Technical Report

Technology for Multilayer Ceramic Capacitors Compatible with High Temperatures for Vehicles

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1. Introduction

Improvements in vehicle fuel efficiency is one example of countermeasures for environmental issues that have continued to advance in recent years.

These improvements were accomplished through electronic control of engine performance and by reducing vehicle body weight.

One method for reducing vehicle weight is to reduce the weight of the wire harness by shortening its length. This is done by installing the unit for controlling the engine closer to the engine itself, which causes the operating temperature to increase. Therefore, electronic components used for this unit must be compatible with high temperatures.

In this document, issues related to compatibility with high temperature will be explained, and our products for vehicles compatible with high temperatures will be introduced based on the title, "Technology for Multilayer Ceramic Capacitors Compatible with High Temperatures for Vehicles."

2. Issues related to making multilayer ceramic capacitors compatible with high temperatures

When multilayer ceramic capacitors are used at high temperatures without carefully considering the usage, there are three main possible problems that can occur.

The first problem related to high temperature is reduced capacitance. This occurs when a high-dielectric material such as barium titanate is used as the dielectric material for multilayer ceramic capacitors. The curie point of barium titanate is 125°C, so the ferroelectric properties are lost when the temperature is over 125°C, and the capacitance suddenly decreases. Therefore, in order to avoid this problem, it is necessary to consider the decreased capacitance at high temperatures.

The next problem when multilayer ceramic capacitors are used in a high temperature environment is that reliability decreases compared to when used at normal temperatures.

This is because the lifespan of the dielectric material used for multilayer ceramic capacitors depends on the temperature and electric field. When used in a high temperature environment, the lifespan becomes shorter. Therefore, to use them at high temperatures, the electric field needs to be reduced or it is necessary to select a product with a sufficient lifespan at high temperatures.

The third problem related to high temperature is a decrease in joint strength reliability between the multilayer ceramic capacitor and the substrate.

This problem occurs for other products in addition to multilayer ceramic capacitors. When the temperature cycle between high and low temperature repeats during operation, or when it is used at a high temperature environment for a long period, the joints deteriorate.

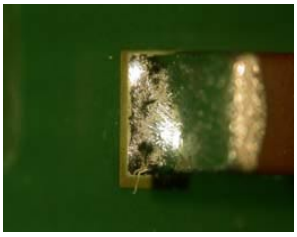
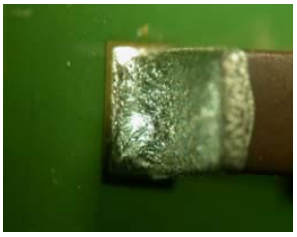
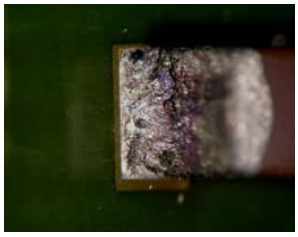
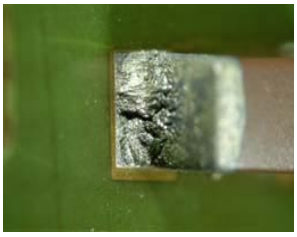
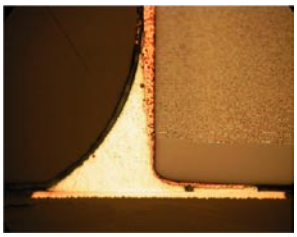
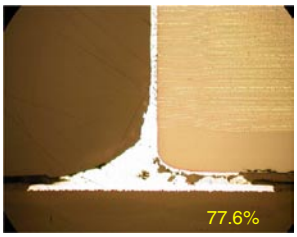
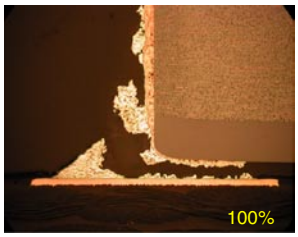
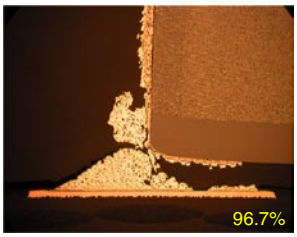
The reason for this is that the linear expansion coefficient between multilayer ceramic capacitors and the substrate are different, so the joint portion received stress that causes it to deteriorate. Another cause it that the Sn used for soldering and other metals create an intermetallic compound at high temperatures, which makes it become brittle and deteriorate joint strength. These phenomena are related to the number of temperature cycles and the temperature difference (Figure 1).

Based on this, when multilayer ceramic capacitors are used in a high temperature environment, it is necessary to select the proper usage method while considering the risks of these problems.

We have developed several countermeasures for reducing these problems, and these will be explained in the following.

Figure 1 Solder crack growth due to temperature cycles

Temperature cycle: –55/+125˚C
Solder: Sn/3.0Ag/0.5Cu

	Initial	1,000 cycles	2,000 cycles	3,000 cycles
Appearance				
Cross-section				

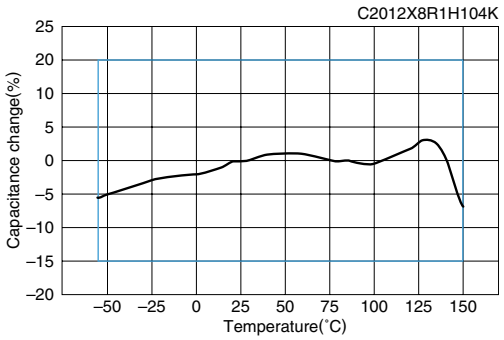
• Numerical values in the cross-section photos show the % of cracking.

Table 1 Capacitance range for X8R products

As of September 2008

Series	C1005[EIA CC0402]					C1608[EIA CC0603]					C2012[EIA CC0805]					C3216[EIA CC1206]					C3225[EIA CC1210]				
Size	L 1.0 × W 0.5mm					L 1.6 × W 0.8mm					L 2.0 × W 1.2mm					L 3.2 × W 1.6mm					L 3.2 × W 2.5mm				
Rated voltage	2A (100V)	1H (50V)	1E (25V)	1C (16V)	1A (10V)	2A (100V)	1H (50V)	1E (25V)	1C (16V)	1A (10V)	2A (100V)	1H (50V)	1E (25V)	1C (16V)	1A (10V)	2A (100V)	1H (50V)	1E (25V)	1C (16V)	1A (10V)	2A (100V)	1H (50V)	1E (25V)	1C (16V)	1A (10V)
0.001µF																									
0.0022µF																									
0.0047µF																									
0.01µF																									
0.022µF																									
0.047µF																									
0.1µF																									
0.22µF																									
0.47µF																									
1µF																									
2.2µF																									
4.7µF																									
10µF																									
22µF																									

Commercialized Developing Development planed



3. Multilayer ceramic capacitors guaranteed at 150℃ (X8R characteristics series)

Our X8R multilayer ceramic capacitors are guaranteed in operating environments from −55 to +150°C.

These products were especially developed to be used in vehicles, and the capacitance variation in the −55 to +150°C temperature range is within ±15% (25°C standard), and reliability is guaranteed at 150°C. We have repeatedly improved the material composition and processing conditions in order to achieve these commercialized multilayer ceramic capacitors.

The X8R products are essential for the development of future car electronics. We will continue to expand the capacitance in order to make a more usable product series (Table 1).

4. Products for high temperature joints (Products compatible with electrically-conductive adhesives)

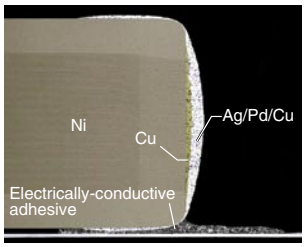
Electrically-conductive adhesives are one method used for joints to ensure joint reliability in operating environments with severe temperature differences such as engine rooms. The resin contained in electrically-conductive adhesives can buffer the difference in expansion and contraction between the substrate and components caused by temperature differences in order to ensure high joint reliability.

However, to make joints using electrically-conductive adhesives, it is necessary to have a compatible external electrode.

This is because the "Ag Filler," which is the electrically-conductive material contained in electrically-conductive adhesives, causes Sn oxidation due to electric potential difference with the "Sn Coating" contained in the external electrode of multilayer ceramic capacitors compatible with normal soldering. As a result, this can cause problems such as increased contact resistance and deterioration of joint strength.

We have developed a commercial product series with an external electrode that uses Ag material so that it is compatible with electrically-conductive adhesives (Figure 2).

Figure 2
External electrode configuration of product compatible with electrically-conductive adhesives



5. Products for high temperature joints (Resin electrodes)

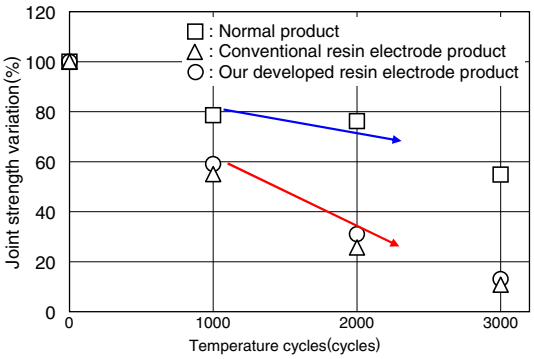
In recent years, lead-free products have become popular as a measure for protecting the environment. Lead-free solder has become more common as a joint solder for vehicle units.

Lead-free solder has a larger Young's modulus than eutectic solder using lead. Therefore, it is easily affected by expansion and contraction due to changes in temperature. Because of this, it is more difficult for electrical components to have secure joint strength in high temperature environments.

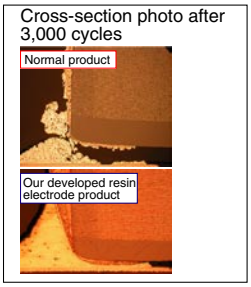
There are products that contain resin in the external electrode in order to buffer the stress caused by changes in temperature for multilayer ceramic capacitors.

We have developed a new resin so that it is possible to make products with improved joint strength in temperature cycles than existing resin electrode products (Figure 3).

Figure 3 Comparison of joint strength related to temperature cycles



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



6. Products for high temperature joints (Mega-cap)

There are multilayer ceramic capacitors with metal plate electrodes for releasing stress from expansion and contraction due to changes in temperature (Our product name: Mega-cap).

With this product, multilayer ceramic capacitors can be installed without touching the substrate. Therefore, this can prevent cracks with multilayer ceramic capacitors caused by stress from the substrate and prevent deterioration of joints as mentioned previously. As a result, it is possible to use large multilayer ceramic capacitors that were formerly difficult to use (Table 2).

7. Conclusion

"Car Electronics" will become even more advanced in the future.

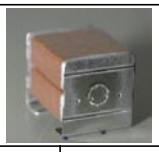
Therefore, "Multilayer Ceramic Capacitors" will need to have "High Temperature Compatibility" to support this development.

We will continue to study and improve the characteristics and reliability of multilayer ceramic capacitors and the reliability of joint strength during operation to contribute toward further developments.

Table 2 Capacitance range for Mega-cap type

As of September 2008

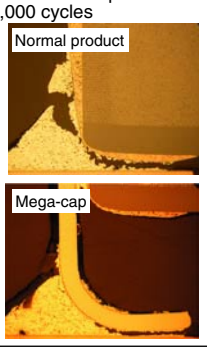
Single layer type															
Series name	CKG32K					CKG45K					CKG57K				
Size	L 3.6 × W 2.6 × T 3.35mm					L 5.0 × W 3.5 × T 2.9mm					L 6.0 × W 5.5 × T 3.35mm				
Rated voltage	2J (630V)	2E (250V)	2A (100V)	1H (50V)	1E (25V)	2J (630V)	2E (250V)	2A (100V)	1H (50V)	1E (25V)	2J (630V)	2E (250V)	2A (100V)	1H (50V)	1E (25V)
0.1μF															
0.15μF	X7R														
0.22μF		X7R									X7R				
0.47μF							X7R								
1μF			X7R	X7R								X7R			
2.2μF						X7R		X7R							
3.3μF			X7S						X7R						
4.7μF					X7R			X7R		X7R			X7R	X7R	
6.8μF				X7S											
10μF				X7S									X7S		
22μF															X7R
47μF															

Two layer type										
Series name	CKG45N					CKG57N				
Size	L 5.0 × W 3.5 × T 3.35mm					L 6.0 × W 5.5 × T 5.0mm				
Rated voltage	2J (630V)	2E (250V)	2A (100V)	1H (50V)	1E (25V)	2J (630V)	2E (250V)	2A (100V)	1H (50V)	1E (25V)
0.1μF										
0.15μF										
0.22μF	X7R									
0.47μF						X7R				
1μF		X7R								
2.2μF							X7R			
3.3μF										
4.7μF			X7R							
6.8μF				X7R						
10μF			X7S		X7R			X7R	X7R	
22μF								X7S		X7R
47μF										

X7R X7S

Temperature cycle: –55/+125˚C
Solder: Sn/3.0Ag/0.5Cu

Cross-section photo after 3,000 cycles



• Please note that the articles from the October 2, 2008 Edition of the Dempa Shimbun contained in this chapter have been edited by our company.