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VOL. 8, NO. 3 • PUBLISHED BY KEMET ELECTRONICS CORP. • P. O. BOX 5928 • GREENVILLE, SC 29606 • (864) 963-6300 • NOVEMBER 1998

KEMET is continually searching for improved tools to aid in the identification and understanding of physical defects in its capacitor products. One tool that has been found to be valuable in recent years is acoustic microscopy. In the following article, Jeff Franklin, a Senior Associate Engineer in KEMET's Ceramic Technology Group, describes the principles of acoustic microscopy and how this technique can be applied to multilayer ceramic capacitors.

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Scanning Acoustic Microscopy - A Valuable Tool

by Jeff Franklin, SeniorAssociate Engineer

Introduction

KEMET uses scanning acoustic microscopy to improve the quality of existing multilayer ceramic capacitors (MLCCs) and to develop new products. This nondestructive technique uses sound waves to identify defects within MLCCs in a fraction of the time that would be necessary using destructive physical analysis (DPA), and without the ambiguity often associated with DPA**.** **C-SAM** ("C-mode Scanning Acoustic Microscopy") translates sound patterns within the sample into a visual image. Figure 1 is a typical image of several MLCCs as "seen" by C-SAM. The white image is a chip with a large crack.

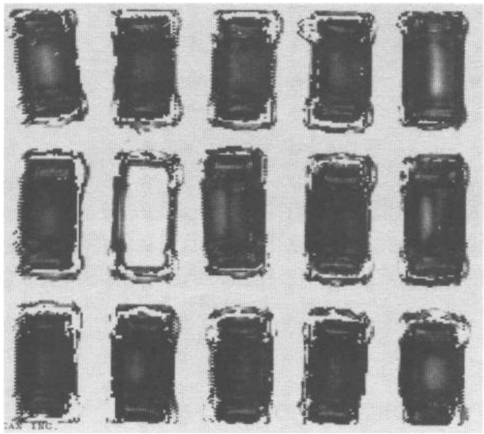

Figure 1. C-SAM Bulk Scan

Principles of Operation and Capabilities

KEMET purchased its first C-SAM in 1992. At that time there were two options for acoustic microscopy: **SLAM** and **C-SAM**. SLAM ("Scanning Laser Acoustic Microscope") operates by transmitting a continuous acoustic plane wave signal to one side of the sample. A focused laser detects the amplitude of transmitted ultrasound from the standing waves that form on a thin gold foil resting on the other side of the sample. Cracks, voids, and other discontinuities in the MLCC structure reduce the amplitude of the transmitted ultrasound signal, distorting the standing wave pattern. This information is then used to create a visual image of the samples being examined. SLAM is an excellent method for quickly finding large defects in components, but lacks the resolution needed for many of KEMET's applications.

With C-SAM, the ultrasonic transducer moves over the sample in a raster pattern at speeds of 8 to 16 inches per second, sending a focused sound wave into the sample while simultaneously detecting echoes from the transmitted signal. The sample and transducer are submerged in water, which acts as a coupling medium. Echoes originate each time the focused ultrasound wave encounters an interface between two materials with different acoustic impedance. The strongest echoes originate from solid-gas interfaces, such as an air-ceramic interface. An image is generated from the echo data received by the transducer. This method of acoustic scanning is called **pulse/echo acoustic microscopy.**

Frequencies of 10 to 100 MHz are commonly used for C-SAM, depending on the sample thickness and desired resolution. Low frequency transducers allow deeper penetration and are therefore required for examining thick samples. High frequencies, on the other hand, provide greater resolution. Voids as small as 36 microns can be detected using a 75 MHz transducer, while a 200 MHz transducer can detect voids as small as 8 microns.

However, the real strength of C-SAM lies in its detection of cracks. Cracks that are barely visible using optical or electron beam microscopy produce strong echoes and are easily detected by C-SAM. Reliance on operator perception of what "may" be a crack with destructive analysis is replaced with a clear visual representation of the crack using C-SAM.

Some recent advancements in acoustic microscopy include **automated inspection** and **3-D imaging**. Automated inspection allows timely accept/reject disposition of capacitors based on preset criteria without the need for operator evaluation. A picture of an array of chips is generated with the defective chips marked as such. 3-D imaging allows an operator to position the image of a sample in the most revealing orientation to view the defect. The image can be turned, opened, and color-coded to study defect sites.

Applications of C-SAM

Figures 2 through 6 are photographs showing optical, acoustic, and destructive physical analysis, respectively, of three MLCCs. Figure 2 is a view of the samples upon initial inspection using a microscope. Failure sites are not evident in this view. The acoustic image in Figure 3 displays defect sites in two of the three MLCCs. The chip on the left generated an echo across the entire chip, which indicates a crack or delamination. The destructive failure analysis of this chip (Figure 4) reveals a crack crossing the ceramic layer. This crack is difficult to see using a microscope, but is readily apparent in the C-SAM image.

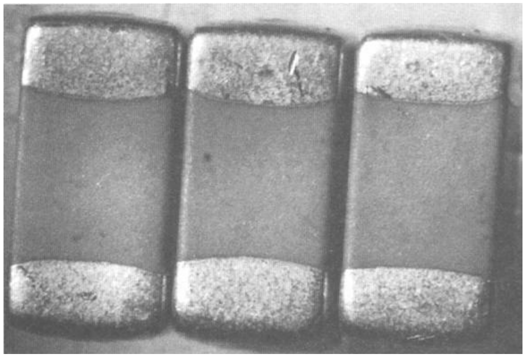

Figure 2. Visual Inspection

The chip in the center of Figure 3 has a circular, localized defect site left of center. The DPA of this chip (Figure 5) revealed a void encompassing two layers with a distorted electrode pattern. These defect characteristics indicate that contamination, which occurred in green chip construction, burned out during the high temperature processing of the chip. The MLCC shown on the right does not exhibit any defect sites in either C-SAM or DPA (Figure 6).

The C-SAM applications discussed to this point have all used the bulk scan imaging mode to locate defects within the X-Y plane of the capacitor. In this mode, defects appear in two dimensions only. To access depth information, a capability of C-SAM called **Q-BAM** (Quantitative B-scan Analysis Mode) can be used to provide defect contour information in the X-Z plane.

C-SAM is routinely used by KEMET to sample product from standard production batches. Defects found at C-SAM are destructively analyzed, root causes assigned, and pareto charts generated. Corrective actions for common root causes are identified and implemented.

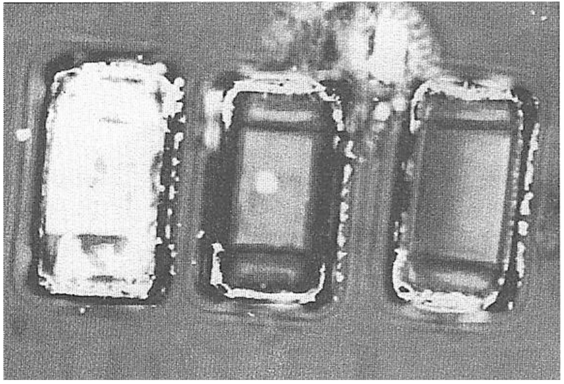

Figure 3. C-SAM Scan with defects present in #1 and #2 chips.

In addition to its usefulness in detecting defects in product on the manufacturing floor, C-SAM is also used by KEMET researchers to identify materials and processing issues during new product development. For instance, C-SAM analysis readily identifies incompatibilities between electrode and dielectric materials, which are a common cause of cracks, delaminations, and poor bonding between layers. Because C-SAM can quickly screen large samples of product during the development process, KEMET can identify these potential problems early, avoiding the time and cost of lengthy reliability tests.

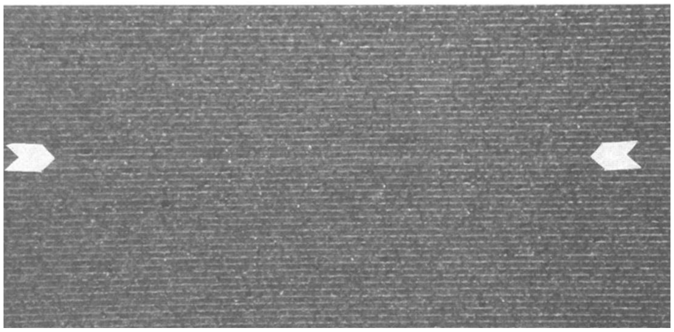

Figure 4. DPA of MLCC with crack.

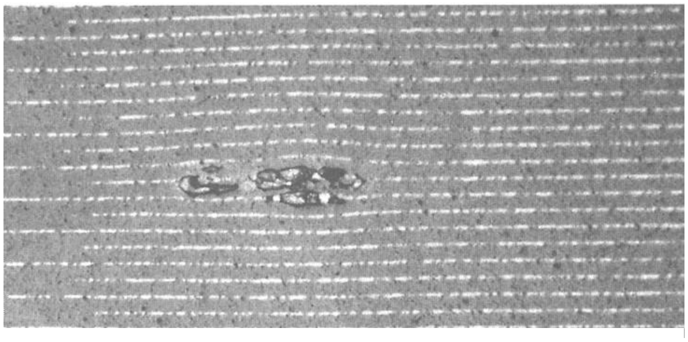

Figure 5. DPA of MLCC with burn-out void.

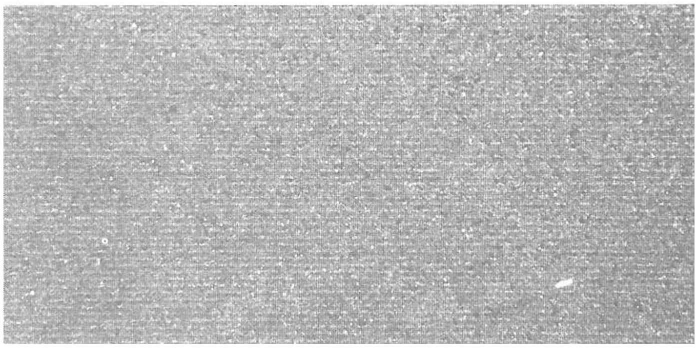

Figure 6. DPA of MLCC with no defect.

Conclusions

Acoustic microscopy in general, and C-SAM in particular, have proven to be powerful aids to identifying and understanding root causes for defects in MLCCs. By using C-SAM, KEMET researchers and testers can "see" the internal structure of MLCCs in a real-time, high-volume, nondestructive manner. C-SAM is also a valuable tool in the development of materials and processes for new MLCC products, reducing the time-to-market period and ensuring that KEMET manufactures only the highest quality MLCC products.