Reducing Solder Cracks in MLCCs Due to Thermal Expansion

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AFTER 3000 THERMOCYCLES, POLYMER DELIVERS MORE STABLE PERFORMANCE THAN METALLIC TERMINATIONS

Multilayer ceramic chip capacitors (MLCCs) are the most widely used surface-mount capacitor devices in the electronics industry, and over time they have experienced additional growth by replacing other capacitor dielectrics due to their evolving capacitance / voltage (CV) capabilities. Some of the applications they are used in - for example, automotive (especially under the hood), drilling and mining, and aerospace - experience rapidly changing thermal environment conditions. In these markets, resistance to heating and cooling cycles is a very important requirement, because the difference of thermal expansion between the PCB and the MLCC body with its termination can result in a solder failure, especially after numerous cycles.

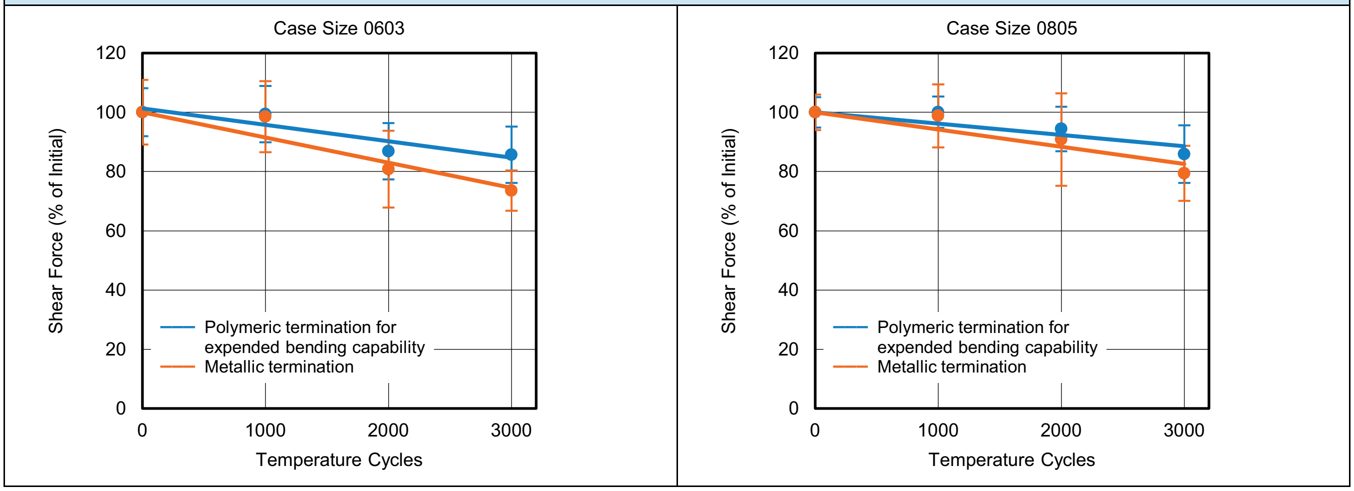
Vishay has developed a polymer termination system with extended bending capabilities that allow it to absorb both board flexure stress and the stress from thermal expansion and contraction, making this termination type more suitable for environments with pronounced temperature variations.

To demonstrate the stable performance of this termination technology during thermal fluctuation, a thermocycle test was chosen that followed the AEC-Q200 and JESD22 method JA-104 standards with temperature cycles from -55 °C to +125 °C. However, instead of the specified 1000 cycles, their number was increased to 3000 in this test.

Two termination electrodes were measured and compared: the standard metallic termination and the polymeric version for extended bending capability. Four different case sizes - 0603, 0805, 1206, and 1812 - were terminated with both types of pastes, soldered to a PCB using lead (Pb)-free solder, and subsequently placed in the thermocycle chamber.

Following assembly, a push test was performed, and the initial shear force was measured. This measurement was repeated after 1000, 2000, and 3000 thermal cycles. Cross-sections of several capacitors were prepared at each measurement stage to study the degradation mechanism.

AVERAGE RESULTS OF SHEAR TEST, NORMALIZED TO INITIAL VALUES



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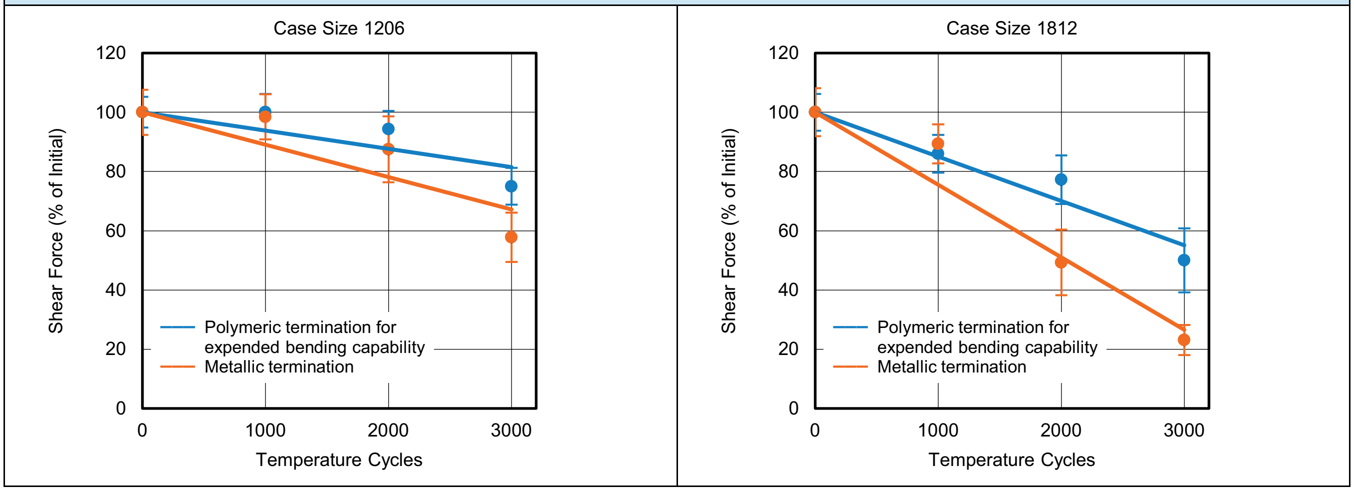
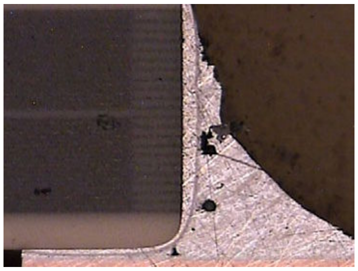
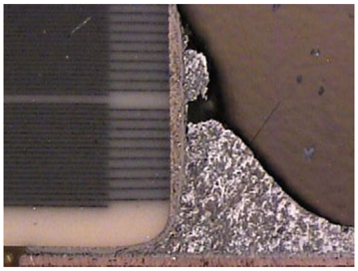
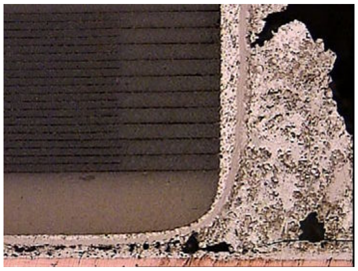
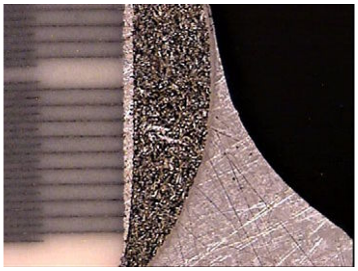
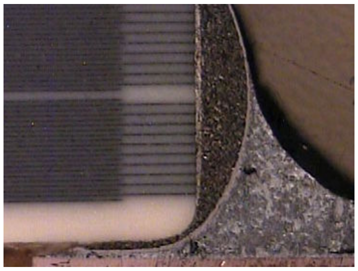
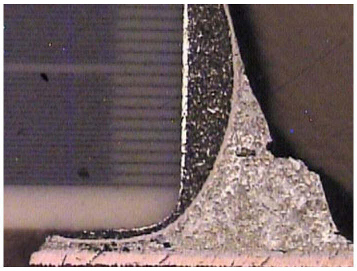


The data show that the shear force degradation is linear up to 3000 cycles, as presented in the above graphs. There is a difference in the length of expansion and contraction of a PCB compared to the MLCC device and the solder, which is more pronounced in the larger body sizes. Therefore, the resistance to thermally induced stresses is lower for such case sizes. After 3000 cycles, the bonding strength of the standard metallic termination decreased by approximately 80 %, while the polymer termination system degraded by less than 50 %. This is because the MLCCs with the flexible polymer termination can better absorb the stress developed by thermocycling.

CROSS-SECTION VIEW AFTER TEMPERATURE CYCLES, 0805 BODY SIZE

TERMINATION	AFTER 1000 CYCLES	AFTER 2000 CYCLES	AFTER 3000 CYCLES
Metallic			
Polymer with extended bending capability properties			

For this test, the most popular and environmentally friendly solder paste, tin-silver-copper (SAC) was used. Evaluation of the cross-sectioned parts showed that the dominant failure mode was cracking of the lead (Pb)-free solder fillet.

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CONCLUSION

Cracks in the lead (Pb)-free solder used in the surface-mount production assembly of MLCCs can occur during the high number of thermal cycles that are often seen in automotive and other high temperature applications. Polymer terminations used to enhance the bending capability of the MLCCs demonstrate an improvement in device flexibility by partially absorbing the stresses caused by the mismatch of thermal expansion between the solder, the capacitor, and the PCB.

Using MLCCs with these polymer terminations is therefore an excellent potential solution for those applications where severe and continuous thermal fluctuations, as well as strong vibrations or board flex stresses (example: during PCB assembly and soldering), are involved.