

Reliability of eWLB (embedded wafer level BGA) for Automotive Radar Applications

by

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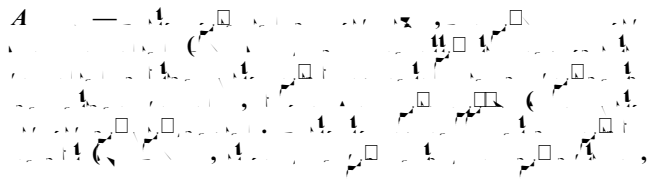
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With Si-based front-end technologies showing improved performance, wireless systems at millimeter wave (mmWave) frequencies become more and more important [3-5]. Adaptive Cruise Control (ACC) radar system at 77 GHz [6, 7], point-to-point radio link at 60 GHz or high resolution radio imaging at 94 and 140 GHz [8] are just a few examples of applications observed for upcoming markets. The impact of packaging on the overall electrical performance of the IC becomes increasingly important with frequencies increasing beyond 10 GHz. Thus, for the crucial development of commercial mmWave applications, the availability of high performance packages for monolithic microwave integrated circuit (MMIC) is crucial.

A few approaches for mmWave packaging solutions have been studied and reported based on Rogers 4350 substrate (low-loss material) surface mount-type (SMT) package for 1-40 GHz applications [9] or 77 GHz ceramic SMT package using an electromagnetic coupling as second-level interconnects [10]. Since they use traditional conventional laminate-based packaging and integration solutions, the packages were expensive and big size.

A very promising solution for mmWave packaging is eWLB package technology [11, 12]. It is based on an embedded device technology with fan-out redistribution. The thin-film redistribution layer (RDL) of the eWLB enables very flexible and highly customizable package

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mount device (SMD) packaging technology. The eWLB package offers these properties and has been proven in a few mmWave applications.

This study focused on 2nd level reliability of the solder joint regarding temperature cycling as one of the major requirements of automotive applications, which requires a higher reliability spec of AEC (Automotive Electronics Council)-Q100 Grade-1. Thus, investigation and optimization of design factors, structure, process and material properties are of interest for eWLB packages development. Comprehensive systematic design and structural parameter study and analysis were carried out to

Table 3 illustrates TCoB board level reliability test results of DOE study of automotive eWLB packages.

$$\underline{F \quad A \quad J}$$

The results from the DOE TCoB reliability studies are summarized as below:

DOE1		
DOE2		
DOE3		
DOE4		

DOE5		

In this study, both DOE 4 and5 UBM samples showed lower solder joint life cycle compared to non UBM samples. For UBM samples, SMD of DOE 4 and5 showed solder fatigue failure in board side as shown in Fig. 7 but NSDM of DOE 4 and 5 did not have major solder fatigue cracks. After further failure analysis of SEM micrographs, the Cu metal pad was observed as broken in conventional WLCSP [17,18,19].

In general, the reliability of WLCSP is dependant of a range of various design factors, for example:

- Dielectric materials property
- Dielectrics thickness
- UBM pad size/thickness
- Cu pad size/ Cu RDL thickness
- Cu pad opening size/Pad overlap size
- Solder materials / Solder ball size

(a)

(b)



III. CONCLUSION

Thanks to its unique materials properties and thin film RLD with encapsulated structure, eWLB technology is an important wafer-level packaging solution that will enable the next-generation of automotive radar applications with its unique superior mmWave high frequency electrical performance. In this study, 9x9mm eWLB reliability was researched on component level and TCoB board level reliability with comprehensive DOE studies. The 9x9mm eWLB passed both AEC-Q100 Grade-1 package level reliability as well as TCoB board level reliability. To investigate dominating design factors for an improvement of TCoB performance, several DOEs were studied with experimental tests.

It was observed that the PCB pad structure and NSMD pads (versus SMD) changed solder fatigue mode, thereby improving the solder joint reliability. FA results showed solder fatigue failure for samples without UBM, but broken metal RDL was observed for samples with UBM samples corresponding to lower solder joint life cycle.

Furthermore, factors such as superior high frequency electrical performance in mmWave range and ability for heterogeneous integration; to integrate passives like inductors/resistor/capacitor into the various thin-film layers, active/passive devices into the mold compound or encapsulation, and achieve 3D vertical interconnections for new 3D SiP and 2.5D/3D packaging solutions, differentiate eWLB from other packaging technologies. eWLB technology provides a more holistic performance, and has potential to be a new packaging platform that widens its application to automotive, 5G and mmWave applications, such as antenna on package (AoP) or antenna in package (AiP).

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