



SOLID ELECTROLYTIC CAPACITOR AND METHOD OF MANUFACTURING THE SAME

Field of the Invention

The present invention relates to a solid electrolytic capacitor and production method thereof which achieve a large capacitance and a low equivalent serial resistance (hereinafter, low ESR).

Background of the Invention

In recent years, the development of more compact electronic devices used for higher frequencies has been advancing. Solid electrolytic capacitors using conductive polymers as solid electrolyte have been commercialized, as capacitors suitable for such electronic devices. Since the solid electrolytic capacitors use conductive polymers of high conductivity as solid electrolyte, they achieve high frequencies characteristics and low impedance. The ESR of these solid electrolytic capacitors is much low comparing to conventional electrolytic capacitors using electrolytic solution as driving electrolytes and solid electrolytic capacitor using manganese dioxide, thereby achieving an ideally large capacitance. In addition, as these new solid electrolytic capacitors are compact, various aspects have been improved, allowing them to be gradually accepted in the market.

With the development of faster and high power consuming CPU for computers, capacitors have come to be required to achieve high frequency transient response characteristics. A large capacitance and a low ESR have also become their essential characteristics. For the solid electrolytic capacitors to satisfy such demand, they need to achieve a large capacitance and low ESR while maintaining the smallest possible mounting area in a device.

To realize this, techniques to laminate flat capacitor elements



or thin sintered elements have been used. However, if conventional solid electrolytic capacitors are used to obtain the capacitance required to back up CPU, five to ten large-capacitance tantalum solid electrolytic capacitors need to be mounted in parallel. Such arrangement increases the mounting area of the capacitor, limiting the reduction of the size of the capacitor.

With the increasing speed of CPU, the amount of the current flowing at high frequencies has significantly increased as well. If the ESR of the capacitor is not reduced, the capacitors will become hotter, increasing the chance of breaking down. These factors heighten the necessity to develop a capacitor of large capacitance and low ESR without increasing its mounting area.

In one technique to increase the capacitance of the capacitor without expanding its mounting area, a plurality of sintered elements are disposed in the same external housing and connected so as to be a single capacitor. In another technique a plurality of flat capacitor elements are stacked to produce one solid electrolytic capacitor.

However, with the technique using the sintered elements, there is a limitation in lowering ESR due to the resistance occurring when pulling out a cathode. Such resistance can not be avoided since thinning of the sintered elements is limited. The solid electrolytic capacitor made of a laminate of a plurality of flat sintered elements has its own problem. The number of the layers can not be increased. The reason is, if there are excessive number of layers, the sintered elements would be deformed due to the difference in thickness between the anode connecting section and the cathode electric conductor laminated section, dielectrics oxide films crack, and a leak current failure occurs.

The present invention aims at providing a solid electrolyte capacitor of large capacitance and low ESR and its production method by dealing with the problems mentioned above.

Summary of the Invention

According to one aspect of the present invention, there is provided a solid electrolytic capacitor comprising:

- at least two capacitor element laminated units which are stacked, each laminated unit comprising:

- a plurality of flat capacitor elements, each element having an anode pulling-out section; and

- a metallic terminal member connected to and covering said anode pulling-out sections.

According to another aspect of the present invention, there is provided a manufacturing method of a solid electrolytic capacitor comprising:

- forming an anode oxide film layer on a surface of a valve metal electrode at least where an element section is to be formed by anodic oxidation;

- forming an element section by layering a solid electrolyte layer including at least conductive polymer and a cathode conductive layer in sequence on said anode oxide film layer;

- producing a flat capacitor element by forming an anode pulling-out section on an exposed portion of said valve metal electrode or on a dielectric oxide film layer;

- stacking a plurality of said capacitor elements on a lead frame having terminal sections to be used as terminal members and electrically connecting said anode pulling-out section and said cathode conductive layer to said terminal sections;

- producing a capacitor element laminated unit by cutting said unit out without severing a connection between said terminal sections and said cathode conductive layer or said anode pulling-out section; and

- connecting at least 2 of said capacitor element laminated units on the lead frame having a comb terminal section.

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Brief Description of the Drawings

Fig. 1 illustrates a partially broken perspective view of a plate capacitor element in accordance with a first preferred embodiment of the present invention.

Fig. 2 illustrates a perspective view of the construction of a laminated unit in accordance with the first preferred embodiment of the present invention.

Fig. 3 illustrates a perspective view of the construction of a solid electrolytic capacitor in accordance with the first embodiment of the present invention.

Fig. 4 illustrates a perspective view of the construction of a laminated unit formed as a continuous hoop in accordance with a fourth embodiment of the present invention.

Fig. 5 is a chart illustrating the impedance and frequencies characteristics of ESR of the solid electrolytic capacitor in accordance

with the first and second embodiments of the present invention.

Fig. 6 illustrates a perspective view of the construction of the solid electrolytic capacitor in accordance with a fifth embodiment of the present invention.

Fig. 7 illustrates a perspective view of the construction of the solid electrolytic capacitor in accordance with the fifth embodiment of the present invention.

Fig. 8 illustrates a perspective view of the construction of the solid electrolytic capacitor in accordance with the fifth embodiment of the present invention.

Fig. 9 illustrates a perspective view of the construction of the solid electrolytic capacitor in accordance with the fifth embodiment of the present invention.

Fig. 10 illustrates a perspective view of the construction of the solid electrolytic capacitor in accordance with the fifth embodiment of the present invention.

Fig. 11 illustrates a perspective view of the construction of the solid electrolytic capacitor in accordance with the fifth embodiment of the present invention.

Description of the Preferred Embodiments

Preferred embodiments of the present invention are described below with reference to the accompanying drawings.

First embodiment

Aluminum foil of 99.9% purity to be used as an electrode body is roughened by electrolytic etching by known method. The aluminum foil then is anodized in a solution of 3% ammonium adipate by applying a voltage of 13 volts for 30 minutes, to form an aluminum oxide layer which functions as a dielectrics. The electrode body is cut 3.5 mm in

width and 6.5 in length. Polyimide tacking tape 2 is attached on the predetermined places on both sides of the electrode body as shown in Fig. 1 before dividing it into an element section 3 and an anode pulling out section 4. The surface of each side of the electrode body, which are exposed by the cutting process, is anodized again in a solution of 3% ammonium adipate by applying a voltage of 13 volts. for 30 minutes.

Subsequently, the element section 3 is dipped in a manganese nitrate aqueous solution and decomposed at 300° to form a conductive manganese oxide layer. The element section 3 is then dipped in a solution containing 0.1 mol of pyrrol and 0.15 mol of alkyl naphthalene sulphonic acid salt. By electrolytic polymerization, a conductive polymer layer 5 comprising polypyrrol is evenly deposited on the element section 3. The electrolytic polymerization is carried out by applying a constant voltage of 2 volts, for 30 minutes through an electrode contacted on part of the manganese oxide. A flat capacitor element 1 described in Fig. 1 is produced after carbon paste layer 6 and a silver paste layer 7 are formed on the element section 3 of a capacitor element 1.

After silver paste is painted as conductive adhesive on the element sections 3, four pieces of flat capacitor elements 1 generated in an above-described manner are stacked in such a way that the element sections 3 as well as anode pulling-out sections 4 are facing each other respectively. And a layered-element 8 is formed as shown in Fig. 2.

Metallic terminal members 9a and 9b are respectively connected to the element sections 3 and anode pulling-out sections 4 of the layered-element 8. The metallic terminal member 9a has three perpendicularly standing faces arranged on the three sides of the section where the element section 3 of the plate capacitor element 1 is placed. The terminal member 9b has a section which can be fabricated to cover the anode pulling-out section 4. The element sections 3 of the layered-element 8 are bonded to the terminal member 9a with silver

paste. The anode pulling-out sections 4 of the layered-element 8 are disposed on the terminal member 9b which has standing faces on two sides. Then, the standing faces are fabricated to cover the anode pulling-out sections 4. Subsequently, four pieces of anodes are welded together by a YAG laser irradiated from above the terminal member 9b, penetrating the anode pulling-out sections 4 of the stacked capacitor elements 1 to form a laminated unit 10. The connection of the four anodes does not have to be provided by penetrating the center of the anode section as shown in Fig. 2. The connection can be made by welding the sides of the anodes of the laminated elements by a laser.

The terminal member 9a made in a manner described above is electrically connected to a comb terminal 11a for connecting element sections with conductive adhesive as shown in Fig. 3. Three laminated units 10 are stacked by epoxy resin based silver paste and cured by heat. The terminal members 9b of the laminated units 10 are electrically connected to a comb terminal 11b oppositely disposed to the comb terminal 11a, by laser welding.

The whole laminated unit is coated by encapsulating resin (not illustrated), and aged. The comb terminals 11a and 11b are bent along the line of the encapsulating resin to generate a solid electrolytic capacitor with a rating of 6.3 V, 150 μ F.

Second embodiment

In this embodiment, solid electrolytic capacitors are produced by the same method as in the first embodiment. The only difference is that the number of the flat capacitor element 1 is changed from two to ten when the laminated unit 10 is formed. The rating of the solid electrolytic capacitors are, according to the number of capacitor elements, 75 μ F, 112 μ F, 150 μ F (as is the case with the first embodiment), 187 μ F, 225 μ F, 262 μ F, 300 μ F, 337 μ F, and 375 μ F at the

voltage of 6.3 volts.

When more than 10 capacitor elements are stacked, the anode section is distorted and the capacitor elements 1 are severed, failing to achieve desirable electrostatic capacitance or resulting in a large amount of leakage current. Due to such problems, it is impossible to generate a solid electrolytic capacitor with more than 10 flat capacitor elements.

Fig. 5 shows the result of the measurement made on the impedance and frequency characteristics of the solid electrolytic capacitor of the first and second embodiments.

As Fig. 5 indicates, the solid electrolytic capacitors of the present invention have large capacitance and idealistic impedance and low ESR characteristics.

Laser welding is used in the first and second embodiments, however, needless to say, other welding methods can also be applicable.

Third embodiment

Three laminated units 10 produced by the same method described in the first embodiment are stacked by providing epoxy resin based silver paste between element sections 3. The anode pulling-out sections 4 of the laminated units 10 are electrically connected by providing epoxy resin based silver paste between the comb terminals 11b and the terminal members 9b and curing it by heat. The whole units are encapsulated with encapsulating resin (not illustrated) and aged. The comb terminals 11a and 11b are bent along the encapsulating resin to produce a solid electrolytic capacitor with a rating of 6.3 V, 150 μ F. As described in this embodiment, the anode sections can be bonded with conductive adhesive.

Fourth embodiment

As Fig. 4 shows, after the element sections 3 are coated with silver paste, the flat capacitor elements 1 are stacked to a continuous hoop lead frame 12 such that the element sections 3 are facing each other. The lead frame 12 is a belt-shaped metallic frame which has continuously arranged wide protruding terminals on the locations corresponding to the anode pulling-out sections 4 and the element sections 3. The layered element 8 is formed by stacking four pieces of anode pulling-out sections 4 on top of the other. The terminal members 9b are fabricated to cover the anode pulling-out sections 4. Then, four pieces of anode pulling-out sections 4 of the capacitor elements 1 are laser welded by a irradiation from above the terminal member 9b, to form the four-layered laminated unit 10.

Of the lead frame 12 having the laminated units 10 thereon, only the parts of the laminated units 10 are cut out to obtain independent laminated units 10 with metallic terminal members 9a and 9b. Subsequently, two independent laminated units 10 are bonded on the laminated unit 10 disposed on the lead frame 12 with silver paste, to form a twelve-layered solid electrolytic capacitor on the continuous lead frame 12 as shown in Fig. 3.

The whole unit is then encapsulated with encapsulating resin (not illustrated) and aged. The terminals are bent along the face of encapsulating resin to complete the manufacturing process of a solid electrolytic capacitor with a rating of 6.3V, 150 μ F.

In this embodiment the lead frames 12 of the same shape are used for producing the laminated unit 10 and the capacitor element 1. However, the shape of the lead frame 12 does not have to be the same. In the above explanation, conductive adhesive is used to connect the terminal members 9a and 9b, when the laminated units 10 are stacked. However, needless to say, laser welding can be used to connect them without affecting the effectiveness.

In the location of the terminal member 9b, a connecting element can be provided separately from the laminated unit 10 to connect anodes.

Fifth embodiment

Figs. 6 through 11 show detailed description of connecting the anode pulling-out sections 4 when three laminated units 10 are stacked in this embodiment.

In Fig. 6, connecting elements 13a, 13b and 13c are provided on the bottom surface of each terminal member 9b of the top, middle and bottom laminated units 10. The connecting elements 13a, 13b and 13c can be connected to the bottom surface of the terminal member 9b by laser welding or resistance welding. The terminal 9b can be bent to give it a shape illustrated in Fig. 6. The connecting elements 13a, 13b and 13c are layered at the tip when the top, middle and bottom laminated units are stacked. In this state, the layered portions of the connecting elements 13a, 13b and 13c can be electrically connected by laser welding as indicated by arrows in the Fig. 6, thereby connecting the anode pulling-out sections 4.

In Fig. 7, connecting elements 13d are provided to the bottom surface of the top and middle terminal members 9b. The connecting elements 13d are connected to the bottom surface of the terminal members 9b by laser welding or resistance welding, or electrically connected to the terminal members 9b by bending them to provide the shape shown in Fig. 7. The connecting elements 13d function as spacers to fill the gap between the top, middle and bottom capacitor element laminated units 10 when they are stacked. The connecting elements 13d and the terminal member 9b at the bottom are electrically connected by laser welding provided from above diagonally as arrows in Fig. 7 indicate. This process of laser welding connects the anode

pulling-out sections 4 with each other.

In Fig. 8, connecting elements 13e are provided to the bottom surface of the top and middle terminal members 9b. The connecting elements 13e are connected to the bottom surface of the terminal members 9b by laser welding or resistance welding, or electrically connected to the terminal members 9b by bending them to provide the shape shown in Fig. 8. When the top, middle and bottom laminated units 10 are stacked, the connecting element 13e at the top sandwiches the terminal member 9b in the middle from the side. Likewise, the connecting element 13e in the middle sandwiches the terminal member 9b at the bottom from the side. In this state, the connecting elements 13e are welded by a laser irradiated from above diagonally or from the side to electrically connecting them to the middle and bottom terminal members 9b, thereby connecting the anode pulling-out sections 4 with each other.

In Fig. 9, connecting element 13f is provided to the bottom surface of the top terminal member 9b. The connecting element 13f is connected to the bottom surface of the terminal members 9b by laser welding or resistance welding, or electrically connected to the terminal member 9b by bending it to provide the shape shown in Fig. 9. When the top, middle and bottom laminated units 10 are stacked, the connecting element 13f at the top sandwiches the middle and bottom terminal member 9b. In this state, the connecting element 13f is welded by a laser irradiated from above diagonally or from the side to electrically connecting it to the middle and bottom terminal members 9b, thereby connecting the anode pulling-out sections 4 with each other.

In Fig. 10, connecting elements 14 are disposed to the sides of the terminal members 9b. The connecting elements 14 are then welded by a laser irradiated from above diagonally or from the side as indicated by arrows in Fig. 10. By the laser treatment, the connecting elements

14 are electrically connected to the top, middle and bottom terminal members 9b, thereby connecting the anode pulling-out sections 4 with each other. The connecting elements 14 are desirably provided with two protrusions so that positioning can be conducted using the space between top and middle as well as middle and bottom terminal members 9b.

In Fig. 11, connecting elements 15 are inserted from the front of the terminal members 9b. In this state, the connecting elements 15 are welded by a laser irradiated from above diagonally or from the side to electrically connecting them to the top and middle terminal members 9b, thereby connecting the anode pulling-out sections 4 to each other. In this case, it is difficult to provide the comb terminal 11b. Therefore, the connecting elements 15 are desirably hoop-shaped to secure stable supply of the laminated unit 10.

In the present invention, the laminated unit comprising at least more than one plate capacitor elements which use conductive polymer as solid electrolyte, are connected parallel to each other on a single lead frame. ESR at high frequencies can be reduced, inversely proportional to the number of the stacked laminated units. Moreover, the total capacitance of the layered capacitor elements amounts to the capacitance of the solid electrolytic capacitor. Thus, the present invention provides a solid electrolyte capacitor of a large capacitance and a low ESR without expanding its mounting area in a device.

CLAIMS

- 1, A solid electrolytic capacitor comprising: at least two capacitor element laminated units which are stacked, each laminated unit comprising:
 - a plurality of flat capacitor elements, each element having an anode pulling-out section; and
 - a metallic terminal member connected to and covering said anode pulling-out sections.
- 2, The solid electrolytic capacitor as set forth in claim 1, wherein said capacitor elements further comprise:
 - an element section comprising an anode oxide film layer, a solid electrolyte including conductive polymer and a cathode conductive layer laminated on the surface of a metallic electrode body in the order, said metallic electrode body being electrically connected to a metallic terminal member.
- 3, The solid electrolytic capacitor as set forth in claim 1, wherein each anode is electrically connected after at least two of said laminated units are stacked, and all laminated units are encapsulated with encapsulating resin.
- 4, The solid electrolytic capacitor as set forth in one of claims 1 through 3, wherein each anode of said laminated units is connected using connecting elements.

5, The solid electrolytic capacitor as set forth in claim 4, wherein the connecting elements are selected from one of:

conductive adhesive;

an integral-type conductive material which is connected to all the electrodes; and

a separate-type conductive material which is connected to each corresponding electrode of said laminated unit.

6, The solid electrolytic capacitor as set forth in one of claims 1 through 3, wherein spacers are provided in a gap between the electrodes of each capacitor units, said gap being created when said laminated units are stacked.

7, The solid electrolytic capacitor as set forth in claim 4, wherein spacers are provided in a gap between the anodes of each capacitor unit, said gap being created when said laminated units are stacked.

8, The solid electrolytic capacitor as set forth in claim 5, wherein spacers are provided in a gap between the anodes of each capacitor unit, said gap being created when said laminated units are stacked.

9, The solid electrolytic capacitor as set forth in claim 1, wherein connecting elements are integrally formed with the metallic terminal members included in said laminated unit.

10, The solid electrolytic capacitor as set forth in claim 4, wherein said connecting element is integrally formed with the metallic terminal member included in said laminated unit.

11, The solid electrolytic capacitor as set forth in claim 9, wherein a metallic terminal member integrally formed with the connecting element is provided like a hoop at predetermined intervals.

12, The solid electrolytic capacitor as set forth in claim 10, wherein a metallic terminal member integrally formed with the connecting element is provided like a hoop at predetermined intervals.

13, A manufacturing method of a solid electrolytic capacitor comprising:

forming an anode oxide film layer on a surface of a valve metal electrode at least where an element section is to be formed by anodic oxidation;

forming an element section by layering a solid electrolyte layer including at least conductive polymer and a cathode conductive layer in sequence on said anode oxide film layer;

producing a flat capacitor element by forming an anode pulling-out section on an exposed portion of said valve metal electrode or on a dielectric oxide film layer;

stacking a plurality of said capacitor elements on a lead frame having terminal sections to be used as terminal members and electrically connecting said anode pulling-out section and said cathode conductive layer to said terminal sections;

producing a capacitor element laminated unit by cutting said unit out without severing a connection between said terminal sections and said cathode conductive layer or said anode pulling-out section; and

connecting at least 2 of said capacitor element laminated units on the lead frame having a comb terminal section.

14, The manufacturing method as set forth in claim 13 wherein said terminal members of said plurality of capacitor element laminated units are electrically connected by laser welding.