Development of "NeoCapacitor," a High-Voltage Functional Polymer Tantalum Capacitor

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Abstract

The NeoCapacitor series are tantalum capacitors made from conductive polymers. NEC TOKIN has been commercializing products with rated voltages from 2.5 to 16V by setting design concepts according to the market requirements for higher CPU speeds, lower power consumption and lower drive voltage. However, the demand for the development of new products is still high from the server and LCD module markets, which necessitates even higher caliber functions and reliability. In order to improve the voltage resistance products with the high rated voltages of 20, 25V and greater, NEC TOKIN has recently developed element technologies and materials and has analyzed the standard products on the market. Simultaneously, it has also introduced quality engineering in order to optimize the design and eliminate turning back and has eventually succeeded in developing products with the target high-voltage of 50V or greater.

Keywords

tantalum capacitor, development of high-voltage product, conductive polymer, quality engineering

1. Introduction

NeoCapacitor is a series of tantalum capacitors that feature the use of conductive polymer in the cathode layer. Conductive polymer has higher electrical conductivity than the previously used manganese dioxide material and allows the equivalent series resistance (ESR) to be reduced significantly. At NEC TOKIN, we have been developing products by setting their design concepts according to the market requirements for higher CPU speeds, lower power consumption and a lower drive voltage. However, as the rated voltages of previous products were limited to the range between 2.5 and 16V, the development of capacitors and higher withstanding voltages of 20, 25V or more has become necessary in order to meet demands from the server and LCD module markets that necessitate even higher functions and reliability. Therefore, we have decided to develop element technologies and materials as well as to introduce quality engineering for optimization of the design and the elimination of turning back as our approach to the development of high-voltage products. We have thus succeeded in developing high-voltage products that can meet the new market demands. We introduce these results in this paper.

2. Approach to Development

In order to ascertain our current technology level we first prototyped 20V and 25V capacitors by applying the product designs of the previous products, which had the relatively low rated voltages of 2.5 to 16V. The results of the voltage withstanding tests of the prototypes are shown in **Fig. 1**. The rated voltage and destruction voltage are usually in a zero-point proportional relationship, which can also be understood from the fact that the rated voltage is proportional to the thickness of the oxide film on the anode. However, the destruction voltages of

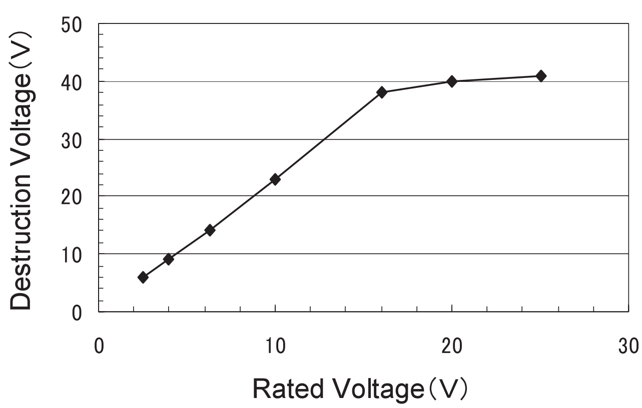


Fig. 1 Destruction voltage of current design.

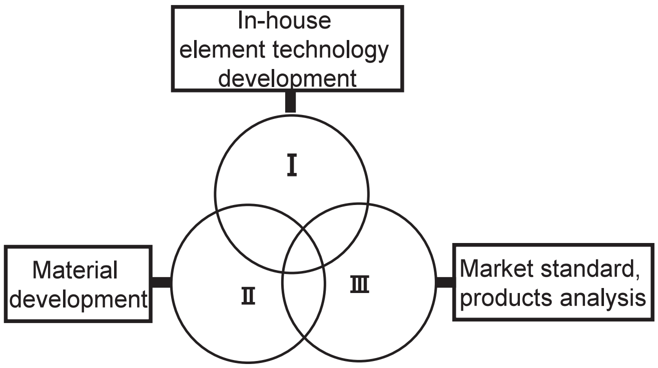


Fig. 2 Development approach categories.

the prototypes failed to increase after the rated voltage exceeded 16V, suggesting that simple application of the current product design cannot lead to implementation of 20 and 25V products. We therefore decided to develop element technologies that were specialized for high-voltage capacitors, and defined the approach method into three categories I to III as shown below **(Fig. 2)**.

Category I covers the development of element technologies conducted in house at NEC TOKIN. We confirmed the prototype's current/voltage characteristic (IV characteristic) in the electrolytic solution during the intermediate steps of polymerization of the conductive polymer and investigated the cause of the drop in withstanding voltage. For the purpose of conformation of the IV characteristics, **Fig. 3** shows the comparison of the IV characteristics of the products with rated voltages of 10V and 25V. The figure shows that there is little variation in the current transition of the 10V products, regardless of the number of polymerizations, but that the current value of the 25V products increases as the number of polymerizations increases and not converged. We selected the control factors based on these phenomena and established the L18 test plan based on quality engineering. In addition, we planned an optimization test covering the effect factors obtained with the L18 test conducted for Category I and the control factors developed

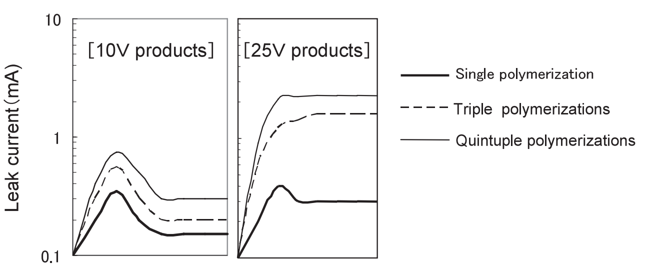


Fig. 3 IV characteristics.

as a result of materials developments in Category II.

Quality engineering is a very effective technique for the development of devices and the optimization of fabrication conditions when the product characteristics are affected by various causes. For example, in the L18 test plan for Category I described above, we performed testing by selecting only 18 kinds of combinations defined by quality engineering them from the eight factors of A to H, and succeeded in identifying the factors that are effective for solving the problems of variance between product properties and improving product quality. The application of quality engineering techniques has made it possible for us to improve product properties and to effectively optimize the fabrication conditions in a short time.

Category II covers the materials development conducted jointly with the materials manufacturers. The development targeted two items; 1) powders with high withstanding voltages and; 2) polymers with high withstanding voltages.

Category III covers the analysis of market-standard products. Here, we analyzed the products regarded as the standards in the market for the 25V rated voltage, and the analyzed items included; (a) polymer type; (b) powder type; (c) pellet design; (d) oxide film thickness; (e) anode structure; (f) undercoating. As we found that there is little difference in design between them and the products that we were intending to develop, we continued development by focusing on Categories I and II.

3. Element Technology Development (Development Approach Category I)

This section reports on the results of the element technology development conducted as development approach category I. In this phase, we extracted the control factors other than those related to the materials development, and conducted the L18 test for the eight control factors.

As a result, we confirmed the effects of three among the eight factors including; (A) sintered compacts design; (E) anode oxidation condition; (H) polymerization process. So we optimized these factors and succeeded in improving the destruction voltage by about 17%. The three control factors were effective in the order of A > E > H. **Fig. 4** and **Fig. 5** show the results of the above.

4. Development of Materials (Development Approach Category II)

In this section, we report on the results of development of materials conducted jointly with the materials manufacturers. The development specifically covered two NeoCapacitor ma-

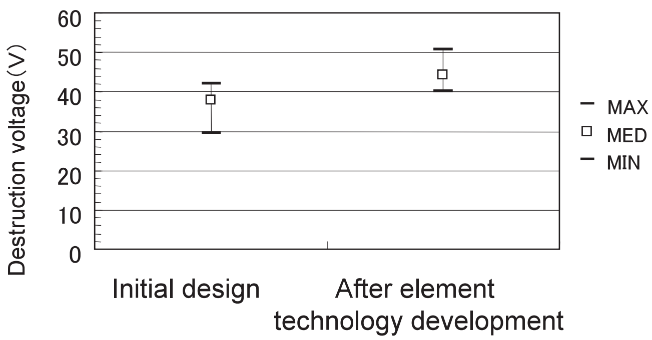


Fig. 4 Effects of element technology development.

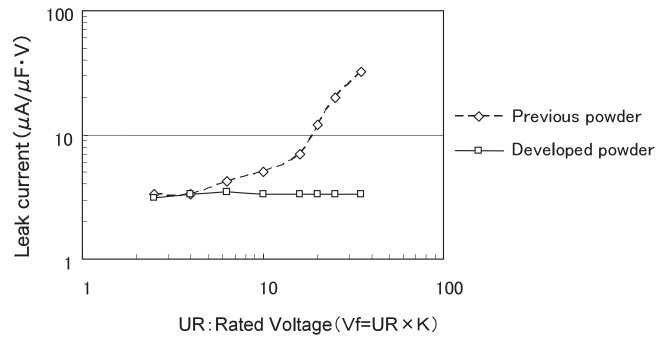


Fig. 6 Leak current characteristic with respect to Vf.

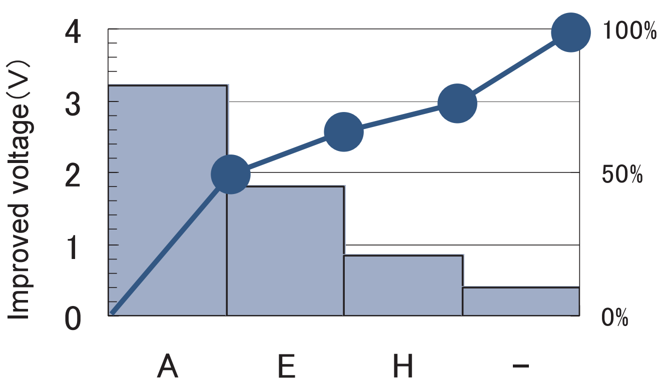


Fig. 5 Contributions to improvement effect per factor.

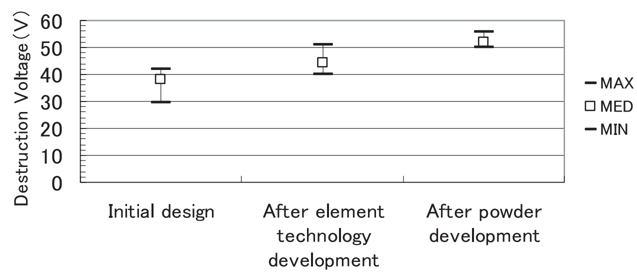


Fig. 7 Effects of powder material development.

terials that were deemed to be the most important for increasing the withstanding voltage; 1) high withstanding voltage powder and; 2) high withstanding voltage polymer. We planned to set the materials obtained by the development in this section as the control factors for use in the final stage of development, which was the optimization, together with the effective factors identified in Section 3 above.

In the development of the high withstanding voltage powder, we examined powder types and investigated the optimum conditions for sintering that compacts the powder into the capacitor element. The effective factors we used here were; (B) powder type and; (D) sintering temperature.

We describe the development of high withstanding voltage powder below. What is necessary for the development of high withstanding voltage powder is to improve the powder strength in consideration of its resistance to thermal and mechanical stress. The standard for evaluation is the leak current with respect to the oxide film generation voltage (Vf). We measured the leak current using the reduced Vf voltage (Vf × 0.9) and obtained the results as shown in **Fig. 6**. This showed that, unlike the powder used for previous products, the powder specially developed for high withstanding voltage presented a flat leak current characteristic without the point of inflection of any current leakage due to oxide film generation voltage (Vf). This result indicated that the required powder bonding strength was obtained and was witness to the effectiveness of the newly developed high withstanding voltage powder.

We then measured the destruction voltages of the product obtained by applying the element technologies obtained in Section 3 above and those obtained using the high withstanding powder developed in this section (**Fig. 7**). The figure shows that the product obtained in this section has improved the destruction voltage by about 17% compared to that obtained in Section 3, and by about 36% compared to the prototype fabricated according to the initial design.

Now let us describe the development of the high withstanding voltage polymer. In the development of the polymer, we extracted the factors associated with the polymerization process including the polymer material, and conducted the L18 test in accordance with quality engineering procedures. The effective factors were; (C) material type, and; (H) cleaning method, and what was required most in the development, was to improve the polymer purity by reducing the degradation of the oxide film caused by the voltage.

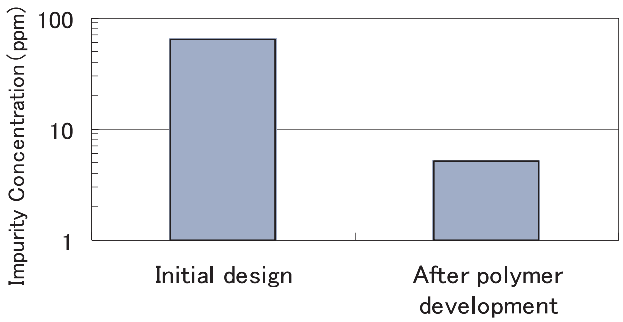


Fig. 8 Polymer impurities concentrations.

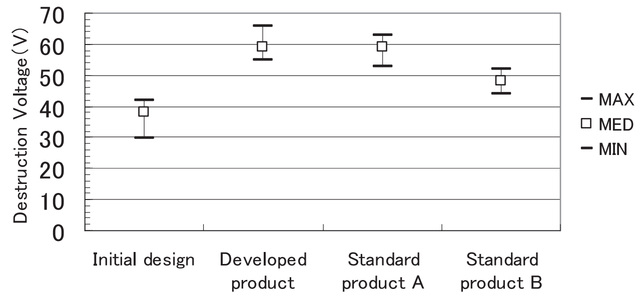


Fig. 10 Comparison of destruction voltage between our products and the market-standard products.

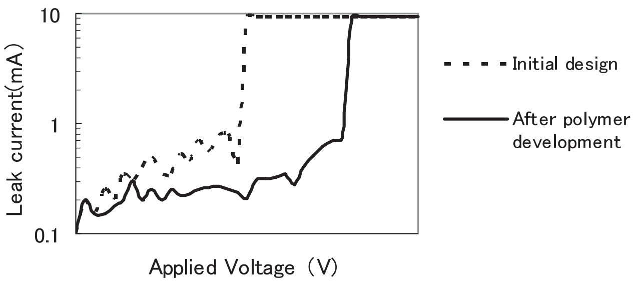
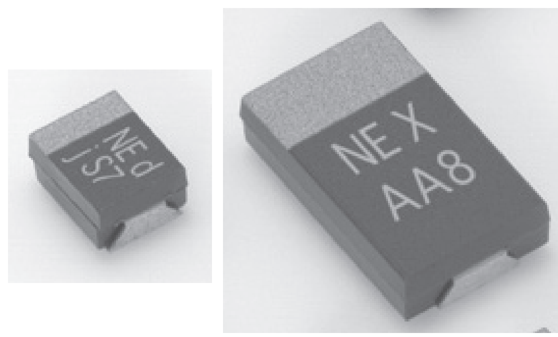


Fig. 9 Current versus voltage characteristic.



【B2】 【V】

Product Dimensions
B2:L3. 5×W2. 8×H2. 1MAX
V :L7. 3×W4. 3×H2. 0MAX

Photo External views of products.

We also measured the IV characteristic in the electrolytic solution in the intermediate steps of polymerization as the standard of evaluation. **Fig. 8** and **Fig. 9** show the purity and IV characteristic of the developed polymer. Fig. 8 shows the purity as it is represented by the impurities ions in the polymer, and confirms that the impurities in the developed polymer are reduced by about 1/10th of the polymer in the initial design. Fig. 9 confirms the significant improvement in the IV characteristic of the products using the developed polymer compared to the products based on the initial designs with a consequent increase of the withstanding voltage due to the polymer.

We finally assessed the values of the effective factors identified in the above element technology and material development, optimized them and compared the destruction voltage of the developed products with the market-standard products. In order that the products might be compared, we selected a newly developed capacitor with the dimensions L7.3mm × W4.3mm × H2.0mm max. (our “V-size”), rated voltage of 25V, rated capacitance of 22μF and ESR of 95mΩ, and compared it with the equivalent models of the market-standard products. For the destruction voltage, our product achieved improvement by 160% compared to the initial design-based products (**Fig. 10**). This result suggested that the development of element technologies and materials (powder and polymer) can offer satisfactory results when they are optimized at an appropriate level. In comparison with the market-standard products, our resulting product is equivalent to or better than standard product A. When it is compared with standard product B, our product is better because the Product B performance is equivalent only to our product rated at 20V. In addition, as the destruction voltage of the developed product exceeded the target of 50V, we confirmed that our initial target value was well cleared.

5. Conclusion

The newly developed high-voltage capacitors (with rated voltages of 20 and 25V) of the PS/L series are mainly “V-size” products. For the future, we are planning to expand the full range of product sizes, particularly focusing expansion on high-voltage products with smaller sizes (see **Photo** showing the external views of the developed products).

In addition, we are also planning to advance the design process by considering the concerns of the semiconductor user of the currently developed products toward their applications in PC power supplies, LCD modules and car-mounted information equipment and to apply the newly developed element technologies to all of the rated voltages aiming at improvements in the reliability of the entire NeoCapacitor series.

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