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Box Type SMD Film Capacitors: Reliable Solder Quality under Mechanical and Thermal Stress Conditions

It is not only the electrical function in the circuit or the observance of particular electric parameters that is important for the functioning of electronic components, but, in addition, the mechanical stability and reliability on the printed circuit board. Especially in the field of SMD technology, the components are subject to much greater mechanical and thermal stress. The following factors are of importance:

- **Handling during production of the components**
- **Packing and transport**
- **Storage of the components by the user**
- **Processing, assembly, soldering, washing, testing**
- **Mechanical and thermal stress in application**

Increased Stress Factors for SMD Components

Conventional wired components are subject to much lower stress. The criteria of packing, transport and storing may be considered equivalent, but the stress factors during processing and application differ considerably.
When being assembled, wired components can be held and guided by the terminating wires. Except for possible slight tension on the wires, mechanical stress does not occur on the active part of the component.
In contrast to this, during the assembly process the SMD components are usually handled by pick and place equipment by means of vacuum suction on the component body and placed on the appropriate solder pad on the printed circuit board. The resulting mechanical stress has a direct effect on the component. The component case, or, in the case of non-encapsulated types, the body of the component has to absorb the resulting stress forces.
Whereas in the case of the conventional wired component, the wire had the function of establishing the contact with the printed circuit board/solder joint or with the circuit, as well as fixing and holding the component, the SMD versions are soldered directly via the end contacts onto the appropriate solder pads of the printed board. In addition, the wire was able to take up and absorb the mechanical stress so that it did not reach the active part of the component. Both the solder joint and the component remained, by and large, unaffected by mechanical stress.
With SMD components, however, mechanical stress caused by the effect of outside forces such as vibration, bumps, warping of the circuit board, and also thermo-mechanical pressure or tension caused by differing coefficients of expansion between the printed circuit board and the component, have a direct effect on the component and the solder joint.
In addition, the much higher thermal stress during the soldering process of SMDs due to the integrated heating of the whole circuit board with the assembled components, must be emphasized.
Thus, thermal and mechanical strength, as well as the way the contact is carried out together with the electrical properties, are important criteria for the evaluation of SMD components.

Picture 1: Box type SMD film capacitor

More Critical Larger Size Codes

The proportion of SMD technology has been increasing for many years. In accordance with the wishes of the users, ever stronger and larger components including types which had so far been unobtainable, have to be made available in SMD versions. In the field of capacitor technology this has led to developments in two directions.
On the one hand, following the demand for miniaturization, generations of smaller and smaller components were developed, down to size codes 0805/0603/0402. With regard to mechanical stability and the mechanical stress on the solder joint, these small components, due to their small mass and size, do not cause any special problems, however they do place increased demands on precision in insertion. In this respect, the components in larger size codes from 1812 and upwards are more critical. The greater mass and larger surface areas which increase with the size codes, lead to distinctly higher stress factors in practical applications.

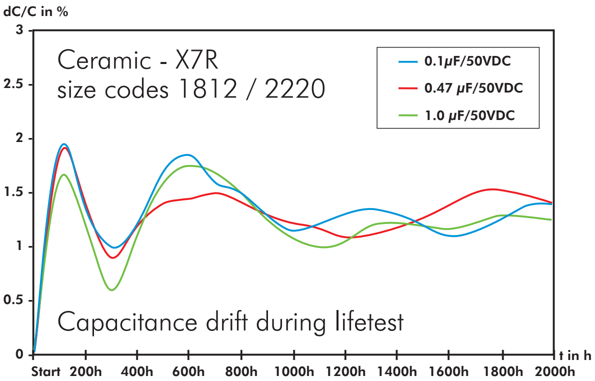
Ceramic Capacitors in Large Size Codes

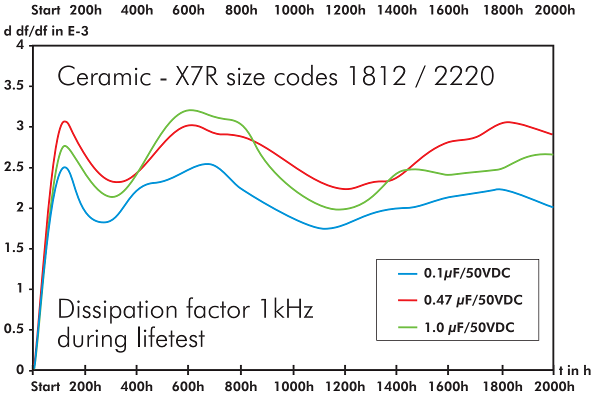
Ceramic capacitors are generally used in standard applications with values in the range of up to C ⩽ 0.1 µF. The smaller capacitance values are covered by regular ceramic versions, the larger values by multi-layer ceramic MLCC. This generally results in size codes ⩽ 1210 (1812). In order to be able to offer even higher capacitance and voltage ratings, the manufacturers of ceramic capacitors have also introduced larger size codes such as 1812 / 2220 / 2824/ (4036). For these, the spectrum of values goes right up to the µF range and to a voltage level of up to 1000 VDC.

Large Size Codes at the Limits of Technology

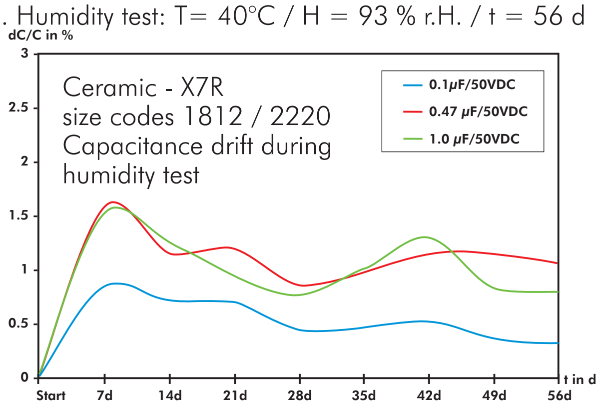
However, practical experience has shown that, because of the properties of ceramic materials and due to the other reasons mentioned above, these large components come up against some sort of technological limits. In this connection, it is not the observance of specified parameters which poses the primary problem. Life duration and environmental behavior tests certify typical values for ceramic capacitors which are in accordance with capacitor technology. The observance of the specified electric parameters is confirmed in the following test results for

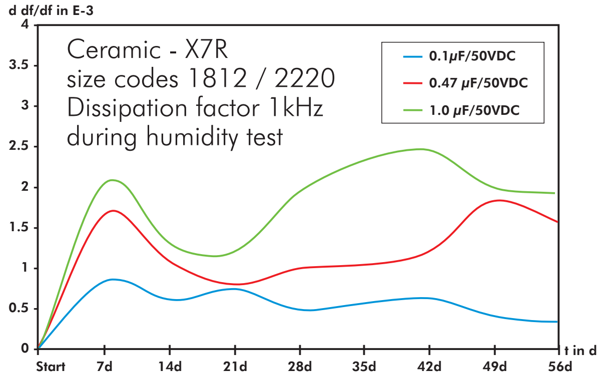
1. Life test: V = Vr / T = 100°C / t = 2000 h





2. Humidity test: T= 40°C / H = 93 % r.H. / t = 56 d

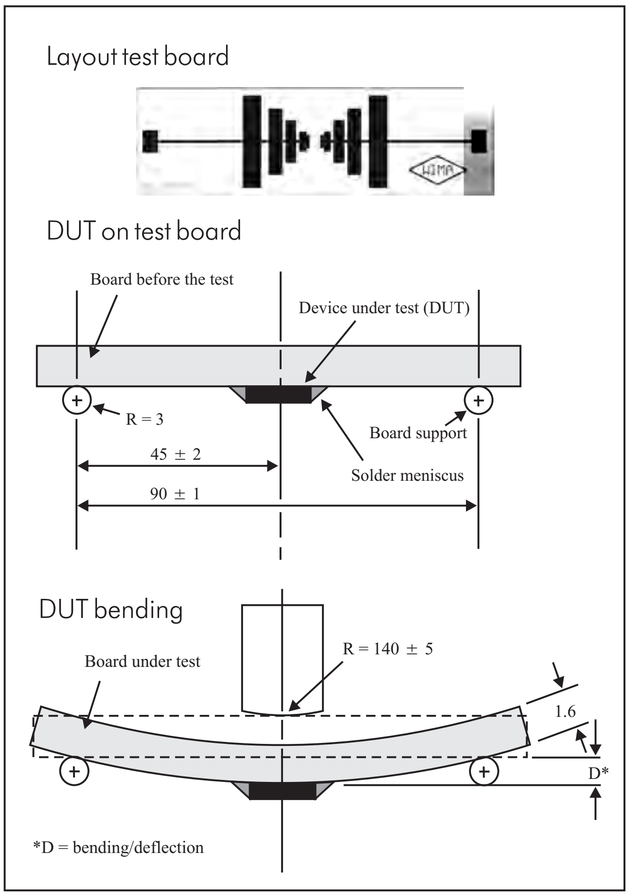




The problems relating to thermal and mechanical stress resistance, mentioned at the beginning, are more critical. Ceramic materials are well known for their ability to stand up to high temperatures and for their mechanical reliability concerning resistance to pressure. However, for the use of large size codes, a more critical factor is the well-known brittleness of ceramics. The considerable mechanical-thermal stress on SMD components during processing and application, discussed at the beginning, poses problems for SMD-ceramic capacitors in large size codes too.

Substrate Bending Test

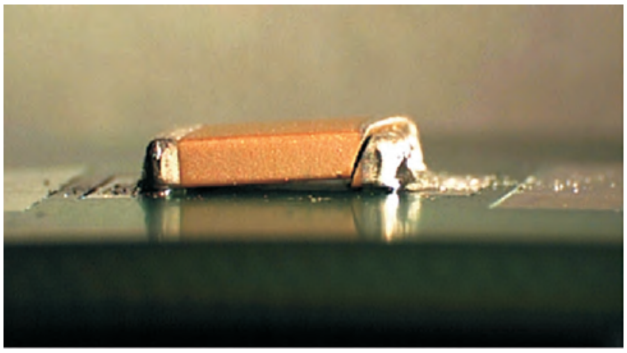
An important criterion for testing practical use in applications is the substrate bending test. In this test, SMD components are soldered on to a 100 mm x 30 mm printed circuit test board standardized, for example, in accordance with IEC 60068-2-21, under real processing conditions. The printed circuit test board is subjected to bending of 1 mm to 5 mm by means of a special tool.



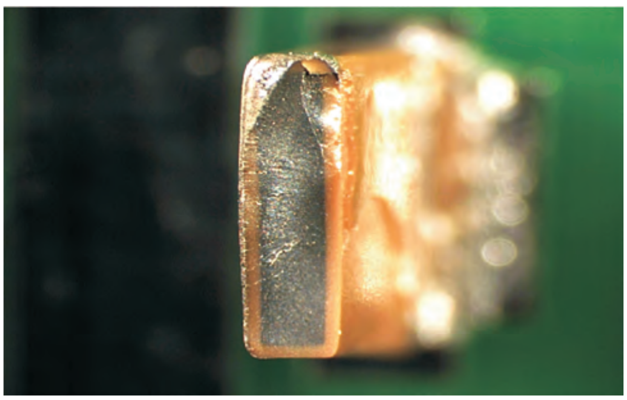
Picture 2: Test configuration in accordance with IEC 60068-2-21

Ceramic capacitors, especially the larger size codes, demonstrate extremely low stress strength.
Tests carried out with ceramic X7R 1812 0.47 μF /63 VDC - X7R 2220 1.0 μF / 63 VDC after only a short storing period of t=24 h after reflow-soldering, constantly resulted in the formation of cracks even when the bending was only 2 mm to 4 mm.
In tests where, in addition, the components had previously been pre-aged by means of storing at high temperatures T=100°C or with rapid change of temperatures T=-40°C /+100°C, crack formation increased. Cracks even occurred, when bending was started, at 1 mm.
As the following photos show, cracks occur in the area of the end-contacts of the capacitors due to the greater forces concentrated there. However, these cracks are not in the end contacts of the capacitors, but clearly across the ceramic material.

MLCC: X7R 1812 0.47 μF / 50 VDC



Picture 3: MLCC–crack on substrate bending test board

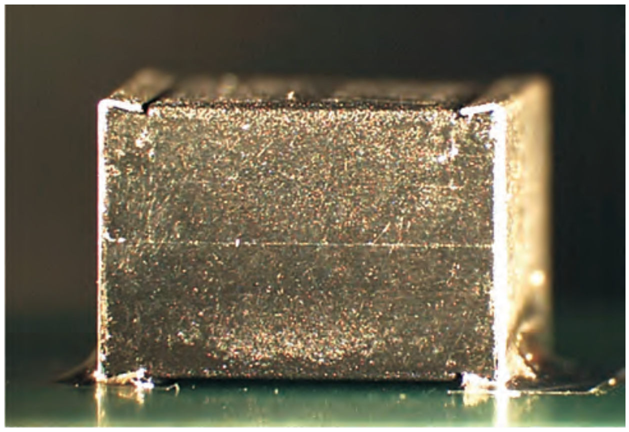


Picture 4: MLCC – crack / cross – section

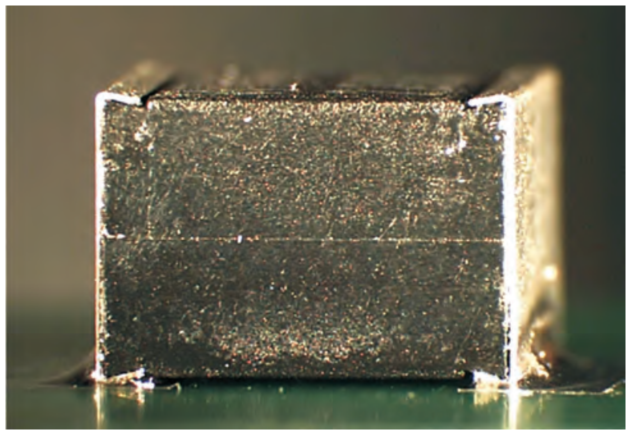
High Mechanical Strength of SMD Film Capacitors

The same tests were carried out with encapsulated SMD film capacitors. Apart from the basic differences in the capacitor technology, completely different concepts are realized with regard to the design of the terminating contacts.
With ceramic capacitors the end contacts are generally made of galvanized layers directly applied on the end surfaces of the ceramic bodies. These end contacts are directly used as solder surfaces.
In contrast to this, the contact surfaces of the SMD film capacitors viewed, are carried out in the form of metal plates, which are clipped round the capacitor case. This results in the mechanical decoupling of the active capacitor element. Mechanical stress on the component is largely absorbed by the suspension effect of the metal plates and does not reach the active part of the component.
This configuration therefore promises a very high level of mechanical robustness which has been confirmed in the tests carried out. Even with bendings of up to 5mm, cracks were not detected, neither with nor without pre-aging. The following series of pictures show a WIMA SMD in size code 2220 1.0 μF / 63 VDC subjected to a bending of D = 0 mm / 3 mm / 5 mm.

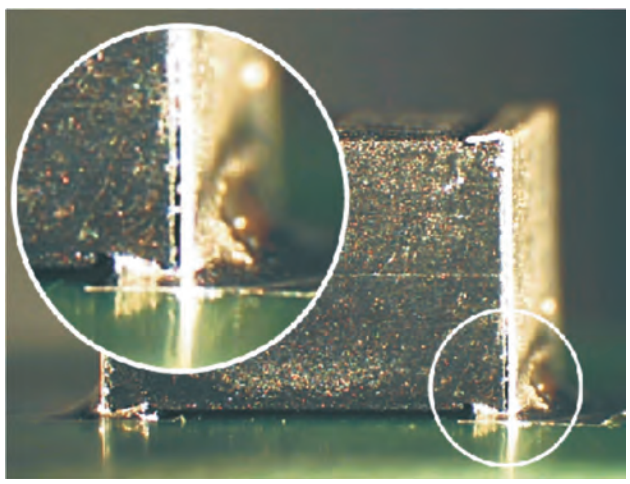
SMD film capacitor 2220 1.0 μF / 63 VDC



Picture 5: D = 0.0 mm



Picture 6: D = 3.0 mm

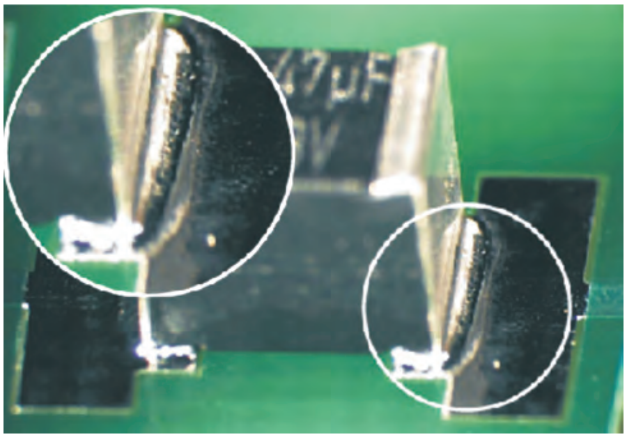


Picture 7: D = 5.0mm

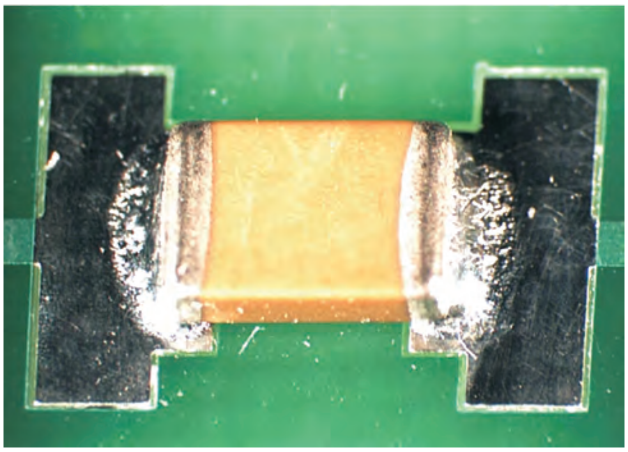
Distortion of the metal plates is visible, as is a slight raising from the capacitor case. At the end of the bending process, the plates go back and lie flat against the case again.

Very Good Soldering Quality of the Metal Plate Configuration

Over and above the good mechanical resistance, the metal plate configuration has a further advantage, namely very good solderability and solderjoint reliability in processing and application.
Regarding the thickness of the layers, the electroplated end contacts of the SMD ceramic capacitors are in the region of < 100 μm and spread very widely. The thickness of the layers of the tested ceramic versions were measured at between 15 μm and 70 μm.
On the basis of the tests carried out, it was established that, in practice, under re-flow soldering conditions, the SMD film capacitors in metal plate configuration which were examined, showed an almost perfect solder quality.
The solderjoint / meniscus of the ceramic versions tends to become a gritty / crystallize surface. To obtain an acceptable soldering quality, the processing temperature in all zones of the reflow equipment had to be increased by 10°C. Even so, the flow quality of the solder paste and the shiny surface was nowhere near as good as in the processing of the WIMA SMD in size code 1812. The following pictures show printed circuit test boards which clearly demonstrate this differing behavior.



Picture 8: Reflow solderability metallized polyester capacitor SMD 1812 0.47 μF / 63 VDC
Process parameters: 200°C/150°C/250°C 0.3 m/min.



Picture 9: Reflow solderability ceramic X7R capacitor SMD 1812 0.47 μF / 50 VDC
Process parameters: 210°C/160°C/260°C 0.3 m/min.

Conclusion

With regard to the realization of large ceramic size codes and the connected spectrum of higher ratings, the observance of the electric parameters can evidently be taken for granted.
However, in practical application, large ceramic types frequently come up against the limits of mechanical and thermal technological possibilities. The higher processing temperatures required, constitute unnecessary stress on all the other components on the printed circuit board and this certainly does not contribute towards increased product reliability.
Equally problematical is the sensitivity with regard to mechanical strength. For example, in automotive applications, where great temperature changes and the resulting thermal stress occur in combination with purely mechanical stresses such as vibrations and shock, the use of ceramic versions is limited.
The use of box type plastic film capacitors in SMD technology provides a high quality alternative. Not only are they basically clearly superior to ceramic versions because of the capacitor technology used, and the far better electric parameters such as

- Stability of capacitance value over temperature
- Stability of capacitance value over applied voltage
- Stability of capacitance over time
- Low dissipation factor
- Low dielectric absorption
- Self-healing capability
- .....

SMD film capacitors also have excellent mechanical stability as well as good soldering properties which enables them to cover especially the upper range of values in the size codes ⩾1210.
Recent developments in the field of encapsulated SMD plastic capacitors have resulted in the construction of very small types up to size code 1210, but also in the production of large size codes such as 6054, covering the upper spectrum of capacitance values and voltages, for example 6.8 μF / 63 VDC or 0.047 μF / 1000 VDC. It is therefore possible to cover a very large range of values with plastic film capacitors in SMD technology, without having to sacrifice the high standards of quality for which conventional leaded versions are well known.

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