Acoustically Guided Destructive Physical Analysis

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When testing or field failure suggest that a part or component may have an internal gap-type structural defect such as a delamination, non-bond, or crack, it may be useful to physically section the part in order to see firsthand whether a defect is present.

If the defect has a relatively large z dimension, an X-ray may be used to provide the x-y location before physical sectioning. But if the defect is very thin, X-ray won't image it because the drop in the absorption of the X-ray at that x-y location is too slight.

The sample being imaged might be 1 cm thick, but the critical defect within it might be only 0.5 micron thick. The technician attempting to investigate the sample may resort to grinding his or her way through the sample from one end, hoping to identify and image any gap that is present. This process can be very time-consuming.

A better way to acquire a view of internal features before sectioning is to use an acoustic micro-imaging tool or acoustic microscope. Tools like those in Sonoscan's C-SAM® series are suitable for samples made of typical production metals, ceramics, and polymers and that have at least one flat surface, as well as for cylindrical samples. Sonoscan calls the method Acoustically Guided Destructive Physical Analysis, or AGDPA. Typical samples are up to a few centimeters thick and are not made of porous or lossy materials.

The C-SAM tool employs a transducer coupled to the flat or curved surface of the sample by a moving column of water. The transducer and water column scan back and forth along the surface at speeds that can exceed 1m/sec. Thousands of times a second the transducer sends a pulse of ultrasound into the surface. When the pulse strikes the interface between two materials within the sample, it sends back an echo that arrives at the transducer a few microseconds after launch. Each of the thousands of pulses launched each second generates one pixel in the acoustic image.

All pulses first strike the top surface of the part, which is the interface between the part and the water column. A portion of the ultrasound is reflected from this interface as an echo, while the remainder crosses the interface and travels deeper. This surface echo is a useful reference point from which to measure the depth of echoes from greater depths. Within the sample, the pulse is to some degree absorbed and scattered by the homogeneous material it is passing through. When it encounters a well-bonded interface between two solid materials -- a polymer and a

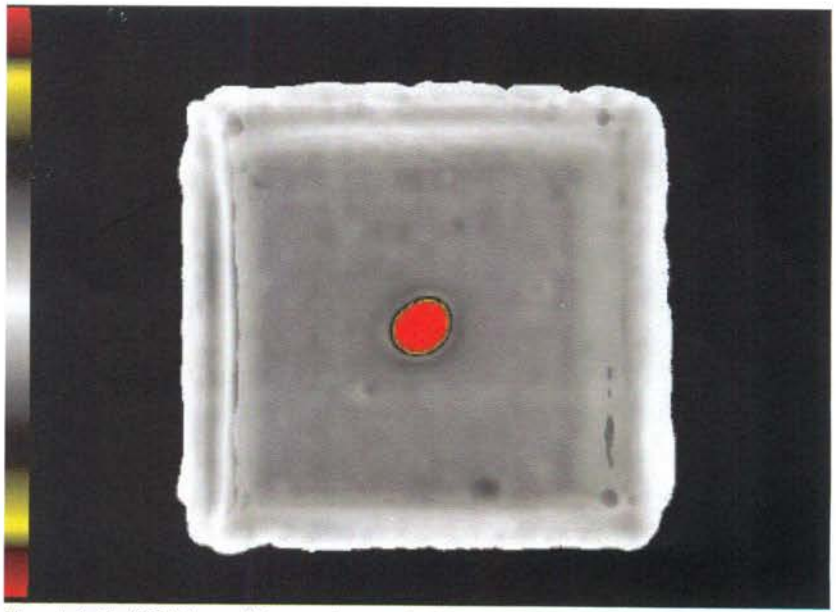


Figure 1: In this C-SAM acoustic image of a ceramic chip capacitor, the red feature is an internal gap.

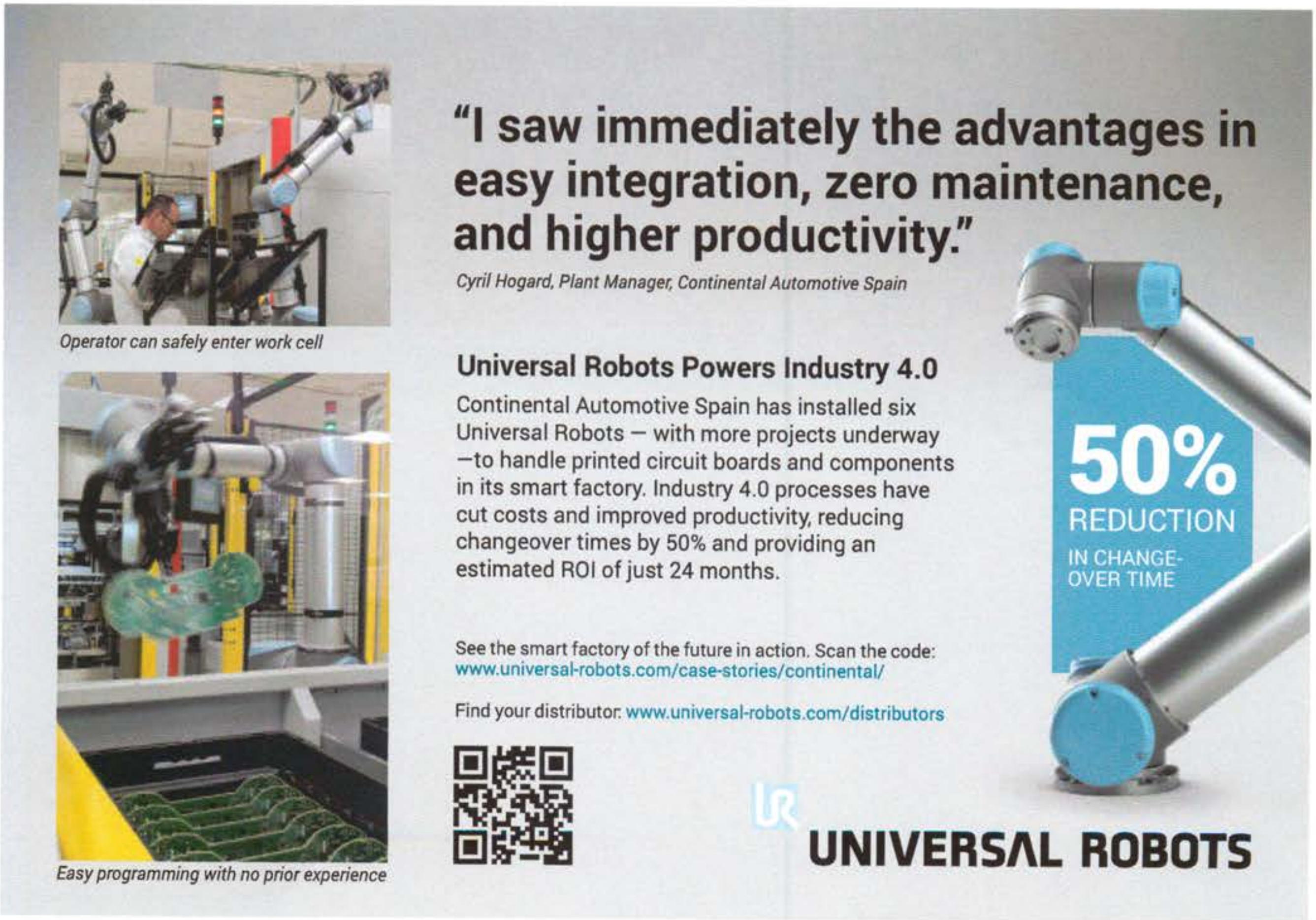
Figure 2: Ceramic chip capacitors such as these have large numbers of alternating dielectric and electrode layers.

metal, for example -- it is again in part reflected and in part transmitted. This echo will become one pixel in the acoustic image.

The outcome is very different if the ultrasound strikes the interface between the solid it is traveling through and a gas such as air. A solid-air interface marks a de-lamination, void, crack, or other gap. The properties of the two materials at this interface differ so strongly that virtually all of the ultrasound is reflected back to the transducer as a high-amplitude echo. None of the ultrasound travels beyond the non-bond or other gap; defects that lie directly below this location will not be imaged by ultrasound pulsed into this side of the sample.

The vertical dimension of the gap is relatively unimportant for acoustic imaging. As long as the air or other gain in the gap has a vertical dimension of a fraction of a micron, reflection is still essentially 100 percent. An extremely thin gap that might grow in area during use can thus be discovered early.

The completed acoustic image will show the entire area of the sample. Gap-type defects of any vertical extent are typically bright white as a result of their high reflectivity; reflections from



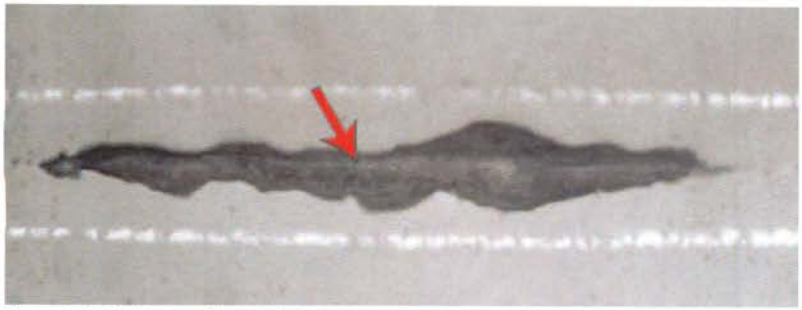


Figure 3: Optical image of the physically sectioned capacitor.

interfaces between two solids are various shades of gray. Both may be pseudo-colored for publication. Viewing the acoustic image, a technician can select exactly the vertical plane through which he or she can physically section the part to obtain the best optical view of the defect revealed by the acoustic micro-imaging tool.

Figure 1 is the acoustic image of a ceramic chip capacitor that has a gap-type defect. The defect, originally white because of its high reflection, has been pseudcolored for use here. Because ceramic chip capacitors have essentially the same structure at all depths, a defect found acoustically at any depth is typically cause for rejection. Delaminations and non-bonds in ceramic chip capacitors are usually horizontal and lie along the interface between an electrode layer and a dielectric layer. They may cause no immediate electrical problem, but they have a tendency to sprout vertical cracks that can become pathways between two electrode layers. The consequences of the electrical failure of a single ceramic chip capacitor can range from minor (a slight brightness change in a display screen) to catastrophic (the loss of an aircraft's guidance system).

Ceramic chip capacitors (shown in Figure 2) may have dozens or even hundreds of electrode and dielectric layers. The depth of the defect in Figure 1 can be measured by the time of flight of the echo returning from the defect. The greater the time, the farther a defect is from the transducer. In this instance, however, the purpose of acoustic imaging was to determine the precise x-y location of the defect so that the capacitor can be sectioned physically and reveal the structure of the defect in cross section.

Figure 3 is the optical microscope photo after sectioning and polishing of the region where the defect was found acoustically. The two horizontal white lines are electrodes. The gray areas above and below the electrodes are dielectric material. The long, irregular black horizontal feature is a region from which dielectric fragments fell out during the sectioning of the capacitor. It appears this once very thin defect generated numerous cracks that extended upward and downward from the defect itself. During acoustic imaging, the spaces between the cracks helped to reflect ultrasound and create the anomaly seen in Figure 1. As the electrode particles were pulled out during sectioning, the black chasm seen in Figure 3 was created.

Horizontal gap-type defects -- whether they generate cracks or not -- are usually found between an electrode and a dielectric in ceramic chip capacitors. But that is not the case here. The red arrow in Figure 3 points to a faint white line that extends the whole length of the black area and beyond it. This line marks the boundary between two dielectric layers that were laid down separately, without an electrode layer between them, during fabrication of the capacitor. In this region, the two layers were not bonded, and this permitted cracks to form. Both the original non-bond and the cracks above and below it reflected ultrasound and contributed to the acoustic image.

Ceramic chip capacitors are only one type of part on which it makes sense to use AGDPA. Samples suitable for C-SAM imaging generally have at least one flat surface into which to pulse ultrasound, although cylindrical samples can also be imaged. The parts might be electronic components, composite materials, gaskets, electronic sensors, wafers, and many other items that can be as simple as a package for a small medical product or as complex as an electronic module.

Acoustic micro-imaging can reveal more than just the x-y outline of a defect or feature. If an internal feature has

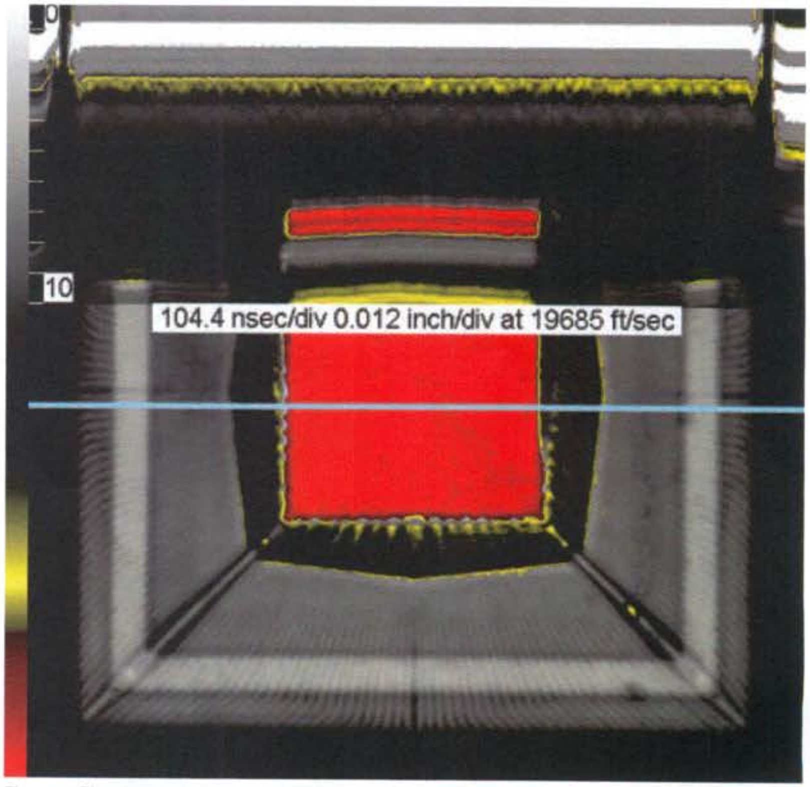


Figure 4: Planar acoustic image (bottom) and Q-BAM acoustic image (top) of a plastic-encapsulated microcircuit.

a non-flat surface, an acoustic micro-imaging tool can map the contours of the buried surface. The same tool, using a different imaging mode, can nondestructively image multiple very thin horizontal slices of a sample. Each slice creates its own image. There is no limit to the number of slices, and a slice-by-slice view can reveal details at very specific depths.

Using another of Sonoscan's imaging modes, the transducer can scan back and forth along a single line, creating a non-destructive cross-section by collecting echoes from a slightly different depth at each pass. As long as the sample is flat, it may be moved or rotated horizontally as desired to nondestructively section precisely as needed. This imaging mode, called Q-BAM™, makes it possible to select the most useful vertical plane before beginning physical sectioning. Comparison of the optical and acoustic images of the same section solves many problems.

Figure 4 includes the Q-BAM image of a plastic-encapsulated microcircuit (PEM). The bottom two-thirds or so of the figure displays the planar image of most of the area of the PEM, along with a horizontal blue line. This line marks the vertical plane through which the Q-BAM image in the top third of the figure was made. The transducer scanned back and forth along this line, beginning at the bottom of the PEM and working upward in small increments. The red color of the die in the planar image in the bottom part of the figure shows the entire top surface of the die is separated from the mold compound. The Q-BAM image in the top part of the figure shows the side-view details: the die is not only separated but also slightly domed in side view. The non-flat nature of the die may explain the lack of bonding to the mold compound.

Plastic encapsulated microcircuits are often imaged acoustically to ensure reliability and for process control. They are sometimes subsequently physically sectioned as well. Acoustic micro-imaging of these parts is straightforward, but physical sectioning presents the difficulty that the mold compound is a polymer that may smear and fill in the defect of interest, especially if it is very thin. There are specialized sectioning techniques that can make the process easier, as well as companies that can successfully section the most difficult parts.

The value of the acoustic imaging modes and methods described here is that they greatly simplify and accelerate physical sectioning that might otherwise be lengthy, costly, and inaccurate. PDD

NewProducts

Metric Rigid Couplings with Step Bores

Ruland (Marlborough, MA) expanded its line of rigid couplings to include metric sizes with step bores for precision servo driven systems or shaft-to-shaft connections. The couplings are available in one- and two-piece clamp styles with or without keyways for superior fit and holding power. Ruland supplies rigid coupling hardware with a proprietary coating called Nypatch to resist vibration and maintain holding power. Nypatch is applied 360 degrees around several threads of the socket head cap screws to prevent them from loosening under vibration, causing a reduction or loss of torque transmission during operation.

- Standard step bore rigid couplings give machine designers more flexibility
- Supplied with Nypatch anti-vibration hardware to maintain holding power
- Two-piece styles have a balanced design for reduced vibration
- All metric hardware tests beyond DIN 912 standards
- Metric rigid couplings are offered in sizes ranging from 3 mm to 50 mm

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Development Kit for Embedded Vision Applications

Basler (Exton, PA) introduced the PowerPack development kit for Embedded Vision Applications. The kit serves as a stepping stone to custom development, illustrating how the camera module can be addressed and configured via the pylon software development kit. It is comprised of a Basler dart camera module with the BCON for LVDS interface and 5 megapixels of resolution, a lens, a processing board with Xilinx Zynq-7010 SoC (system-on-chip), cables, and additional accessories.

- Kit is comprised of Basler dart camera module with BCON for LVDS interface and 5 megapixels of resolution, a lens, a processing board with Xilinx Zynq-7010 system-on-chip, cables, and accessories
- PowerPack kit includes a reference implementation demonstrating FPGA-based image capture by the Zynq SoC
- Includes connection of a dart BCON camera module to the Basler pylon camera software suite

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