Package-related Failure Mechanisms and Attributes

Ball Lifting

Ball lifting, is the detachment of a ball bond from the bond pad of a semiconductor device.
See separate article on *ball lifting*.

Bond Shorting

Bond Shorting is the presence of an unintended electrical connection between two bonds. The electrical connection may be in the form of bonds touching each other, or stray conductive materials bridging one bond to another. Bond placement problems involving adjacent wedge bonds with long tails in a die with tightly-packed bond pads are the most common form of touching bonds.

Design rules for bond pad size and spacing, bond size, bond position, and bond deformation can easily prevent touching bonds. Die attach material that accidentally falls or drips on the die surface, or reach it in whatever way, can bridge one bond to another. Stray wires that somehow get into hermetic packages can also bridge one bond to another. Eutectic flakes or balls from highly oxidized eutectic die attach material can get loose inside the package and likewise act as bridges between bonds. Aluminum squeeze-outs around the wedge bonds can also get loose and short bonds.

Brand Failure Attributes

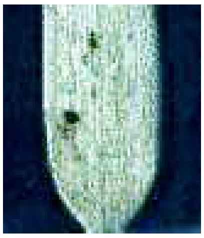
Poor markability is the condition wherein the package is difficult or impossible to mark or brand correctly and/or the mark or brand on the package exhibits insufficient permanence. Ink markability problems are often due to the inability of the ink to adhere to the surface of the package. Laser markability problems are often due to improper branding equipment set-up, but may sometimes be due to textural problems on the surface of the package as well.

Poor adhesion of ink marks or brands on the package is usually caused by the presence of a thin film or layer of foreign material on the package surface. For instance, packages with excessive amounts of mold release agent on their surfaces are likely to exhibit poor markability. It may also be due to the use of an incorrect, incompatible, or expired ink.

Poor laser markability is usually caused by wrong laser branding settings. Packages with textural problems or defects may likewise exhibit poor contrast after laser marking. For example, reworked packages that have undergone sand blasting generally exhibit illegible marks.

Contamination, External

External contamination is the presence of a foreign material, whether attached or unattached, anywhere on the external portions of the package and leads. The criteria for rejecting external contamination depends on its location, extent, and composition. Some contaminants are rejected because it results in cosmetic failure, while others are rejected because of the reliability risk involved, mainly with regard to lead corrosion and solderability issues, as well as electrical leakage between pins.



External contaminants can come from anywhere. If all the units are affected, it is likely that it has come from an equipment used in the process, or a bad batch of raw material has been used. If the contaminated units are isolated, it may have been produced by a random or non-repeating event.

Common external contaminants include but are not limited to the following : grease or oil from equipment; flux or solder on package; oxides on leads; fingerprints; and organic contaminants on package or leads (as shown in picture).

Contamination, Internal

Internal contamination is the presence of a foreign material, whether attached or unattached, anywhere inside the package of the device. The criteria for rejecting internal contamination depends on its location, extent, and composition. Internal contaminants are rejected generally because of the quality and reliability risks involved, mainly with regard to bond pad/die corrosion, electrical shorts, and electrical degradation such as leakage between active metallizations and surface charging.

Internal contaminants can come from anywhere. Common internal contaminants include but are not limited to the following : organic residues on leadframes (shown in picture above), die attach material on the die; epoxy resin bleed-out on the package and bonding posts; silicon sawdust; organic contaminants containing halides such as spittle; solder balls inside the cavity; and molten/burned lint and fibers from production materials.

Cratering

Cratering is a partial or total fracture of the silicon material underneath the bond pad. Cratering is commonly due to excessive stresses on the bond pads from a poorly set up wirebonding machine. Bonding time, force and power are critical parameters when dealing with cratering.

Die Chip-outs

Die chipping is the breakage of a part or parts of the die away from the die itself. The damage on the die is referred to as a 'die chip-out.' Die chip-outs are often caused by purely mechanical means, although some cracks can be propagated by thermomechanical stresses until a fragment chips off the die, resulting in a chip-out.

The die corners are most vulnerable to chipping, since they are the most physically exposed portions of the die.

Die chip-outs are often due to mishandling. For instance, picking up a die carelessly with a tweezer for eutectic die attach can result in the tweezer slipping out of position, chipping the die edge in the process. Improper equipment set-up can cause probe needles, dispense tools, and the like to land on and chip off a corner of the die. Manual capping of ceramic packages prior to sealing may also cause a die chip-out, if the cap or lid hits a corner of the die during capping.

Die Corrosion

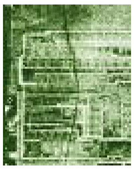
Die corrosion refers to the corrosion of the metal areas on the surface of the die.

See separate article on *die corrosion*.

Die Cracking

Die cracking is the occurrence of fracture(s) in or on any part of the die. Die cracks may be due to a variety of causes, although its major sources are related to die attach problems and/or mechanical stresses on the package.

Excessive voids in the die attach act as stress concentrators that can result in cracks at the backside of the die. These cracks can propagate upward to the active circuitry, and subsequently to the surface of the die. Units using eutectic die attach are especially vulnerable to this mechanism. During thermal stressing, the eutectic die attach material expands more rapidly than the silicon, exerting stresses on the die that tends to split its backside. The presence of voids, crevices,

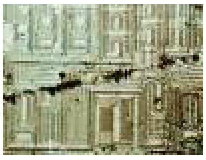


incomplete fillet, die overhang and other die attach imperfections amplify the stresses acting on the die backside. This stress concentration phenomenon occurs in all type of die attach material.
Imperfections in the die itself can also result in cracks. Backgrinding defects at the backside of the die also act as stress concentrators, and can serve as crack initiation points once the package is subjected to thermomechanical stresses. Other die imperfections that can lead to die cracks include microcracks or chip-outs from wafer saw, or ejection pin damage during die attach.
Improper equipment set-up can cause probe needles, die overcoat dispense tools, and the like to land on and crack the die. Excessive mechanical stresses on the package can also be transmitted down to the die, causing it to crack. For thin packages like SOICs, these stresses may be transmitted down to the die without damaging the package itself, making the problem even less detectable. The common sources of these mechanical stresses are the mechanical deflash, trim, and form processes, especially if the package nests employed by the steps contain debris or particles that can act as fulcrums for aggravating the stresses.

Die Lifting

Die lifting is the disbonding or detachment of the die from its die pad or die cavity. Die lifting may be due to a number of reasons: a fracture on the backside of the die, a fracture within the die attach material itself, delamination between the die backside and the die attach material, or delamination between the die attach material and the leadframe or cavity.
Excessive voids in the die attach act as stress concentrators that can result in contiguous cracks at the backside of the die, especially in units that use eutectic die attach. These cracks can propagate to a point wherein the upper part of the die is separated from the bottom part. In most cases such a failure would be classified as die cracking (see Die Cracking), but extreme cases can give the impression that the die has lifted off from its resting place. Imperfections on the die backside caused by die sawing and/or die ejection, e.g. microcracks and microchip-outs, can also lead to the above mechanism.
Excessive voids in the die attach material also lowers its fracture strength, which can lead to a cohesion failure within the material if the unit is subjected to thermomechanical stresses. When this happens, the die attach material fractures in the middle, leaving die attach material still sticking on both the die backside and the die pad. Mechanical degradation can also be due to corrosion/oxidation in the case of eutectic die attach. An inadequate bond line thickness can also result in cohesion failures.
Contaminants on the die backside and die pad can lead to die attach-to-die and die attach-to-die pad delaminations, respectively. Eutectic die attach delaminations may also be due to inadequate scrubbing, incorrect preform size, and improper equipment settings.

Die Scratches



Die scratch is the presence of abrasion, scraping, or laceration damage on the surface of the die. Die scratches are caused by mechanical means, usually by a pointed object that accidentally touches and sweeps across the die surface.
Scratches on die are often due to mishandling. For instance, picking up a die carelessly with a tweezer for eutectic die attach can result in the tweezer slipping out of position while scratching the die surface. Improper equipment set-up can cause probe needles, die overcoat dispense tools, and the like to land on and scratch the surface of the die. Foreign materials and dirt embedded at the pick-up tool tips of pick-and-place machines during die attach can also cause die scratches. Similarly, the use of defective, worn-out, or damaged pick-up tools can scratch the die surface. Manual capping of ceramic packages prior to sealing may also cause a die scratch, if the cap or lid inadvertently gets into contact with the surface of the die.

Heel Breaks

Heel Breaking is the severing of the wire from its wedge or crescent bond due to a fracture in the heel. The heel is the portion where the wire tapers off into the bond. Heel break is commonly due to poor wirebonder set-up. Poor set-up includes improper bonding parameter settings, bondhead movement settings, and worn-out or contaminated tools. Incorrect bonding parameters can deform the bond excessively, resulting in a thin and weak heel which can easily fracture. Improper bondhead movements and low loop settings may subject the wires to excessive stresses that tend to pull them backward and away from the bonds, resulting in gross heel cracks which may propagate to fracture. Worn-out and contaminated tools can produce defects in the wires which can act as starting points for crack propagation.

Studies in the past have likewise traced some cases of heel breaks to mechanical stresses applied on hermetic packages, particularly the high-frequency vibrations produced by ultrasonic cleaning or sandblasting. These tend to subject the wires to violent vibrations that can easily propagate heel cracks to fracture.

Heel breaks due to corrosion also occur. Commonly encountered corrrosive contaminants in the wires and bonds include Cl and S.

Lead/Leadframe Corrosion

Lead/Leadframe corrosion, as the name implies, refers to the corrosion of the lead or leadframe itself. See separate article on *lead/leadframe corrosion*.

Lead Pulling

Lead pulling is the condition wherein the leads are yanked out of the package without breaking. This phenomenon results if the axial stress on the lead exceeds the sum of the adhesion strength between the lead and the plastic package and the flexural strength of the plastic inside the leadfinger's anchor hole without exceeding the fracture strength of the lead itself. Lead pulling does not happen in normal units, since the lead would break first before the lead-to-plastic anchoring and adhesion fail.

Lead pulling generally indicates a weakness in the attachment of the leads to the package. Design problems such as improper/inadequate lead geometry or dimensions can result in this problem. The presence of anchor holes in the lead fingers greatly helps in preventing lead pulling.

Lead pulling may also indicate the presence of package anomalies such as cracks and delaminations. In fact, if the package is properly designed, lead pulling can only occur if there are cracks or delaminations in the plastic material surrounding the affected lead. Partial lead pulling may not produce visible cracks but may result in second bond breaks.

Lead Tearing

Lead tearing is the ripping apart of the lead somewhere along its length, usually at the bends. It is often due to a problem in the raw material, i.e., the leadframe used is defective or inherently weak. Lead tearing can not be detected readily prior to assembly. In fact, lead tearing manifests only after the leads have been subjected to the mechanical stresses of the DTFS process of Assembly.

Lead tearing damage is cumulative. It occurs at the bended portion(s) of the lead, and starts at the sides of the lead. The tearing at both sides propagates inward as the lead is subjected to more mechanical stresses, until the fractures meet in the middle, at which time the lead breaks into two.

Neck Breaks

Neck Breaking is the severing of the wire from its ball bond due to a fracture in the neck. The neck is the portion where the wire meets the ball bond. Neck Breaking is commonly due to poor wirebonder set-up. Poor set-up includes improper bonding parameter settings, bondhead movement settings, and worn-out or contaminated tools. Incorrect bonding parameters can deform the bond excessively, resulting in a thin, weak, or cracked neck which can easily fracture. Improper bondhead movements and low loop settings may subject the wires to excessive stresses that may result in gross neck cracks which may propagate to fracture. Worn-out and contaminated tools can produce defects in the wires which can act as starting points for crack propagation.

Die overcoat material reaching the neck regions of the bonds can likewise cause neck breaks. Gelcoat exerts tremendous stresses on the wires during thermal stressing. This mechanism can be easily prevented though by limiting the gelcoat thickness.

Neck breaks as a result of wiresweeping during molding can also occur. Excessive wiresweeping produces both a linear and angular displacement of the wire, which tend to pull on and twist the neck of the ball bond. The neck is severed if its fracture strength is exceeded by the resultant stress. Taut wires and low loop heights aggravate the effects of wiresweeping. Die-to-plastic delaminations, such as those induced by an improper DTFS process, can likewise result in neck breaks, since any movement of the delaminated plastic with respect to the die would tend to pull away the wires from the die.

Neck breaks due to corrosion also occur. Commonly encountered corrrosive contaminants in the wires and bonds include Cl and S.

Package Cracking, Ceramic

Ceramic package cracking is the occurrence of fracture(s) anywhere in or on a ceramic package.
See separate article on *ceramic package cracking*.

Package Cracking, Plastic

Plastic package cracking is the occurrence of fracture(s) anywhere in or on a plastic package.
See separate article on *plastic package cracking*.

Package Delamination, Plastic

Plastic delamination refers to the disbonding between a surface of the plastic package and that of another material. Plastic delamination may therefore occur at an interface of the plastic and the leadframe, die, die paddle, or die attach material.
See separate article on *plastic package delamination*.

Seal Cracking

Solder seal cracking is the occurrence of fracture(s) anywhere in the solder seal of a ceramic package that uses a combo lid, e.g., sidebrazed, LCC, and JLCC packages. *Seal glass cracking* is the occurrence of fracture(s) anywhere in the seal glass of a Cerdip package.
See separate article on seal cracking.

Wedge Lifting

Wedge lifting is the detachment of a wedge bond from the bond pad or bonding post, or the crescent bond from the leadframe bonding finger.
See separate article on *wedge lifting*.

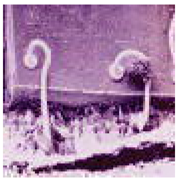
Wire Breaking, Midspan

A midspan wire break, or broken wire, is simply the disconnection of the first bond from the second bond, because of a total fracture somewhere along the length of the wire itself. Broken wires are often due to package mishandling, particularly when the package has not yet been encapsulated or sealed. Wires being hit by the lid or cap during capping, or accidentally touched by the operator prior to encapsulation/sealing, or smashed by an equipment tool getting out of control, all suffer a midspan break after the incident.

Wire nicks and similar defects can act as crack initiation points on the wire. Incipient cracks can easily propagate during thermomechanical stressing once they have formed from these defects. Broken wires can also be caused by corrosion, which is often brought about by Cl contamination of the wires. Wiresweeping during molding is another primary cause of broken wires.

Wire Depression

Wire depression is a condition wherein one or more wires of the device are deformed or pressed downwards. Wire depression is caused by purely mechanical means, usually by mishandling. Wirebonded leadframes prior to encapsulation are very vulnerable to wire depression, especially if these are being handled manually. Improper stacking of the leadframes, fingers coming into contact with wires, or leadframes slipping out of control prior to or during the molding process are common causes of depressed wires.



Equipment problems can also result in wire depression. For example, overcoat dispense tools that are improperly set up can land on the wires and depress them.

Wire-to-Die Shorting

Wire-to-die shorting is the presence of an unintended electrical connection between one or more wires and the die. The electrical connection may be in the form of a wire directly touching an edge of the die, or stray conductive materials bridging a wire to the die edge. Mishandling of packages prior to encapsulation/sealing can result in depression of the wires, shorting them against each other and to an edge of the die. Excessively low loop profiles and very short wires increase the likelihood of, if not lead to, wire-to-die shorting. Die attach material that accidentally falls or drips on the die surface, or reach it in whatever way, can short the bond and wire to the die edge. Stray wires and loose eutectic flakes inside the package can also short the wires to the die edge.

Wire-to-Wire Shorting

Wire-to-wire shorting is the presence of an unintended electrical connection between two wires. The electrical connection may be in the form of wires directly touching each other, or stray conductive materials bridging one wire to another. Stray wires that somehow get into hermetic packages can bridge one wire to another. High loop profiles and excessively long wires increase the tendency of wires to get shorted. Wiresweeping during molding may lead to wire-to-wire shorts, although it may break the wires first before shorting occurs. Mishandling of packages prior to encapsulation/sealing can result in depression of the wires, shorting them against each other.

Wrong Bonds

Bond Misassignment, or wrong bonding, is simply the bonding of the first or second bond to the wrong bond pad or bonding post/finger, respectively. It may be considered as a misrouting of the bonds, such that the bond pads are not connected to their corresponding external terminations. Bond misassignment can only happen if a wrong bonding program is retrieved and used.