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Taking a Look at Wafer-Level Packaging

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Meeting consumer demand for increased features on camera phones and other mobile devices

An image sensor packaged at wafer level and provided with a ball grid array interface to simplify and reduce the cost of attachment to a printed circuit board. Comparison of a conventional cell phone camera with an OptiML module from Tessera.

Mobile devices have become a ubiquitous part of our lives. Cell phones alone are everywhere. In East Africa, for example, there is one doctor for every 50,000 people, yet 97 percent of the population has access to a cell phone.

An analysis of the mobile phone market by Gartner Dataquest (Stamford, Conn.) shows mobile phone trends rising from about 800 million units in 2005 to 1.4 billion next year. This includes basic phones, enhanced phones and smart phones.

Most of these phones have digital cameras and consumers are demanding even more functions and features. One way to provide all much of this—including better resolution on the cameras—is with wafer-level packaging (WLP).

“Wafer level is becoming by far the most prevalent packaging,” says Mike Bereziuk, Executive VP Imaging & Optics at Tessera (San Jose, Calif.). “In 2007, about 39 percent of CMOS sensors were in wafer-level packages. They project that by 2012 it will be over 76 percent.”

What is it?

Wafer-level packaging is simply the technology of packaging an integrated circuit at wafer level, instead of the traditional package of each individual unit after wafer dicing. There are at least four major WLP technology classifications,

according to research organizations Prismark Partners LLC (Cold Spring Harbor, N.Y.) and TechSearch International (Austin, Texas). They are Redistribution and Bump technology; Encapsulated Copper Post technology; Encapsulated Wire Bond technology; and Encapsulated Beam Lead technology.

“The advantage of our technology is, first of all, we are working from a wafer,” says Jacky Perdrigeat, CEO of Nemotek Technologie (Rabat, Morocco). “We are making and designing it from an eight-inch glass wafer. We design the lens and to produce it, we go to micromilling equipment to design a master lens shape wafer. We stamp from others to replicate the image of the master on wafer glass. During the process we replicate the image of a network of lenses on wafer glass.”

Perdrigeat says about 3,000 lenses can be produced on the eight-inch wafer, which gives a manufacturer the productivity and capacity that the ever-growing market requires.

The Process

The manufacturing process delivers a more cost-effective and miniaturized wafer level and hinges on the use of reflow-compatible materials. Reflow compatible means the complete camera module can be assembled directly to the phone board and placed on a solder machine withstanding a high degree of heat without damage, making the manufacturing process of the phone board less expensive for the device while allowing defective pieces to be easily reworked and sent through the soldering process again. Since this is the same solder reflow process used for assembling other electronics, customers save time by using the same procedure throughout the production cycle. A fixed focus optics feature also eliminates the high costs of manual focus adjustments present in other non-wafer offerings.

The process flow of a typical camera module is that the sensor is shipped to the camera module manufacturer. Generally, it's chip-on-board. They purchase the lens and put over the sensor.

“The problem with that,” says Bereziuk, “is that chip-on-board techniques require a clean room. If a particle of dust drops on a pixel..... Second, as the pixel size continues to decrease the number of pixels increases and again, you can damage it if particles fall on the pixels. Now, the trend is toward packaging—if dust falls on a package sensor it can be cleaned because it's a glass surface.”

Tessera licenses its technology to Nemotek and to Q-Technologies (Kunshan City, Jiangsu Province, China). It includes OptiML Wafer-Level Camera (WLC), as well as Shellcase Wafer-Level Chip Scale Packaging (WLCSP). (Tessera bought wafer-level-packaging expert Shellcase Ltd. (Jerusalem); Digital Optics Corp. (Charlotte, N.C.), a specialist in wafer-level micro-optics technology; and

Eyesquad (Tel Aviv, Israel), which has autofocus and optical-zoom expertise. Shellcase provides wafer-level packaging for both surface-mount and wirebond cameras. Digital Optics applies microelectronics techniques to optics, allowing production of well-aligned lenses on wafers. Eyesquad's digital focus technology becomes crucial when wafer-level cameras need 2-megapixel resolution or better. Its autofocus and digital zoom offer depth-of-field for higher-resolution cameras without using moving parts.)

Tessera's OptiML WLC technology promises scalability with pixel size as well as reflow compatibility. The process of aligning and bonding the lenses at the wafer level eliminates the need for manual focusing. The optical elements use reflow-compatible materials and are available in both wirebond and (ball grid array) BGA formats. The imager package must have a BGA interface on its rear surface. A BGA is a standard component interface in the semiconductor assembly industry and comprises an array of solder spheres of closely dimensioned size in specified locations. Having a BGA interface allows the imager to be placed together with other components on a common printed circuit board (PCB) and all to be attached and interconnected by exposure to a single reflow soldering cycle. This process is known as surface mount assembly. When BGA is used, the optical element can be directly placed on a board.

The process works in three segments, according to a white paper by Hongtao Han and Keith Main of Tessera's Charlotte, N.C. facility: fabrication and singulation of wafer-level optics; wafer-level chip scale packaging and singulation of image sensors; and integration of wafer-level optics with packaged image sensors.

The fabrication step begins with UV replication of micro-optics on a wafer scale. Depending upon the optical design, micro-optics can be fabricated on both sides of glass wafers. Next comes wafer bonding, optical testing and singulation (conversion of wafers into separate dies) of the optics wafer stack.

The wafer-level chip scale packaging of sensors has three configurations, depending upon how electrical I/Os of the image sensor are accessed (wire bonding from sensor to a substrate; edge connect and BGA; or Si via (TSV) and BGA. Finally, the integration segment is done with die attach equipment.

Assembly

The optical element, which eliminates such parts as plastic molds and flex-lead cables, has an X-Y dimension smaller than that of a sensor chip. As for height—usually a challenge for camera modules—Tessera says the Z dimension for the OptiML WLC's VGA implementation comes in at 2.5 mm. Conventional modules range from 3.5 mm to more than 5 mm, according to the company.

“Once you've got the sensor and go into the flow, then you assemble the lenses

in the lens barrel, allow for focus and put on the image sensor,” Bereziuk explains. “We saw the benefit of the economies of scale and advanced sensor alignment technology to eliminate manual focusing of the lens in the lens barrel.”

Once the lenses, whether two- or three-element, are aligned and bonded, they’re put on the glass surface of the image sensor wafer with very little manual intervention. “The final piece,” Bereziuk says, “is manufacture of the camera module with reflowable passive materials that can be used right on the circuit board. [The benefits are that it] eliminates contaminants and manual alignment and uses reflow materials.”

Nemotek’s Perdrigeat adds that another advantage of the glass is that it keeps its shape during heating, where plastic optics might move or lose their shape. The solution works not only for cell phone cameras, but PC cameras, gaming consoles and security cameras. The OptiML single-element VGA lens is designed to work with 2.2µm pixel size VGA image sensors. Again, the reflow compatibility allows soldering of the camera modules without damage.

The number of lens wafers required to build the optical module is set by the optical requirements of the camera module. The lens wafers are then aligned and bonded at the wafer level, and diced into individual, integrated optical stacks that are mounted on top of a wafer-level packaged image sensor. The accuracy of the wafer stacking process optimizes the performance of integrated optics and packaged image sensors.

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