ESD Exposure to Sensitive Devices During Device Packaging and Assembly

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Abstract–This paper examines ESD exposure to the devices during back-end process and electronics assembly. Paper focuses on actual data collected during examination of the processes and provides explanation of ESD occurrences. Factual analysis of ESD exposure in the process is encouraged.

Keywords – ESD, ESD Event, ESD exposure, back-end, device packaging.

1. INTRODUCTION

Smaller geometry of semiconductor devices increases their sensitivity to electrostatic discharge. As more and more manufacturers switch to 65, 45 or even 32nm, it takes progressively less energy to damage the devices. High speed of new devices makes it extremely difficult to implement effective ESD protection on silicon without compromising signal integrity. These technology trends indicate that manufacturers need to pay more attention to the actual ESD exposure, not just to rely on conventional assumption-based static control methodology.

2. ESD EXPOSURE AT VARIOUS STEPS OF THE PROCESS

The examples provided in this paper focus on the most probable “culprits” in the process. Due to limitations of the size of this paper some data are omitted to fit the format. Readers are welcome to contact the author for additional details. Measurements of ESD exposure were done using 3M EM Aware ESD monitor, though other equipment, such as a high-speed digital storage oscilloscope could be partially utilized, albeit without correlation data with the established ESD models.

2.1 Wafer Saw

This is one of the first steps at the back end of device manufacturing. A wafer is being sawed into dies while these dies still remain together on a backing of a Mylar film. The process of sawing is capable of creating substantial charge due to significantly different positions on the tribocharge scale between the steel blade of the saw and the silicon. Even though the rim of the saw is made of diamond abrasives, its thickness is small and sooner or later steel sides of the blade come into contact with silicon.

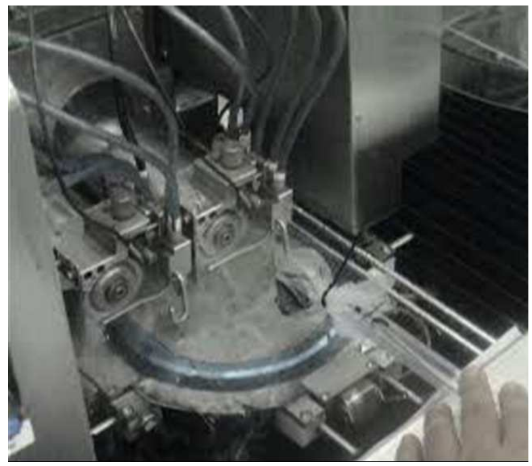

Figure 1. Wafer Saw Process with ESD Sensor

To alleviate this problem the DI water or alternative fluids in which the sawing takes place is made partially conductive, such as using CO_2 (carbonation). Often, resistivity of such fluid is usually kept within 12…18 MOhms.

This may create other problems – the short distances between the saw and the exposed pads (i.e. low resistance) and the high voltage generated during sawing may expose devices to EOS. Careful experiments must be conducted in order to set the optimal resistivity of fluid.

Submerge the sensor wrapped in the chemically-insulative enclosure into the fluid during the process to test for ESD Events and for static field resulting from charge

2.2 Die Attach

This is a two-step process – die separation from the wafer and die placement on the leadframe.

Separation

The sawn wafer is typically held on a Mylar backing. As an insulator, the wafer must be considered to be charged. If a vacuum pick is conductive, there is always a possibility of a discharge during contact. Then, during separation of the die from the Mylar backing the die attains high charge level due to significantly different positions of Mylar and silicon on the tribocharge scale. When the die is rapidly lifted, the voltage on the die increases due to its reduced capacitance vs. the rest of the wafer according to a fundamental formula

$$V = \frac{Q}{C} \qquad (1)$$

As the voltage increases, there is a possibility of a discharge between lifted die and the dies left on the Mylar backing. Where the discharge has happened or not, the die can still be charged.

Die Placement

When a charged die is placed on the leadframe, here is a strong possibility of a discharge.

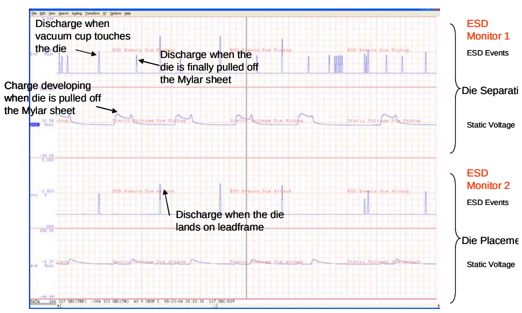

Figure 2. ESD Exposure in Die Attach Process

Figure 2 shows the actual ESD exposure during this process. The two ESD sensors were positioned in the process, both measuring static voltage and ESD Events. As seen from the top two chart (die separation), the first discharge occurs during the contact between the vacuum pick and the die. Then in several milliseconds the die is being pulled off the Mylar sheet and the developing static voltage is shown on the second chart. It is clearly seen where the die is separated from the backing. As the die is being lifted, a discharge occurs within few milliseconds.

Now, the die still retains some charge vs. ground – the last discharge has occurred between the two non-grounded objects. When this die is placed on the leadframe, yet another discharge occurs as shown in the third chart.

Due to rapid movements in the process, ionization cannot be fully effective in reducing charges on the dies, though proper selection of an ionizer and its proper placement help in reducing the charges.

2.3 Wire Bonding

Out of two most popular bonding methods – ultrasonic and EFO, the latter is much more prone to inflict damage to the devices. Electric Flame-Off bonding process melts the gold bonding wire and produces a soft gold ball at the end of it which gets attached to the pad of the device. The melting of the wire is done by a spark to the wire generated outside the device. By itself, this spark is normally not a problem. However, if the bonding wire' grounding is intermittent, the energy of EFO pulse can be briefly stored in the spool of wire and then transmitted to the pad.

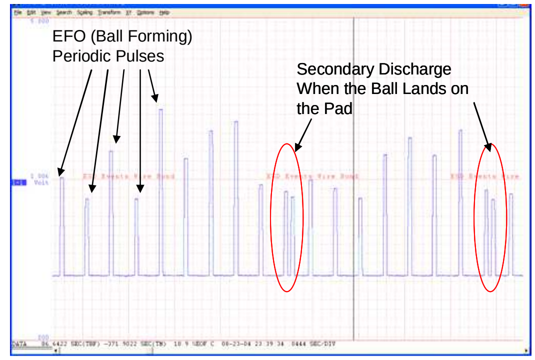

Figure 3. ESD Exposure in Wire Bonding Process

Figure 3 shows discharges captured by an instrument during bonding process. As seen, every time there is an EFO action, this event is captured. In a properly bonded device one can know how many pins were bonded by simply counting number of such discharges. However, if the tool is not properly maintained, there may be secondary discharges – they can be easily recognized when using proper tools. Unfortunately, a commonly-used high-speed oscilloscope won't be able to recognize such pulses as out-of-sync due to triggering issues.

2.4 Singulation

This is a process where an array of leaded devices still connected together by joined leadframe is separated into individual devices. This process can be either sawing or stamping. Either way this process is one of the "usual suspects" for significant ESD exposure due to multiple metal-to-metal contacts in the tool.

ESD exposure is aggravated if the internal parts of the tool itself are not properly grounded – in such cases different metal parts can have voltage on them and they can also produce discharges during operation.

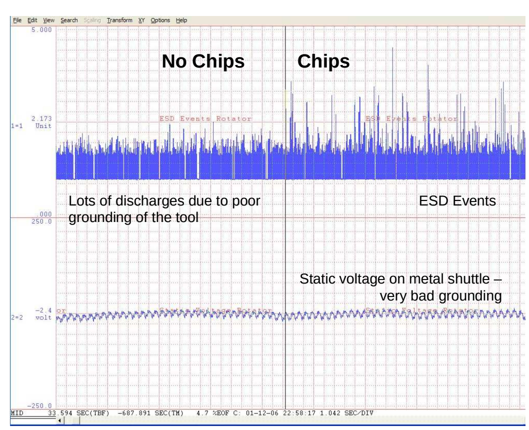

Figure 4. ESD Environment in a Singulator

Figure 4 presents a typical, though, not a desirable ESD environment in a singulator. This particular tool has serious grounding problems between its various internal parts and this is clearly seen on the bottom chart of that figure – a static voltage on a metal shuttle that moves back and forth vs. the ESD sensor. This grounding problem causes multiple discharges between parts of the tool as shown on the left part of the top chart of Figure 4. These ESD events occur even before the devices arrive into the process. However, once the devices arrive (right part of the same chart), one can see increased ESD activity with discharges exceeding in this case 200V CDM.

2.5 BGA Ball Attach

In this process each individual ball is capable of discharging to the pad of the IC. During mounting, often balls are held by a vacuum chuck made of anodized aluminum – an insulator. Thus, each ball retains its charge. Discharge from each ball is focused on individual pin hitting the target precisely.

Unlike with the leaded devices where the first few contacts discharge the device, ESD Events to BGA chip do not diminish with each ball contact.

Figure 5 shows clusters of discharges during such operation.

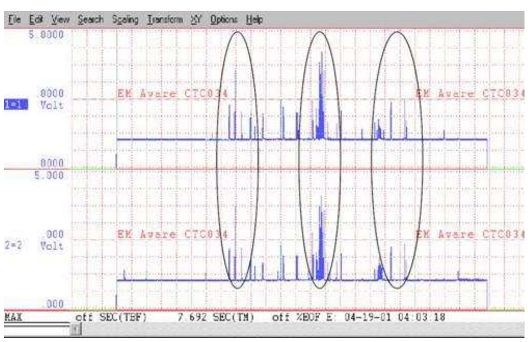

Figure 5. ESD Events During Ball Attach

2.6 Flip Chip

One of the most dangerous steps in flip chip manufacturing is application of the solder paste to the die. The paste is applied via the screen to the pads. The device itself is not grounded -- it rests on its silicon back. The screen may or may not be conductive and may or may not be grounded. If the screen is conductive, ESD Event may occur when the screen is pressed against the die. However, the most damaging step is perhaps application of solder paste. Solder paste sometimes is squeezed from the insulative plastic tube which acts as Leiden jar. In such cases the solder paste must be considered charged and due to its nature, it can store significant energy. Thus, contact between the solder paste and the exposed pads can produce undesirable ESD exposure.

2.7 IC Marking

Out of two kinds of such processes – laser and pad markings – the latter is a significant contributor to ESD exposure. The typical setup for pad printing is shown in Figure 6.

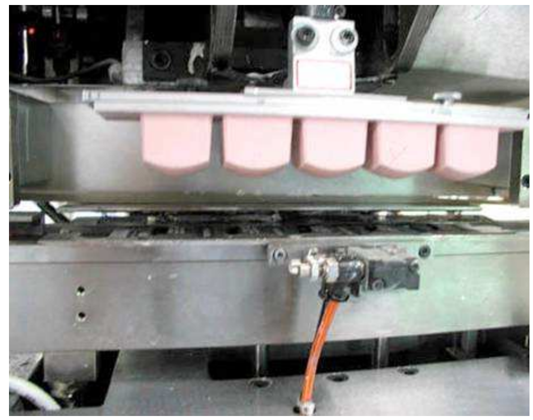

Figure 6. Pad Printing Setup

Printing pads are easily charged during contacts and are difficult to discharge. Rapid movement of highly-charged pads induces voltage into ICs and adjacent parts. Rapid movement makes it very challenging to provide discharge via conventional means. Intermittent contacts during pad marking process can generate strong ESD Events.

Laser marking does not that this particular problem, but is not free of ESD problems due to transport issues.

2.8 IC Handlers

This is where most of the damaged devices are discovered. This, however, may not be the place where the devices were damaged – there are ~17 steps in the back-end semiconductor manufacturing and the IC test is almost the last one. Nevertheless, IC Handler (and Tester) are significant contributors to ESD exposure due to excessive metal-to-metal contacts.

Figure 7 shows the typical places of discharges in the IC handlers. As seen, every place where the device is lifted or put down, discharge is highly probable. Some discharge locations present more danger than the others. Starting from lifting the IC from the test socket, though placing and lifting the IC to and from the shuttle and to placing the IC into the exit tray, there is no possibility to discover damaged device. This may result in shipping to the customer defective components while being convinced otherwise. Only diligent ESD diagnostics with proper tools can discover ESD exposure at each step of the process.

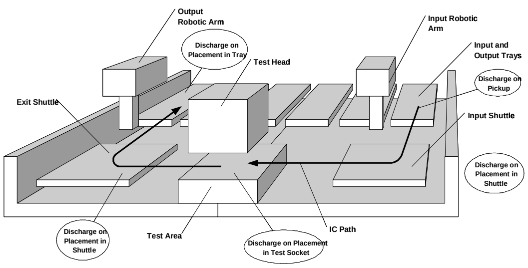

Figure 7. Discharges in the IC Handler

Often, IC gets charged during handling by a vacuum pick. Figure 8 shows the mechanism of such occurrence.

When IC is released by the vacuum pick, the encapsulation of the IC is charged from separation from the vacuum cup. The substrate/leadframe of the IC is also charged. When the IC touches the shuttle, the tray or the test socket, ESD Event occurs.

A conductive vacuum cup cannot take the charge off the encapsulation because encapsulation is an insulator. Ionizer does not have sufficient time to discharge the IC.

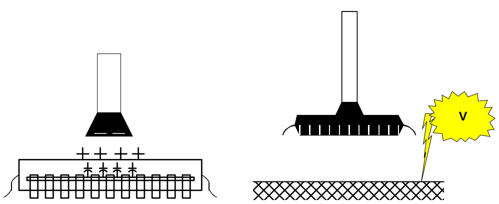

Figure 8. Charge and Discharge of the IC During Handling

2.9 Pick and Place Process

There isn't much difference in ESD exposure between SMT machine and IC handler. In each tool the IC is lifted from the transport and it is charged. IC is placed on metal pad – resulting discharge.

Whether an IC is charged or not, pads on the PC board may be significantly charged. Figure 9 shows static voltage on the PC fabs in a process of automated SMT assembly. As shown, a bare PC Fab is unpacked and placed on a conveyer to go through different stages of assembly. As the board is taken out of the package, it is already charged. This charge does not diminish as the board progresses through the process. Sensors of ESD monitor were placed under the board in its path. As it can be seen, the voltage on the boards exceeded 200V. When a sensitive device is placed on such charged board, an ESD Event is inevitable.

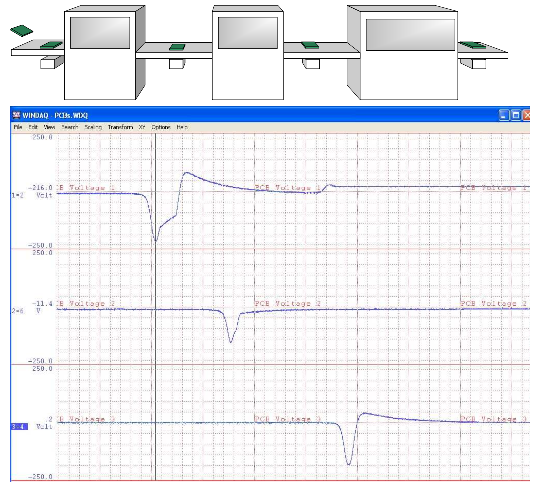

Figure 9. Static Voltage on PC Fabs in SMT Assembly

It should be noted that at one of the observed lines there was an ionizer which purpose was to dissipate the charge from the Fabs. However, the type of ionizer was such that each board, even the one that wasn't charged before, was charged by this ionizer to over 50V.

2.10 Does ANSI/ESDA S.20.20 Help?

Every standard has its advantages, but it also has its limitations. No standard in the ESD Association provides verification that your devices had no ESD exposure in the process. So, if your factory is compliant with ESDA S.20.20, would it help?

- You are better of with it than without it
- No, your components are never safe from ESD in production environment
- ESDA S.20.20, however good advice it provides, offers no verification of safety of your ESD environment, that means actual ESD exposure to the devices
- After a successful ESDA S.20.20 audit, if your best customer asks you what is the actual ESD exposure to the components at each step of the process, would you be able to tell?
- ESDA S.20.20 is targeted to HBM. How often your components are being handled by hand? Tweezers is not HBM model
- Still, ESDA S.20.20 is a good start on a long road

3. CONCLUSION

Many companies spend significant amounts of money on ESD protection. Yet, if asked what is actual exposure to the devices at each step of production, there responses would be ambivalent and non-committal. How then it is possible to assure your customers that none of their devices were exposed to ESD level higher than specified? After all, the factory that is ISO9000 certified should be able to provide such response.

Only measurements of actual ESD exposure to the devices in process can provide factual information rather than guesswork and assumptions.

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