



# Perfecting the Package – Cu Pillars

Understanding Ultrasonic Technology for Advanced Package Inspection



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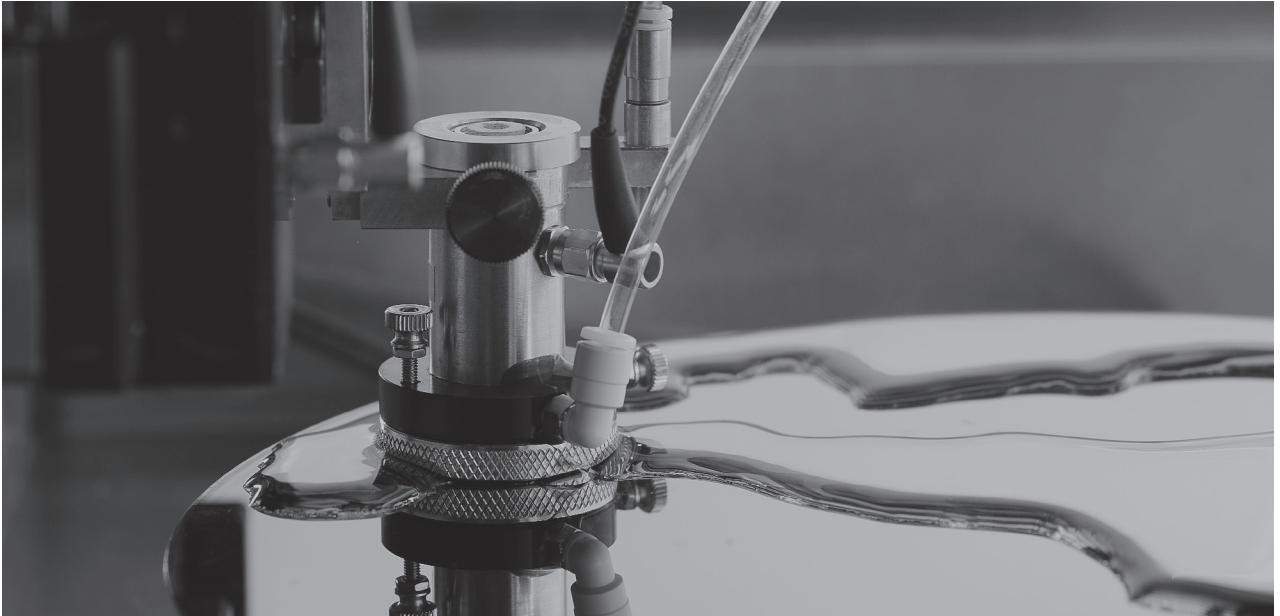
### Understanding Ultrasonic Technology for Advanced Package Inspection

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 Cu pillars, thinner dies, stacked dies 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 copper pillar inspection challenges we see today.

We also offer white papers for advanced MUF inspection and bare or overmolded stacked die 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.



## Cu Pillar Inspection

Thinner, lighter, more powerful mobile devices have created a demand for higher-density interfaces with improved electrical conductivity, thermal management and overall reliability. Copper pillars outperform solder bumps in all these respects<sup>1</sup>, enabling more reliable interconnects with a lower height, greater connection density and a pitch of 50µm or less.

While copper pillars enable package fabricators to pack more logical capabilities in a smaller dimension, it's essential to ensure that signals can get through each pillar at optimum frequency and amplitude. With pillar diameters as small as 10–30µm, a slight manufacturing defect can lead to cracks or voids that can alter or block the signal. In some cases a pillar may even be completely missing.

An effective inspection system for copper pillars must be able to:

- Verify proper wetting of the pillars to the die and the substrate, ensuring electrical continuity and mechanical strength of electrical interconnects
- Identify cracking or voids in individual pillars
- Identify missing pillars
- Image voids or delaminations in the underfill, which can lead to overheating or shear failures
- Identify variation in density of the underfill region
- Measure pillar diameter and pitch to help identify variations that might indicate process issues such as excessive bonding pressure

1. Rich Pell, May 30, 2012, "Die-to-die bonding using copper pillars." <http://edn.com/design/components-and-packaging/4374172/Die-to-die-bonding-using-copper-pillars>

## Inspection Challenges

**Image resolution at small scale.** An ultrasonic frequency typically in the UHF range is required to clearly image features at the scale of copper pillars. At ultra-high frequencies, however, signal penetration into the sample becomes an issue. Gain and focus must be set very precisely to ensure clear imaging of the desired features at a very specific depth.

Achieving the desired spatial resolution becomes even more challenging with each additional layer the signal must penetrate, since the boundaries between layers cause reflections that weaken the propagating signal and may tend to obscure features deeper in the sample. Also, any warping in thin dies can leave areas of the image out of focus.

**Edge resolution.** One benefit of copper pillars is that their small scale and fine pitch allow thousands of connections to be made on a single die, including the ability to place copper pillars very close to the edge of the die. The pillars at the edges can be difficult to inspect as a portion of the ultrasonic beam falls outside the sample, weakening the signal in the region of interest and making small-scale features hard to distinguish.

**Contrast.** Copper pillars do not provide the same image contrast as solder bumps. An intact solder bump appears very dark on an ultrasonic image, while a crack or void appears very bright. The contrast makes it easy to see the defects. Copper pillars appear to be relatively bright compared to solder, so differentiating a good pillar from a defect can be more challenging.

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Finding the right balance of setup parameters to optimize the image is essential – including selecting the right transducer, focus position, gates and other factors.

**Metallization.** It can be difficult to distinguish underfill voids from metallization layers, especially when multiple metal layers are stacked up to provide all the interconnections required by the extremely dense circuitry in copper pillar and other advanced package designs.

**Signal attenuation at polyimide layers.** A layer of polyimide resin is often used for passivation and dielectric insulation. Polyimide attenuates the ultrasonic signal – especially when high frequencies are required – and in some cases inconsistencies in the polyimide composition can even cast shadows on the regions of interest.

These properties can make accurate inspection difficult, requiring changes to the inspection setup – such as a longer focal length and/or lower frequency – that can also affect image quality. Finding the right balance of setup parameters to optimize the image is essential – including selecting the right transducer, focus position, gates and other factors.

## Inspection Recommendations for Cu Pillars

The challenges posed by advanced semiconductor packages call for advanced inspection technologies. Sonix offers several solutions that can be used in combination to achieve the best possible inspection results for any package type and production goal.

### UHF Transducers

Choosing the optimum transducer frequency is crucial for achieving the sample penetration and image resolution required for a particular inspection application. For Cu pillar inspection, we typically recommend transducer frequencies in the UHF range – 200 MHz or in some cases 300 MHz.

Our proprietary transducers are designed in-house to provide the clearest possible imaging specifically for the packaged semiconductor industry. At all frequencies – and UHF frequencies in particular – 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.

### pulse2 Pulsar/Receiver

A general-purpose pulser/receiver may not deliver the signal quality and image resolution required for extremely dense 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 – even when using UHF transducers with their inherently weaker signal.

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

### 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. We offer a patented 40°C heated water system as part of our Image Enhancement Suite, which we recommend for all advanced package designs, including Cu pillar inspection.

### 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 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.

### 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. This capability is particularly useful when inspecting small-scale features such as Cu pillars.



## 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.

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For more information, visit our website at [www.sonix.com](http://www.sonix.com).

We look forward to helping you solve your most difficult package inspection challenges.





## 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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