Technical Report

Multilayer Ceramic Capacitors for Power Electronics

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1. Introduction

In recent years, interest in global environmental issues and energy issues has increased. In the power electronics field, power generation systems using natural energy sources such as wind and solar power have been developed. More energy-efficient home appliances have also been developed.

Emissions and fuel efficiency regulations have been implemented in the vehicle market, which has caused the development of Hybrid Electric Vehicles (HEVs) and Electric Vehicles (EVs) to become more popular in order to achieve better fuel efficient and lower carbon emissions. Therefore, in order for power electronics to improve, it is vital to improve the electronic components that are used for them.

Based on the title of this document, "Multilayer Ceramic Capacitors for Power Electronics," the following will explain our products that have been developed to contribute toward smaller size and better efficiency of power electronics.

2. Multilayer ceramic capacitors rated for 100V/125℃ (X7S characteristics series)

Multilayer ceramic capacitors need to be small, have high capacity, and have a long lifespan in order to reduce the size of power electronics products. If the size can be minimized and capacity can be improved, it would be possible to reduce the installation space and reduce the number of components. In addition, if the lifespan can be increased, the packaging density would increase making it possible to guarantee stable operation at higher peripheral temperature environments.

We have been making efforts to produce smaller products with larger capacity that are rated for 100V. We have been miniaturizing materials and optimizing additives in order to improve the reliability of thin dielectric layers. Compared to our conventional products, the size was reduced by about 50% while maintaining the same capacitance, and the capacity was doubled while maintain the same size (Table1).

In addition, the capacitance variation is ±22% (25°C standard) in the range from −55 to +125°C, and reliability is guaranteed up to 125°C for 2,000 hours.

3. Multilayer ceramic capacitors rated for 250 to 630V/12℃ (X7T characteristics series)

HEVs use 200 to 300V high-voltage batteries for motor efficiency. However, many electrical devices such as for electric power steering and power windows operate at a low voltage (14V). Therefore, a DC to DC converter is used by HEVs to convert the voltage from the high-voltage main battery to a lower voltage. Multilayer ceramic capacitors used for such converters need to be small and have a large capacity. However, when multilayer ceramic capacitors used for high voltage are made smaller and with larger capacity using thinner and multiple dielectric layers, two problems occur with multilayer ceramic capacitors using ferroelectrics. One problem is capacity degradation at the operating voltage, and the other problem is reliability degradation due to electrostrictive strain.

We have been able to successfully develop a material that can reduce capacitance degradation due to superimposed voltage and is not strained when voltage is applied. Compared to our conventional products, the size can be about 50% smaller while maintaining the same capacitance, and the capacity can be doubled while maintaining the same size (Table 2).

The efficiency of the capacitance degradation depends on the type of circuit that is used, but the size can be at least 50% smaller.

For example, when the DC-Bias characteristics of the 0.22μF product of C5750 type and 0.15μF product of C3225 type are compared, there is almost no difference in the capacitance in the range above DC.400V (Figure 1).

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Table 1 Capacitance range for X7S characteristic's series

Size	C1005 [EIA CC0402] (1.0×0.5mm)	C1608 [EIA CC0603] (1.6×0.8mm)	C2012 [EIA CC0805] (2.0×1.25mm)	C3216 [EIA CC1206] (3.2×1.6mm)	C3225 [EIA CC1210] (3.2×2.5mm)	C4532 [EIA CC1812] (4.5×3.2mm)	C5750 [EIA CC2220] (5.7×5.0mm)
Rated voltage	2A 100V	2A 100V	2A 100V	2A 100V	2A 100V	2A 100V	2A 100V
1,000pF							
1,500pF							
2,200pF							
3,300pF							
4,700pF							
6,800pF							
10,000pF							
15,000pF							
22,000pF							
33,000pF							
47,000pF							
68,000pF							
100,000pF							
150,000pF							
220,000pF							
330,000pF							
470,000pF							
680,000pF							
1,000,000pF							
1,500,000pF							
2,200,000pF							
3,300,000pF							
4,700,000pF							
6,800,000pF							
10,000,000pF							
15,000,000pF							

In mass production(X7R series) New product(X7S series) X7S series(Release at Oct.'09)

Table 2 Capacitance range for X7T characteristic's series

Size	C2012 (2.0×1.25mm)			C3216 (3.2×1.6mm)				C3225 (3.2×2.5mm)			C4532 (4.5×3.2mm)			C5750 (5.7×5.0mm)		
Rated voltage	2W 450V	2V 350V	2E 250V	2J 630V	2W 450V	2V 350V	2E 250V	2J 630V	2W 450V	2E 250V	2J 630V	2W 450V	2E 250V	2J 630V	2W 450V	2E 250V
1,000pF																
1,500pF																
2,200pF																
3,300pF																
4,700pF																
6,800pF																
10,000pF																
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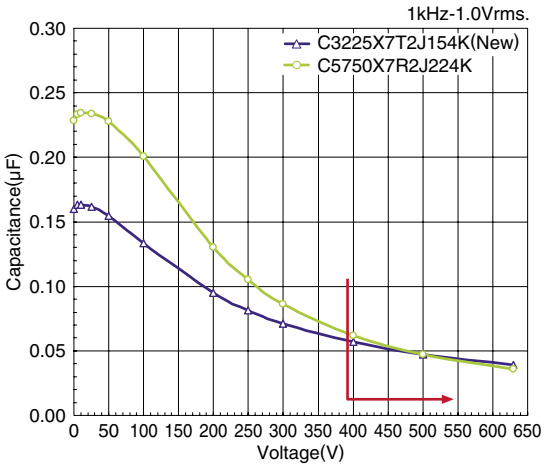
68,000pF																
100,000pF																
150,000pF																
220,000pF																
330,000pF											304					
470,000pF																
680,000pF																
1,000,000pF																
1,500,000pF																
2,200,000pF																
3,300,000pF																
4,700,000pF																
6,800,000pF																

In mass production(X7R series) New product(X7S series) X7S series(Release at Oct.'09)

The capacitance variation is +22%/−33% (25°C standard) in the range from −55 to +125°C, and reliability is guaranteed up to 125°C.

Figure 1 Comparison of DC-Bias characteristics between conventional products and X7T



4. Conductive resin terminal type multilayer ceramic capacitors

Recently, lead-free soldering has become common as a measure for protecting the environment. However, lead-free soldering has a higher Young's modulus than conventional eutectic solder with lead. As a result, it is easy to experience expansion and contraction due to changes in temperature. Countermeasures must be used to prevent cracks caused by thermal impulse or long-term exposure to high temperatures. It is also necessary to implement countermeasures to prevent cracks caused by bending of the substrate, impact from being dropped, as stress between the terminal electrode and dielectric.

There are products that contain a conductive resin layer in the terminal electrode to release external stress and protect the ceramic body. This conductive resin layer can absorb small amounts of external stress, but if there is a large amount of stress, this lay can peel off preventing cracks even when a large amount of stress is applied to the ceramic body. We use a flexible conductive resin to improve degradation of joint strength caused by temperature cycles of conventional products and conventional resin electrode products (Figure 2).

Currently, this terminal configuration can only be applied to products with a size from 1005 (1.0×0.5mm) to 3225 (3.2×2.5mm). However, it will be made compatible with other size products.

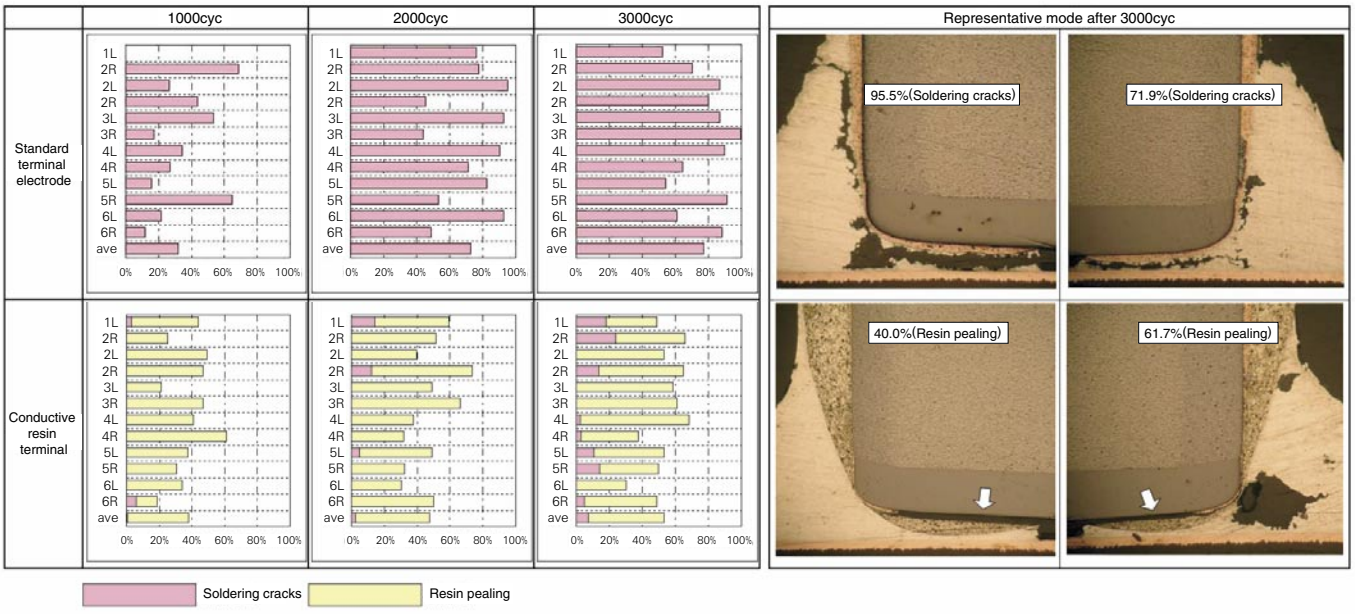
5. Conclusion

Power electronics technologies will continue to develop, especially in the vehicle market. Therefore, we believe that multilayer ceramic capacitors will continually need to be made smaller with larger capacity and longer life spans. It will also be necessary for them to maintain reliability at temperatures over 150°C.

We will continue to make effort to produce smaller, larger capacity, higher temperature resistant, and longer lasting products, and will improve our products so that they meet the needs of the market and contribute to the development of power electronics technologies.

Figure 2 Soldering cracks after temperature cycle

Temperature cycle: −55 to +125˚C
Solder: Sn-3.0Ag-0.5Cu



• Please note that the articles from the August 20, 2009 Edition of the Dempa Shimbun contained in this chapter have been edited by our company.