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Board Flexure Comparison between Surface Mount Multi-Layer Ceramic and Film Capacitors

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INTRODUCTION

Surface mount production techniques are now the standard in electronics manufacturing; components are now subjected to mechanical stresses during both assembly and use. Flexure or printed wiring board (PWB) bending is a significant source of these stresses that can lead to component breakage and failure. Flexure or bending can come from a number of sources such as soldering, panel separation, or rough handling after soldering during installation or product use. Ceramic capacitors are hard and brittle and can exhibit catastrophic failure if cracked during PWB bending if the crack propagates across opposing electrodes and there is sufficient energy present in the power supply. Multilayer film capacitors are made with polymer films, are not brittle under normal conditions and are more forgiving when stressed on a bending PWB. Flexure damage for both types of surface mount capacitors commonly used in high density switching power supplies is compared for similar sized capacitors exposed to the same flexure stress.

BOARD FLEXURE TESTING TECHNIQUES

General Procedures

Most common test procedures follow EIAJ specification RC3402[1] where a capacitor is reflow soldered to pads on a test PWB. The assembly is mounted component face down, supported on the PWB ends and bending stress is applied to the backside of the assembly with a ram directly behind the component under test. The basic setup is shown in Figure 1. Capacitance shift is used to detect failure under test conditions but may not detect cracking[2] of ceramic capacitors. The ram radius was reduced from 140mm in the specification to approximately 10mm to allow a more parabolic bend[3] during testing which is more consistent with observed real world stress than allowed by much larger ram radius used in the standard. The standard also uses a 1mm deflection as an acceptance level for no failures. A test PWB with 1mm of deflection is shown in Figure 2. A maximum deflection of only 1mm is difficult to achieve at every step of PWB assembly and final product manufacturing to eliminate flexure cracking of ceramic capacitors.

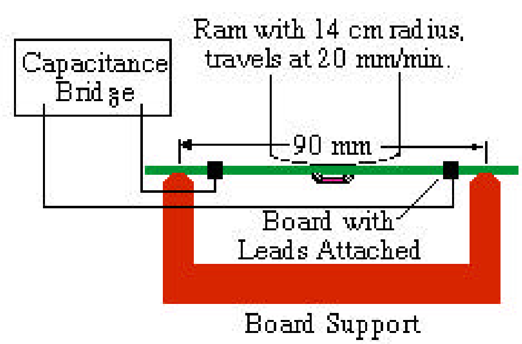

Figure 1. EIAJ RC3402 Board Flexure Test Assembly

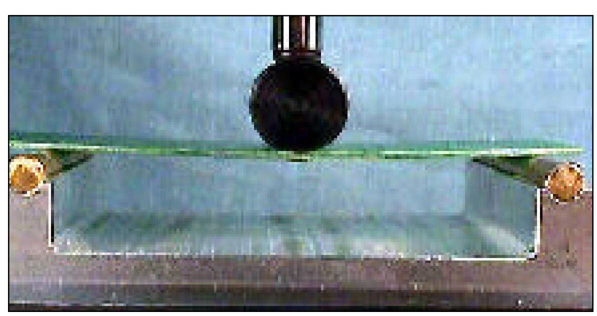

Figure 2. 1mm Deflection

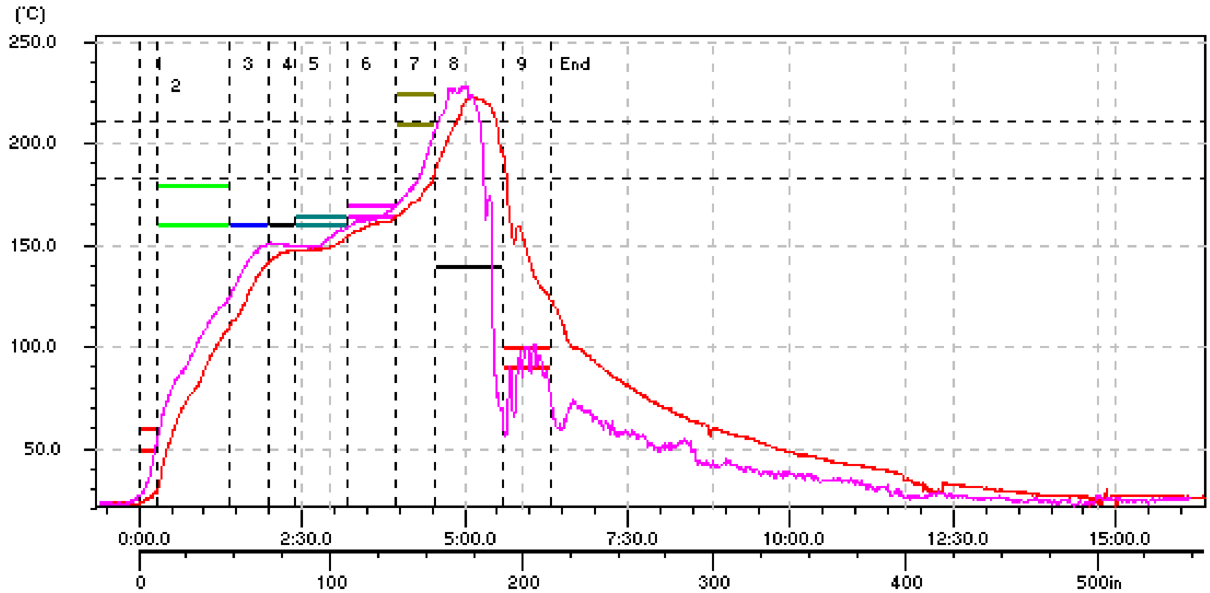

Figure 3. Reflow Profile

Procedures for This Study

A number of factors can influence flexure testing results including pad size, termination band spacing, pad separation, solder fillet size[4], capacitor length[5], PWB thickness, number of glass layers in the PWB[2], dielectric material, and electrode density or cover layer thickness. Each test PWB had Sn62 no-clean solder paste applied to each pad; capacitor mounted and reflowed in a convection reflow furnace. The reflow profile is shown in Figure 3 and is within component and solder paste recommendations. This process allows for uniform solder fillet size and minimizes possible variations. Test boards were from the same lot, made of FR-4, .062" or 1.6mm thick to minimize those test variations. Ceramic chip capacitors were X7R dielectric from the same manufacturer, nickel barrier termination and were inspected for uniform termination length. The 1812 and 2225 chips had radically different electrode densities, dielectric thickness and side/end margins.

The fixture shown in Figure 4 was mounted in an end mill with the ram perpendicular to the test board long axis. Each test PWB was bent to the desired deflection at approximately 20mm per minute, soaking for approximately 10 seconds at that deflection and then allowed to relax at approximately 20mm per minute. There seemed to be little influence on ram speed during testing and ceramic capacitor cracking. When a ceramic capacitor failed it was very audible.

Instead of using capacitance monitoring during flexure, ceramic capacitors were potted and sectioned still soldered to the PWB after bending so internal flaws or anomalies could be examined without introducing possible secondary cracks during removal from the test PWB. Film capacitors also remained on test boards, had capacitance, DF and IR recorded, burned in under DC bias elevated temperature and then had critical parameters measured and recorded after flexure.

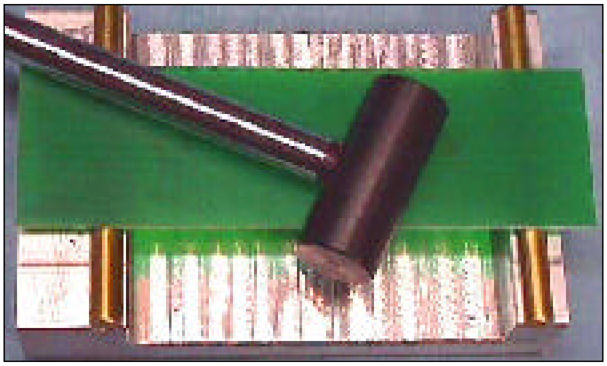

Figure 4. Test Fixture

Ceramic capacitors used consisted of commercially available 2225 X7R single stack J leaded chip (1.5 uF, 100V) and two surface mount chips 1812 (.82 uF, 50V) and 2225 (1000 pF, 1000V). Two suppliers of ceramic capacitors were used in this study. Surface mount multilayer film capacitors consisted of an 1812 (.22 uF, 100V), 2824 (1 uF, 100V), 3827 (2.2 uF, 100V), and gull wing leaded 1 uF, 100V and 4 uF 100Vcapacitors supplied by ITW Paktron.

EXPERIMENTAL RESULTS

Ceramic Capacitors

Initial flexure testing limits were chosen based on personal experience and published results[2,3,4,5] starting with deflections of 1mm and continuing in 1mm increments until ceramic capacitors had cracked or 8mm deflection was reached. The flexure limit of 8mm for leaded capacitors was somewhat arbitrary but it exceeds practical flexure limits for 1206 and 0805 sized chips other surface mount components and solder joints. All 1812 ceramic chips failed between 3 and 4mm of deflection with a typical failure shown in Figure 5. The high voltage chip was larger but samples did not crack until exposed to between 5 and 6mm of deflection and a typical failure which was carefully removed from the test PWB is shown in Figure 6. Figure 7 shows a test board at 4mm of deflection. The high voltage part probably would not fail catastrophically because the crack did not cross-opposing electrodes. There was a very loud snap when parts failed which was verified during sectioning. The difference between the two part sizes is because of internal construction differences between a high value 50V rated part and larger a 1kV rated part. The high voltage part had fewer electrodes; thicker dielectric layers and thicker cover layer and end/side margins. Capacitor length is a significant factor for flexure crack sensitivity with all other factors being equal so a larger part was expected to fail more quickly than actually measured. This is due in part to a small sample size of a few dozen parts; they were visually selected for physical uniformity they had different internal construction and probably these parts were very robust. Variations of different lots, values, rated voltage and vendors would probably yield different test results.

Leaded 1.5 uF 2225 capacitors exhibited no discernable failure mechanisms when test boards were deflected to 8mm. One part exhibited a small amount of termination separation from the capacitor body in the middle of the chip body. This may be due to a capacitor-manufacturing anomaly, flexure stress or may be a sectioning artifact. This anomaly was several tens of mils wide across the capacitor end.

There were no visible internal cracks observed during sectioning parts that were on test PWB that were deflected less than parts that failed. It merits further study to flex ceramic parts just less than ceramic rupture and then do a life test comparison between parts that are from the same lot, exposed same reflow soldering profile, flexed and not flexed.

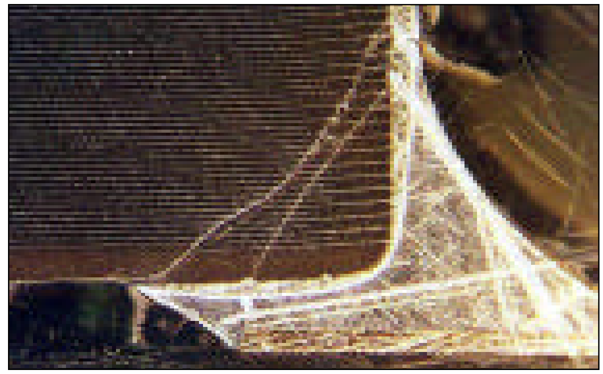

Figure 5. Typical 4mm Deflection 1812 Failure

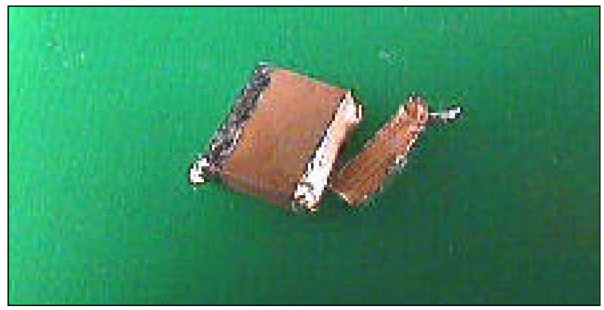

Figure 6. Typical 6mm Deflection 2225 Failure

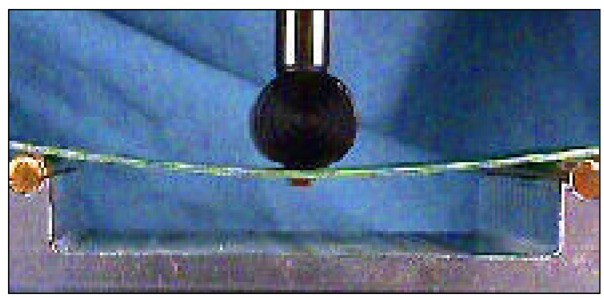

Figure 7. Test Board at 4mm of Deflection

Multi-Layer Film Capacitors

Surface mount film capacitors were tested at the same test deflections as the ceramic capacitors with no audible cracking except for an 1812 chip at 7mm of deflection. Both chips in 1812, 2824 and 3827 case sizes and two gull wing leaded configurations were tested. Figure 8 is of that capacitor that was exposed to 7mm deflection. Test PWB deflection was limited to 5mm for 2824 and 3827 chip sizes, up to 7mm for 1812 film chips, and 8mm of deflection for the gull wing leaded film capacitors. There is some separation between the aluminum and copper layers of the termination and there is some film layer distortion near the capacitor bottom at the solder joint interface in the 1812 chip that was deflected 7mm. This separation was not visible from the outside on the solder fillet and was primarily in the middle of the capacitor termination near the PWB capacitor interface. Figure 9 is of new capacitor termination/film interface and Figure 10 shows 8mm of deflection exerted on a test PWB. There was no appreciable loss or change of capacitance and parts passed 500 hours of burn in at 125˚0C at 100V DC bias. Even the part that had an audible snap at 7mm of deflection passed burn in without degradation or failure. No film capacitor exhibited capacitance loss or parametric failure after deflection. Life test results are summarized in Table 1.

Table 1. Film Capacitor Life Test Data Summary after 500 Hours at 125˚C and 100V DC

Parameter	**Part Number (Limit/Actual Average)**
	224K100ST1812
% Delta Cap	5.00/2.1
% DF	1.00/0.55
IR (Meg Ohm)	1000/100,000
	105K100ST2824
% Delta Cap	5.00/1.75
% DF	1.00/0.51
IR (Meg Ohm)	1000/70,000
	225K100ST3827
% Delta Cap	5.00/1.91
% DF	1.00/0.54
IR (Meg Ohm)	454/15,000
	105K100ST3
% Delta Cap	5.00/3.09
% DF	1.00/0.55
IR (Meg Ohm)	1000/100,000
	405K100CB4
% Delta Cap	5.00/2.28
% DF	1.00/0.54
IR (Meg Ohm)	250/12,000

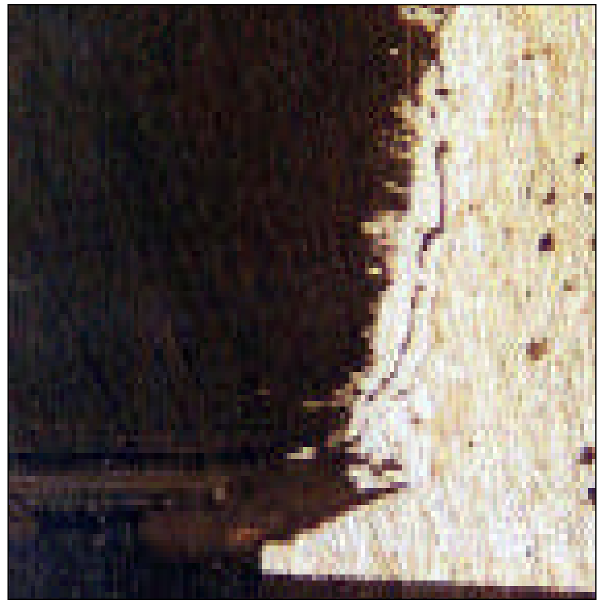

Figure 8. 1812 Film CapacitorTermination after 7mm Deflection

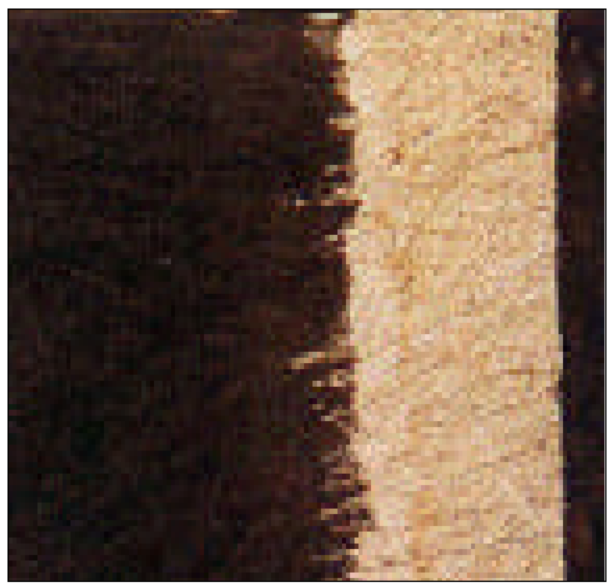

Figure 9. A New 1812 Film Capacitor Termination

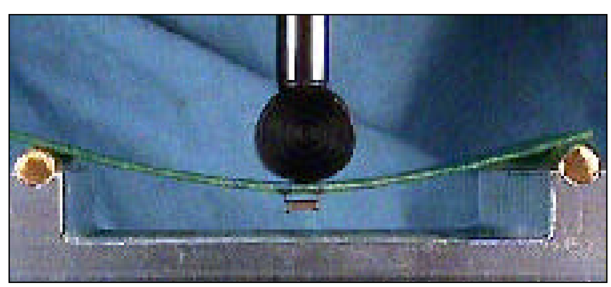

Figure 10. 8mm of Deflection

CONCLUSIONS

Surface mount film capacitors did not exhibit failure or degradation when tested at or beyond deflection values that cracked ceramic capacitors of similar size and values. Most discussion is on ceramic capacitor failures because those parts did crack under observed test PWB deflections where the film capacitors did not when tested under the same or more stringent conditions.

Gull wing and J lead surface mount capacitors of either type survived extreme test PWB deflection without degradation or failure. There was a limited number of vendors and sizes used in this study. More work is needed to compare performance differences using different sizes, values, voltage ratings, and vendors. The results for surface mount chips indicate that leaded film capacitors will hold the edge in mechanical robustness under PWB flexure conditions over ceramic counterparts.

Surface mount electronic assemblies with large capacitors mounted near a PWB edge that could experience flexure stress may be better served if a surface mount film capacitor was used instead of a more fragile ceramic capacitor. This is especially true if those capacitors are across a high-energy power source. Ceramic capacitors can experience catastrophic failure if cracked during PWB flexure and the crack propagates across opposing electrodes. Examples of high deflection or stress zones are score and break panel separation PWB edges, break out tabs for panel separation, mounting holes, parts mounted near test probe points, PWB edges slide into card slots, and mounting capacitors adjacent to high mass components like transformers and inductors.

REFERENCES

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