing tape UV curing dosage, amount of staging time, staging temperature, and relative humidity.

Table 1. List of potential contributing factors to die sticking quality issue for TnR packaging.

Contributing Factor	Setting for the DOE Conditions		
	Low	Medium	High
Dicing Tape UV Cure Dosage (Joules/cm2)	90	180	300
Pressure of the TnR tape winding	Loose	-	Tight (Normal)
Heat-sealing Temperature (degree C)	180	-	200
Carrier Tape depth *Ko* value (mm)	0.37 +/- 0.05	-	0.45 +/- 0.05
Staging Time of the sealed reel samples	2 days	-	4 days
Staging Temperature (degree C)	25 (*Ref.*)	45	60
Relative Humidity (RH) of the test chamber for staging	60% RH	-	85% RH

After running the above DOE, the die sticking phenomenon was able to be simulated, and the issue was clearly observed for some of the DOE legs. An image of humidity chamber, and sample defective images can be seen in Fig. 1. From the DOE results, it was found that carrier tape shallow depth *Ko*, and carrier tape pocket being out of spec. (poor incoming material from supplier), along with exposure to high temperature and high humidity were the key contributors for the die units sticking to the cover tape.

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Fig. 1. Example of DOE setup and samples showing the simulation of die sticking to cover tape failure.

Further studies also reveal that the choice of *dicing tape* is also critical because poor quality dicing tape allows some adhesive tape residues remain on the backside of dies, once after UV cure to release the dicing tape, followed by the pick and place process. These tape residues on die backside surface later may come in physical contact with cover tape that could lead to die sticking issue.

Tape-and-Reel Design Guidelines for WLCSP Devices

Based on the DOE results and further understanding of failure modes that led to poor quality issues, new carrier tape (pocket tape) design requirements and guidelines for WLCSP devices are formulated and outlined as below:

1. Carrier tape must be designed with a *pocket hole* at the middle of carrier tape pocket, as shown in Fig. 2.

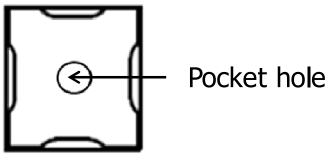

Fig. 2. Carrier tape with a pocket hole

2. Regarding the x- and y- dimensions of the die unit fitting into the carrier tape pocket length and width (*Ao* and *Bo*), the allowed clearance for *Ao* and *Bo* (minimum die size relative to maximum pocket size movement) must be greater than or equal to 0.03mm and must be less than or equal to 0.25mm, as in Fig. 3.

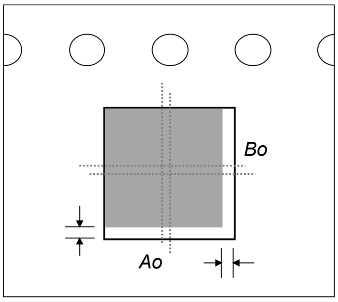

Fig. 3. Clearance of *Ao* and *Bo* of carrier tape, relative to the x- and y- dimensions of the die.

3. For carrier tape pocket depth (*Ko*) clearance, the minimum *Ko* clearance is defined as the difference equal to ([Min. pocket *Ko* value] - [Max. device package thickness]) ≥ 0.05mm, as illustrated in Fig. 4. Then, the maximum *Ko* depth value must be less than two times the minimum device overall package thickness.

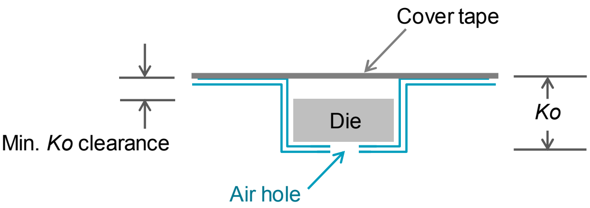

Fig. 4. Schematic to show the minimum *Ko* clearance.

4. For the device unit fitting into pocket tape, from the carrier tape *fit analysis*, Die Rotation shall be less than or equal to 10 degrees, as shown in Fig. 5.

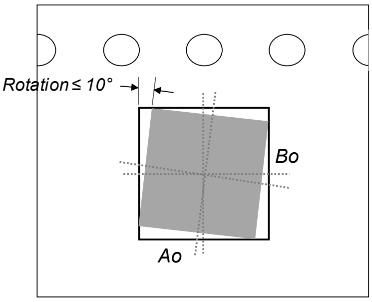

Fig. 5. Schematic to show allowed die rotation ≤ 10 deg.

5. From the carrier tape *fit analysis*, Die Tilt within the pocket tape shall be less than or equal to 20 degrees, as shown in Fig. 6.

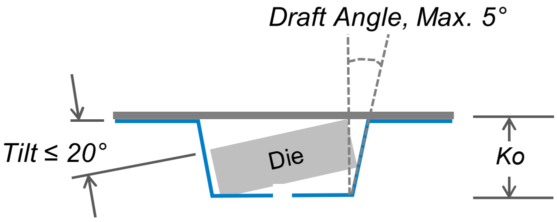

Fig. 6. Diagram to illustrate *Die Tilt* and *Draft Angle*.

6. The *Draft Angle* of carrier tape, as shown in Fig. 6, shall be 0 - 5 degrees. Maximum allowed draft angle should be set at 5 degrees, and if it gets higher than 5 degrees there is potential risk of die sticking issue.

7. The carrier tape thickness for TnR packaging reel must be more than or equal to 0.25mm.

8. When vacuum sealing is applied as part of the finished reels packed into the ESD or MBB bag, the vacuum pressure inside the bag shall be in the range of 0.4 - 0.8 bar. Once the ESD or MBB bag is sealed, the reel shall not be allowed to move while it remains sealed inside the bag. This is critical not to allow vacuum pressure gets too high such that cover tape sags and comes in physical contact with die backside surface.

9. The adhesive side of the *cover tape* for WLCSP package reel shall be able to withstand more than or equal to 60 degrees Celsius in temperature, to ensure that the adhesive would not become "activated" (that is, its adhesive properties altered to be more sticky), as to prevent the cover tape sticking onto die surface once there is physical contact.

10. The *cover tape* thickness for TnR package reel must be more than or equal to 0.048mm.

Besides the above ten guidelines, there are more analysis and further advanced design simulations could be done, such as "nested" carrier tape simulations, as shown in Fig. 7. The aim of the nested simulation is to predict what would happen once the carrier tape is winded on the lokreel tightly, and the two stacking pockets align right on top of one another.

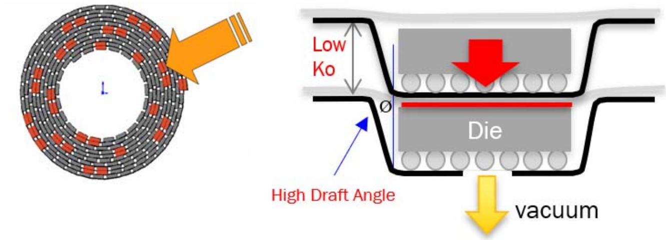

Fig. 7. Diagram to illustrate "nested" carrier tape scenario.

Conclusions

Potential contributing factors to die sticking issue were explored in this paper, and the results of various DOEs showed the importance of carrier tape pocket dimensions conforming to design spec., such as pocket depth *Ko*, pocket draft angle, and vacuum pressure within sealed bag are the more critical factors. Based on latest DOE results, and after discussions with key carrier tape suppliers, new and improved ten TnR design guidelines were formulated, for robustness and to avoid potential die sticking quality issue. Further investigations are on-going, as well as to evaluate the effectiveness of the new guidelines, and to further uncover other potential root causes to die sticking issue.

Acknowledgments

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References

1. EIA-481 Industry Standard, "Taping of Surface-Mount Components for Automatic Placement", *Electronic Industries Alliance* (EIA).