

SOLID ELECTROLYTIC CAPACITOR AND ITS MANUFACTURING METHOD

FIELD OF THE INVENTION

5 The present invention relates to a solid electrolytic capacitor provided with a solid electrolyte layer formed of a conductive polymer, and its manufacturing method.

BACKGROUND OF THE INVENTION

10 FIG. 2 shows a cross-sectional view of a prior art solid electrolytic capacitor. It is to be noted that a thickness of each of respective layers in FIG. 1 and FIG. 2 is exaggerated for the purposes of illustration.

 In FIG. 2, valve metal 13 provided with a roughened surface layer 14 formed by an etching process is divided into a anode lead out area 12 and a capacitor element area 11 by means of a resist 19 applied onto the roughened surface layer 14.

 The capacitor element area 11 is formed on a surface of the roughened surface layer 14 first by depositing dielectric oxide layer 15 by anodization and then a solid electrolyte layer 16, a carbon layer 17 and a silver paint layer 18 in succession. A lead terminal (not shown in FIG. 2) is connected to the anode lead out area 12 and the capacitor element area 11, respectively, thus completing a capacitor element. Then, the entire capacitor element is encapsulated in a packaging resin by resin moulding.

 It is known that there are a method of electrolytic oxidation polymerization and a method of chemical oxidation polymerization in forming the solid electrolyte layer 16. When the method of electrolytic oxidation polymerization is employed, a manganese dioxide layer is formed in advance on the dielectric oxide layer 15 and the solid electrolyte layer 16 is deposited on the manganese dioxide layer. When the method of chemical oxidation polymerization is employed, the solid electrolyte layer 16 is formed directly on the dielectric oxide

layer 15.

With a solid electrolytic capacitor as shown in FIG. 2, valve metal 13 provided with roughened surface layer 14 is divided into an anode lead out area 12 and a capacitor element area 11 by a resist 19. However, solid electrolyte layer 16 is likely to creep to the anode lead out area 12 from the capacitor element area 11 through gaps between the resist 19 and the roughened surface layer 14, often resulting in causing defective insulation or an electrical breakdown.

In order to address the problem, such attempts as increasing the pattern width of resist 19, adopting a material having good adhesion to the valve metal 13 and the like have been made. However, it is not easy to obtain good results for many production lots and achieving a low defective insulation rate constantly, and it has been a big problem in view of costs.

The present invention aims to address the foregoing problem and to provide a solid electrolytic capacitor and its manufacturing method, in which the probability of the conductive polymer layer to reach the anode lead out area and cause defective insulation or an electrical breakdown is remarkably reduced. In addition, the present invention provides a solid electrolytic capacitor and its manufacturing method, which do not worsen a good productivity so far enjoyed, while solving the foregoing problem.

SUMMARY OF THE INVENTION

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

(A) a capacitor element comprising:

a dielectric oxide layer formed on a roughened surface layer on a part of an outer surface of an anode body made of a valve metal;

a solid electrolyte layer formed on the dielectric oxide layer;

a cathode formed of a conductor layer disposed on the solid electrolyte layer, and

an anode lead out area on a remaining part of the outer surface of

the anode body;

(B) lead terminals connected to the cathode and the anode lead out area of the capacitor element; and

(C) a packaging resin encapsulating the capacitor element with parts of the respective lead terminals exposed outside,

wherein a first separation strip and a second separation strip are formed on a part between the cathode and the anode lead out area of said roughened surface layer, the second separation strip being superimposed on the first separation strip, and an insulating material is disposed on the surfaces of said first and said second separation strips.

According to an embodiment of this aspect of the present invention, a solid electrolyte layer does not extend to the anode lead out area to cause defective insulation, thereby allowing the probability of an electrical breakdown to be reduced remarkably. Moreover, using the present invention does not necessarily require the use of special jigs and processes and provides a solid electrolytic capacitor without worsening the productivity so far enjoyed.

According to a second aspect of the present invention, there is provided a manufacturing method of solid electrolytic capacitors comprising the steps of:

roughening a surface of a valve metal;

forming a dielectric oxide layer on said roughened surface of said valve metal;

forming a first separation strip on said roughened surface of said valve metal, said first separation strip separating an anode lead out area and a cathode;

forming a second separation strip on said first separation strip;

providing an insulating material on said first and said second separation strips;

forming a solid electrolyte layer on a surface of said dielectric

oxide layer;

forming a conductor layer on a surface of solid electrolyte layer;

bonding lead terminals to said anode lead out area and said conductor layer to form a capacitor element; and

encapsulating said capacitor element by a packaging resin while leaving parts of said lead terminals exposed outside.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a cross-sectional view of a capacitor element of an aluminum electrolytic capacitor in an exemplary embodiment of the present invention.

FIG. 1B is a partially enlarged cross-sectional view of separation strips of the capacitor element.

FIG. 2 is a cross-sectional view of a capacitor element of a prior art solid electrolytic capacitor.

DESCRIPTION OF PREFERRED EMBODIMENTS

In the following, preferred embodiments of the present invention are described with reference to the drawings.

First Exemplary Embodiment

FIG. 1 shows how the a capacitor element of an aluminum solid electrolytic capacitor in the first exemplary embodiment of the present invention is

structured. FIG. 1A is a cross-sectional view of the capacitor element and FIG. 1B is a partially enlarged cross-sectional view of separation strips of the capacitor element. In FIG. 1A, (X) indicates a cathode area of the capacitor element, (Y) indicates a separation strips area and (Z) indicates an anode lead out area.

5 The cathode area (X) of the capacitor element is formed of a roughened surface layer 1, which is prepared by roughening an aluminum foil electrochemically, a dielectric oxide layer 2 formed on a surface of the roughened surface layer 1, a solid electrolyte layer 3 formed on the dielectric oxide layer 2, a carbon layer 4 formed on the solid electrolyte layer 3 and a silver paint layer 5 formed on the
10 carbon layer 4.

 The separation strips area (Y) is formed of a first separation strip 6, which is located on a part of roughened surface layer 1 on an aluminum foil and has a smaller surface area in comparison with the surface area of the roughened surface layer 1, a second separation strip 7, which is located on a part of the first
15 separation strip 6 and has a much smaller surface area than the first separation strip 6, and insulating material 8 applied onto a surface of the first separation strip 6 and the second separation strip 7. Insulating material 8 is applied onto the first separation strip 6 so as to have the width thereof a same or less as the width of the first separation strip 6.

20 In the foregoing arrangement, making a "smaller surface area" of roughened surface layer 1 means to reduce a porous portion of an aluminum foil created by the surface roughening treatment by such steps as compressing, cutting, melting and the like method applied to the porous portion.

 Next, a description is given to the specific methods for producing respective parts that constitute the capacitor element. First, an aluminum foil of
25 3 mm by 4 mm is subjected to an electrochemical etching process, to be formed a roughened surface layer on the aluminum foil.

 Then, a dielectric oxide layer 2 is formed on a surface of the roughened surface layer 1 of the aluminum foil by performing anodization using
30 a 0.3 % ammonium dihydrogen phosphate aqueous solution under conditions of

an applied voltage of 12 V, solution temperature of 70 °C and period of 30 minutes.

First separation strip 6 is then formed on a predetermined part of the aluminum foil, on which roughened surface layer 1 is formed, by compression by a pressing. Further, a second separation strip 7 is formed on a part of the first separation strip 6 by another compression by a pressing. With these series of operation, most the porous portions of the aluminum foil are compressed, thereby remaining virtually no porous portions on the part of second separation strip 7. Further, in the present exemplary embodiment, a heat resistant silicone adhesive is applied onto a surface of the first separation strip 6 so as to cover the second separation strip 7 and a heat resistant tape is attached onto the adhesive, thereby forming insulating material 8. Accordingly, the cathode area (X) and the anode lead out area (Z) are separated from each other by the first and the second separation strips 6 and 7, and also porous portions, which remain in a minimum amount, are blocked by the insulating material 8.

Further, a heat resistant tape with a heat resistant silicone adhesive coated thereon may be adhered on the separation strips 6 and 7 as the insulating material 8.

Then, after the cathode area (X) is immersed in a 30% manganese nitrate aqueous solution and subjected to air drying, followed by a heat treatment for decomposition at 300 °C for 10 minutes, thereby producing a manganese oxide layer that forms a part of the solid electrolyte layer 3.

Next, an aqueous solution containing 0.5 mol/litre pyrrole monomer and 0.1 mol/litre sodium propylnaphthalene sulfonate is added with water, a solvent, and propyl phosphoric acid ester acting as a pH controller to adjust pH of a polymerization solution for a solid electrolyte to be a pH value of 2. The cathode area (X) of the capacitor element is immersed in the polymerization solution and electrolytic oxidation polymerization takes place while an electrode for polymerization in contact with the surface of the cathode area (X), thereby producing a solid electrolyte layer 3 formed of a conductive polymer (polypyrrole).

Then, a colloidal carbon suspension is applied onto the surface of the solid electrolyte layer 3 and is dried, thereby producing a carbon layer 4. A sil-

ver paste is applied onto the carbon layer 4 and is dried, thus producing a capacitor element. The carbon layer 4 and the silver paste layer 5 together form a conductor layer to serve as a cathode lead out area.

Finally, a cathode lead is attached to the conductor layer of the capacitor element while an anode lead is attached to the anode lead out area, and then the capacitor element thus provided with the leads is encapsulated by an epoxy resin with part of respective lead terminals exposed outside, thus completing the production of an aluminum solid electrolytic capacitor.

10 Second Exemplary Embodiment

An aluminum solid electrolytic capacitor is prepared in the same manner as in the first exemplary embodiment except for producing second separation strip 7 by a melting and solidifying roughened surface of the aluminum foil by a laser machining.

15 Third Exemplary Embodiment

An aluminum solid electrolytic capacitor is prepared in the same manner as in the first exemplary embodiment except for producing second separation strip 7 by removing the roughened surface layer of the aluminum foil by a scraping to make the base material of the aluminum foil exposed outside.

20 Fourth Exemplary Embodiment

An aluminum solid electrolytic capacitor is prepared in the same manner as in the first exemplary embodiment except for using as insulating material 8 an insulating polymer paint applied onto the surfaces of the first separation strip 6 and the second separation strip 7.

The insulating polymer paint used here is a paint prepared with a polyurethane resin serving as a main ingredient and this paint is applied by an ink jet method (using EXCEL170iTM supplied by VIDEOJETTM).

Fifth Exemplary Embodiment

An aluminum solid electrolytic capacitor is prepared in the same manner as in the first exemplary embodiment except for replacing the pyrrole monomer in the polymerization solution for forming a solid electrolyte with ethylene dioxythiophene monomer.

Sixth Exemplary Embodiment

An aluminum solid electrolytic capacitor is prepared in the same manner as in the first exemplary embodiment 1 except for replacing sodium propyl naphthalenesulfonate in the polymerization solution for forming a solid electrolyte with sodium dodecylbenzenesulfonate.

With the solid aluminum electrolytic capacitors thus prepared in the first through sixth exemplary embodiments and also with a prior art solid aluminum electrolytic capacitor, data on electrical characteristics and a yield in terms of leakage current, which are fundamental parameters for this kind of product, are measured and compared. The results are shown in Table 1. The rating of the capacitors is 6.3 V in working voltage and 47 μ F in capacity. Each respective value in Table 1 is an average of 200 samples.

Table 1

	120 Hz		Leakage Current After 2 Minutes (μ A)	Yield in terms of Leakage Current (%)
	Capacitance (μ F)	$\tan \delta$ (%)		
Embodiment 1	46.8	1.2	0.097	97
Embodiment 2	46.7	1.1	0.091	98
Embodiment 3	46.8	1.3	0.095	97
Embodiment 4	46.9	1.2	0.090	97
Embodiment 5	47.1	1.2	0.082	98
Embodiment 6	47.0	1.2	0.087	98
Prior Art	47.3	1.4	1.031	81

As clearly seen in Table 1, the aluminum solid electrolytic capacitors in the first through sixth exemplary embodiments of the present invention show almost the same fundamental electrical characteristics as the prior art aluminum solid electrolytic capacitor, but, regarding the yield in terms of leakage current, the aluminum solid electrolytic capacitors of the present invention show a better results than the prior art capacitor.

In the first exemplary embodiment, the porous portions of the aluminum foil are compressed and sealed by the first separation strip 6 and the second separation strip 7 formed by compression by the pressing and also by the insulating material 8. This allows the leakage current to be suppressed to the lowest possible level since a cathode material path mainly formed by a polymerization solution and leading to the anode side is blocked, thereby establishing insulating resistance between the cathode and the anode.

In addition, as are shown in the second and third exemplary embodiments, when the second separation strip 7 is formed by the melting and solidifying by a laser processing or by removing the porous portions by a scraping, the path from of the cathode material to the anode side is similarly blocked. Accordingly, whatever methods are employed, the provision of the first separation strip 6 and the second separation strip 7 contributes to improve the yield of aluminum solid electrolytic capacitors in terms of leakage current.

Furthermore, as is shown in the fourth exemplary embodiment, an insulating polymer paint is used as the insulating material 8 in place of a heat resistant tape and, upon drying and solidifying the insulating polymer paint, almost the same results with the heat resistant tape can be obtained. Although an ink jet method is employed to apply the paint in the foregoing description, such methods, as a generally used paste applying method, as a printing method, a spray method and the like are arbitrary used.

As seen from the results of the fifth and sixth exemplary embodiments, even when such heterocyclic compounds as thiophene and the like are used in stead of pyrrole as a material for conductive polymer, almost the same results as

pyrrole can be obtained.

Although the description in the foregoing exemplary embodiments is described based on the solid electrolyte layer 3 that is formed by the electrolytic oxidation polymerization, a chemical oxidation polymerization can be used in forming the solid electrolyte layer 3, instead.

In the foregoing exemplary embodiments, although aluminum is used as an example of valve metals, a metal selected from the group of tantalum, niobium, zirconium and titanium, or a composite or an alloy thereof are used.

As described above, a solid aluminum electrolytic capacitor of the present invention comprises a capacitor element that comprises, a cathode formed of a dielectric oxide layer, a solid electrolyte layer and a conductor layer formed on a part of the outer surface of an anode body formed of a valve metal, on the surface of the valve metal a roughened surface layer is formed by a roughening process, and an anode lead out area provided on a remaining part of the outer surface of the anode body. On the roughened surface layer, a first separation strip to divide the anode body into an anode lead out area and the cathode area and, also, a second separation strip are provided and an insulating material is applied onto the surfaces of the first and the second separation strips. The first and the second separation strips together with the insulating material prevent a conductive polymer, which serves as the cathode material, from creeping into the anode lead out area, thereby allowing the possibilities of extending of the solid electrolyte layer to the anode lead out area, which may cause defective insulation or an electrical breakdown, to be reduced significantly. Furthermore, the manufacturing method of the present invention does not involve any complex processes, thereby allowing solid electrolytic capacitors to be produced without worsening the good productivity that has been so far enjoyed.

Claims:

1. A solid electrolytic capacitor comprising:
 - (A) a capacitor element comprising:
 - a dielectric oxide layer formed on a part of an outer surface of an anode body of a valve metal having a roughened surface layer thereon;
 - a solid electrolyte layer formed on said dielectric oxide layer;
 - a cathode formed of a conductor layer formed on said solid electrolyte layer; and
 - an anode lead out area provided on a remaining part of the outer surface of said anode body;
 - (B) lead terminals connected to the cathode and the anode lead out area of said capacitor element; and
 - (C) a packaging resin encapsulating said capacitor element with parts of said lead terminals exposed outside;wherein a first separation strip and a second separation strip are formed on a part between the cathode and the anode lead out area of said roughened surface layer, the second separation strip being superimposed on the first separation strip; and an insulating material is disposed on the surfaces of said first and said second separation strips.
2. The solid electrolytic capacitor according to claim 1, wherein an area of said second separation strip is smaller than an area of said first separation strip.
3. The solid electrolytic capacitor according to claim 1, wherein said first separation strip is one of a compressed roughened surface layer and a melted and solidified roughened surface layer.
4. The solid electrolytic capacitor according to claim 1, wherein said second separation strip is one of a compressed portion of the first separation strip, a melted and solidified portion of the first separation strip and an exposed base material at a portion of the first separation strip of said valve metal.
5. The solid electrolytic capacitor according to claim 1, wherein a width of said insulating material located between said cathode and said anode lead out

area is equal to or smaller than a width of said first separation strip and larger than a width of said second separation strip.

6. The solid electrolytic capacitor according to claim 1, wherein said insulating material is one of a tape-like insulating material with an adhesive provided thereon and an insulating polymeric material.

7. The solid electrolytic capacitor according to claim 1, wherein said valve metal is at least one selected from a group consisting of aluminum, tantalum, niobium, zirconium and titanium, and a composite or an alloy thereof.

8. The solid electrolytic capacitor according to claim 1, wherein said valve metal is in a form of a metal foil.

9. The solid electrolytic capacitor according to claim 1, wherein said solid electrolyte layer is one of polypyrrole, polythiophene and a derivative thereof.

10. A manufacturing method of solid electrolytic capacitors comprising the steps of:

- roughening a surface of a valve metal;

- forming a dielectric oxide layer on said roughened surface of said valve metal;

- forming a first separation strip on said roughened surface of said valve metal, said first separation strip separating an anode lead out area and a cathode;

- forming a second separation strip on said first separation strip;

- providing an insulating material on said first and said second separation strips;

- forming a solid electrolyte layer on a surface of said dielectric oxide layer;

- forming a conductor layer on a surface of solid electrolyte layer;

- bonding lead terminals to said anode lead out area and said conductor layer to form a capacitor element; and

- encapsulating said capacitor element by a packaging resin while leaving parts of said lead terminals exposed outside.

11. The manufacturing method of solid electrolytic capacitors according to claim 10, wherein an area of said second separation strip is smaller than an

area of said first separation strip.

12. The manufacturing method of solid electrolytic capacitors according to claim 10, wherein said first and said second separation strips are formed by pressing.

13. The manufacturing method of solid electrolytic capacitors according to claim 10, wherein said second separation strip is formed by one of a pressing, a melting and solidifying of said first separation strip and a cutting of said first separation strip.

14. The manufacturing method of solid electrolytic capacitors according to claim 10, wherein said second separation strip is covered with an insulating polymeric material and a tape like insulating material is adhered on a surface of said first separation strip.

15. The manufacturing method of solid electrolytic capacitors according to claim 10, wherein said insulating material is an insulating polymeric material.

16. The manufacturing method of solid electrolytic capacitors according to claim 15, wherein said insulating polymeric material mainly consists of a polyurethane resin.

17. The manufacturing method of solid electrolytic capacitors according to claim 15, wherein said insulating polymeric material is applied and solidified paint.

18. The manufacturing method of solid electrolytic capacitors according to claim 17, wherein said paint is applied by one of an ink jet method, a coating method, a printing method and a spray method.