

NSOP REDUCTION FOR QFN RFIC PACKAGES

Mumtaz Y. Bora
 Peregrine Semiconductor
 San Diego, CA, USA
 mbora@psemi.com

ABSTRACT

Wire bonded packages using conventional copper lead frame have been used in industry for quite some time. The growth of portable and wireless products is driving the miniaturization of packages resulting in the development of many types of thin form factor packages and cost effective assembly processes. Proper optimization of wire bond parameters and machine settings are essential for good yields. Wire bond process can generate a variety of defects such as lifted bond, cracked metallization, poor intermetallic etc. NSOP – Non- stick on Pad is a defect in wire bonding which can affect front end assembly yields. In this condition, the imprint of the bond is left on the bond pad without the wire being attached. NSOP failures are costly as the entire device is rejected if there is one such failure on any bond pad. The paper presents some of the failure modes observed and the efforts to address NSOP reduction [1].

Key Words: NSOP , QFN, wire-bonding, wafer , AOI

INTRODUCTION

Wire bonding process is one of the most critical processes in the integrated circuit(IC) package .Typical bond pad metallization consists of Aluminum with1% Silicon and 0.5% copper. The quality of the bond pad surface used for gold wire bonding is very critical for the overall package performance. For example the bond pad surface affects the wire bonding processibility during the package assembly

process. A poor quality bond pad surface can result in NSOP and therefore a low yield during the wire bonding process. The paper addresses the quality issues affecting NSOP failure mode. It summarizes the different failure modes observed from wafer fabrication as well as wafer backend operations of laser scribe, singulation and wire bond assembly operations [2].

OVERVIEW OF ASSEMBLY PROCESS FLOW

The package assembly is preceded by wafer back end processes which may include wafer probe, back grinding, wafer saw, singulation all of which can affect bond pad quality if not properly controlled and optimized. . Figure 1 shows the wafer backend process flow.

Wire bonded assembly has a unique process flow and material set to provide optimum yield. Wire bond assembly operations are separated as front end of line (FOL) and back end of line (BOL). FOL includes die attach, wire bond and 3rd Optical inspection. EOL includes mold, cure, mark, plate and singulation processes as shown in Figure 2.

After completing assembly, packages go through Test, Tape and Reel and are then packaged for shipment.

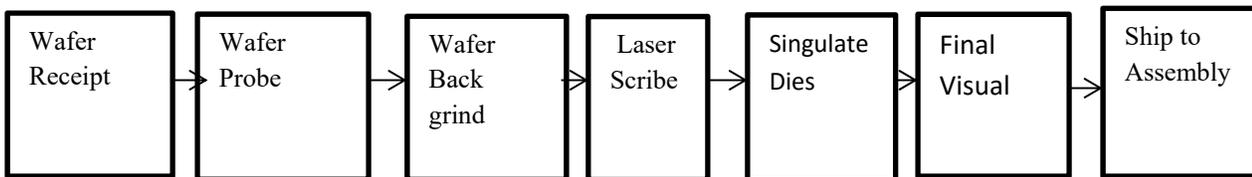


Figure 1: Wafer Backend Process Flow

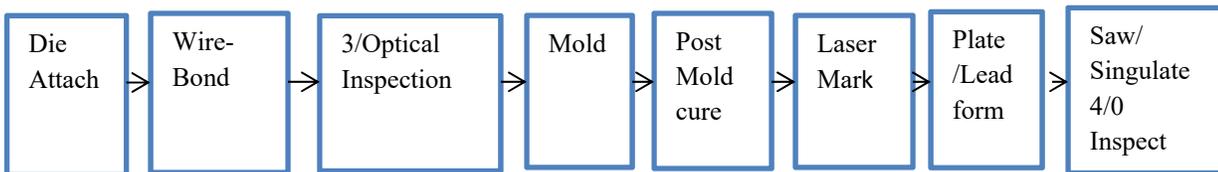


Figure 2: Wire Bond Assembly (Metal lead frame, gold wire)

INCOMING DEFECTS EVALUATION

Prior to initiating die attach and wire bond operations, the wafer are subjected to incoming quality inspection and sort to minimize escape of defects to the assembly operations. There is a variety of wafer back end defects that can escape to assembly if not properly screened. Figure 3 shows the IQC process flow.

The wafer IQC is done at LTPD 95/5 with a sample size of 45 per wafer. 10 dies are inspected per quadrant of wafer and 5 dies are inspected in the center of the wafer. The lots were experiencing a high rejection rate due to defects such as contamination, broken die, metal scratch, foreign material etc. Figure 4 shows typical defects seen at IQC.

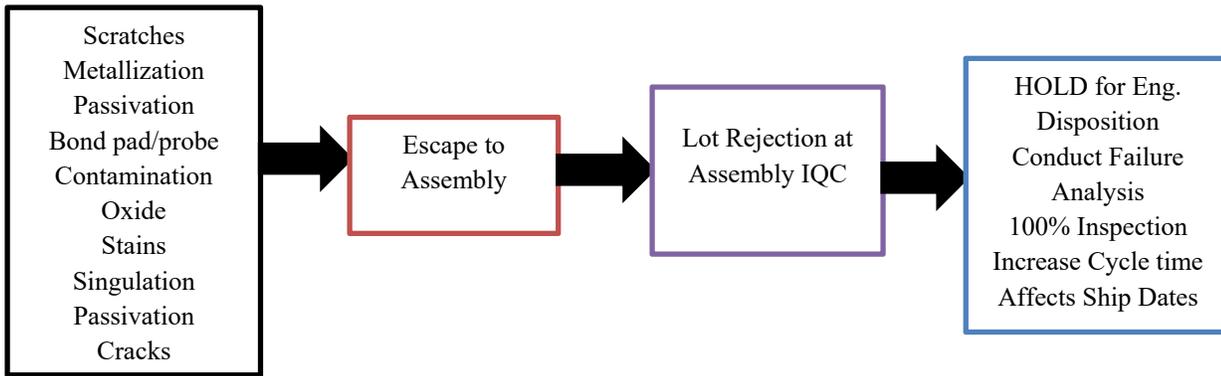


Figure 3: Incoming Quality Process Flow

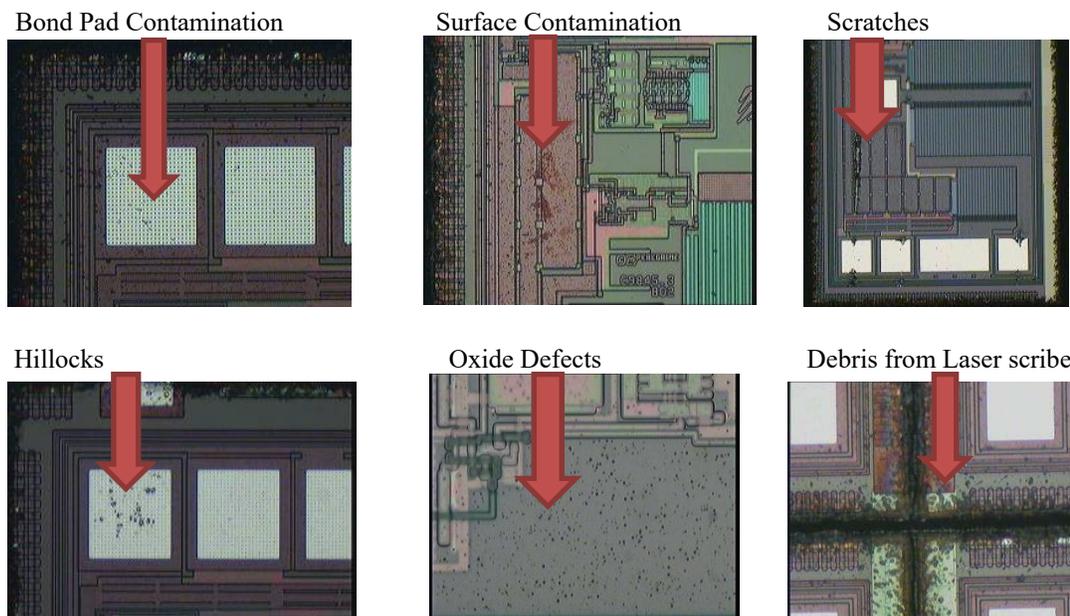


Figure 4: Typical Defects at IQC

FAILURE ANALYSIS

Contamination, scratches, foreign material etc. seen on the bond pads are of prime concern to wire bonding yields. However, some of the defects seen on the passivation layer and other areas of the die were also characterized to see if they were embedded or removable by wash operations. One such defect was showing up as contamination on the die surface. SEM/EDX analysis was conducted to get a better understanding of this defect. Figure 5 shows the SEM image of the surface contamination. This image is showing the dirt

and particles on the die surface. These are presumed to be from the laser scribe operation.

Figure 6 is an EDX dot map for aluminum. Concentrations of aluminum are indicated by the yellow contrast.

Defect characterization was needed to understand the failure mode and clarify the acceptance criteria at IQC. Another defect that was characterized was “Hillocks” seen on the bond pads. It was seen both on the passivation layer and the

bond pad and the concern was damaging the wire bonds. Hillocks in both areas were analyzed to understand the composition and height of the hillocks. Figure 7 shows the SEM image of the hillock on passivation layer and Figure 8 shows the hillock on the bond pad.

After failure analysis it was determined that Hillocks were not a major issue for NSOP, so the IQC acceptance criteria for hillocks was revised.

Surface Particles

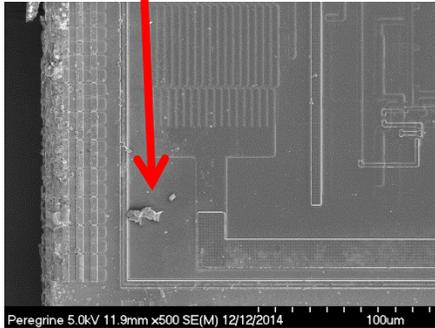


Figure 5: surface contamination

Aluminum particles

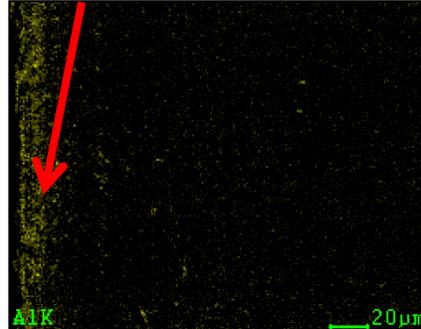


Figure 6: Aluminum particles

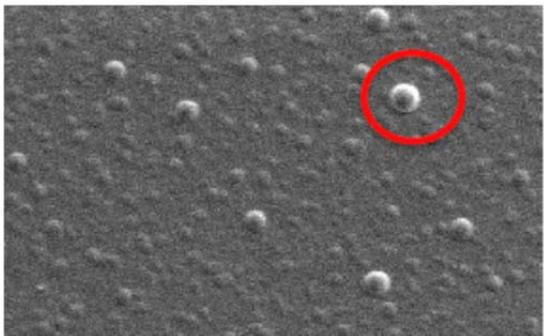


Figure 7: Hillocks on passivation

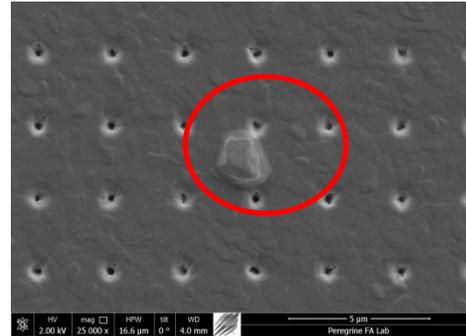


Figure 8: Hillocks on bond pad

WAFER BACKEND PROCESS IMPROVEMENTS

In order to address defect escape, failure analysis was conducted as shown above and defects were categorized as wafer incoming, and defects induced in the backend process. The goal was to characterize the top 3 defects and reduce lot rejection rate at IQC. In order to accomplish this, Automated Optical inspection (AOI) was added to screen defect before shipping to assembly. AOI acceptance criteria

was defined for each defect and programmed in the machine. This replaced the optical inspection and improved the cycle time. AOI also helped tracking repetitive defects and isolating defect categories by product type. At the same time an effort was made to root causes the defects at the backend process. By using a multiple screening approaches and focusing on the backend processes, the defect escape was reduced, as shown in Figure 9 and Figure 10.

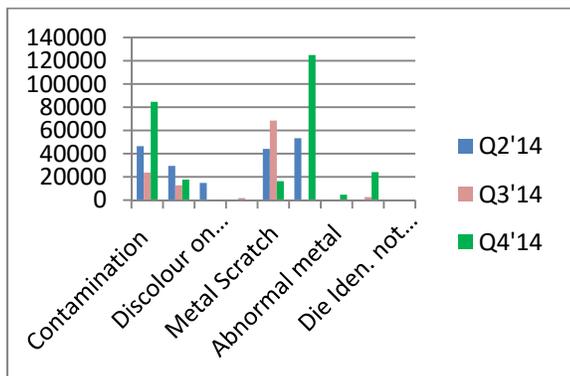


Figure 9: 2014 IQC Defect PPM

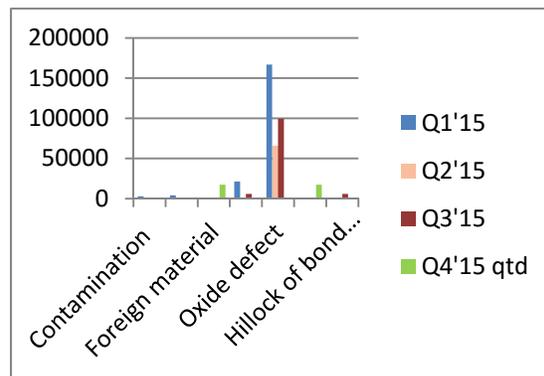


Figure 10: 2015 IQC Defect PPM

ASSEMBLY PROCESS OPTIMIZATION

Wire bond process optimization begins with a clear understanding of the bonding equipment, machine set up, the response variables involved and their relationship to one another. [3]. Surface cleanliness and bond pad metallurgy are critical for successful wire bonds. Evaluating these parameters is time well spent and an important step towards developing a robust wire bond process. Well optimized processes lead to improved Cpk (process capability index) and good yields. For volume manufacturing, consideration should also be given to cost, portability of the process and reliability.

When the wire bond assembly was initiated for production, designed experiments were conducted to dial in the wire bond process using bond power, bond force, and bond time and bond temp. as the variables. The key bond parameters were compared for several packages to understand package commonality. Capillary design and dimensions are also an important variable for optimization. Typical response variables of a wire bond process is wire pull data (5gms min) and ball shear data. (15gms min).

During the wire bond process, the dies that exhibited “Non Stick on Pad” (NSOP) condition were isolated and mapped to the position on the wafer map. This was done to enable the location on the wafer where contamination was occurring and use this data to provide feedback to the wafer fabs. SEM/EDX analysis was performed on the NSOP dies to understand the type of contamination. The mapping is shown in Figure 11.

The results of SEM/EDX analysis showed high% atomic oxygen and carbon elements on the pads with contamination. The results also showed some Na, Cl, N, Fe Zn, Mg and K on the NSOP dies. Some fluorine element was also seen on good units. It is possible that Na, K and Mg might come from handling and finger touching, but the other contamination was not induced in the assembly process. Table 1 shows EDX analysis of good units and Table 2 shows the EDX analysis of NSOP units.

The process mapping experiments assisted in verifying the root cause of NSOP was bond pad contamination. As a follow up parallel efforts were put in addressing the defect escape from back end processes. It was observed that the high carbon on bond pads was contributed by the tape residue from the back end operations. Rinse operations were optimized by adjusting the spray pressure and angle of the spray to facilitate proper removal of the residue and minimize escape to assembly operations. Recipes for laser scribe operations were optimized to minimize debris from backend laser scribe operations. By putting controls in the backend operations and screening defects using AOI, outgoing DPPM was reduced and this facilitated in improving lot rejection rate at assembly IQC and reduced the NSOP defect at wire bond assembly. This was achieved with team efforts of in-house manufacturing and quality organizations and subcontract process engineering teams. Figure 12 shows the 2014 NSOP PPM and Figure 13 shows the reduction in 2015 NSOP DPPM.

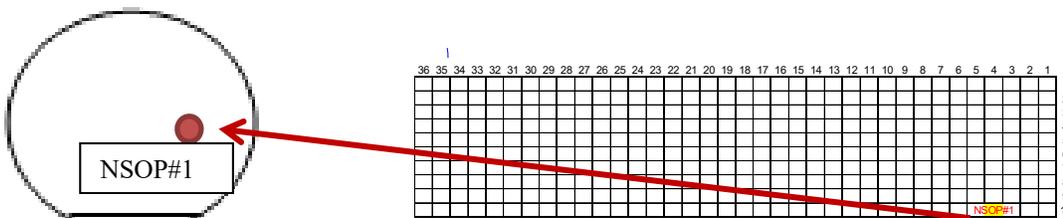


Figure 11: Process mapping of NSOP location on lead frame to die position on wafer.

Table 1: EDX Analysis – Good Units)

Unit	O	Al	C	F
1	1.5	98.5	0	0
2	1.62	98.38	0	0
3	1.48	98.52	0	0
4	1.56	98.44	0	0
5	1.61	98.39	0	0
6	1.65	98.35	0	0
7	1.36	98.64	0	0
8	1.60	98.4	0	1.12

Table 2: EDX Analysis – NSOP Units

Unit#	Point	O	Al	C	F
1	1	9.27	81.55	9.18	0
	2	14.79	0	18.91	0
2	1	4.28	37.30	5.96	0
	2	3.00	93.32	2.21	1.47
3	1	1.79	94.72	2.39	1.10
	2	0	0	100	0
4	1	18.34	36.76	31.76	0
	2	13.00	14.51	43.74	0
5	1	7.59	36.60	7.71	0
	2	16.22	1.54	54.06	0

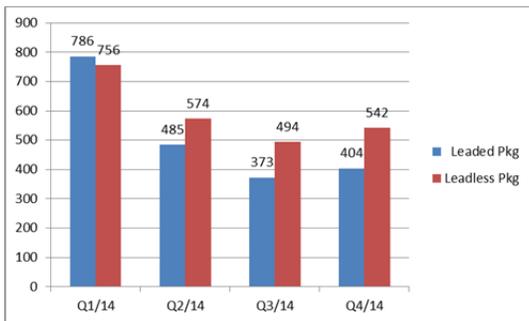


Figure 12: 2014 NSOP PPM

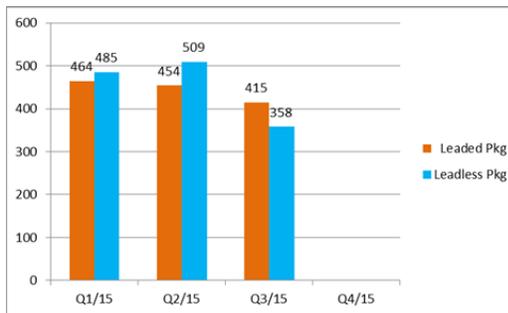


Figure 13: 2015 NSOP PPM

CONCLUSION

Die bond pad quality can be affected in numerous ways during processing and handling. Both wafer fabrication and assembly facilities as well as intermediate process owners such as probe/back grind/laser scribe/singulation operations need to address outgoing quality issues with proper detection and preventive methods. Automated Optical inspection (AOI) is a valuable tool in screening defects and categorizing them. Successful and reliable wire bonding can be achieved by contamination free surface, machine maintenance, optimized process settings and providing an optimal bonding environment.

REFERENCES

1. Wire Bonding in Microelectronics – Materials, Processes, Reliability and Yields George Harman
- 2 Reducing non-stick on pad for wire bond: A review RSsethu AJME Vol.9, No.2 pp 147-157
- 3 Bonding Process P.S. Chauhan et al. DOI 10.1007/978/-14614-5761-9_2

ACKNOWLEDGEMENTS

The author would like to acknowledge assistance of John Gao, Robert Lima, Premajit Singh, Kirby Koetz, Evelyn York and several internal and outside labs for failure analysis, and subcontract engineering teams for their assistance in conducting these evaluations.