Wire-Bonding Reliability Evaluation

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Abstract – In microelectronic devices, wire bonding is the most common first-level interconnection method between die and lead. Failure of wire bonding causes component failure. Component failure may lead to system or sub-system failures, which often have very expensive consequences. Such failures are even more severe in the harsh operating conditions of the Oil and Gas industry, where services such as rig charge are extremely expensive. We have developed a robustness-evaluation method for microelectronic components using construction analysis.

1. Introduction

Electronics are so much part of our daily lives we can barely think of the way the world would be without electronics. Most equipment is only as reliable as electronic components used inside. Complexity of electronic is increasing. Electronic components need to perform multiple functions as ever-increasing complexity of equipment demands it. Electronic packaging technology can address increased functionality and performance required.

Wire-bonding is the most widely used microelectronics packaging technology in the electronic industry [1]. (see Figure 1). However, it tends to be the weakest part of the design. In wire bonding, reliability of ball and stitch bonds is the upmost challenge. Testing is the general practice for component reliability assessment. Our wire-bonding-robustness-evaluation method uses construction analysis instead.

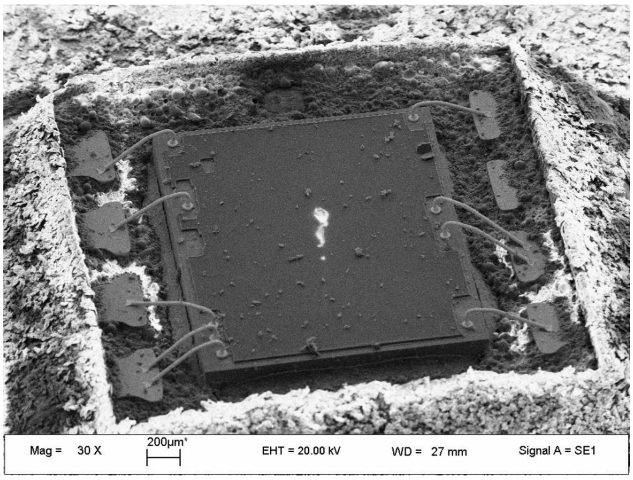

Figure 1: Typical wire-bonding in microelectronic packaging

1.1. Wire-bonding failures

Wire-bonding-reliability evaluations are necessary to understand potential failure modes and mechanisms and how to maximize reliability [1].

Wire-Bonding could have several failure modes and mechanisms. Although failure modes are different from one another, they could have similar root causes. The most common failure modes are the followings.

1.1.1. Ball bond failure

Ball bond failure is the most common failure mode in microelectronic packaging [2]. It is usually due to intermetallic growth caused by thermal aging. Microcracks from in intermetallic layer and weaken the bond [3]. Ball bonding Au, Cu, Ag base wires to Al metallization form intermetallic compounds (aluminides) on thermal ageing. [4] A limited amount of interfacial IMC formation in dissimilar metal ultrasonic or thermosonic wire bonds increases the bond strength. But excessive IMC formation could result in the performance degradation of the bond. Increased thickness of IMC would produce higher electrical resistance, leading to a higher heat generation when current flows. This results in a multiplier effect, as the formation of additional IMC in the bonded interface is promoted by the heating due to elevated resistivity [5]. IMCs formation and related voids and cracks at the interface determine the strength and reliability of the bonds. The IMCs formation is beneficial to bonding strength but their excessive growth can increase brittleness of bonds and the contact resistance, thus leading to bonds failure [6].

1.1.2. Wire rupture

Wire rupture usually occurs due to excessive stress on wire or some imperfection in the component design or manufacturing. The root cause of wire rupture is self-generated stress caused by CTE mismatch between different materials used in the plastic package assembly (Figure 2).

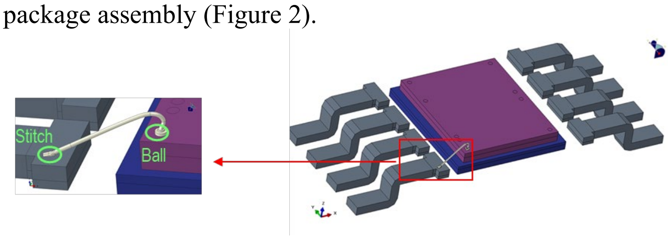

Figure 2: Plastic package wire-bonding

1.1.3. Stitch bond failure

Stitch bond failure is more common when assemblies are exposed to severe temperature cycling and shock. Temperature cycling can result in moulding compound to wire delamination. Delamination causes high stress around stitch area. Failure occurs when the stitch area is over-stressed [3].

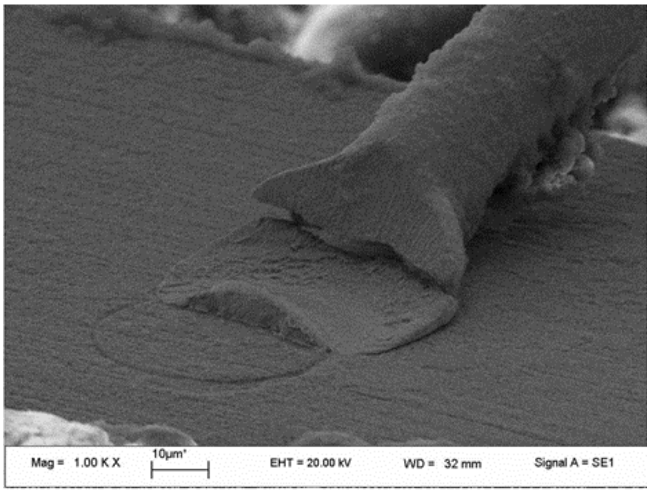

Figure 3: Stitch bond failure

Our research [7] identified the impact of different design parameters on stitch bond reliability :

Component-level parameters:

a) Component design including material properties and component dimensions.
b) Lead frame materials and plating.
c) Bond-wire dimensions and geometry of the bonds
d) Component weakness or defect such as delamination pre-reflow and post-reflow and progressive delamination due to the effects of harsh operating environments.

Board-level parameters:

a) Printed-wire assembly (PWA) design and form factor including component positioning on the board.
b) Board potting or coating including material properties.

This study focuses on the stitch bond failure.

2. Research approach

2.1. Motivation

We observed failures of encapsulated electronic components used in several designs; there are cases where we have multiple component failures on one board.

Extensive failure analysis on different components revealed that they all suffered wire-bonding failure. Figure 3 shows an image of a typical failure observed. Stitch-bond rupture is clearly visible in all components affected. These failures caused several service-quality issues and production delays and the consequences are very expensive.

2.2. *Approach*

Root-cause analysis led to a list of parameters affecting stitch-bond reliability. The first step was to evaluate the impact of each parameter on stress/strain by simulation (Figure 4 and Figure 5). The simulation highlights the important parameters, on which we shall focus. Once simulation results are validated by laboratory testing, future products will not need as much experimental test.

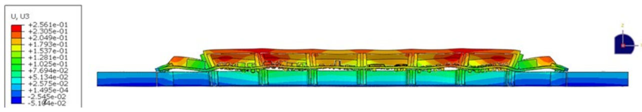

Figure 4: Board level simulation

The next step was validation, we ran experiments to validate the simulation and define acceptance criteria for different parameters. The experiment was designed based on Highly Accelerated Life Test (HALT) on an actual board.

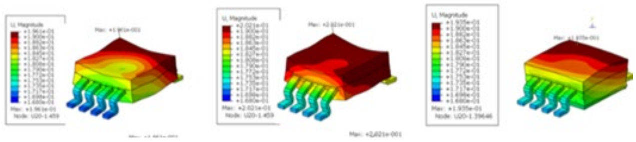

Figure 5: Plastic-component simulation

The last step was construction analysis with focus on stitch bond geometry. Wire-form factor and stitch- bond dimensions were measured on all components used in this testing program. Stitch design parameters were identified by simulation (Figure 6).

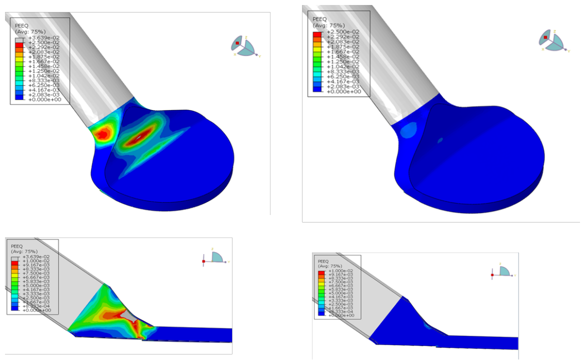

Figure 6: Stitch bond Simulation

Finally, we combine simulation, physical testing and construction analysis to define design acceptance criteria for different components.

2.3. Testing

HALT was run on a testing board specifically designed for this research. Components with known reliability history were grouped and placed in 5 pockets across the board. Two end pockets were left blank to minimize the edge effect. Figure 7

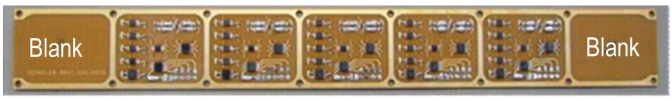

Figure 7: Borad layout

Components were chemically opened after the tests and their status was evaluated in correlation with parameter H of the stich bond geometry. Results are demonstrated in Table 1.

Table 1:Component status vs stitch thickness (Figure 8)

Component	U1	U2	U3	U4	U5	U6	U7	U8	U9
H (µm)	20	9.4	17	12.7	8.2	8	16.3	14	5.9
Status	Pass	Fail	Pass	Pass	Fail	Pass	Pass	Pass	Fail

3. Results

In this study, FEA identifies the most critical parameters. Samples from same batch (date code) of components used in the test board are selected. Wire-form factor and stitch-bond dimensions (Figure 8) were measured on all components used in this testing program.

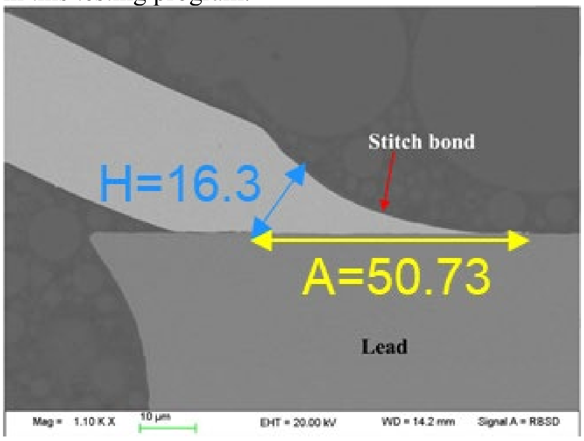

Figure 8: Stitch bond critical dimensions

Parameters H and A are identified as critical parameters that could impact the stitch bond reliability by simulation. These records are used in modeling to improve FEA accuracy. We combined construction analysis, simulation, and testing to define component-acceptance criteria. Test results and simulation agree that parameter H is the most important parameter that impacts stitch bond reliability.

4. Conclusion

Results demonstrate that the reliability of microelectronic wire-bonding strongly depends on design and process. Robust components are built that way and can be identified at the design phase or lot acceptance evaluation. Component manufactures can improve stitch bond reliability by implementing better design features and enhancing process controls. We can evaluate wire-bonding robustness by construction analysis.

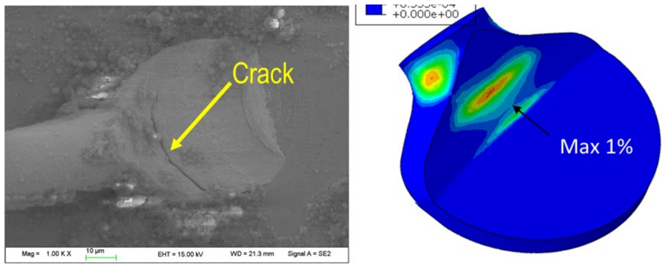

Figure 9: Simulation vs test result

Common failure-modes and mechanisms that can cause microelectronic stitch-bond failures in harsh oil and gas operations are shown in the results of this study. Simulation results agree very well with laboratory testing (Figure 9) and validate the models for use in initial evaluations of components in the assembly design phase. This validated model can replace much of the physical testing required for component qualification.

Acknowledgements

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