

## **Latest Technological Trends for Solid Tantalum Electrolytic Capacitors**

### **Highly Reliable Resin-Molded Series for Temperatures up to 135°C**

With the dizzying pace of technological advancement in automotive electronics in recent years, we are seeing an increasingly wider range of high-end functions in car electronics systems. To improve environmental performance, companies must not only create better control technology but also smaller and lighter equipment which would enable such control technology. To overcome the space limitations of increasingly larger circuit boards and to reduce their weight by eliminating the number of wire harnesses, circuit boards are frequently being placed under the hood of the car or mounted directly onto the engine itself. This subjects these circuit boards to extremely high temperatures, therefore the electronic components on these pc boards must be not only small and highly functional but also be capable of withstanding high temperatures.

Nichicon has released a 135°C-resistant highly reliable resin-molded series of electrolytic capacitors to meet such market needs. This device maintains its electrical properties in a category temperature range of -55°C to 135°C, surpassing that of previous products (-55°C to 125°C).

Normally, as temperatures rise, capacitors experience increasing leakage current passing through the dielectric. This is also true with tantalum electrolytic capacitors. The heat expansion of the molded resin on the exterior causes stress on the interior elements which can damage the dielectric. This results in even more leakage current to the damaged part, causing Joule heating that result in further deterioration of the dielectric. This vicious cycle creates increasing leakage current over time.

Looking at property changes in equivalent series resistance (ESR), the heat expansion coefficient is different for each of the different structural parts of the capacitor, shown in figure 1-1. This difference results in warping, which compromises the adhesion of the various layers and deteriorates the capacitor.

Here is how the problems mentioned above—(1) deterioration of properties caused by leakage current, and (2) deterioration due to ESR properties—are generally dealt with.

(1)

To deal with deterioration of properties caused by leakage current in a high temperature environment, generally the dielectric can be made physically thicker to create a substance that is resistant to higher temperatures. This lowers the absolute value of leakage current. Because increasing the thickness of the dielectric decreases capacity, assuming conventional tantalum powder is used, the capacitor with the thicker dielectric has a lower capacity and lower voltage than one of the same size with a thinner dielectric. To achieve products with the same rating as previous ones, more tantalum powder must be used and the case size must be made larger.

(2)

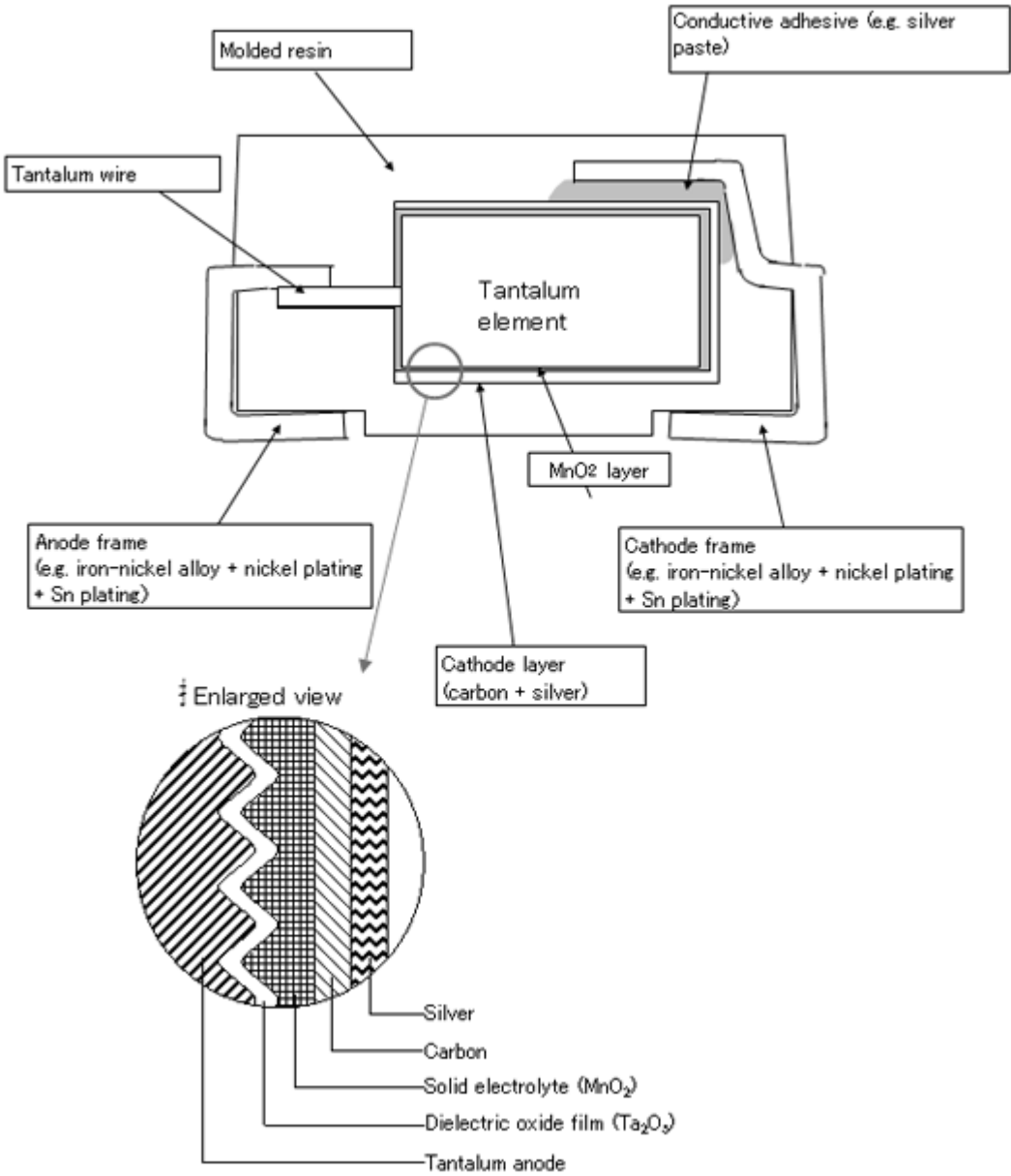
To deal with deterioration due to ESR properties, as long as the temperature does not exceed 150°C, the same material structure as previous products will suffice. However, it is important that the MnO<sub>2</sub>, carbon, and silver layers that make up the cathode extraction layer have greater adhesive strength than that of previous products, and that the interior elements, conductive adhesive, and lead frame have more stable connections. Although different companies have different ways to make their products resistant to temperatures above 150°C, most do so by altering the electrode plating material.

When Nichicon was investigating making products resistant to temperatures above 125°C, actual temperatures for the environment of the main applications we were targeting, such as under-the-hood and headlight peripherals, were approaching 125°C. Therefore, we decided to begin development of parts capable of functioning at 135°C.

First, we confirmed exactly to what degree molded resin is affected by heat contraction, which is the cause of increased leakage current at high temperatures. Figure 1-2 shows a comparison between previous products and a low-stress resin product with higher filler content with regards to temperature properties of leakage current at high temperatures. You can see that the low-stress resin product experiences a slower increase in leakage current at higher temperatures. Next, because the insulating property of the dielectric is affected by the concentration of the impurity, we worked with a material manufacturer to jointly develop an element using tantalum powder with a low concentration of impurity. We further reduced the impurity content of this element in-house to create a product under the prescribed process flow. Figure 1-2 showing a comparison of this product and a previous product with regards to leakage current temperature properties at high temperatures. You can see that the product with the lower concentration of impurity has a smaller rise in leakage current at high temperatures compared to the previous product. From this basic data we created a prototype: we used low-stress resin, which has more low-impurity concentration elements and filler than previous products; increased the base thickness of the MnO<sub>2</sub> and carbon layers that make up the layer protecting the molded resin against the stress; and improved the adhesive strength. We tested this prototype against the previous product for reliability. Figure 1-3 shows the results of a durability test at 135°C. While the previous product shows rising leakage current after about 1,000 hours, the prototype is still stable after 2,000 hours.

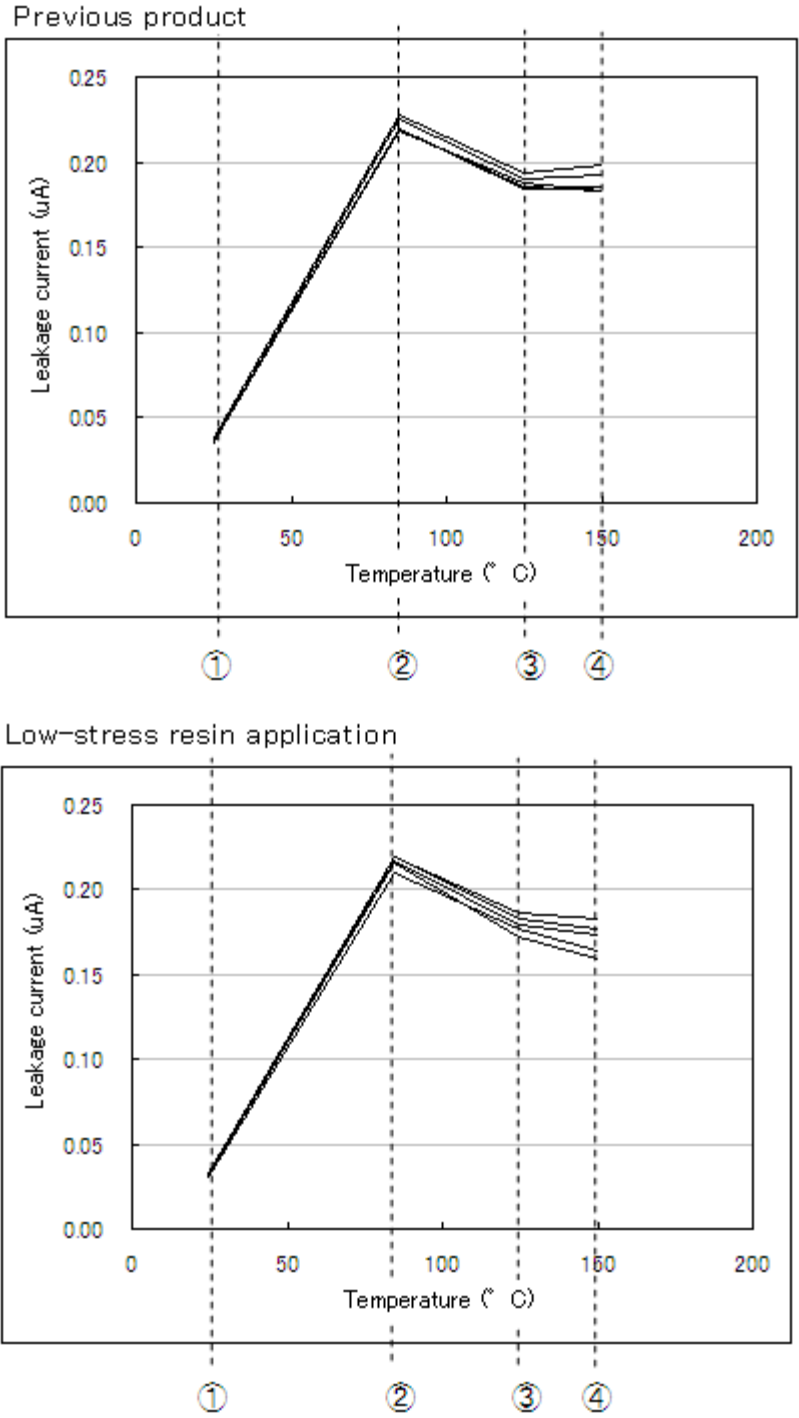
Using this method, we created the F97 Series of highly reliable capacitors. The market for such products is expected to grow, and products resistant up to about 150°C will likely be required. We therefore are currently developing 150°C-resistant products while continuing to offer products equivalent to our 135°C-resistant lineup.

【 Figure 1-1】 Structure of Resin-Molded Product

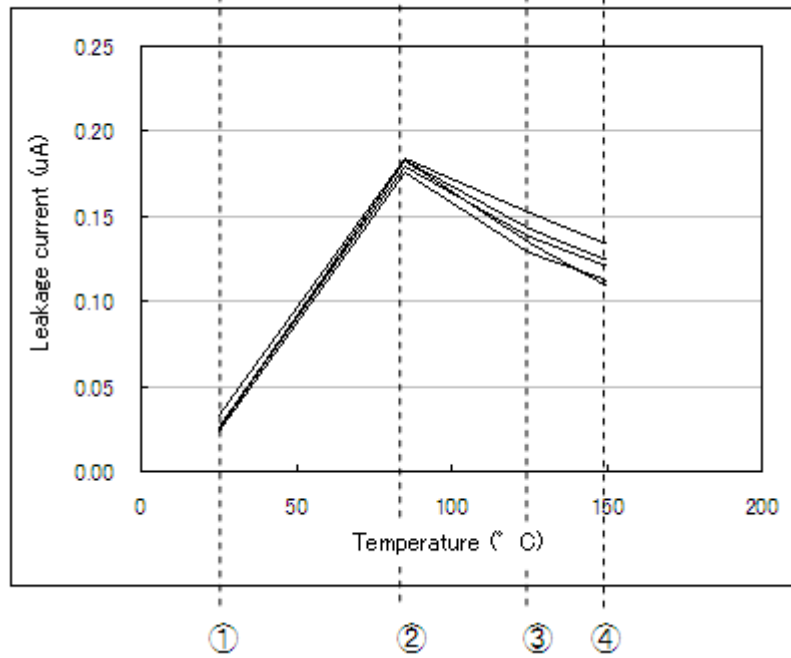


【 Figure 1-2】

Degree of effect of heat extraction on molded resin at B case representative rating, and degree of effect of impurity concentration in the tantalum element



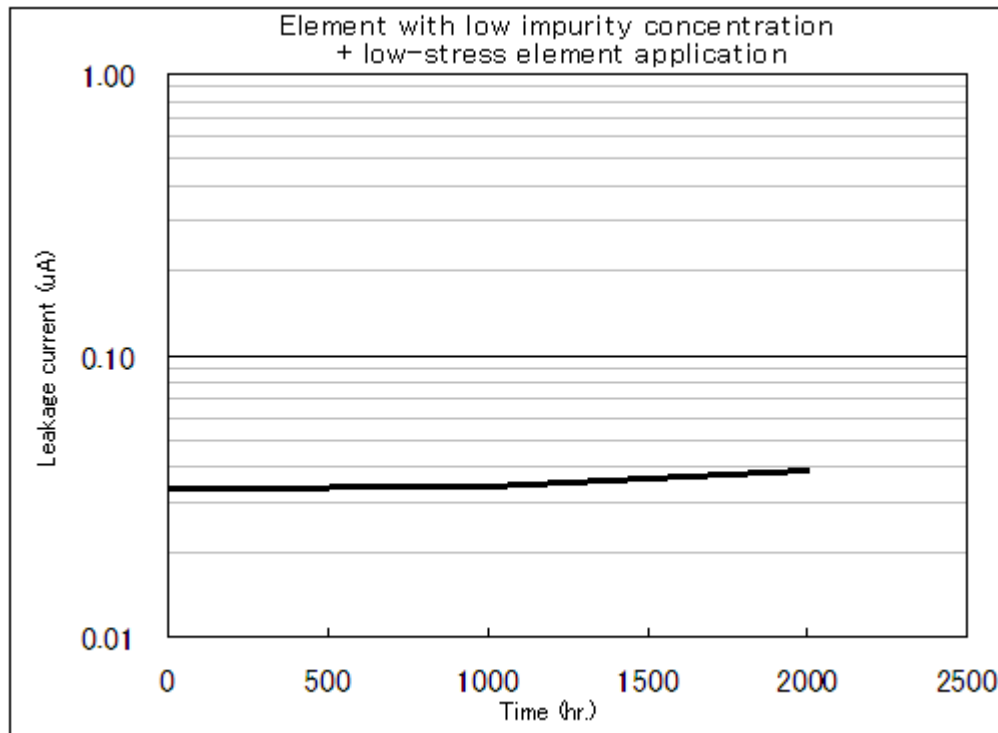
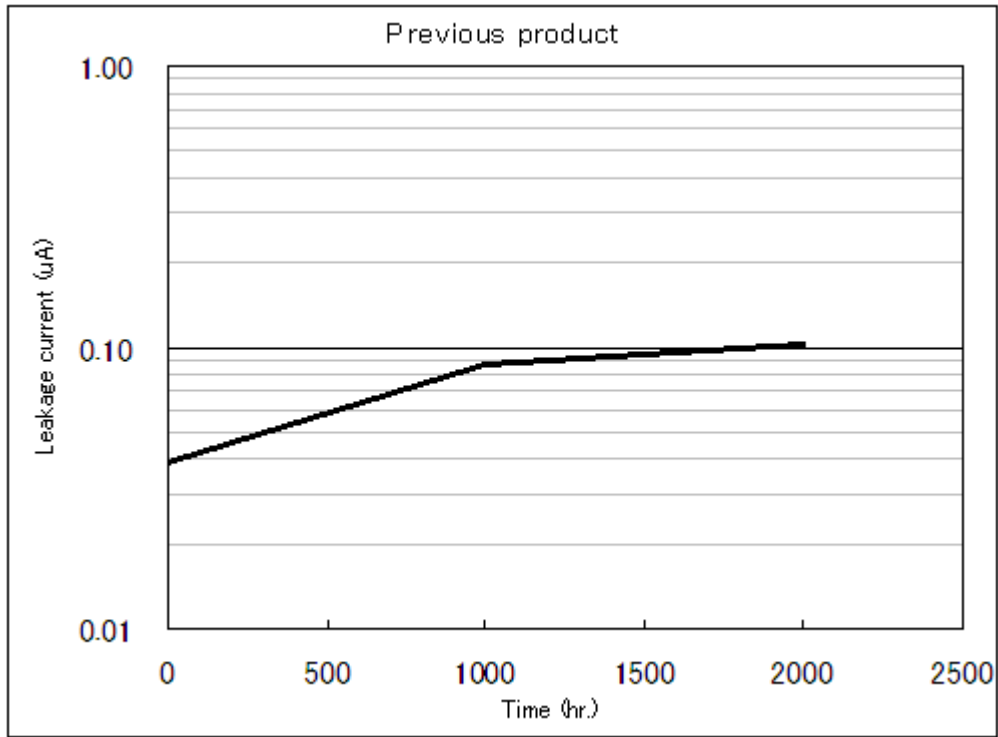
Element application with low impurity concentration



5 pieces measured at the same rating. Comparisons were made with a reduced applied voltage at 125°C and 150°C so that the dielectric would not deteriorate.

- ① 25°C : Rated voltage applied
- ② 85°C : Rated voltage applied
- ③ 125°C : 2/3×Rated voltage applied
- ④ 150°C : 1/2×Rated voltage applied

【 Figure 1-3】 Durability test at B case representative rating: 135°C-2/3RV (n=10 average)



## Solid Tantalum Electrolytic Capacitors with Safety Mechanisms

In the field of consumer electronics, the dissemination of small and highly functional products like smartphones and tablet PCs is occurring at breakneck speed. Since these products require capacitors that are compact and have high capacity, many of them use tantalum electrolytic capacitors, which boast superior mounting efficiency per volume. In particularly high demand are tantalum electrolytic capacitors with improved safety for use with mobile phones, portable game consoles, and other products that people keep on their person. And in the fields of industrial equipment and in-vehicle products, manufacturers of application products are moving toward increasingly safer designs for circuits requiring tantalum electrolytic capacitors, with their superior temperature properties and bias properties, and in many cases the use of tantalum electrolytic capacitors with safety mechanism is mandatory. Previous products with safety mechanisms had low mounting efficiency per volume, so to ensure the necessary pressure resistance and capacity, larger capacitors had to be used, and as a result circuit boards had to be larger. Circuit board designers thus sought packages that had safety mechanism yet were compact and high capacity.

Figure 2-1 shows the structure of general tantalum electrolytic capacitors with safety mechanisms: consisting of the capacitor's internal elements and a lead frame (the exterior electrode), between which is a material that functions as a fuse. As you can see from the pattern diagram placing the fuse material inside means that there is much less room for capacitor elements to be placed inside the same package. The result is the loss of several advantages of tantalum electrolytic capacitors: their compact size, thinness, and high capacity.

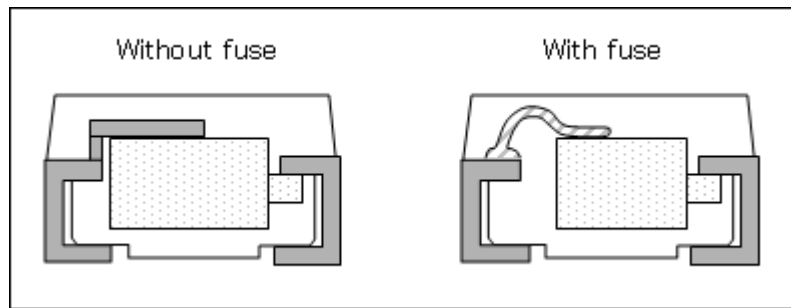
Nichicon sought to solve this problem with the development of a new type of structure for tantalum electrolytic capacitors with safety mechanisms. By using our F98 Series frameless resin-mold high-capacitance face-down electrode-type tantalum electrolytic capacitor as the basic structure, and by placing minute materials with a fuse function inside the electrode substrate, we were able to create a product that is compact and high-capacity, as well as safe, without sacrificing the mounting efficiency per volume of our previous product of the F98 Series as shown in figure 2-2. In other words, despite having an internal fuse, the F97 Series maintains the same specifications as the F98 Series: 10 to 25V and 1 to 33 $\mu$ F for the 1608 size (L1.6 x W0.85 x H0.8 mm); and 10 to 35V and 1 to 47 $\mu$ F for the 2012 size (L2.0 x W1.25 x H0.8 mm). For example, while a competitor requires a 3216 size to deliver a capacitance of 22 $\mu$ F at 10V, the Nichicon product for the same capacitance rating requires just a 1608 size, a full two sizes smaller.

Another feature of Nichicon products is outstanding fusing properties. (See figure 2-3.) Compared to competitors, Nichicon products boast superior fusing properties in a short time at even low current values. Stable fusing properties can be achieved even in products with relatively small circuit currents, like smartphones and communication modules. Furthermore, by optimizing things like the material quality, shape, and internal mounting method for the internal fuse material of Nichicon products, we have also achieved favorable frequency properties as shown in figure 2-4. Compared with the fuse material of our competitors, we have achieved dramatically reduced ESR and impedance, comparing favorably with our previous product of the F98 Series. To summarize, Nichicon's newly structured tantalum electrolytic capacitor with safety mechanisms can be called the ideal tantalum electrolytic capacitor: it boasts the highest level of mounting efficiency per volume in the industry, like the F98 Series, and it features improved safety performance.

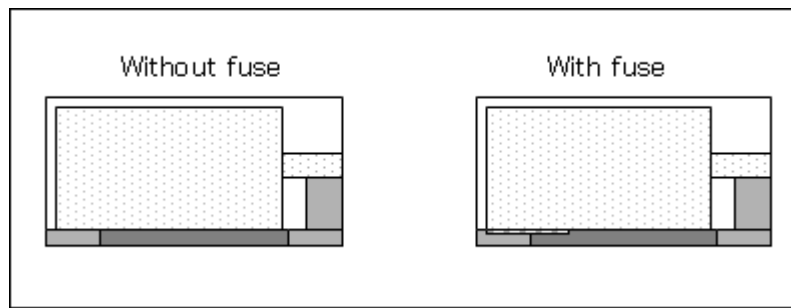
As we have discussed here, the tantalum electrolytic capacitors with safety mechanisms developed by Nichicon have redefined the concept of tantalum electrolytic capacitors and have spurred new growth in the market. We have already received a flood of inquiries about this product, which is sure to contribute to making smartphones and other digital mobile products smaller, thinner, and more functional. We will continue to keep our eye on what customers want as we develop new products

with a focus on achieving higher ratings.

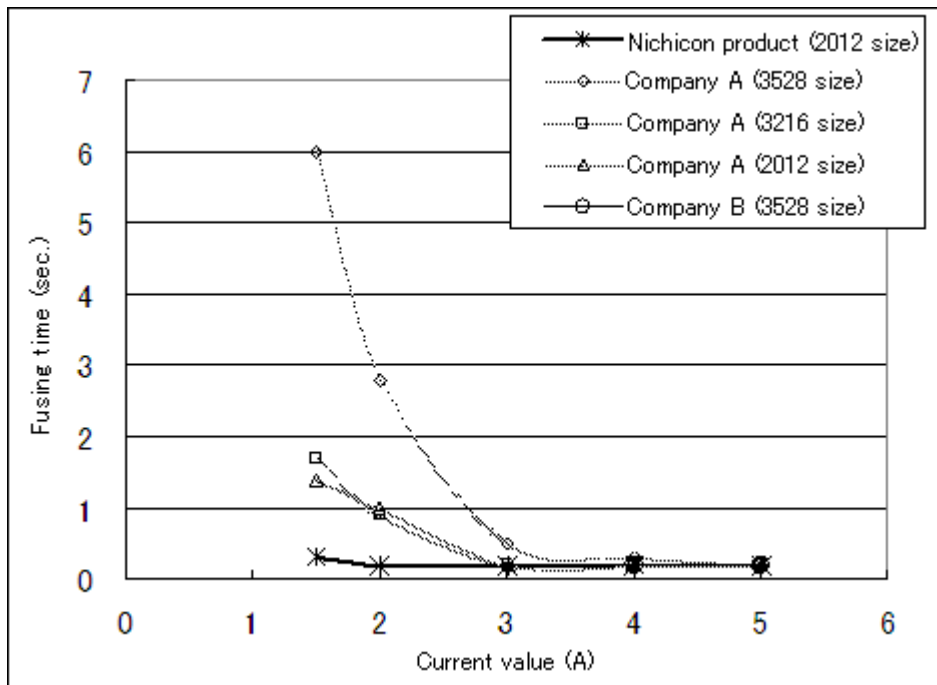
【 Figure 2-1】 Structure of resin-molded product with safety mechanism (general product)



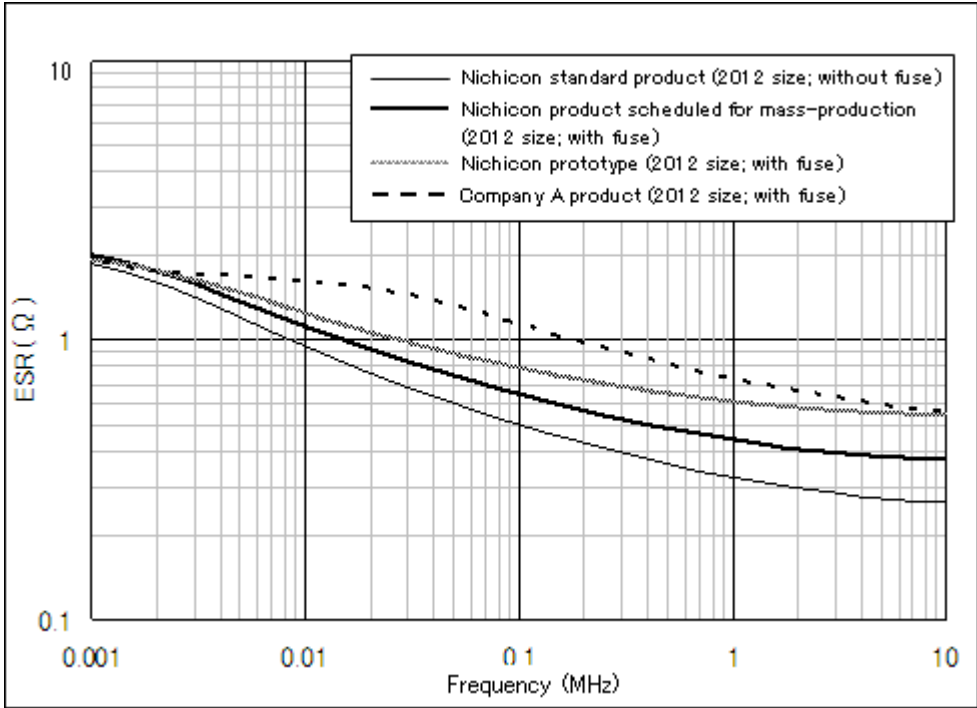
【 Figure 2-2】 Structure of resin-molded product with safety mechanism (Nichicon product)



【 Figure 2-3】 Fusing properties



【 Figure 2-4】 Frequency properties



Nichicon Tantalum Corporation  
From the Dempa Shimbun, January 26, 2012