Modern Manufacturing

➤ High-Tech Applications
➤ Going Lean
➤ Glass Defects
Multi-layer ceramic chip capacitors (MLCCs) are usually the least expensive components on a printed circuit board. When an MLCC experiences an electrical failure in service, the consequences can range from a minor current fluctuation to complete system failure.

In medical, military, aerospace and other applications where high reliability is critical, MLCCs are often inspected by acoustic micro-imaging systems before assembly to spot any existing internal structural defects such as delaminations, voids or cracks. No one wants an ultra-expensive satellite to lose an important function because a microscopic void in one of the MLCCs caused a short.

Understanding Micro-Imaging

In its primary mode, an acoustic micro-imaging system pulses high-frequency ultrasound into a single MLCC—or a tray of hundreds or thousands of MLCCs—via a scanning transducer that receives the echoes from the interior of the MLCC a few microseconds after the pulse is launched. The amplitude of the echo at each x-y location, of which there may be thousands or millions, is converted into a pixel in the acoustic image of the parts. High-amplitude echoes create bright white pixels, while low-amplitude echoes create dark or black pixels.

Acoustically, MLCCs are an oddity. They consist of numerous layers of metal and ceramic, which would normally cause a storm of material-interface echoes. Actually, and fortunately for engineers who look for internal defects, the metal and the ceramic are extremely thin and very similar in their material properties. To the ultrasonic transducer, an MLCC looks like a block of homogeneous material, so the ultrasonic pulse travels through it without much reflection. Typically, the non-defect regions of the MLCC are a medium shade of gray.

The real targets of inspection are the delaminations, voids and cracks; all of these defects involve some type of gap. An ultrasonic pulse finds the interface between the ceramic material and an empty gap. The difference in material properties between the ceramic and the vacuum (or gas) in the defect is so enormous that > 99.99% of the ultrasonic pulse is reflected. Gap-type defects therefore appear very bright in the acoustic image. When imaging hundreds of MLCCs in a tray, engineers find it helpful to arrange the MLCCs in organized groups to make it easier to match the acoustic image with the tray and pick out the defective units.

Figure 1 is an acoustic image of an MLCC that has two large delaminations (the bright rounded features) just below its surface. The other dark spots at the left and right are additional delaminations located more deeply in the MLCC. The problem with delaminations, voids and other anomalies is not that they necessarily cause immediate electrical problems, but that they may grow, sprout cracks, and cause electrical failures in service.

Smaller and Smaller

The recent introduction of smaller MLCCs like 0402s, 0201s and 01005s means that the targets for acoustic micro-imaging have become smaller. Typically, MLCCs have been imaged at acoustic frequencies of 50-100 MHz. New, smaller MLCCs seem to benefit from imaging at higher frequencies, such as 230 MHz, which makes it possible to see defects capable of causing electrical anomalies in these smaller sizes.
Higher frequencies can only be used successfully on some smaller MLCCs. On others, results are marginal. The chief difficulty is that the smaller MLCCs tend to have rounded edges and therefore less surface area flat enough to permit acoustic imaging. Some smaller capacitors also tend to curl during firing because they are very thin.

Engineers solved this problem by designing and manufacturing a customized 100 MHz transducer that minimizes the effects of the rounded surface and still produces a good acoustic image. This transducer works well with 0402s (see Figure 2, where white areas are internal defects), and it functions fairly well with 0201s to the extent that gross defects are evident but not truly tiny.
defects. However, 01005s generally require a higher frequency, such as 230 MHz.

One of the demands in the industry over the past decade, especially among makers of handheld devices, was to increase the capacitance of MLCCs without increasing the footprint. As a result, MLCCs became thicker as layers of ceramic and electrode were added. In the end, some MLCCs became square or very nearly square.

Since MLCCs have no surface labels or markings, it became impossible for the operator of an acoustic micro-imaging system to know which side was the top. This is important because the internal layers need to be horizontal for imaging. Engineers developed a method for finding internal defects that is effective no matter how the MLCC is oriented. This made it unnecessary to rotate each one by 90° and image the tray again.

In recent years, laboratory personnel also noticed that internal cracks in MLCCs imaged before assembly were becoming much less frequent because the manufacturing processes for MLCCs had improved. A decade or more ago, cracks in incoming MLCCs were roughly as frequent as voids or delaminations. The rarity of cracks in as-manufactured MLCCs becomes significant when one considers the characteristics of counterfeit MLCCs.

The Black Market

The routes of electronic supply are rife with counterfeit components. Engineers are eager to identify counterfeit MLCCs and separate them from genuine MLCCs; in order to do this properly, some background information is important.

First, with MLCCs (as with other component types), it may be difficult to find clear-cut differences between a counterfeit and a genuine part. A plastic-encapsulated microcircuit that has a glaring misspelling on its top surface is a dead giveaway, but most counterfeits are not so obvious; they may not have any surface markings at all, and more than one method may be needed to identify them.

Second, “counterfeit” refers to components with two different sources. The vast majority of plastic-encapsulated microcircuits are simply recycled; that is, they are removed from boards and relabeled. The die inside is genuine, but it could be old, abused and perhaps not what the label says it is. A few plastic-encapsulated microcircuits, though, are made from scratch. Nearly all counterfeit MLCCs are recycled.

Tom Sharpe, vice president of SMT Corp., an independent distributor of electronic components located in Sandy Hook, Conn., has visited counterfeiting operations in China. He has not encountered made-from-scratch counterfeit MLCCs, but he he says he thinks that low labor costs and the simplicity of MLCC design means that they may appear if they are not being produced and distributed already.

How are MLCCs and other components recycled? Sharpe saw containers of used PC boards arrive from the U.S. at Chinese ports. A board was typically held over an open flame until the solder reflowed. The board was then struck to make the components fall off. The components from many boards were loaded into a bag. They were next washed, in some instances in a river, to remove the residue from heating. They were sorted and dried (see Figure 3, p. 29). Sorting consisted of dumping the components through a series of four or five sieves with progressively smaller openings. Large components, such as ball grid arrays (BGAs), were caught by the top sieve; small MLCCs, such as 0402s, 0201s and 01005s, came out the bottom.

The MLCCs were then placed onto tape and a reel. According to Sharpe, counterfeiters try to get new-looking reels; they will keep an old reel as a reference from which to print new labels with the right numbers. Note that all of the MLCCs on a reel may look like 0402s, but they may have different capacitance values.

Engineers have begun to examine MLCCs to learn how to identify the counterfeits. First, under optical magnification, counterfeit MLCCs are likely to reveal small fractures and chipouts as a result of rough handling. Second, when acoustic micro-imaging reveals internal cracks in unmounted, off-the-reel capacitors, as shown in Figure 4, alarm bells should sound. While internal delaminations and voids are fairly common, new capacitors rarely have internal cracks because they have never been exposed to uncontrolled thermal and mechanical stresses.

For more information about MLCC micro-imaging, contact Sonoscan at 2149 E. Pratt Blvd., Elk Grove Village, IL 60007; (847) 437-6400; e-mail info@sonoscan.com; or visit www.sonoscan.com.