Military & Aerospace ELECTRONICS®

ANALYSIS

# Acoustic micro imaging helps assure reliability of plastic COTS parts

By Tom Adams

Undiscovered defects in supposedly protective packaging — not external forces — often are to blame for failures in integrated circuits (ICs). These defect-caused faults are a growing issue as military and aerospace systems designers move to commercial off-the-shelf (COTS) parts. The issue centers on well-known ceramic vs. new plastic IC packaging.

As U.S. military officials begin their cost-trimming change from ceramic-packaged ICs to plastic-packaged COTS ICs, their challenge will be to ensure high reliability while using an unfamiliar packaging material

Years ago, plastic (or more accurately epoxy) IC packages had serious reliability problems. They did not handle temperature cycling well, and they were likely to absorb moisture over time. A plastic IC package could absorb moisture while simply sitting on a shelf. A frequent scenario: internal moisture would collect in an internal delamination or other anomaly, then flash into steam when exposed to heat during mounting. The resulting pressure often caused various degrees of damage.

IC damage also stemmed from factors different from temperature. Defects along the lead frame, for example, could permit moisture — and ionic contaminants — to reach and corrode aluminum bond pads on the chip.

Ceramic packages have the advantage of hermeticity, which protects vital chip parts from potentially damaging moisture. In many ceramic packages, a protective lid covers the die. The die and lead frame sandwich between two ceramic slabs and are fired at low temperature.

While the hermetic seal around the die gives ceramic IC packages at least the aura of reliability, they still suffer from many internal defects similar to those found in plastic packages — die attach defects, for example.

Despite the potential for defects, the switch to plastic packages is beginning to accelerate. "Makers of ceramic packages are getting out of the business partly because the cost of producing the ceramic packages is going up," explains Bob Brough, senior engineer at the Lockheed Martin Electronics and Missiles division in Orlando, Fla. "At the same time, plastic packages have demonstrated high reliability in many applications."

Two changes in recent years have made the switch from ceramic to plastic packages a realistic choice. "First there have been great improvements in the plastic themselves. They have better resistance to humidity and, largely because the auto industry has driven their development so hard, better tolerance for high temperatures," says Kerry Oren, an acoustic microimaging specialist at AcousTech Inc., an electronics and manufacturing analytical service company in Fort Wayne, Ind. "Second, the tools for nondestructively inspecting finished packages have become more sophisticated and powerful."

Two of the most important nondestructive internal inspection methods for IC packages are X-ray and acoustic imaging. X-ray, the older method, depends on differences in atomic weight in package materials. "X-ray is good at imaging the very fine gold bond wires in a package because gold has a much higher atomic weight than the surround materials," Lockheed Martin's Brough explains. "But it will miss aluminum wires of the same size." When the difference in atomic weight is less, X-ray depends on the overall volume of a material. It images relatively large three-dimensional voids in plastic or ceramic, but not thin, essentially two-dimensional delaminations or cracks.

The development of acoustic micro imaging has roughly paralleled the development of IC packages. Technicians made the first acoustic images of the first plastic IC packages in 1978; the first C-SAM reflection-mode acoustic micro imaging system was introduced in the mid-1980s; and experts performed the first high-speed automated acoustic image in 1996. These and other advances took place at Sonoscan Inc. of Elk Grove Village, Ill., where engineers built the first commercially available scanning laser acoustic microscope in 1974.

The very high frequency ultrasound in acoustic micro imaging behaves differently from X-ray. Imaging depends on internal interfaces rather than on atomic weight. Ultrasound is pulsed by the transducer into an IC package. When the ultrasound strikes a well-bonded interface, a portion of the ultrasound reflects back to the transducer. The return echoes create the image of the bonded interface.

But if the ultrasound strikes a "gap-type" defect — a delamination, crack, void, or disbond — all of the ultrasound reflects. Total reflection of ultrasound from these defects makes acoustic micro imaging sensitive to precisely the internal defects that X-ray is most likely to miss.

Most of the internal defects that will destroy the reliability of an IC package are gap-type defects. Each package type has its own particular locations where these defects are likely to occur — delaminations between the plastic and the die face, for example, or cracks in the die attach material. Experts find some of these internal defects because the defects cause immediate damage during the manufacturer's electrical tests.

More significant for long-term reliability are the hidden internal gap-type defects. Test engineers will notice no electrical anomalies, for example, in a package with a die attach defect that has not yet caused the chip to overheat.

MIL-STD 883 Method 2030 describes the percentage area of acoustically visible delamination allowed between a die and its substrate — that is, in the die-attach zone — even though such defects cause no initial problems. Test engineers originally wrote this method for ceramic packages. They recognized that even in hermetically sealed package such delaminations could grow and eventually cause a failure. Later they applied the same method to plastic packages.

Hidden internal gap-type defects tend to grow over time by sending out thin cracks. “The mechanism of growth is often the repeated thermal cycling of normal operation, although mechanical shock and environmental contaminants can also cause defects to grow,” explains AcousTech’s Oren. “A relatively few defects do not grow. Suppose there is a small void in the die attach material under a chip.

If the defect is near the center of the chip it is much less likely to grow than if it is near a corner of the chip. That’s because the stresses resulting from differences in coefficient of thermal expansion are much less at the center. But an identical defect near a corner of the chip is subjected to greater stresses and is more likely to expand.”

MIL-STD 883 Method 2030 recognizes these differences. A defect in the die-attach material near the center of the chip is very likely — but not certain — to retain its initial size. In low-cost plastic IC packages it may be economically feasible to reject even those packages having internal defects which are probably — but not absolutely — harmless.

In performing acoustic imaging to reveal hidden internal defects, there are significant differences between ceramic packages and plastic packages. The most important difference is in design: many ceramic packages have a cavity etched into the upper ceramic slab to accommodate the lid over the chip. Between the lid and the die is an air space — a relatively gigantic gap across which ultrasound will not pass. Scanning the ultrasonic transducer above the topside cannot image such a package. The solution is to flip the ceramic package over and image it from the backside. If the package has already been mounted on a board, the die region is inaccessible from either side. Plastic packages lack this gap, so a board-mounted plastic package can still be imaged nondestructively. In this respect, the switch from ceramic to plastic has an extra payoff — plastic packages are easier to image acoustically.

The locations of hidden internal gap-type defects in ceramic and plastic packages are somewhat similar. A variety of die attach defects are common to both — voids, delaminations, and cracks — the types varying to some degree with the kind of die attach material used. Delaminations along lead fingers occur in both package types. Cracked die and defects such as voids and cracks in the bulk of the packaging material itself can occur in both ceramic and plastic, but are arguably more prevalent in plastic.

“The concept that you can see internal bonding — and lack of bonding — nondestructively is still new enough that some engineers are meeting it for the first time,” AcousTech’s Oren notes. “One group visiting our lab was excited to find that they could actually see the bonding of their device to its substrate — in other words, they could verify the bonding without cutting the package open. The acoustic image gave them the proof of reliability that they needed.”

The conventional acoustic image is a planar image — an acoustic look straight down into the package. Because the echoes from various internal interfaces arrive back at the transducer at slightly different times, the return echoes can be, and usually are, gated electronically. This way the acoustic image is limited to a specific depth such as the die face or lead frame. But many non-conventional variations have been developed.

First, the Thru-Scan method puts a second transducer below the package and collects the ultrasound that has traveled through the entire thickness of the package. Gap-type defects show up as acoustic shadows. This is a quick method for determining whether a defect exists anywhere in a package.

Then there is the Q-BAM method, which makes a virtual cross-section of a package along a vertical plane determined in planar imaging. Q-BAM is the equivalent of physical cutting of the package, but is nondestructive and therefore repeatable on the same package.

Other approaches involve successively deeper scans of a package that stack electronically to create a three-dimensional acoustic solid, a virtual representation of the package.

The acoustic solid contains all of the acoustic data about internal features. Its sections — geometrically, by acoustic properties, by depth — reveal internal features.

Perhaps the most useful acoustic image in a high-throughput environment is the automated system that uses a very high-speed transducer to scan JEDEC trays of packages. The system finds and images hidden internal defects in as many as several thousand packages per hour by scanning each tray as though it were a single large package, but maintaining single-package image resolution. A pick-and-place machine can remove marginal or reject packages from the trays and replace them with good packages.

ACOUSTECH

**Reprint courtesy of:**
**AcousTech Inc.**
**(219)637-2167**
**www.acoustech-inc.com**