

TITLE OF THE INVENTION

Solid Electrolytic Capacitor and Manufacturing Method and
Manufacturing Apparatus for Manufacturing the Capacitor

5 FIELD OF THE INVENTION

The present invention relates to a solid electrolytic capacitor used
in various electronic appliances, and a manufacturing method and a
~~manufacturing~~ apparatus for manufacturing the capacitor.

10 BACKGROUND OF THE INVENTION

Recently, as the digital appliances are advanced, a capacitor
having a low impedance even in a high frequency and an excellent high
frequency characteristic is demanded. To reply the demand, capacitors
using conductive polymer having high conductivity obtained by electrolytic
15 polymerization as solid electrolyte are being developed and put in market.

Fig. 17 is an exploded perspective view showing a configuration of
the solid electrolytic capacitor. A capacitor element 48 is formed as
follows. A surface of an anode element 40 made from an aluminum foil, a
valve metal, is etched to be roughened. The element is anodized to form
20 a dielectric oxide layer 41 on the surface and stamped out into a desired
shape. The anode element 40 is separated into an anode part 46 and a
cathode part 47 with an insulating resist 45. Then, on the cathode part
47, a manganese dioxide layer 42 (a conductive substance) and a solid
electrolyte layer 43 made of conductive polymer such as polypyrrole,
25 polythiophene, or polyaniline are formed. A cathode layer 44 composed of
a carbon layer and a silver paste conductor layer is disposed on the
electrolyte layer 43.

The capacitor element 48 is used alone, or plural elements 48 are laminated. An anode terminal 49 and a cathode terminal 50 are connected to the anode part 46 and cathode part 47 of the capacitor element 48, respectively. With the anode terminal 49 and cathode terminal 50 being partially exposed outside, the capacitor element 48 is covered with an external resin 51, thereby composing a solid electrolytic capacitor.

Fig. 18A and Fig. 18B show a method of manufacturing the capacitor element 48 in detail. As shown in Fig. 18A, an anode element 40 made of a valve metal foil having the dielectric oxide layer and a conductive substance on the surface is formed in a comb shape. At the projecting portion of the element, a resist layer 52 is formed with an electrically-insulating resin coat or a resin tape, and the portion is divided into an anode contact portion 40a and an anode foil portion 40b. Then, as shown in Fig. 18B, a positive electrode 54 supplying a voltage contacts with the anode foil portion 40b in a polymerization solution 53 and applies the voltage between the portion and a negative electrode 55 for performing electrolytic polymerization. Then, a conductive polymer layer is formed on the surface of the anode foil portion 40b.

Then, a carbon layer, i.e., a cathode contact layer and a silver paste are sequentially formed on the conductive polymer layer for forming the capacitor element 48.

The solid electrolytic capacitor having such configuration has a low resistance of the solid electrolyte layer 43, i.e., a low equivalent serial resistance (ESR).

In the conventional manufacturing method of the solid electrolytic capacitor, feeding electrodes 54 contact with anode foil

portions 40b of anode elements 40 with a complicated process. Hence, that makes an efficient mass-production of the capacitor difficult.

When the cathode layer 44 is formed with the carbon layer and the silver paste as the conductor layer, the high viscosity of the silver paste makes the thickness of the layers uneven with a immersion or a application process. It is hence extremely difficult to form a thin, uniform conductor layer.

A method to solve the latter problem has been known. As shown in Fig. 19A and Fig. 19B, a band-shaped anode element 40 coated with a silver paste 57 passes between elastic scraping plates 56a, 56b disposed oppositely to each other. The silver paste 57 applied on the solid electrolyte layer of the anode element 40 is scraped off with the leading ends of the scraping plates 56a, 56b.

In such method of adjusting the thickness of the silver paste 57 depending on the elasticity of the scraping plates 56a, 56b, it is difficult to form the uniform, thin silver paste 57. And the scraped silver paste 57b accumulating in the scraping area must be often removed. And further, as shown in Fig. 19B, the anode element 40 where the silver paste 57a, which is not scraped sufficiently, is adhered at a lower portion causes serious quality and productivity problems.

In the solid electrolytic capacitor having the cathode layer 44 composed of such silver paste 57 having the uneven thickness, the contact resistance between the cathode terminal 50 and cathode layer 44 increases, and the ESR characteristic is often poor, and the product yield is low.

Since it is difficult to form a thin conductor layer, the cathode layer 44 is likely to be thick. Accordingly, the volume of the capacitor

element 48 increases, and thus, the capacity per volume decreases.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention, there is provided a manufacturing method of manufacturing a solid electrolytic capacitor using a manufacturing apparatus including a polymerization tank and a negative electrode installed in the polymerization tank, said manufacturing method comprising the steps of: forming a dielectric oxide film layer on of an anode element made of valve metal; forming a conductive substance layer on the dielectric oxide film layer; forming a solid electrolyte layer on the conductive substance layer, said forming the solid electrolyte layer including the sub-steps of: adhering a conductive tape to the anode element; conveying the anode element into said polymerization tank; making a first feeding roller contact the conductive tape; peeling the conductive tape from the anode element; making a second feeding roller contact the conductive tape and penetrate the conductive tape; and applying voltages to the first and second feeding rollers and the negative electrode; and forming a cathode layer on the solid electrolyte layer.

Typically, when the conductive tape forming the solid electrolyte layer contacts with the second feeding roller, the tape scrapes off a substance adhering to a feeding boss penetrating into the tape. Accordingly, the second feeding unit applies a voltage to the conductive tape without failure, and a uniform solid electrolyte layer is thus formed efficiently by the electrolytic polymerization.

According to a second aspect of the present invention, there is provided a manufacturing method for manufacturing a solid electrolytic capacitor using a manufacturing apparatus including a

polymerization tank and a negative electrode installed in said polymerization tank, said manufacturing method comprising the steps of: forming a dielectric oxide film layer on an anode element made of valve metal; forming a conductive substance layer on the dielectric oxide layer; forming a solid electrolyte layer on the conductive substance layer; including the sub-steps of: adhering a conductive tape to the anode element; conveying the anode element into said polymerization tank; making a first feeding roller contact the conductive tape; peeling the conductive tape from the anode element; making a second feeding roller contact the conductive tape and penetrate the conductive tape; and applying voltages to the first and second feeding rollers and the negative electrode; and forming a cathode layer including the sub-steps of: applying and drying carbon paste on the solid electrolyte layer; forming a silver paste film by applying silver paste on the carbon paste; adjusting a thickness of the silver paste film by blowing a first gas to the silver paste film; and drying the silver paste film.

According to a third aspect of the present invention, there is provided a manufacturing apparatus for manufacturing a solid electrolytic capacitor, comprising: an anodizing unit for anodizing a dielectric oxide layer on an anode element; a polymerization unit for forming a solid electrolyte layer on the dielectric oxide layer, including: an electrolytic polymerization tank; a first feeding roller for applying a first voltage to a conductive tape adhered to the anode element; a first feeding unit disposed at an upstream portion of a conveying route of the anode element, said first feeding unit having said first feeding roller; means for peeling the conductive tape from the anode element;

5a

a second feeding roller having a protruding feeding boss disposed on a circumference of said second feeding roller, said protruding feeding boss contacting and penetrating the conductive tape; a second feeding unit disposed at a downstream portion of the conveying route of the anode element, said second feeding unit applying a second voltage to the conductive tape through said second feeding roller; a negative electrode disposed in said electrolytic polymerization tank; and power supply units coupled to said first and second feeding units and said cathode unit, respectively; and a cathode forming unit for forming a cathode layer on the solid electrolyte layer.

According to a fourth aspect of the present invention, there is provided a manufacturing apparatus for manufacturing a solid electrolytic capacitor, comprising: an anodizing unit for forming a dielectric oxide layer on an anode element; a polymerization unit for forming a solid electrolyte layer on the dielectric oxide layer, including: an electrolytic polymerization tank; a first feeding roller for applying a first voltage to a conductive tape adhered to the anode element; a first feeding unit disposed at an upstream portion of a conveying route of the anode element, said first feeding unit having said first feeding roller; means for peeling the conductive tape from the anode element; a second feeding roller having a protruding feeding boss disposed on a circumference of said second feeding roller, said protruding feeding boss contacting and penetrating the conductive tape; a second feeding unit disposed at a downstream portion of the conveying route of the anode element, said second feeding unit applying a second voltage to the conductive tape through said second feeding roller; a negative electrode disposed in said electrolytic polymerization tank; and power supply units coupled to said first and second feeding units and said negative electrode, respectively;

5b

and a cathode forming unit for forming a cathode layer on the solid electrolyte layer, including: a carbon layer forming unit for applying and drying carbon paste on the solid electrolyte layer; a silver paste applying unit for forming a silver paste film by applying silver paste on the carbon layer; a first nozzle unit for adjusting a thickness of the silver paste film by blowing a first gas to the silver paste film; and a drying unit for drying the silver paste film.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view of an electrolytic polymerization apparatus for a solid electrolytic capacitor according to exemplary embodiment 1 of the present invention.

5 Fig. 2A is a plan view of a band-shaped anode element of the solid electrolytic capacitor according to embodiment 1.

Fig. 2B is a sectional view of the band-shaped anode element of the solid electrolytic capacitor according to embodiment 1.

10 Fig. 3 is a perspective view of an electrolytic polymerization tank according to embodiment 1.

Fig. 4 is a sectional view of the electrolytic polymerization tank according to embodiment 1.

Fig. 5 is a sectional view of a first driven roller according to embodiment 1.

15 Fig. 6 is a perspective view of a first feeding roller according to embodiment 1.

Fig. 7 is a sectional view of the first feeding roller according to embodiment 1.

20 Fig. 8 is a sectional view of a first tension roller according to embodiment 1.

Fig. 9 is a perspective view of a peeling roller according to embodiment 1.

Fig. 10 is a perspective view of a second feeding roller according to embodiment 1.

25 Fig. 11 is a sectional view of the second feeding roller according to embodiment 1.

Fig. 12A is a sectional view showing the state where a boss of the

second feeding roller contacts with a conductive tape according to embodiment 1.

Fig. 12B is a sectional view showing that the boss of the second feeding roller pokes into the conductive tape according to embodiment 1.

Fig. 12C is a sectional view showing that the boss of the second feeding roller penetrates the conductive tape according to embodiment 1.

Fig.13 is a perspective view showing an essential portion of an apparatus for manufacturing a solid electrolytic capacitor according to exemplary embodiment 2 of the present invention.

Fig. 14 is a sectional view showing a first nozzle unit of manufacturing apparatus according to embodiment 2.

Fig. 15 is an essential side view showing a second nozzle unit of the manufacturing apparatus according to embodiment 2.

Fig. 16 is a plan showing an air blowing direction from the first nozzle unit of the manufacturing apparatus according to embodiment 2.

Fig. 17 is an exploded perspective view showing a configuration of a solid electrolytic capacitor.

Fig. 18A is a front view of a capacitor element of a conventional solid electrolytic capacitor.

Fig. 18B is a sectional view of an electrolytic polymerization apparatus for the conventional solid electrolytic capacitor.

Fig. 19A and Fig.19B are perspective views of essential portions of manufacturing apparatus for the conventional solid electrolytic capacitor.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

(Exemplary embodiment 1)

Referring to the drawings, exemplary embodiment 1 of the present invention will be described below.

Fig. 1 is a sectional view of a manufacturing apparatus for a solid electrolytic capacitor in exemplary embodiment 1 of the present invention, particularly showing a configuration of an electrolytic polymerization apparatus. A long polymerization tank 8 is filled with polymerization solution 9. A first driven roller 13 and a first tension roller 14 are disposed at the upstream portion and the down stream portion of the polymerization tank 8, respectively, and the rollers are partly immersed in the polymerization solution 9. At the further upstream portion beyond the first driven roller 13, a first feeding roller 20 and a roller 21 are disposed. At the further downstream portion beyond the first tension roller 14, a peeling roller 24 for peeling a conductive tape 7 from a band-shaped anode element 1 is disposed. At the further downstream portion, a roller 25, a second feeding roller 26, and a roller 27 are disposed. A negative electrode 10 is disposed in the polymerization tank 8.

In the electrolytic polymerization apparatus having such a configuration, the conductive tape 7 and the band-shaped anode element 1 are individually conveyed and are held between the first feeding roller 20 and the roller 21. Thus, as shown in Fig. 2A and Fig. 2B, the conductive tape 7 is adhered to an anode contact portion 5 of the band-shaped anode element 1.

A capacitor element 3 is composed of the anode contact portions 5 and an anode foil portions 6. An insulating tape 4 for isolating the anode contact portion 5 and anode foil portion 6 is adhered to the face and back sides of both surfaces of the anode element. Slits 2 separate the anode foil portions 6.

The band-shaped anode element 1 having the conductive tape 7 adhered to the anode contact parts 5 is conveyed by the first driven roller 13 and first tension roller 14 and is immersed in the polymerization solution 9. After leaving the polymerization tank 8, the anode element 1 has the conductive tape 7 peeled off by the peeling roller 24, and is conveyed by the roller 25, second voltage feed roller 26, and roller 27. A voltage is applied between the conductive tape 7 and negative electrode 10 while the anode element 1 is being conveyed in the polymerization solution 9. The voltage produces a polymerization reaction starting from the surface of the conductive tape 7 to the anode foil portion 6, and thus, forms a conductive polymer layer on the anode foil parts 6.

In this electrolytic polymerization apparatus, plural long polymerization tanks 8 are arranged in parallel as shown in Fig. 3. The polymerization solution 9 flows into the polymerization tank 8 from a first port 11 at one end of the tank 8 as shown in Fig. 1, and flows out of the tank 8 from a second port 12 at the other end of the tank 8. Further, as shown in Fig. 4, a lid 18 is put on the upper opening of each long tank 8, and the lower portion of a spacer 19 provided at the lower side of the lid 8 is immersed into the polymerization solution 9.

The negative electrode 10 is provided above the lower end of the spacer 19, and the band-shaped anode element 1 to which the conductive tape 7 is adhered passes beneath the spacer 19.

Plural first driven rollers 13 are disposed at the upstream portion of the polymerization tank 8 arranged in parallel as shown in Fig. 3, respectively. A single through-shaft 15 penetrates the first driven roller 13 along the center axis of the roller 13, and plural ball bearings 16 are disposed between the through-shaft 15 and first driven roller 13 as shown

in Fig. 5.

At the further upstream portion beyond the first driven roller 13, as shown in Fig. 6, a first feeding roller 20, which is voltage applying means, is disposed. The feeding roller 20 and a feeding roller 21 beneath
5 the roller 20 press and adhere the conductive tape 7 to the anode element 1. A spring 23 presses the roller 20 to the tape 7, and thus, makes a stable voltage be applied to the tape 7. Therefore, a conductive polymer layer is formed stably.

Fig. 7 is a sectional view showing the first feeding roller 20 and
10 roller 21. The roller 20 is provided with a guide 22 for preventing the conductive tape 7 from lateral deviation. Plural ball bearings 33 are disposed between the roller 20 and through-shaft 32, and a voltage applying unit 32a is provided at the through-shaft 32. The feeding roller 20 having the through-shaft 32, to which a voltage is applied, applies the
15 voltage with a smaller failure due to wearing out than a feeding brush, so that the roller may apply a stable voltage.

The first tension rollers 14 are disposed at the other ends of the downstream portion of polymerization tanks 8 arranged in parallel, respectively, as shown in Fig. 3. A single driving shaft 17 is fitted along
20 the central axis of each of first tension rollers 14 arranged in parallel, as shown in Fig. 8. The driving shaft 17 applies a tension to the anode element 1.

At the downstream portion beyond the tension roller 14, as shown in Fig. 9, a peeling roller 24 for peeling the conductive tape 7 from the
25 anode element 1, and a roller 25 are disposed. At the further downstream portion, a second feeding roller 26 is disposed.

A roller 27 pinches the conductive tape 7 with the circumference

of the second feeding roller 26, as shown in Fig. 10. Protruding feeding bosses 31 are provided on the outer circumference of the roller 26. The conductive tape 7 is held between the rollers 26 and 27 by a spring 28. At this moment, the protruding feeding bosses 31 poke and tear the surface of the conductive tape 7.

More specifically, as shown in Fig. 11, a groove 27a formed at the roller 27 does not prevent the feeding bosses 31 in the second feeding roller 26 from poking. Plural ball bearings 30 are disposed between the feeding roller 26 and through-shaft 29, and a voltage applying unit 29a is provided at the through-shaft 29. The feeding roller having the through-shaft 29, to which a voltage is applied, applies the voltage with a smaller failure due to wearing out than a feeding brush, so that the roller can apply a stable voltage.

The second feeding roller 26 has a curved outer circumference 26a of which center projects in an outer circumferential direction. Therefore, the conductive tape 7 is hardly deviated from the center of the circumference of the second feeding roller 26, and thus, the manufacturing apparatus operates with a high rate.

A conductive polymer layer formed by electrolytic polymerization is adhered on the surface of the conductive tape 7. As shown in Fig. 12A, a deposit 34 included in the conductive polymer layer is attached to the second feeding roller 26 and protruding feeding bosses 31. When poking through the conductive tape 7, as shown in Fig. 12B, the surface of the tape 7 rubs off the deposit 34 while the bosses 31 penetrates into the tape 7. Therefore, as shown in Fig. 12C, the bosses 31 deeply poke into the conductive tape 7, and thus, contacts the tape 7 securely. As a result, a stable voltage is applied to the conductive tape 7 and decreases a

polymerization failure.

According to this embodiment, as shown in Fig. 12C, the protruding feeding bosses 31 penetrate into the conductive tape 7. Even if the leading ends of the bosses 31 may stop in the midst of the conductive tape 7 and may not penetrate through the tape, the same effect is obtained.

(Examples)

On an aluminum foil (100 μ m thick) having both surfaces roughened electrochemically, an anodized film is formed at an anodizing voltage of 35V. Then, slits are formed in specified intervals at both sides of the foil by cutting the foil, and thus, a band-shaped anode element having capacitor elements disposed at the sides is obtained. Then, anode contact portions and anode foil portions are separated by an insulating tape attached on both surfaces of the anode element. Dimensions of the capacitor element are 3mm $\times$ 4mm. Then, an anodized film is formed at the side of the slit in the anode element. Then, the anode foil portions to which a manganese nitrate aqueous solution are applied are pyrolyzed for five minutes at 300°C, and thereby, a manganese dioxide layer is formed on the anode foil portions as a conductive substance layer.

A conductive tape is adhered to the band-shaped anode element thus prepared, and a conductive polymer layer is formed on the surface of the anode element in the polymerization tank shown in Fig. 1.

The polymerization solution is an aqueous solution of 0.2mol/liter of pyrrole and 0.1mol/liter of alkyl naphthalene sulfonate. During electrolytic polymerization, the conductive tape which is a polymerization electrode as a common positive electrode and the stainless steel plate

disposed beneath a liquid level as a negative electrode applies a voltage. For about thirty minutes from the entry into the polymerization tank to the exit, a conductive polymer layer is formed on the entire anode foil portions on both surfaces of the anode element.

5 Leaving the polymerization tank, the conductive tape is peeled off the band-shaped anode element and is taken through the second feeding roller. The anode element is taken out and sent to the next process where a carbon layer and a silver paint layer are formed on the entire anode foil parts, and thereby, a cathode contact portion is formed. Being cut,
10 capacitor elements are obtained. An anode lead and cathode lead are taken out of the anode contact portion and the cathode contact portion, respectively. Then, the capacitor element is coated with an epoxy resin, and a solid electrolytic capacitor is obtained.

15 (Comparison)

On an aluminum foil (100 μ m thick) having both surfaces roughened electrochemically, an anodized film is formed at an anodizing voltage of 35V. Then, slits are formed in specified intervals on both sides of the foil by cutting the foil, and thus, a band-shaped anode element
20 having capacitor elements disposed at both sides is obtained. Then, the anode contact portions and anode foil portions are separated by an insulating tape attached on both surfaces. Dimensions of the capacitor element are 3mm $\times$ 4mm. Then, an anodized film is formed at the side of the slit in the anode element. Then, a conductive polymer film of
25 chemical oxidation polymerization of pyrrole is formed on the surface of the anode element. As shown in Fig. 13, the electrodes contact the elements, respectively, and electrolytic polymerization is performed on the

conductive polymer film of chemical oxidation polymerization. Then, a carbon layer and a silver paint layer are formed on the entire anode foil portions. Then, being cut, a capacitor element is obtained. An anode lead and cathode lead are taken out of the anode contact portion and the cathode contact portion, respectively. Then, the capacitor element is coated with an epoxy resin, and a solid electrolytic capacitor is thus obtained. Ammonium persulfate is utilized for the oxidizing agent for chemical oxidation polymerization.

Table 1 shows initial characteristics of a capacitance, a leak current (a voltage of 10V is applied for two minutes), and withstanding voltage (a breakdown voltage at a voltage elevation of 0.2V/sec.) of solid electrolytic capacitors of the example and the comparison.

Table 1

Capacitor (6.3WV, 150 μ F)

	Capacitance (μ F)	Leak current (μ A)	Withstanding voltage (V)
Example	152	15	23
Comparison	148	28	20

As resulted from Table 1, the solid electrolytic capacitor of the example has a small leak current and high withstanding voltage. The band-shaped anode element has a plurality of protruding capacitor elements at both sides. And, a voltage is securely applied to the conductive tape from both upstream and down stream portions of the electrolytic polymerization tank as a polymerization electrode. As a result, plural capacitor elements can be electrolytically-polymerized more easily and continuously as compared with the comparison.

In this embodiment, the band-shaped anode element is made of the aluminum foil, and may be made of tantalum, titanium and others. The shape and dimensions are not limited to the example.

(Exemplary embodiment 2)

Referring to the drawings, exemplary embodiment 2 of the present invention will be described.

Fig. 13 is a perspective view showing an essential portion of an apparatus for manufacturing a solid electrolytic capacitor according to embodiment 2. Fig. 14 and Fig. 15 are a side sectional view and an essential side view of the apparatus, respectively. A band-shaped anode element 35 is conveyed at a constant speed in the direction of an arrow shown in the drawing.

The anode element 35 is formed as follows. A band-shaped aluminum foil supplied from a feeder (not shown) has a surface roughened by etching. Then, the element is anodized to form a dielectric oxide film on the surface, and then is stamped out into a desired shape. The element is separated into an anode part and cathode part by an insulating resist. Then, on the cathode part, a manganese dioxide layer and a solid electrolyte layer of conductive polymer by a polymerization unit (not shown) are formed. Further, a carbon layer is formed on the solid electrolyte layer, and a silver paste is applied on the carbon layer.

In a first nozzle unit 36 and second nozzle unit 37, nozzles are disposed symmetrically in pair as if the nozzles hold the band-shaped anode element 35 from above and beneath. Through a filter 38, air around the ends of the first nozzle unit 36 and second nozzle unit 37 are sucked by a driving source for suction (not shown).

Fig. 14 is a side sectional view showing an essential portion of the first nozzle unit 36 of the manufacturing apparatus shown in Fig. 13. The nozzle unit 36 blows air to the silver paste 39 applied on the band-shaped anode element 35, and forms the silver paste 38 uniformly and thinly with the air.

Fig. 15 is a side view showing an essential portion of the second nozzle unit 37 of the manufacturing apparatus shown in Fig. 13. The nozzle unit 37 blows air to the silver paste 39 applied on the anode element 35 to adjust the thickness of the silver paste 39 and to blow away the silver paste 39 accumulated at the edge of the anode element 35. Further, since the vicinity of the leading ends of the nozzle parts 36, 37 is sucked through the filter 38, scattering silver paste 39 does not leak to the outside of the apparatus.

The anode element 35 is impregnated with manganese sulfate aqueous solution, is dried in air, and is pyrolyzed at 300°C to form a manganese dioxide layer.

Instead of the manganese dioxide layer, a pre-coat layer made of conductive material such as conductive polymer may be used.

The solid electrolyte layer of conductive polymer is formed by electrolytic polymerization by a voltage applied to the anode element from an external electrode in a polymerization solution containing heterocyclic monomer, such as pyrrole or thiophene. As a result, a solid electrolytic capacitor having excellent characteristics is obtained stably in a relatively short time.

Specific examples will be explained below.

(Example 1)

An aluminum foil has a surface roughened by etching and expanded by 125 times. The aluminum foil is separated into an anode portion and a cathode portion by an insulating resist tape. A band-shaped anode element has capacitor elements having an effective area of
5 3.2mm $\times$ 3.9mm disposed every 4mm. To the anode element, a DC voltage of 12V is applied for 20 minutes in aqueous solution of 0.3wt% of ammonium dihydrogenphosphate at a temperature of 70°C. Then, an anodized film is formed on the surface of the element.

The anode element is immersed in aqueous solution of 20wt% of
10 manganese nitrate at a temperature of 25°C for three seconds, and then, is taken out. Then, the excess aqueous solution of manganese nitrate attached to the surface is blown away by air. Then, the anode element is heated at over 250°C in one minute and is pyrolyzed for five minutes at 300°C, so that a manganese dioxide layer may be formed on the surface of
15 the anode element.

This anode element is immersed in aqueous solution of 0.3wt% of aluminum dihydrogenphosphate at a liquid temperature of 70°C. Then, a DC voltage of 10V is applied for ten minutes to anodize the anode element again. On the manganese dioxide layer formed on the anode
20 element, a solid electrolyte layer made of conductive polymer of polypyrrole film is further formed by electrolytic polymerization method.

The solid electrolyte layer is impregnated with pH 10 aqueous solution of 5wt% of carbon particles and ammonia and is dried at 150°C to form a carbon layer. On the carbon layer, a silver paste with kinematic
25 viscosity adjusted to 6.0 Pa $\cdot$ s at 25°C and 50 rpm is applied. This band-shaped anode element is conveyed at a speed of 1m/min. Then, the applied silver paste is adjusted to a desired thickness by the

manufacturing apparatus shown in Fig. 13 through Fig. 15 and is heated and dried, so that a capacitor element having a cathode conductive layer thereon is obtained.

For adjusting the thickness of the silver paste, the air blow ports
5 of the first nozzle unit are disposed above and beneath positions at 2mm away from the anode element. An air blow direction is inclined at $\theta = 10^\circ$ to the orthogonal direction to the conveying direction of the band-shaped anode element as shown in Fig. 16, and the pressure of the air blow is 0.1MPa.

10 The air blow ports of the second nozzle unit are disposed above and beneath at positions 3.5mm away from the anode element, and air is blown at a pressure of 0.1MPa to blow out an excess silver paste. Then, the blown silver paste is collected with a filter.

The silver paste applied thinly and uniformly is heated and dried,
15 and a capacitor element is thus fabricated. Then, an anode terminal and a cathode terminal are connected to the anode element and cathode conductive layer of the capacitor element, respectively. Then, the capacitor element is molded with insulating external resin, and a solid electrolytic capacitor as shown in Fig. 17 is thus manufactured
20 (Dimensions: 7.3mm $\times$ 4.3mm $\times$ 2.8mm).

(Example 2)

A solid electrolytic capacitor is manufactured in the same manner as the example 1, except that the thickness of the applied silver paste is
25 adjusted under an air blow pressure at the first nozzle unit of 0.05MPa and that at the second nozzle unit of 0.05MPa.

(Example 3)

A solid electrolytic capacitor is manufactured in the same manner as the example 1, except that the thickness of the applied silver paste is adjusted under an air blow pressure at the first nozzle unit of 0.10MPa
5 and that at the second nozzle unit to 0.05MPa.

(Example 4)

A solid electrolytic capacitor is manufactured in the same manner as the example 1, except that the thickness of the applied silver paste is
10 adjusted under an air pressure at the first nozzle unit of 0.10MPa and that at the second nozzle unit of 0.15MPa.

(Example 5)

A solid electrolytic capacitor is manufactured in the same manner
15 as the example 1, except that the thickness of the applied silver paste is adjusted under an air pressure of the first nozzle unit of 0.15MPa and that at the second nozzle unit of 0.10MPa.

(Example 6)

20 A solid electrolytic capacitor is manufactured in the same manner as the example 1, except that the thickness of the applied silver paste is adjusted under an air pressure at the first nozzle unit of 0.15MPa and that at the second nozzle unit to 0.15 MPa.

25 (Example 7)

A solid electrolytic capacitor is manufactured in the same manner as the example 1, except that the thickness of the applied silver paste is

adjusted under an air blow angle (θ) of the first nozzle unit of 5° .

(Example 8)

A solid electrolytic capacitor is manufactured in the same manner
5 as the example 1, except that the thickness of the applied silver paste is
adjusted under an air angle (θ) of the first nozzle unit of 15° .

(Example 9)

A solid electrolytic capacitor is manufactured in the same manner
10 as the example 1, except that the thickness of the applied silver paste is
adjusted under an air blow angle (θ) of the first nozzle unit of 20° .

(Comparison 1)

A solid electrolytic capacitor is manufactured in the same manner
15 as the example 1, except that the silver paste is applied under an air
pressure at the first and second nozzle units of 0.

(Comparison 2)

A solid electrolytic capacitor is manufactured in the same manner
20 as the example 1, except that the cathode conductive layer is formed by
adjusting the thickness of the silver paste applied on the anode element
by scraping off by the spatula-like scrapers as explained in Fig. 19A and
Fig. 19B.

25 Table 2 shows measurements of the thickness of the cathodes of
the capacitor elements in the example 1 through example 9 and
comparisons 1 and 2. Table 2 also shows measurements of initial

capacitance and equivalent serial resistance (ESR) characteristics of the solid electrolytic capacitor fabricated where four capacitor elements of the examples are laminated. The measuring temperature ranges 25 to 30°C. The capacitance is measured at 120Hz, and the ESR is measured at 100kHz. The measurements are the averages of thirty samples, respectively.

Table 2

(Capacitor 6.3WV, 47 μ F)

	Cathode thickness			ESR (m Ω)	Capacitance (μ F)
	Average	Maximum	Minimum		
Example 1	185	190	182	15	47.2
Example 2	184	188	180	14	47.5
Example 3	186	191	178	16	47.0
Example 4	181	187	176	15	47.6
Example 5	182	188	176	14	47.6
Example 6	181	186	177	14	47.1
Example 7	188	193	183	15	47.1
Example 8	184	188	180	15	47.6
Example 9	190	196	186	17	47.1
Comparison 1	275	320	251	26	46.8
Comparison 2	230	267	194	21	46.4

As shown in from Table 2, in the solid electrolytic capacitor according to the embodiment, the cathode of the capacitor element is formed thinly and uniformly. Accordingly, the solid electrolytic capacitor manufactured by laminating plural capacitor elements has a low contact resistance between elements and excellent ESR characteristics to the comparisons.

Thus, according to the manufacturing method for manufacturing the solid electrolytic capacitor of the present invention, when the protruding feeding bosses of the second feeding roller poke through the surface of the conductive tape, the inner texture of the tape is exposed for the first time. Then, a deposit attached to the feeding boss is scraped off, and thus, the contact failure between the feeding roller and the tape is reduced. Therefore, the apparatus has the maintainability enhanced, and has a smaller size and lower cost. The apparatus has an operation efficiency improved

Moreover, since the thickness is adjusted by a blowing air to the

silver paste after applying the silver paste for forming the cathode
conductive layer of the capacitor element, a thin and uniform cathode
conductive layer is formed. Therefore, a solid electrolytic capacitor has a
low contact resistance, a small thickness, and an excellent volume
5 efficiency.

CLAIMS

1. A manufacturing method of manufacturing a solid electrolytic capacitor using a manufacturing apparatus including a polymerization tank and a negative electrode installed in the polymerization tank, said manufacturing method comprising the steps of:

forming a dielectric oxide film layer on of an anode element made of valve metal;

forming a conductive substance layer on the dielectric oxide film layer;

forming a solid electrolyte layer on the conductive substance layer, said forming the solid electrolyte layer including the sub-steps of:

adhering a conductive tape to the anode element;

conveying the anode element into said polymerization tank;

making a first feeding roller contact the conductive tape;

peeling the conductive tape from the anode element;

making a second feeding roller contact the conductive tape and penetrate the conductive tape; and

applying voltages to the first and second feeding rollers and the negative electrode; and

forming a cathode layer on the solid electrolyte layer.

2. A manufacturing method for manufacturing a solid electrolytic capacitor using a manufacturing apparatus including a polymerization tank and a negative electrode installed in said polymerization tank, said manufacturing method comprising the steps of:

forming a dielectric oxide film layer on an anode element made of valve metal;

forming a conductive substance layer on the dielectric oxide layer;

forming a solid electrolyte layer on the conductive substance layer, including the sub-steps of:

adhering a conductive tape to the anode element;

conveying the anode element into said polymerization tank;

making a first feeding roller contact the conductive tape;

peeling the conductive tape from the anode element;

making a second feeding roller contact the conductive tape and penetrate the conductive tape; and

applying voltages to the first and second feeding rollers and the negative electrode; and

forming a cathode layer including the sub-steps of:

applying and drying carbon paste on the solid electrolyte layer;

forming a silver paste film by applying silver paste on the carbon paste;

adjusting a thickness of the silver paste film by blowing a first gas to the silver paste film; and

drying the silver paste film.

3. A manufacturing apparatus for manufacturing a solid electrolytic capacitor, comprising:

an anodizing unit for anodizing a dielectric oxide layer on an anode element;

a polymerization unit for forming a solid electrolyte layer on the dielectric oxide layer, including:

an electrolytic polymerization tank;

a first feeding roller for applying a first voltage to a conductive tape adhered to the anode element;

a first feeding unit disposed at an upstream portion of a conveying route of the anode element, said first feeding unit having said first feeding roller;

means for peeling the conductive tape from the anode element;

a second feeding roller having a protruding feeding boss disposed on a circumference of said second feeding roller, said protruding feeding boss contacting and penetrating the conductive tape;

a second feeding unit disposed at a downstream portion of the conveying route of the anode element, said second feeding unit applying a second voltage to the conductive tape through said second feeding roller;

a negative electrode disposed in said electrolytic polymerization tank; and

power supply units coupled to said first and second feeding units and said cathode unit, respectively; and

a cathode forming unit for forming a cathode layer on the solid electrolyte layer.

4. The manufacturing apparatus of claim 3, wherein the circumference of the second feeding roller has a curved surface of which center portion projects in a radial direction.

5. The manufacturing apparatus of claim 3 or 4, wherein the second feeding roller further has a through-shaft and ball bearings, and wherein said second feeding unit applies a second voltage to said through-shaft.

6. A manufacturing apparatus for manufacturing a solid electrolytic capacitor, comprising:

an anodizing unit for forming a dielectric oxide layer on an anode element;

a polymerization unit for forming a solid electrolyte layer on the dielectric oxide layer, including:

an electrolytic polymerization tank;

a first feeding roller for applying a first voltage to a conductive tape adhered to the anode element;

a first feeding unit disposed at an upstream portion of a conveying route of the anode element, said first feeding unit having said first feeding roller;

means for peeling the conductive tape from the anode element;

a second feeding roller having a protruding feeding boss disposed on a circumference of said second feeding roller, said protruding feeding boss contacting and penetrating the conductive tape;

a second feeding unit disposed at a downstream portion of the conveying route of the anode element, said second feeding unit applying a second voltage to the conductive tape through said second feeding roller;

a negative electrode disposed in said electrolytic polymerization tank; and

power supply units coupled to said first and second feeding units and said negative electrode, respectively; and

a cathode forming unit for forming a cathode layer on the solid electrolyte layer, including:

a carbon layer forming unit for applying and drying carbon paste on the solid electrolyte layer;

a silver paste applying unit for forming a silver paste film by applying silver paste on the carbon layer;

a first nozzle unit for adjusting a thickness of the silver paste film by blowing a first gas to the silver paste film; and

a drying unit for drying the silver paste film.

7. A solid electrolytic capacitor manufactured according to the manufacturing method of 1 or 2, or using the apparatus of any one of claims 3 to 6.

8. The solid electrolytic capacitor of claim 7, wherein the thickness the silver paste film ranges 10 to 25 μ m.