Advanced Packaging for Automotive Dashboard Application

by

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Abstract

The current automotive market for the IC (integrated circuit) packaging industry has grown significantly due to the increasing need for automation and higher performance in vehicles. These changes in the automotive market will enable cars to be more reliable and intelligent. To address the increasingly complex demands of the automotive market, the semiconductor packaging industry is shifting its focus to prioritize the development of advanced packages for next generation automotive market requirements.

Automotive IC's are traditionally wirebond packages. Due to the increasing complexity and higher performance requirements of automotive applications, the packaging industry is moving towards high performance flip chip and advanced fan-out packages for automotive infotainment, GPS, and radar applications. In this study a comprehensive view of the changing packaging landscape from traditional wirebond to flip chip interconnect to advanced fan-out wafer level packages will be discussed. The pros and cons of each packaging technology will be examined. Packaging roadmap details will be discussed along with assembly process information, determining the right BOM (bill of materials), cost data, and extensive package and board level reliability.

Keywords: automotive, wirebond, flip chip, fan-out, reliability, dashboard

Introduction

There is a huge number of electronics systems in the automotive cars and trucks today and it is increasing year over year due to new regulations established by the National Transportation Safety Board (NTSB), strong demand from the consumer markets and so many other factors. Autonomous or driver free cars are accellerating demand for more electronics systems in automobiles. Also the total number of vehicles sold in global markets is also significently increasing due to growing demand in Asia and Latin America. The automotive market is expected to be one of the leading growth segments in the semiconductor industry. Figure 1 shows the recent growth of the automotive IC market.

Typical electronics systems in new vehicles are engine control units, power steering, transmission control, anti-lock brakes, stability control, airbag, infotainment, safety sensors, cameras and Advanced Driver Assistance Systems (ADAS). Some of the components located under the hood of the vehicle run at very high temperatures while components in the dashboard or cabin operate in a less harsh environment and lower ambient conditions.

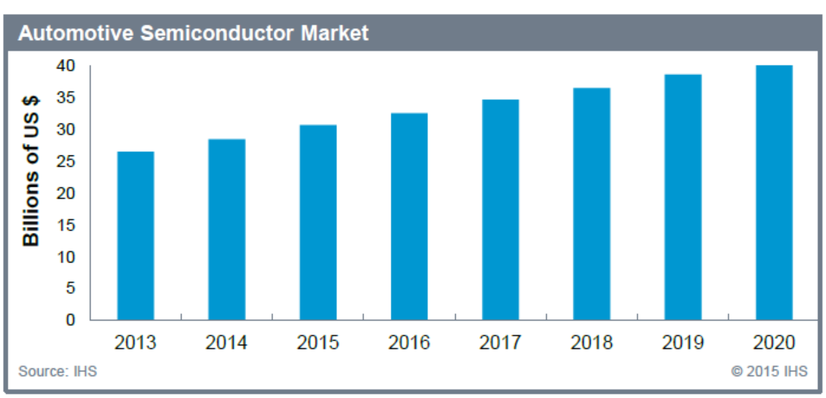

Figure 1: Automotive IC market growth (Source: IC Insights)

The automotive industry has gone through many different phases of technology evolution, primarily due to serious concerns with safety regulations. Examples of recent areas of evolution are ADAS, infotainment, and cameras. The mandates from worldwide regulatory agencies, new market demands, and aggressive targets for assisted and autonomous driving have created tremendous momentum across the automotive industry supply chain.Various semiconductor packaging opportunties are opening up in the growing automotive market. However, numereous barriers or challenges still exist in the market such as:

1. How to make automobiles safer?
2. How to integrate entertainment, communication, navigation, and safety features in the car?
3. How to drastically improve the life of electronic products from 2 years which is typical in the consumer or mobile market to 10+ years for the automotive market?
4. How to meet very high quality, reliablity and handling requirements at a lower cost?

To successfully address these challenges, the entire automotive industry is undergoing a major restructuring, and is collaborating with different companies to develop solutions that meet the essential requirements of the automotive market.

Automotive Requirements

Automotive semiconductor components must be compliant with the following criteria:

1. AEC-Q100 with capabilities for each temperature grade
2. ISO TS 16949 certified
3. Zero manufacturing defects
4. Complete tracking and monitoring of the entire manufacturing, shipping and supply chain process with detailed information.

The Automotive Electronics Council (AEC) established a standard grade called AEC-Q100 which must be meet for all IC supply chain makers. The main objective of AEC-Q100 is to determine that an IC component is capable of passing the specified stress tests, and thus can be expected to deliver a certain level of quality and reliability in the application field. The AEC-Q100 temperature grades are as follows.

AEC-Q100	Minimum Ambient Temperature	Maximum Ambient Temperature
0	-40^{0}C	150^{0}C
1	-40^{0}C	125^{0}C
2	-40^{0}C	105^{0}C
3	-40^{0}C	85^{0}C
4	0^{0}C	70^{0}C

Table 1: Automotive AEC-Q100 Grades

The grades represent various application spaces in the automotive market from extreme under the hood applications to very mild application conditions. Beyond AEC-Q100 certification, automotive vendors need a specialized manufacturing flow and a bill of materials (BOM) with increased inspection and screening, both in manufacruring and relaibility testing. Typically IC companies perform both package and system level tests, however, assembly suppliers can also perform package level and board level tests to verify the assembly porcess and BOM. In 2015, the AEC introduced a new set of AEC-Q006 requirements for qualification of copper (Cu) wire interconnect for the components used for automotive applications. AEC-Q006 applies to mainly wirebond packages such as FBGA, QFN, PBGA, etc. The AEC-Q006 process helps to identify Cu lead frame cracks, Cu wire /lead frame delamination, failures, etc in the assembly process. An automotive IC assembly factory has to be ISO certified with TS 16949. In addition to factory certification, an assembly supplier has to maintain a dedicated manufacturing line and equipment, operators, process and control plan to ensure an automotive line is very robust and error-proof. Wirebond packages require special material for wire type and size, lead frame type, die attach epoxy type, and mold compound type.

Gold (Au) wire has been used in the automotive industry for many years due to its low inductance, ductility and no oxidation properties. Over the last decade, Au prices have significantly increased, forcing the IC industry to look for an alternate material. Palladium (Pd) coated Cu wire is one of the best alternatives to Au wire for automotive electronics. There are various challenges that Cu wire assembly suppliers have been addressing such as cracks in the ball bond area, lower shear strength, oxidation, voids, intermetallic formation, etc. Assembly suppliers are swiftly moving to qualify Cu wire for various grades of automotive qualificiation.

Punched QFN or side solderable QFN with half cut in the assembly process packages are typically used for automotive applications. Roughened lead frame is used to improve epoxy molding compound (EMC) delamination whereas a side solderable design provides ease of inspection of the swan QFN package. Typical side solderable swan QFN is shown in Figure 2.

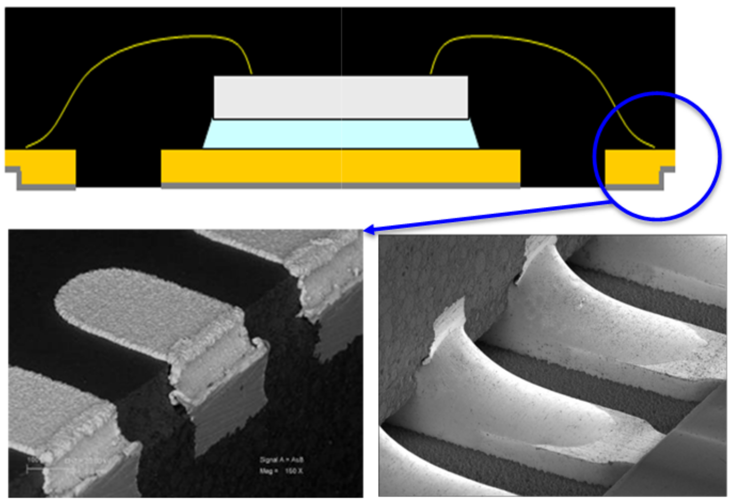

Figure 2: Typical Side solderable swan QFN package

Automotive IC Packaging Trends

Due to the increasing complexities and higher performance, pin count, power, and cost requirements of automotive applications, the packaging industry is moving towards high performance packages such as flip chip or wafer level fan-out packaging for automotive infotainment, GPS, and radar applications. About a decade ago automotive ICs were primarily low lead count,high power wirebond packages used in engine control modules to small dashboard applicatoions and sensors. Figure 3 shows a typical roadmap for IC automotive packages used in dashboard applications.

Silicon integration in the automotive industry is gaining traction in both System-on-Chip (SoC) and System-in-Package (SiP) areas. Both SoC and SiP technologies have a much higher potential to improve performance and power while reducing size and cost for automotive applications. Today, SiP technology is expanding into market segments such as automotive due to the rapid time–to-market and overall cost savings that can be achieved. An important innovation in IC packaging happened in the area of auto safety and ADAS which uses bug free software and hardware to alert drivers to potential hazards and problems to prevent collisions. Wafer level chip scale packaging (WLCSP) and wafer level fan-out packaging, also known as embedded wafer level ball grid array (eWLB), are commonly used for 60 to 79 GHz ADAS radar applications. It provides a smaller form factor and much less interconnection parasitic which is very critical for high frequency applications. Other advanges of wafer level processing are smaller tolerances which enable better assembly yield results and a lower cost.

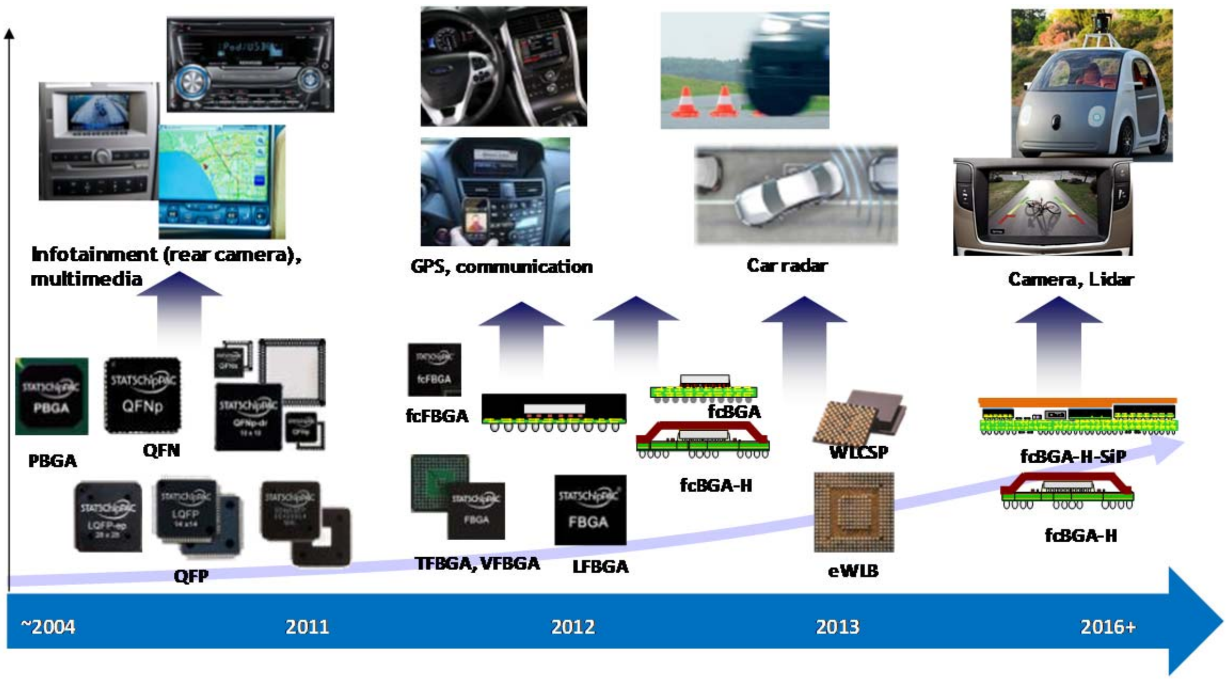

Figure 3: Typical IC packages roadmap for automotive dashboard applications

System level integration is also happening in flip chip and wafer level packages. Figure 4 shows a multi-chip fan-outeWLB SiP. The standard fan-out package eliminates the need for a laminate substrate and replaces it with Cu redistribution layers that inherently have a much shorter connection from die to the circuite board with a significantly reduced impedence. Advanced FOWLP is now becoming an attractive solution for thinner profile and higher level of integration packages in a wide range of applications. The design flexibility of this method allows for integration of multiple dies, passives, and other discrete components in the package.

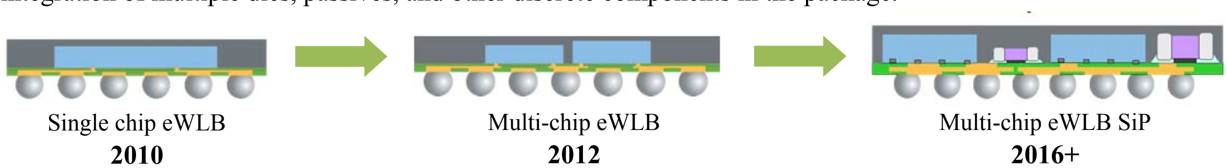

Figure 4: Multi Chip FOWLP (also known as eWLB) SiP

Package and Board Level Qualification Data

One of the basic requirements for automotive ICs is to qualify the package with AEC-Q100. In most of the cases, both package and board level package qualification reliability tests are performed by theIC customer, although sometimes the package assembly vendor has to conduct the tests to ensure their capability. Reliability tests for in cabin or dashboard applications are not as harsh compared to under the hood applications.Standard IC package reliability tests are pre-conditioning, temperature cycling, high temperature storage life, temperature humidity bias, unbiased highly accelerated tests, board level thermal cycling and drop tests. Typical grades for in cabin applications are between grade 2 to 3. However, today IC vendors are required to qualify to grade 1 even for dashboard applications. Wirebond packages with Au wire can comfortably meet grade 1 requirements. Cu wire is a challenge in meeting grade 1 due to mold compound delamination, IMC issues, etc. Flip chip packages are primarily for grade 2. However, similar to wirebond requirements, some IC vendors are looking for grade 1 in flip chip technology. As demand for FOWLP emerges in the automotive area, there was a big concern if FOWLP can fulfill grade 2 or grade 1 requirements. Some of the recent fan-out data shown in Table 2 below proves that fan-out packages are robust for in cabin applications.

eWLB size (mm2)	Die size (mm2)	Pitch (mm)	*Die No. / RDL No.*	I/O	AEC-100 Qualification Reliability Test
6x6	3x3	0.5	1-Die 1-L	76	Pass
8x6	5x4	0.5	1-Die 1-L	114	Pass
5x5	2x3	0.5	1-Die 1-L	58	Pass
9x9	6x6	0.5	1-Die 1-L	230	Pass
7x7	5x4	0.5	1-Die 1-L	160	Pass

Table 2: Fan-out wafer level package DOE for AEC-Q100 test

Test		Condition		Status
Package Level	MSL1	MSL1, 260C Reflow (3x)	-	Pass
	Temperature Cycling (TC) after Precon**	-55 C to 125C	1000x	Pass
	HAST (w/o bias) after Precon	130C / 85% RH	96hrs	Pass
	High Temperature Storage (HTS)	150C	1000h	Pass
	HAST with Bias after Precon	130C / RH 85%	168hrs	Pass
	Temperature Humidity Bias (performed mounted on PCB)***	85C/85%RH	1000 hrs	Pass

• **Results based on Package eTest : <u>** Customer qualified TC_C -65/150C 1000x</u>**

Board Level Reliability				
Board Level	Temperature cycling on board (TCoB)	-40C to 125C, 1cy/hr	500x	Pass
	Drop Test	JEDEC		Pass

Table 3: Fan-out Package and Board Level Reliability Test Results

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