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Ball Crack Mitigation through Wirebond Process Optimization

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Authors' contributions

This work was carried out in collaboration among the authors. All authors read, reviewed and approved the final manuscript.

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ABSTRACT

Intermetallic is a critical factor that is controlled and limit during manufacturing of integrated units. Through improving the ball flatness response of the semiconductor wire significantly impact the outcome for the intermetallic characteristic between metal such as Gold-Aluminum connection. The implementation of this study on the actual manufacturing control eliminates escapee of poor intermetallic that would impact the reliability and integrity of the package upon its application to the end product.

Keywords: Ball crack; design of experiments; intermetallic; wirebond process.

1. INTRODUCTION

Wirebonding or the process of connecting semiconductor wires of either Gold (Au), Silver (Ag) or Copper (Cu), to the and input/output (I/O) bonding pad assembly of typically Aluminum (Al) in material is one of the key processes under integrated circuit manufacturing to incorporate electrical connectivity between silicon die and printed-circuit board (PCB) application. An intermetallic connection is formed between semiconductor wires and bonding pad through

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thermocompression process or the application of heat to the metal layers to produce "material softening" and force that is applied on the semiconductor wire to mechanically establish the interface. In addition, the intermetallic formation between the wire and the bonding pad is one of the critical factors in determining the reliability and integrity of wirebonding [1-4].

During manufacturing, the behavior of inter-metallic compound between multiple combinations of elements Au and Al is studied and measured through cross-sectional and intermetallic coverage (IMC) measurement. The reliability of the intermetallic is determined by the percentage formed between metals. On standard criteria, the IMC should have acceptance limit of greater than 75% to produce a robust intermetallic interface between metals. Important to note that with new state-of-the-art machines and platforms and continuing technology trends, challenges and varying requirements in semiconductor packaging are inevitable [5-8]. In this study, a ball crack shown in Fig. 1 was detected, with poor IMC shown in Fig. 2 was measured.

The reliability and functionality test required to detect the robustness of IMC on a single product is known to be time consuming that can take 6-8 weeks due to process of thermal cycling and packing testing. For fast-phasing project, it is better to detect and captured early manifestation of defects to avoid probable delays. In this paper, the importance of Semiconductor wire ball flatness is discussed and explained to achieve good intermetallic and robust wire connection. Through optimizing the segmented bonding parameter and application of design of experiment produces good ball flatness and IMC growth on Au-Al intermetallic.

2. PROCESS IMPROVEMENT

The design of experiment has a primary objective of improving the ball flatness and IMC growth between Ag and Al. To create a suitable parameter 2 segment parameter, force and scrub was proposed and defined from the start of the study, as shown in Fig. 3.

A workability build is proposed to measure the initial impact of the parameter and measure a baseline result. Fig. 4 shows the initial cross section result and IMC measurement. A design of experiments (DOE) given in Fig. 5 is proposed to identify the critical parameter that would significantly affect the wire ball flatness.

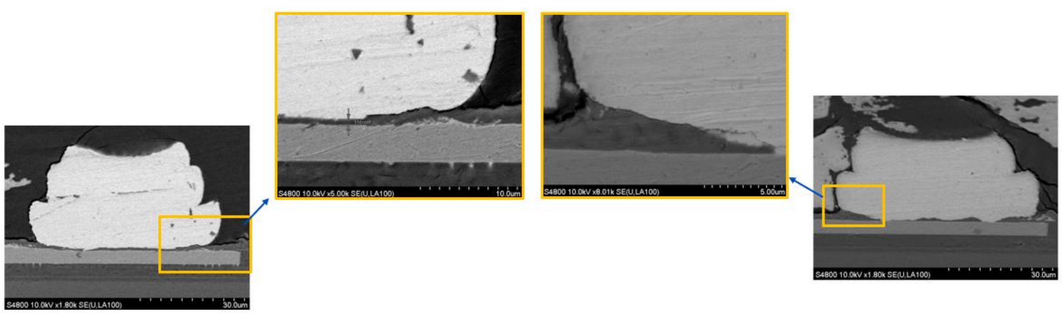

Fig. 1. Cross sectional view of a semiconductor wire and bonding pad

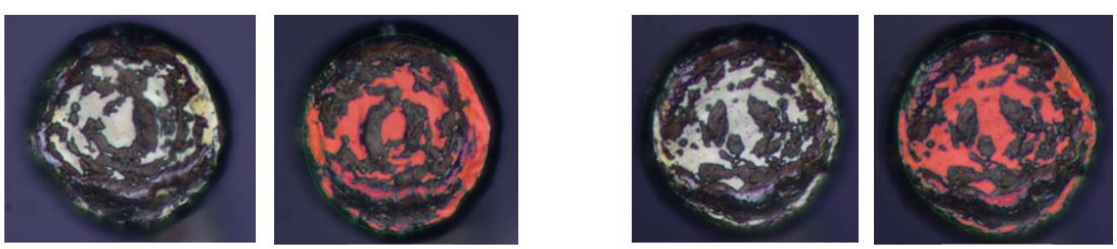

Fig. 2. IMC measurement

Fig. 3. 2-segment parameter

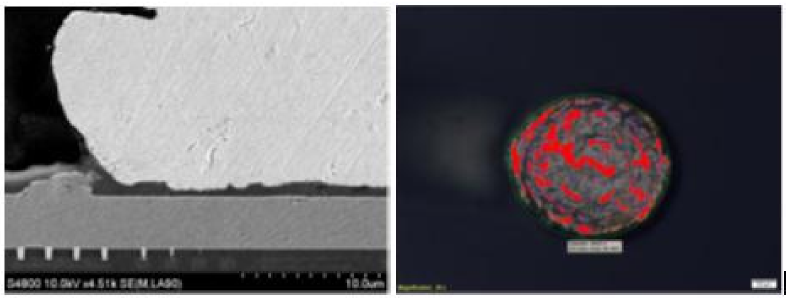

Fig. 4. Workability result

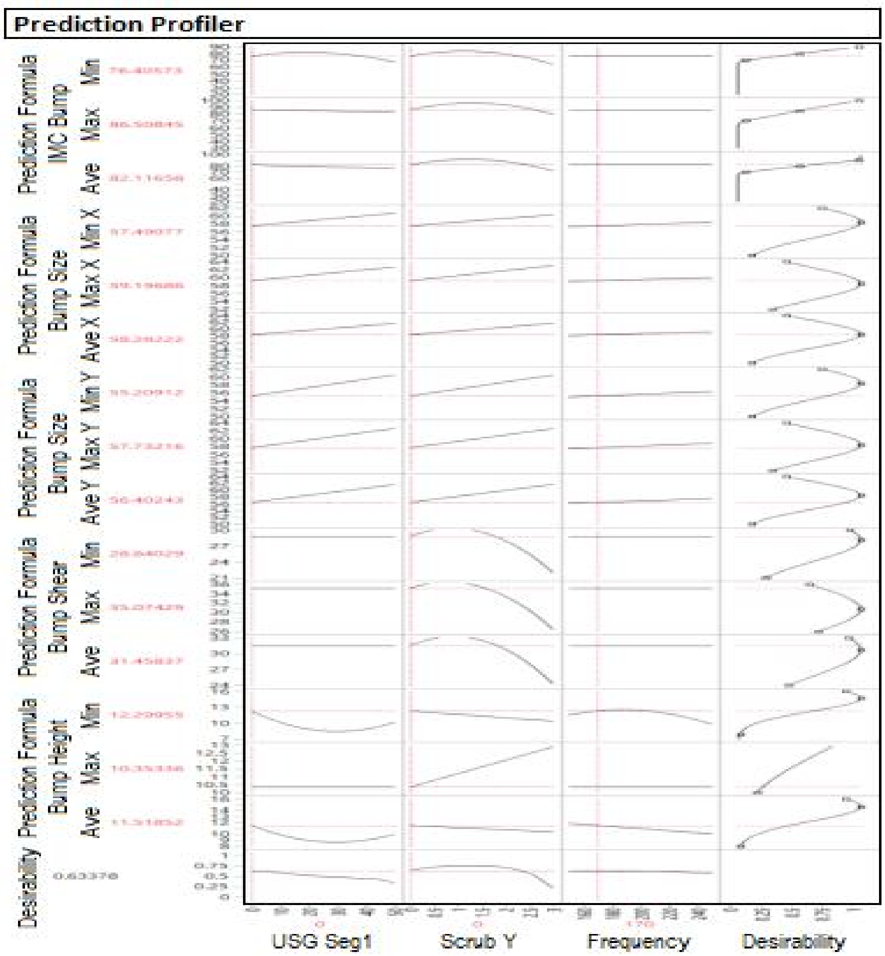

Fig. 5. DOE result

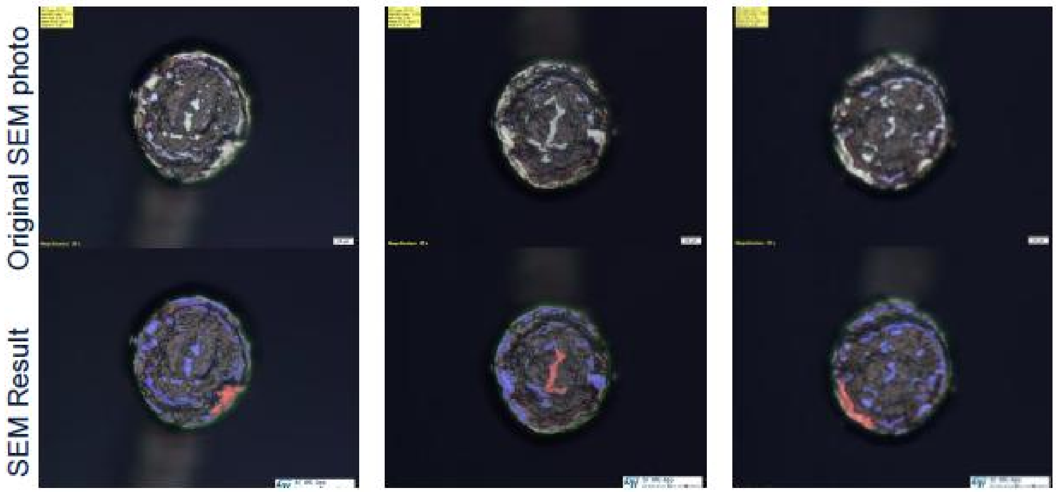

Fig. 6. IMC result

The ball flatness as shown in the workability shows no crack or delamination of Au wire to the Al bonding pad. There is also no penetration of Au wire to the Cu layer underneath the Al layer of the bonding pad when the wire is bonded. A certain distance of 10 microns is maintained between Au wire and the underneath Cu layer.

The IMC growth of the initial parameter has above 75% IMC measurement as depicted in Fig. 6. Likewise, the design of experiment can use this parameter as baseline to provide a suitable range of limits.

3. CONCLUSION AND RECOMMENDATIONS

The result concludes that ball crack is directly impacted by higher parameter of force through USG1 and scrub through Scrub Y, and with addition of higher input parameter for frequency produces poor intermetallic signature. Implementing and identifying a defined control limit for parameters that has significant impact for the parameter eliminates the occurrence of poor intermetallic between metals. The learnings on this study could be used on future works with comparable requirement on IMC and ball crack mitigation.

It is recommended that a comparison of this study should be made with other works in the same field. Study of material properties on the delamination and ball crack phenomenon could also be explored. Works in [1-4, 9-12] are helpful in reinforcing robustness and optimization of assembly processes particularly at wirebonding process.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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