Solid State Science and Technology, Vol. 16, No 2 (2008) 92-98
ISSN 0128-7389

CONSTRUCTIONAL ANALYSIS FOR QFN STACKED DIE FAILURE IDENTIFICATION

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ABSTRACT

The electronic industry has always set for the highest standards in quality and reliability. To ensure the reliability of final semiconductor products, evaluation and characterization at process development and product stage are conducted. In this paper, constructional analysis (CA) technique is used as a tool to determine failure mode in QFN stacked die package that will affect reliability. The procedure in CA involves package decapsulation, cross sectioning and SEM analysis. Failure mode and its causes will also be addressed.

INTRODUCTION

In constructional analysis (CA) technique, decapsulation and cross sectioning through QFN packages is usually done to reveal internal feature and materials used. Figure 1 shows the flow diagram of CA procedures for QFN stacked die failures identification.

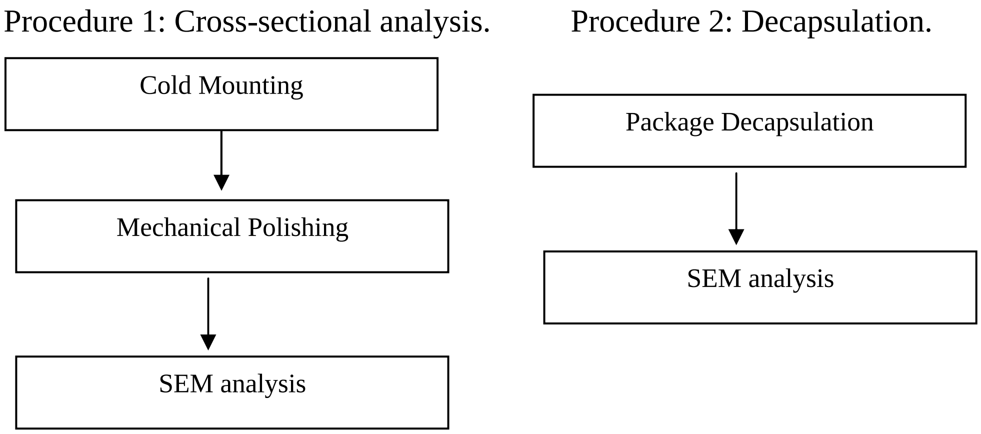

Figure 1: Flow diagram of CA procedures for QFN stacked die failures identification.

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EXPERIMENTAL METHOD

Cold Mounting

Cold mounting is especially suited for mounting samples that are sensitive to heat or pressure. The resin, a mixture of two or three components, is poured over the sample after it has been placed in a mounting cup. After curing, the sample can be taken out of the cup and processed.

Mechanical Polishing

Grinding and polishing are standard operations in material processing. It is important to inspect and classify the potential defects existing on the product surfaces after grinding and polishing in order to obtain high quality in both functionality and aesthetics [4]. All samples for microstructure analysis were grind and polished using appropriate abrasive (usually in sizes from 15 microns down to 1 micron) and carrier. Rough polishing is usually done with the laps rotating at 500 to 600 rpm. Cloths with a medium or high nap are ordinarily used on slow rotating laps (less than 300 rpm) for intermediate and final polishing.

Decapsulation

Decapsulation is a failure analysis step performed to open a plastic package to facilitate the inspection, chemical analysis, or electrical examination of the die and the internal features of the package. The failed devices were then decapsulated using wet-chemical techniques and failure causes were identified using scanning electron and optical microscopy [1].

Manual chemical etching consists of manually dispensing some acid on the surface of a package to remove the plastic material covering the die. Red fuming nitric acid (HNO3) or sulfuric acid (H2SO4) is often used for this purpose. A cavity is first milled on the top surface of the package. Red fuming nitric acid heated to about 85-140 deg C or sulfuric acid heated to 140 deg C is then repeatedly dropped into the cavity to remove the plastic material covering the die. When the die has been exposed adequately, the unit is rinsed with acetone then with D/I water, before being blow-dried carefully.

Manual etching may also refer to the process of soaking the package entirely in a beaker of sulfuric acid heated to about 140 deg C. This process will totally destroy the unit, leaving behind the silicon die and bits and pieces of undissolved metal piece parts.

SEM Analysis

The scanning electron microscope (SEM) is a type of electron microscope capable of producing high-resolution images of a sample surface. Due to the manner in which the image is created, SEM images have a characteristic three-dimensional appearance and are useful for judging the surface structure of the sample.

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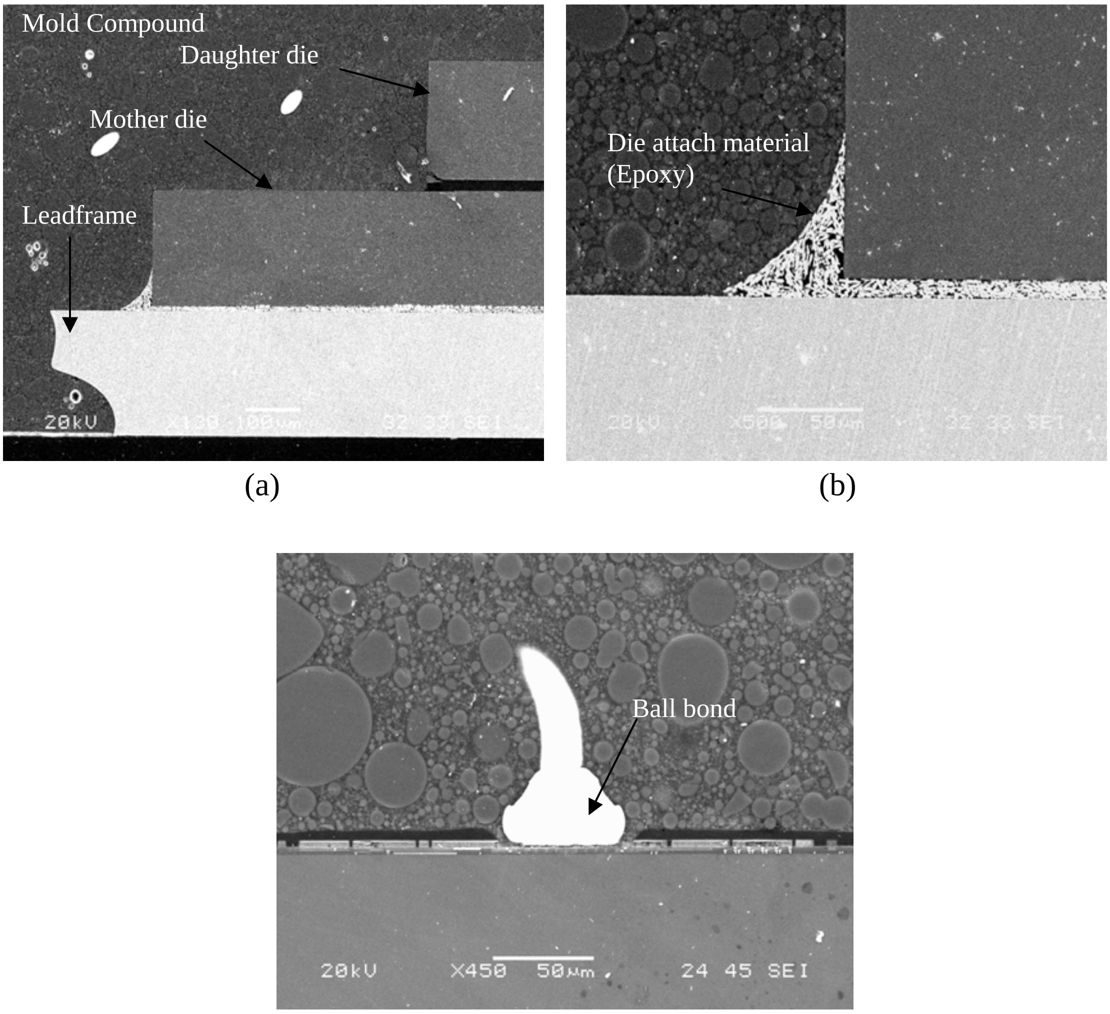
RESULTS AND DISCUSSION

Cross-sectional Analysis

SEM micrographs of cross sectional QFN stacked die package are shown in Figure 2(a), (b), and (c). Figure 2 (a) is the left edge of full package consist of leadframe, die attach, mother die, daughter die and mold compound. The cross section of the package revealed the type of die stacking which is pyramidal stacked die. In Figure 2(b), from SEM analysis it is clearly see that die attach material of package invested is made from epoxy. While in Figure 2(c) shows ball bond with bell shape.



(a) (b)

(c)

Figure 2: (a) SEM micrograph of the left edge of QFN package at the 130x magnification, (b) SEM micrograph of epoxy die attached material between leadframe and mother die at the 500x magnification, (c) SEM micrograph of ball bond with bell shape at the 450x magnification.

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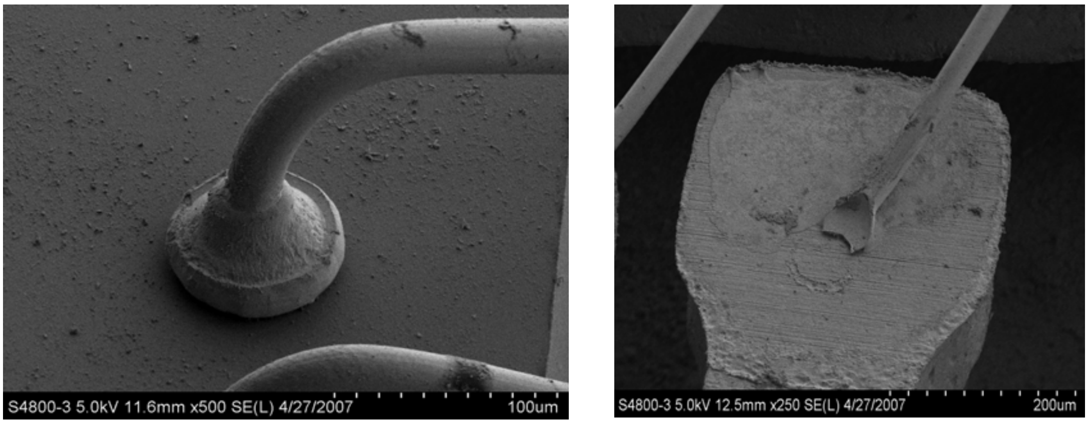
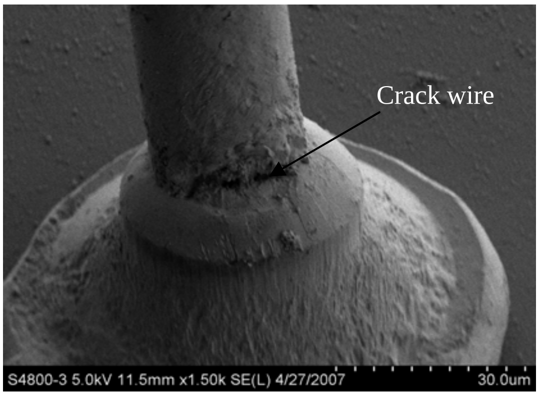
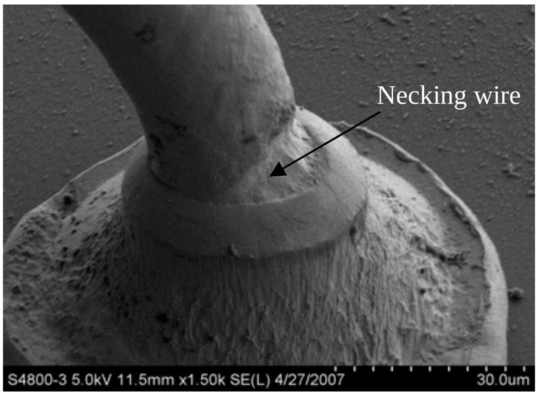


Figure 3: (a) and (b): The good wire bonding and good wedge bond of package respectively.





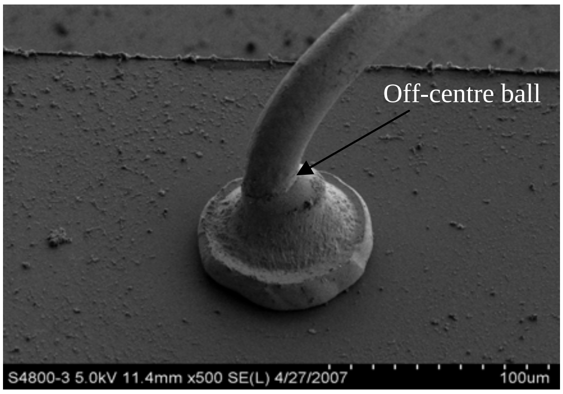


Figure 6: SEM micrograph for wire bonding failure mode shows off-center ball

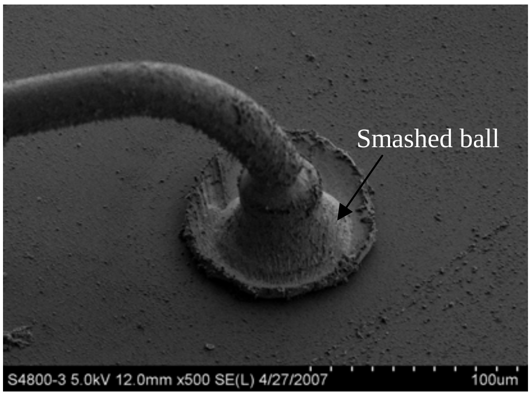


Figure 7: SEM micrograph for wire bonding failure mode showssmashed ball.

Decapsulation Analysis

Decapsulation procedure used to reveal internal features especially to look for failure that will affect the reliability performance of the QFN package. The SEM micrographs reveal there are four types of wire bonding failures mode occurred

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during the inspection. In power electronic packages wire bonding is used for the electrical contact of the chips and for interconnections on the module substrate. Limiting factors for the reliability are solder fatigue and wire bond failures [3].

Figure 3(a) and 3(b) show the good wire bonding and good wedge bond of QFN package. The four types of wire bonding failure modes are shown in Figure 4 for wire crack, Figure 5 for wire necking, Figure 6 for off-centre ball and Figure 7 for smashed ball.

1) Voiding in the Bonds

Atomic interdiffusion between different metals is a natural phenomenon in a wirebond metallurgical system. If left unchecked, however, this can lead to voids in the bond that can result in significant degradation of the bond's mechanical strength and electrical conductivity.

Voiding is generally caused by unequal diffusivities exhibited by the different metals used in the wire bond, a phenomenon known as 'Kirkendall Effect.' In gold ball bonding, for example, the rates of diffusion of gold atoms from the gold ball into the aluminum bond pad and the aluminum atoms from the bond pad into the gold ball bond are unequal. Voiding failures from such interdiffusion process can be accelerated by long exposure to high temperatures and the presence of contaminants. Halogen contaminants can also cause voiding failures. For instance, aluminum bromide formed from free bromine can volatilize, creating voids within the bonds.

2) Presence of Contaminants

The presence of halogen contaminants on the bond pads can cause the bond pads to corrode in the presence of moisture. Corrosion per se is a major cause of bond failure as the bond and wire are eaten away. The formation of corrosion byproducts are harmful too, especially if already present at the time of bonding, since these can impede the sticking of the bonds onto the bond pads. The presence of other types of contaminants on the bond pad such as unetched glass or silicon dust also impede proper bond formation between the wire and the bond pad.

Contaminants on the lead fingers where second bonds are formed likewise cause weak bonds, or even non-sticking. Such contaminants include residual plating bath components as well as metallic impurities. Organic contaminants in raw leadframes are a common issue too.

3) Looping Problems

Correct wire looping is important during wire bonding. Lack of adequate wire looping can result in excessive stresses at the bond neck or heel, which can lead to neck and heel breaks when the device is subjected to thermo-mechanical stresses. Excessive wire looping, on the other hand, can result in sagging wires and wire sweeping, both of which can cause wire shorting. Voiding is generally caused by unequal diffusivities exhibited by the different metals used in the wire bond, a

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4) Bond Placement/Geometry Problems
The bond must be placed well within the bond pad. A bond that is partially positioned outside the open window of the bond pad can result in weak bonding or, worse, shorting with an active metal or another bond. Inferior bond geometry as characterized by under- or over-sized bonds and/or incorrect aspect ratio can also lead to weak bonds.

5) Bonding Site/Substrate Issues
Aside from surface contamination, there are other wire bonding site or substrate problems that can lead to bonding failures. Common bonding site/substrate issues include excessive probe digging on bond pads, lifting of the bond pad metal, voids in the silver plating of the lead fingers, silicon nodules on the bond pad and silicon damage beneath the bond pad which can lead to cratering. Cratering is generally attributed to fractures caused by overbonding.

6) Equipment-related Problems
Equipment-related issues that can cause wirebond failures include incorrect parameter settings, incorrect equipment set-up, calibration issues, dirty, damaged, or worn-out capillaries/bonding tools, excessive vibrations and reverse motion/looping control problems.

CONCLUSION

Constructional analysis for failure identification is significant to make sure any issue related to the product can be detected at earlier stage. This can help the production to improvise the package design in order to prevent the failure from happened again. One thing that must be concerned in constructional analysis is the quality of sample preparation which is must be the best one to guarantee the result delivered is accurate.

ACKNOWLEDGEMENT

The authors would like to thank Ministry of Science, Technology and Innovation Malaysia (MOSTI) for the financial support of this work under the grant no. 03-01-01-0089 PR0075/09-09. The supply of samples from Infineon Technologies (Kulim) Sdn Bhd is also gratefully appreciated.

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