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... THE LEADING EDGE

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Welcome to the inaugural issue of *TechTopics…The Leading Edge*. This bulletin will focus on technical developments at KEMET and issues of importance to the technical community.

Articles presented in each issue will be a synopsis of a KEMET Engineering Bulletin, Application Note, or a special technical paper. For more information ask your area KEMET sales representative.

This inaugural issue presents two summaries of papers to be presented at the Capacitor and Resistor Technology Symposium (CARTS) in March. We hope you find them informative.

Dr. John Piper
Vice President, Technology

Termination Materials Effect on Thermal Robustness

by: Larry Mann

KEMET Electronics has been at the forefront of efforts to understand and eliminate the root causes for thermal shock cracking of ceramic chip capacitors. An aspect that has been largely ignored in the numerous articles that appear in the literature on this subject is the contribution made by the materials used in the termination to the thermal robustness of the chips.

Terminations for ceramic chip capacitors consist of three layers. The first layer is formed by firing a mixture of silver powder and glass frit onto the end of the capacitor. The primary purpose of the frit is to bond the silver to the ceramic. Without the frit, the termination could be taken off with your fingernail! The frit is usually based on a leadborate glass system, with various additives to tailor its physical and chemical properties. Layers of Ni and Sn are then plated over the silver to provide leach resistance and solderability.

The composition of the frit, the amount of frit, and the firing profile have all been found to affect the thermal shock performance of ceramic capacitors. If one considers that the glass frit diffuses into and reacts with the ceramic when the termination is fired, this should not be surprising. The glass must surely modify the coefficient of thermal expansion, fracture toughness, and other properties that affect its thermal shock robustness. KEMET has an ongoing program to evaluate terminations that are offered commercially and are available to all ceramic capacitor manufacturers. Our results have shown that the unique termination materials developed by KEMET offer superior performance.

The table below summarizes data from a study that compared one of our proprietary terminations to several commercial materials. It is obvious from the data how important the termination is to the thermal shock robustness of ceramic chips.

Comparisons of the Performance of Commercial Terminations and a Proprietary Termination – Thermal Shock Tests

Commercial Termination	NPO	X7R
A	N/A	23/400
B	31/40	100/400
C	12/40	43/400
D	8/120	9/400
E	6/40	22/400
F	10/40	15/400
G	26/40	27/400
Proprietary Termination	1/400	0/400

All KEMET ceramic capacitor terminations are made from glass frits that are tailored to achieve optimum performance in concert with the ceramic dielectrics used in our capacitors.

The impact of the termination composition on thermal shock performance and other properties of ceramic capacitors will be discussed in more detail in papers that will be given at the 1991 Capacitor Resistor Technology Symposium and 1991 Electronic Components and Technology Conference.

Mechanical Strength Properties of Multilayer Ceramic Chip Capacitors

by: Jim Bergenthal

The mechanical strength of multilayer ceramic chip capacitors has been investigated at various times. It has been difficult to classify. Numerous articles have related the problems.

Research by KEMET Electronics and others has now found mechanical strength *can be* categorized and measured. In addition, the factors that influence the mechanical strength can be understood and improvements made in the mechanical strength of the product.

Mechanical Strength Characteristics

During the surface mount placement process the capacitor is subjected to stresses from the placement machine. Similar stresses can also occur during the tape and reel packaging or testing process at the manufacturers location. The mechanical strength characteristic used to classify the capacitor's ability to withstand these types of stresses is break strength (sometimes referred to as flexural strength).

Flexural or Break Strength Characteristics

The mechanical break strength of MLC chip capacitors has historically been measured with the 3-point bend test.

The strength properties of MLC chip capacitors were thought to be affected by the combination of the materials and the processes used in the manufacture of the capacitor. The properties of the ceramic material and the electrode materials contribute to the overall strength. In addition, the strength may be weakened as a result of internal or external defects. Internal defects such as voids are known as volume flaws.

Modulus of Rupture (MOR) has been found to be a useful characteristic for normalizing break strength data. The Modulus of Rupture (MOR) is calculated using the following equation.

$$s = \frac{3PL}{2bd^2}$$

where σ = Modulus of Rupture (MOR)
P = Break Strength
L = Fixture Span Length
b = Capacitor width dimension
d = Capacitor thickness dimension

Test Results

A large number of parts, from a representative cross section of MLC chip capacitor manufacturers, were tested for break strength.

Mean

The ***mean values of the Modulus of Rupture (MOR)*** were analyzed for different dielectrics and chip sizes. Monolithic chip capacitors manufactured with NPO dielectric materials typically exhibited MOR values near 300 Megapascals. Chip capacitors manufactured with X7R materials exhibited MOR values from 160 to 330 Megapascals.

Further study of the MOR results of the X7R dielectric materials indicated a strong relationship with the electrode material. The higher the percentage of silver in the electrode the higher the MOR value. The reason for this relationship has been tied to the material modifiers used with the Barium Titanate. These are affecting the microstructure of the ceramic composite and increasing the strength of the ceramic chip. The percentage of silver is an indicator of the firing temperature and the material modifiers used.

Variation

The ***variation of MOR*** is also important. A good distribution should be statistically normal and tightly distributed.

When the MLC chip capacitor is stressed in the break strength test, the failure initiates at a "defect" site in the capacitor. Test results demonstrate parts manufactured in clean room facilities exhibit tighter distribution of break strength.

To insure adequate break strength in the application, a manufacturer using materials and processes which result in lower MOR values must manufacture the chip with a greater thickness. A manufacturer using materials with higher MOR values will be able to use less thickness to obtain the same or higher break strength.

Understanding of the mechanisms influencing break strength has led to improved performance in ceramic chip capacitors from KEMET. KEMET's X7R and NPO dielectrics are amongst the strongest in the industry. A Z5U dielectric has been formulated in the lab, and initial results indicate its MOR is nearly equivalent to that of the X7R and NPO.