

# Acoustic Microscopy of Tightly Closed Delaminations in Multilayer Ceramic Chip Capacitors

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## Abstract

Acoustic microscopy is a well-established technique to nondestructively evaluate multilayer ceramic chip capacitors (MLCCs) for flaws such as delaminations, cracks and voids. Results of destructive physical analyses (DPA) by cross-sectioning correlate well with results of the nondestructive evaluation in most cases. However, if the delaminations are tightly closed, optical and scanning electron microscopy of the sectioned samples may be inconclusive. An acoustic micro imaging technique, *Rayleigh wave imaging*, which is performed on the surface of the physically sectioned sample, is introduced in this paper. This technique is sensitive to delamination defects (even if they are tightly closed) and other flaws close to the surface of the sectioned sample and is ideally suited for verification of conventional acoustic micro imaging data.

## 1. Introduction

Acoustic microscopy is widely used to nondestructively detect delaminations and internal flaws in multilayer ceramic chip capacitors and other IC packages. For the sake of brevity, conventional acoustic microscopy is not explained in this paper. The principles can be found in literature [1,2]. Several studies have been published documenting the generally good agreement between acoustic microscopy and DPA (for example, [3]). However, in some cases, because the acoustic microscope is very sensitive to air spaces, conventional acoustic microscopy may reveal flaws in the component that may be very difficult to see using traditional DPA techniques. In such situations,

non-standard techniques might be necessary for correct validation of the acoustic microscopy data.

One such technique, *Rayleigh wave imaging*, also involves acoustic micro imaging, but is performed on the physical cross-sectioned DPA sample. Rayleigh waves exist only at boundaries of solids unlike compressional and shear waves that propagate into the bulk. The depth of penetration of Rayleigh waves is limited to approximately one wavelength from the surface of the specimen [4]. Thus, Rayleigh wave imaging is sensitive to cracks that are perpendicular to the surface because the propagating Rayleigh waves impinge broadside on such cracks. Even a tightly closed crack presents a significant obstacle to the propagation of Rayleigh waves. Therefore, Rayleigh wave imaging is ideally suited for imaging the physical cross-sections of delaminations or other tightly closed flaws.

## 2. Experimental Procedure

The C-SAM<sup>®</sup> acoustic microscope was used for the nondestructive evaluation of multilayer ceramic capacitors (prior to sectioning) and for imaging the DPA samples using Rayleigh waves (after sectioning). The first step in the inspection consisted of imaging the capacitors using compressional waves focused inside the sample. Two modes of conventional acoustic micro imaging – “bulk scan” and “loss of back wall echo scan”, were used for evaluating the capacitor prior to sectioning.

The term “bulk scan” represents the case where the transducer is focused inside the capacitor and all reflections from the material in between the front and back surface of the capacitor are included in the image (Figure 1). Thus, discontinuities inside the sample will show up as bright areas while good

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areas without discontinuities would show up as dark areas. The term “loss of back wall echo scan” represents the mode of imaging where the transducer is focused inside the capacitor as in the earlier case, but only the reflection from the back surface is included in the image. In essence, the loss of back wall echo image is analogous to a shadow image. A flaw will appear as a dark region in the image (because defects block ultrasound) while defect free good areas will appear bright.

After inspection by C-SAM, a few of the defective capacitors were sectioned and polished on a plane perpendicular to the delamination using industry standard techniques. Bright and dark field optical microscopy techniques were employed to examine the cross-section for defects. Other techniques, such as etching the ceramic along the defect using  $\text{CF}_4$  plasma, etching back the actual plates using acid and high magnification scanning electron microscopy (50,000 X), were attempted on some of the samples to investigate the delaminations in the cross-section. However, the delaminations were so tightly closed that the difference between the good and defective areas was not unambiguous.

Cross-sectioned and polished (un-etched) samples that did not reveal the presence of delaminations by conventional optical microscopy were imaged using Rayleigh waves. A suitable transducer (100 MHz to 230 MHz) capable of exciting Rayleigh waves in the capacitor was selected and focused on the surface of the specimen. Next, the transducer was lowered (defocused) slightly until the Rayleigh wave was separated from the front surface reflection. The Rayleigh wave signal was selectively gated for generating the image.

### **3. Results and Discussion**

Figure 2a is the bulk scan image of a capacitor and Figure 2b is a loss of back wall echo scan. The bright areas in the capacitor in Figure 2a and the corresponding dark areas in Figure 2b are delaminations or poorly fused areas parallel to the metallized electrodes. The defective capacitors were cross-sectioned using standard techniques, and optical micrographs of the defective areas were obtained. The bright field image of the previously discussed capacitor (shown in Figure 3a) did not reveal the presence of the delamination. The dark field image (Figure 3b) did reveal the delamination, but the evidence was not conclusive. The Rayleigh

wave image of the polished cross-section (shown in Figure 4), however, conclusively established the presence of the delamination.

Another example of a capacitor with internal delaminations is shown in Figures 5 and 6. Figure 5 is a bulk scan acoustic image of a capacitor showing multiple delaminations. From the A-scan, it was determined that these delaminations existed at different levels. This capacitor was sectioned, and polished, along the dotted line shown in Figure 5. Optical examination of the destructively cross-sectioned sample proved inconclusive in verifying the presence of the delaminations. Rayleigh wave inspection (Figure 6) with the 230 MHz transducer clearly revealed the presence of three delaminations. In addition, the higher resolution of the 230MHz transducers revealed the presence of the electrodes.

### **4. Conclusions**

Rayleigh wave acoustic imaging of the physically cross-sectioned sample is demonstrated to be a potentially attractive technique for correlative analysis of tightly closed cracks when the flaws are not visible by optical microscopy. Results of this study serve to illustrate the importance of selecting the correct mode of imaging in the acoustic inspection of components because different modes are sensitive to different flaws. Special techniques, such as Rayleigh wave imaging of the cross-sectioned samples, might be required to verify the accuracy of conventional acoustic data if cracks in the samples are tightly closed.

### **References**

1. L. W. Kessler, “Acoustic Microscopy,” in Metals Handbook, American Society for Metals, Metals Park, Ohio, v17, pp. 465-482 (1989).
2. L.W. Kessler, “Scanning Acoustic Microscopy,” in Plastic-encapsulated Microelectronics, Ed. M.G. Pecht, L.T. Nguyen, E.B. Hakim, John Wiley, New York, pp. 365-383 (1995).
3. G. Love and G. J. Ewell, “Acoustic Microscopy of Ceramic Capacitors,” IEEE Transactions on Components, Hybrids, and Manufacturing Technology, CHMT-1 (3), pp. 251-257 (1978).
4. K. Graff, “Wave Motion in Elastic Solids,” Dover Publications, New York (1991).

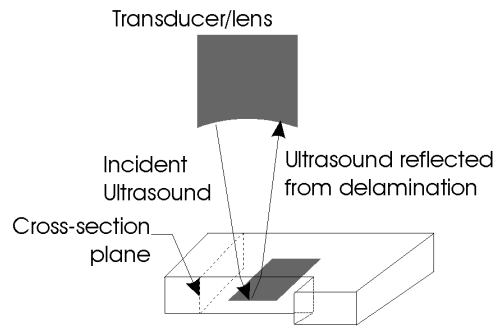


Figure 1. Schematic showing the conventional compressional wave imaging in acoustic microscopy.

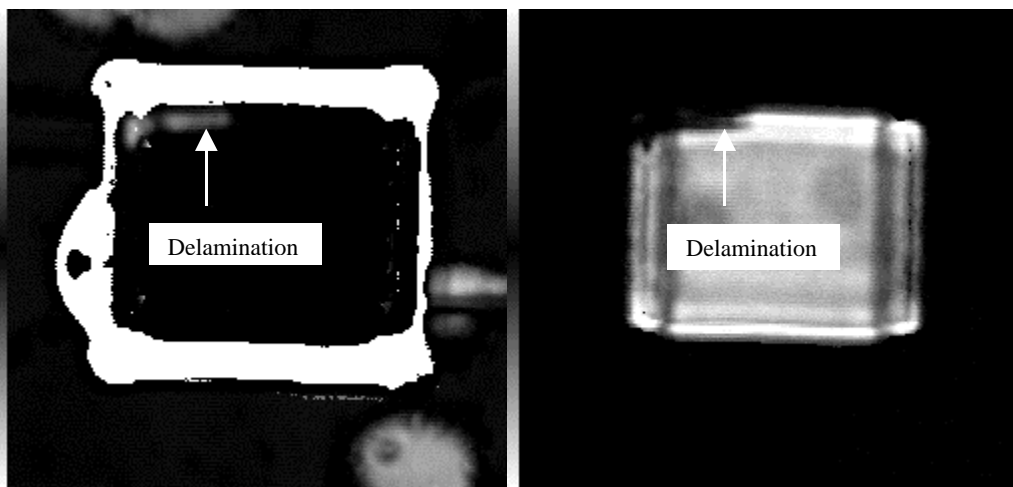


Figure 2. a) Internal delamination in a capacitor revealed by a bulk volume scan b) internal delamination revealed as a dark shadow in the loss of back echo scan

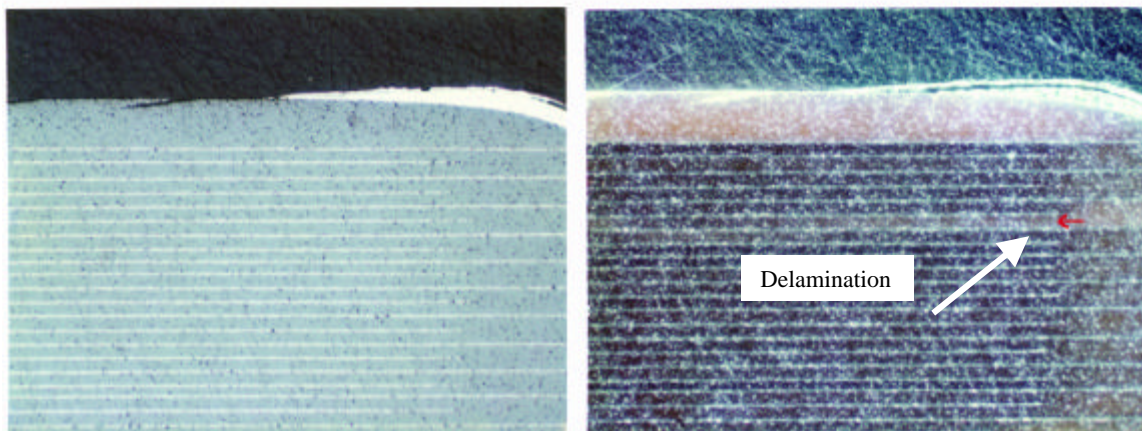


Figure 3. a) Bright field optical micrograph of the defective region does not reveal the presence of the delamination b) Dark field optical micrograph of the defective region reveals the presence of the delamination but not very conclusively.

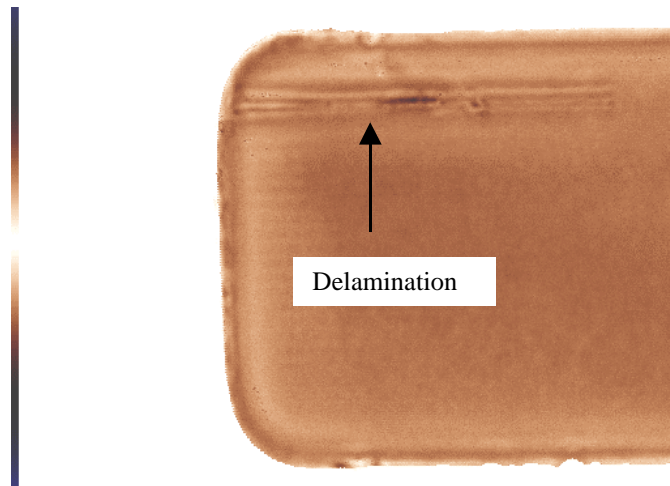


Figure 4. The Rayleigh wave acoustic micrograph clearly reveals the presence of the delamination.

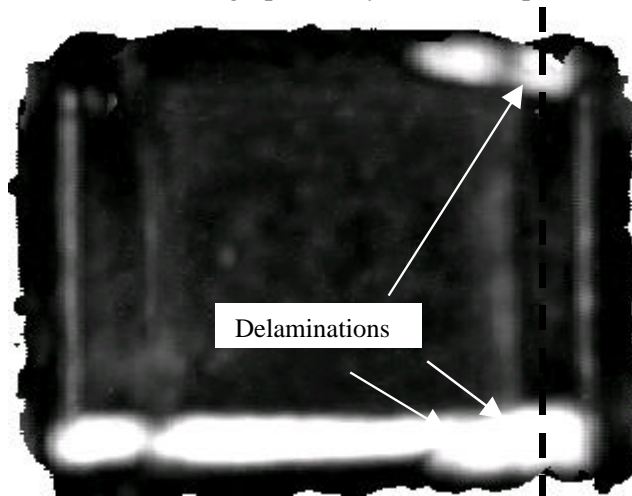


Figure 5. Bulk scan image of a capacitor showing the presence of delaminations and subsequently cross sectioned along dotted line.

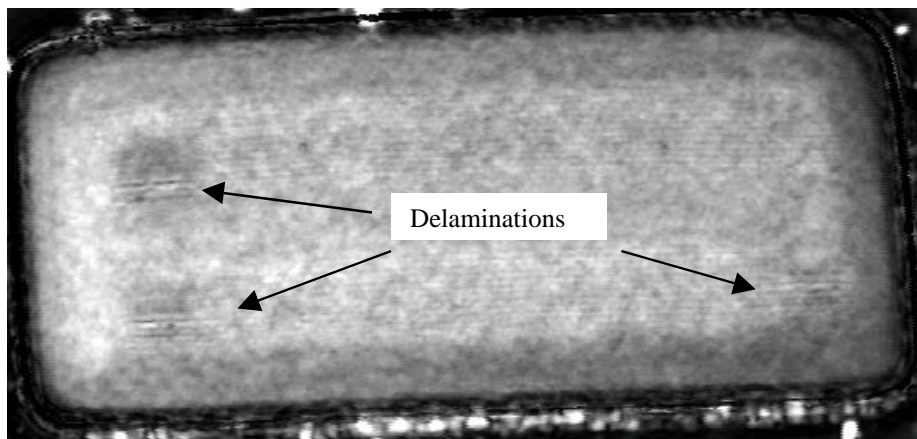


Figure 6. Rayleigh wave image of the cross-sectioned capacitor using a 230 MHz transducer showing clearly the delaminations that could not be observed optically. Additionally, the electrodes are also visible.