Perfecting the Package – Bare and Overmolded Stacked Dies

Understanding Ultrasonic Technology for Advanced Package Inspection

A Sonix White Paper

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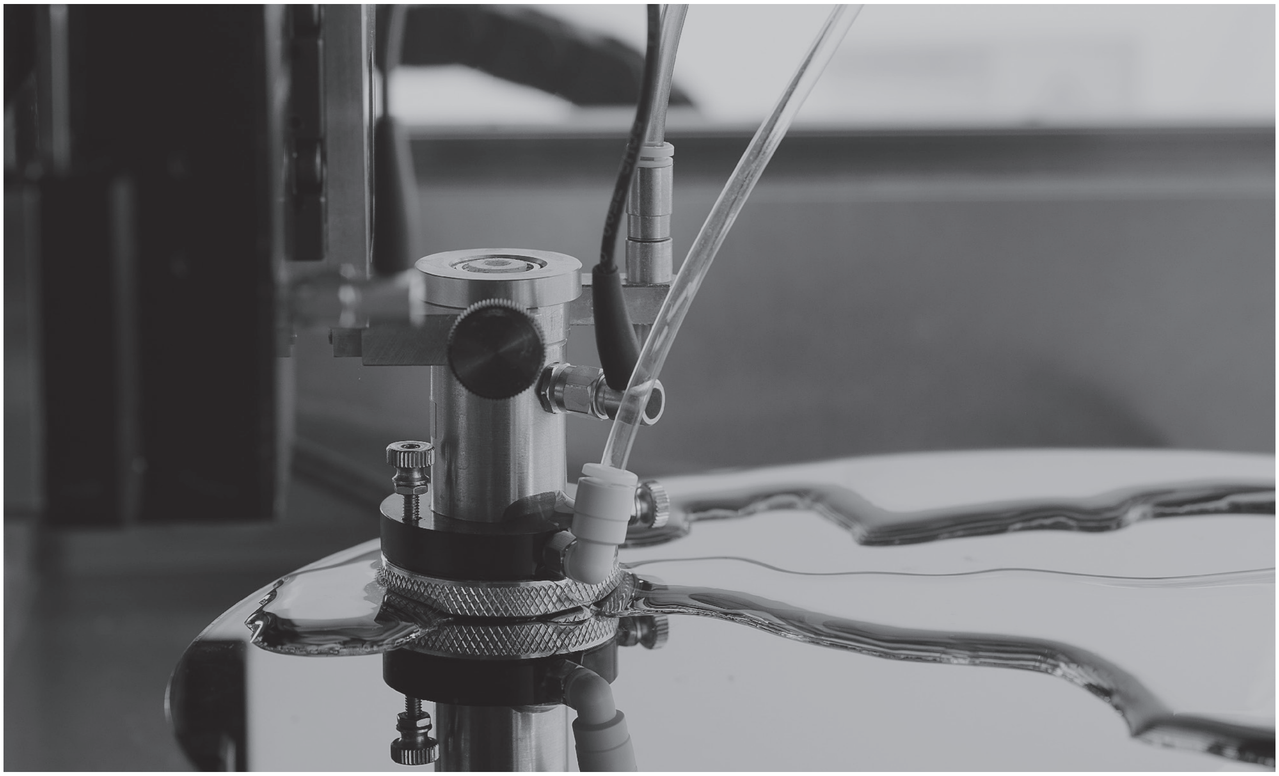
Understanding Ultrasonic Technology for Advanced Package Inspection

Advanced silicon package manufacturers are literally changing the world – enabling devices that are smaller, more powerful, more robust, more affordable. But all these advancements depend on techniques – such as stacked dies, Cu pillars and molded underfill – that make package inspection much more challenging than in the past.

Production yield and quality assurance will always be crucial to success, and the limitations of the inspection system should never stand in the way. To the contrary – no matter how difficult the challenges, package inspection should play an integral role in helping identify and correct production problems, and validating the quality of every package that comes off the production line.

Sonix stays current with the latest in advanced package technology, including how packages are fabricated, where problems may occur, and how to penetrate the most difficult molded layers and stacked dies to clearly reveal any defects. This white paper provides an overview of the most common challenges we see today for inspecting bare and overmolded stacked die packages.

We also offer white papers for advanced Cu pillar inspection and molded underfill (MUF) inspection. All papers in our advanced package inspection series provide recommendations for overcoming the specific challenges of each package type to get the clearest inspection images possible while maintaining production-line speeds.



Bare or Overmolded Stacked Die Inspection

When inspecting stacked dies, manufacturers are typically looking for defects at the die attach layers. They may also want to detect warped dies and characterize their metrology, whether for fine-tuning designs in the lab, diagnosing and fixing production problems, or providing quality assurance for finished products. In addition to die-attach defects, hybrid packages also call for validation of the interconnecting bumps or pillars.

An effective inspection system for stacked die packages must be able to clearly image defects that may include:

- Delaminations and voids in die-attach layers
- Warping of dies
- Defective bump or pillar interfaces (if present)

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Inspection Challenges

Scattering of the signal from filler particles in overmolded stacked dies

Filler particles in the overmold compound tend to scatter ultrasonic signals, especially at higher frequencies, causing attenuation and scattering effects that can degrade the image. This is a problem for hybrid stacked die packages since the interface features can be an order of magnitude smaller than the particles. This scattering effect adds another challenge beyond the issue of multiple internal reflections in conventional stacked die packages, as discussed below.

Resolving of stacked interfaces

Because stacked dies are so thin (typically 50μm or less) and the attach layers even thinner (20μm or less), getting good image resolution at deeper interfaces can be a challenge. UHF transducers can provide exceptional resolution for most bare stacked die applications. However, the addition of a particle-filled overmold layer calls for lower frequencies to achieve the required penetration while mitigating problems of signal scattering and internal reflection.

Die warping

Stacked die packages are assembled from thin dies, and warping can be a problem. Warping in a die layer can affect the quality of the die attach, and manufacturers can use ultrasonic metrology to map the degree of warpage to help address production problems. It's also important to account for warping when scanning for defects in die attaches and interfaces – otherwise, inspection images may drift in and out of focus as the scan proceeds over an uneven plane.

The addition of a particle-filled overmold layer calls for lower frequencies to achieve the required penetration while mitigating problems of signal scattering and internal reflection.

Multiple internal reflections

Ultrasonic signals are inherently reflected at material boundaries due to the mismatched impedance encountered there. Depending on the degree of mismatch, a certain percentage of signal energy will be reflected back while the remaining signal continues through the sample until it reaches another material boundary. Unwanted reflections cause interference that must be accounted for when choosing the ideal gain setting.

For stacked dies, there's a more serious inspection challenge. With multiple layer boundaries under inspection, reflections will resonate back and forth within each individual die and between multiple dies in very complex ways. These multiple internal reflections can cause issues such as phase distortion and time-of-flight differences that can obscure images from deeper within the stack or cause the image from different depths to overlap one another.

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Inspection Recommendations for Bare and Overmolded Stacked Dies

SDI™ (Stacked Die Imaging)

Inspection systems for 3D packaging require the ability to penetrate multiple stacked silicon dies as well as overmolding, metallization and dielectric layers. Signal reflections occur at each interface, weakening the amount of ultrasound that can propagate to the deepest layers. As gain is increased to penetrate to the deepest layers, reflections from the shallowest layers can become saturated, hiding defects.

In the past, it was necessary to perform multiple scans on a stacked die package using different gain settings. However, our patented SDI technology now allows you to set a gain profile, based on reflection strength and time values, to equalize the amplitude of all wanted reflections. The result is a clear view of each layered interface, without requiring multiple scans and without obscuring defects in shallow images through oversaturation.

S-series transducers:

- **Bare stacked dies:** UHF transducers, typically 200MHz for optimum resolution
- **Overmolded stacked dies:** 75 MHz to 150 MHz transducers for optimum penetration/resolution when scanning through particle-filled overmold

Choosing the optimum transducer frequency is crucial for achieving the sample penetration and image resolution required for a particular inspection application. Bare stacked die packages can be inspected at UHF frequencies to achieve high-resolution images. Overmolding causes signal attenuation and scattering, requiring lower frequencies in the range of 75MHz to 150MHz to achieve adequate penetration.

Our proprietary transducers are designed in-house to provide the clearest possible imaging specifically for the packaged semiconductor industry.

At UHF frequencies, precise selection and control of signal gain and focal length is imperative to ensure effective signal penetration and bring regions of interest into the best possible focus without unwanted image artifacts. At lower frequencies, advanced image enhancement and analysis technologies can improve spatial resolution and contrast for more precise defect detection.

pulse2 Pulser/Receiver

A general-purpose pulser/receiver may not deliver the signal quality and image resolution required for complexly layered advanced packages. Our next-generation pulse2 pulser/receiver provides 12 dB of extra gain and a 4x improvement in signal-to-noise ratio to remove low-level background noise and generate clear images.

pulse2 also supports higher-frequency pulse echo and through-transmission (TT) images for improved resolution of features and defects throughout the package, including:

- Multiple stacked die layers
- Substrate layers
- Metal/dielectric layers
- Flip chip/molded underfill (MUF) packages

Inspection Recommendations for Bare and Overmolded Stacked Dies

Heated Water

Water is used as a coupling medium to transmit ultrasonic frequencies between the transducer and the sample under inspection. Heated water provides much more efficient acoustic coupling than cold or room-temperature water. This can improve UHF signal penetration when inspecting bare stacked dies. When inspecting overmolded stacked dies at lower frequencies, use of heated water can allow for a somewhat higher frequency to improve image resolution.

To help deliver the best possible inspection results, we offer a patented 40°C heated water system as part of our Image Enhancement Suite, which we recommend for all advanced package designs.

Time of Flight (TOF) imaging

By measuring the changes in the time it takes for ultrasound to reflect off a particular interface, it's possible to gauge the relative depth of regions of the interface across the area of the sample. In this way, tilting or warping of the interface can be accurately characterized. The thickness of layers can also be calculated from the TOF data by accounting for the sound velocity of the material.

Flexible TAMI™

Our innovative Flexible TAMI™ (Tomographic Acoustic Micro Imaging) feature allows you to specify multiple "slices" of a sample to be imaged in a single scan. This allows for quick, efficient investigation of multiple interfaces in 3D packages.

Our MFCI™ technique can improve defect detection in any package application where ultrasonic signals may be scattered by particles in mold compounds or filler layers.

Our most advanced TAMI technology is called "Flexible" because you can set the spacing and length for each gate in the TAMI region independently, ensuring that each gate contains meaningful data and that fewer gates are required, minimizing setup time and file size.

Subsurface Follower (SSF)

For in-focus imaging across a warped die, without requiring multiple scans, our subsurface follower (SSF) tracks the internal warped surface and triggers the appropriate gating for the interface scan. SSF compensates for height variations to give a clear, complete view of the interface being analyzed.

MFCI™ Technique

Sonix has developed an exclusive Molded Flip Chip Imaging technique for improving spatial resolution, contrast and edge resolution when imaging complex packages.

Although our MFCI™ technique was originally developed to improve molded flip chip imaging, it can improve defect detection in any package application where ultrasonic signals may be scattered by particles in mold compounds or filler layers.

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The Sonix Advantage

Sonix has been the innovation leader since 1986.

Today, the ECHO line of scanning acoustic microscopes sets the standard for package inspection speed and image quality to help you keep pace with new packaging materials and difficult form factors. The ECHO platform will remain at the forefront as we continue to add features and enhance performance for years to come.

Choose our ECHO scanning acoustic microscope for package inspection of stacked dies, complex flip chips and more traditional plastic packages. ECHO VS adds industry-leading features for the clearest imaging of Cu pillar, molded flip chip (MUF), CSP, MCM, stacked die, hybrids, and other advanced package inspection applications.

Sonix is ISO 9001/2008 Certified. All of our tools are Semi S2/S8 certified.

For more information, visit our website at www.sonix.com.
We look forward to helping you solve your most difficult package inspection challenges.

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About Sonix

Established in 1986, Sonix is solely focused on leading the industry in the development of non-destructive ultrasonic testing solutions for microelectronics. We are the world's largest supplier of automated ultrasonic solutions for nondestructive wafer inspection, with over 70 percent market share.

Sonix is solely owned by Danaher ($18B, NYSE: DHR), providing financial stability with access to resources for investment and information sharing across sister company platforms and technologies.

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