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(54) SOLID ELECTROLYTIC CAPACITOR AND METHOD FOR MANUFACTURING SOLID ELECTROLYTIC CAPACITOR WITH IMPROVED ANODE LEAD-OUT WIRE

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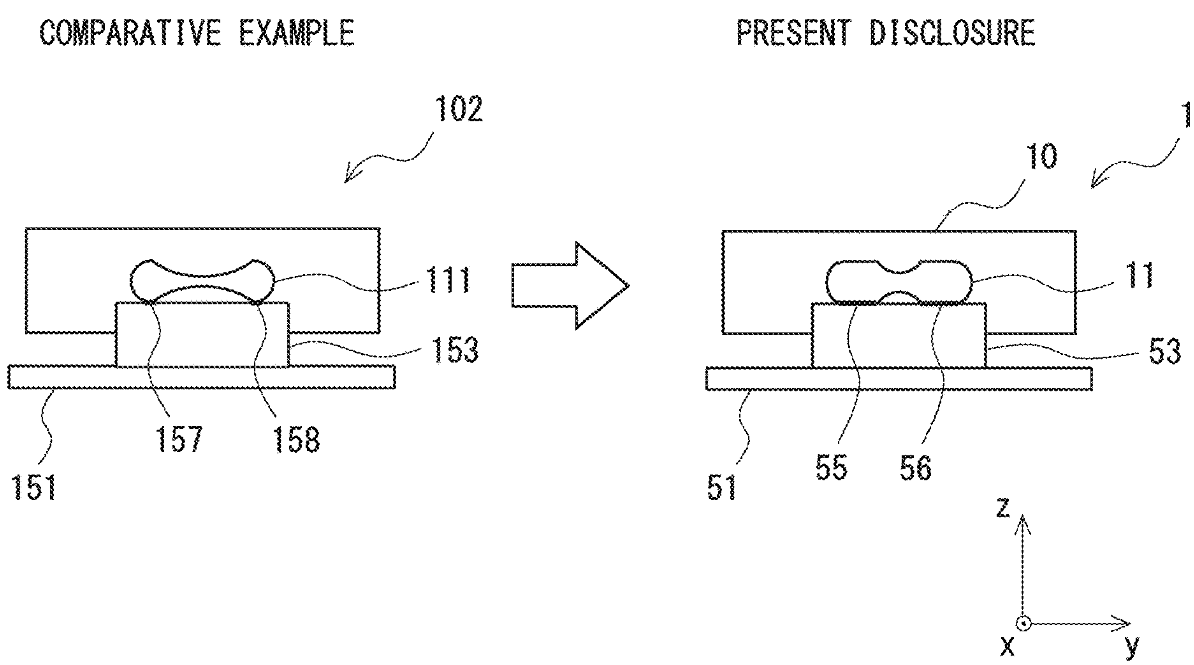
CPC *H01G 9/04* (2013.01); *H01G 9/0036* (2013.01); *H01G 9/08* (2013.01); *H01G 9/15* (2013.01)

(57) **ABSTRACT**

A solid electrolytic capacitor capable of improving manufacturing yield is provided. A solid electrolytic capacitor according to one aspect of the present disclosure includes an anode lead-out wire and a capacitor element in which the anode lead-out wire is embedded. The cross section of at least a part of the anode lead-out wire in a direction in which the anode lead-out wire is extended has a flat shape, and a recess provided in a central part, a first linear part that is extended outward from one side of the recess, and a second linear part that is extended outward from another side of the recess are formed in at least one of an upper surface and a lower surface of the anode lead-out wire having the flat shape.



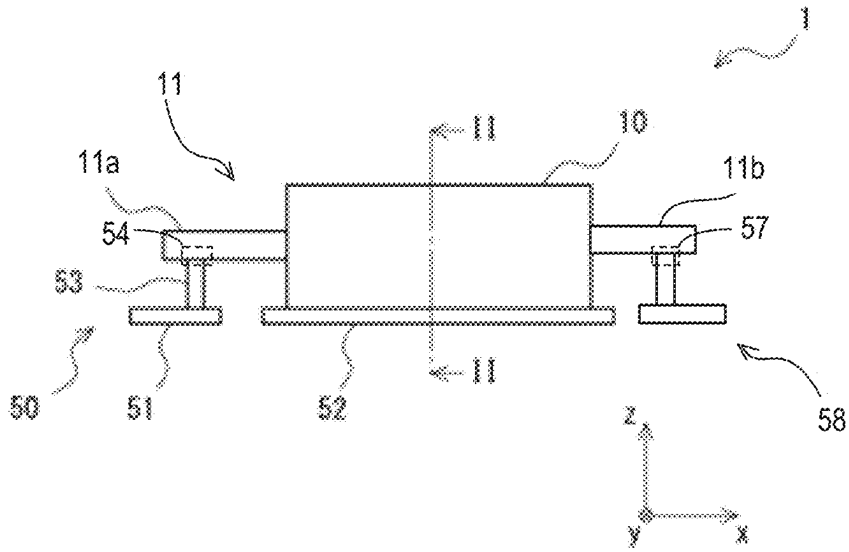

1
11
II
10
11a
11b
54
57
53
50
51
52
II
58
z
y
x

Fig. 1

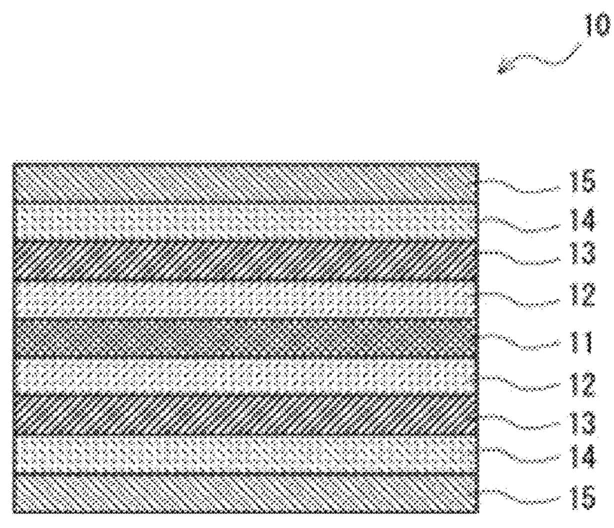

10
15
14
13
12
11
12
13
14
15

Fig. 2

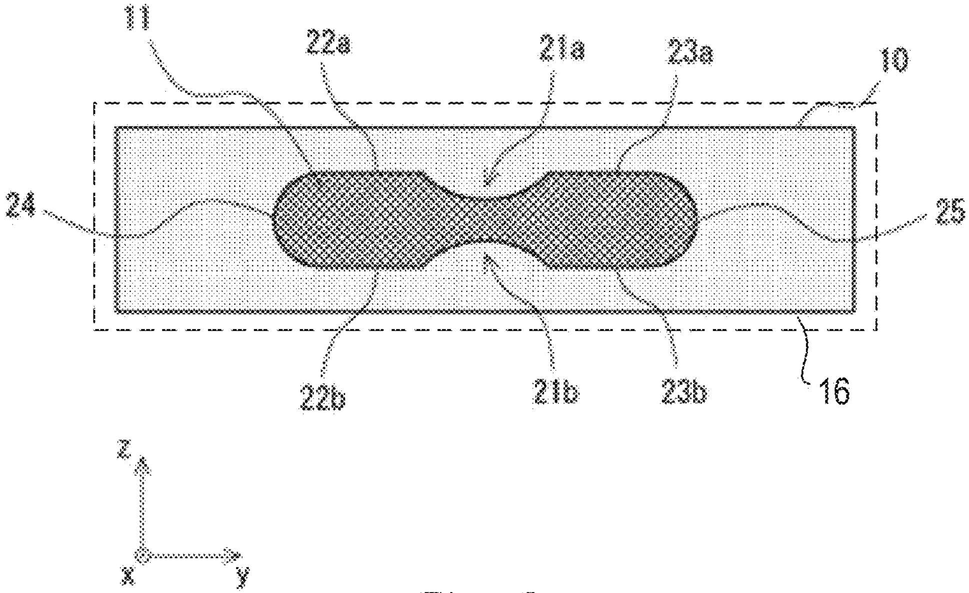


Fig. 3

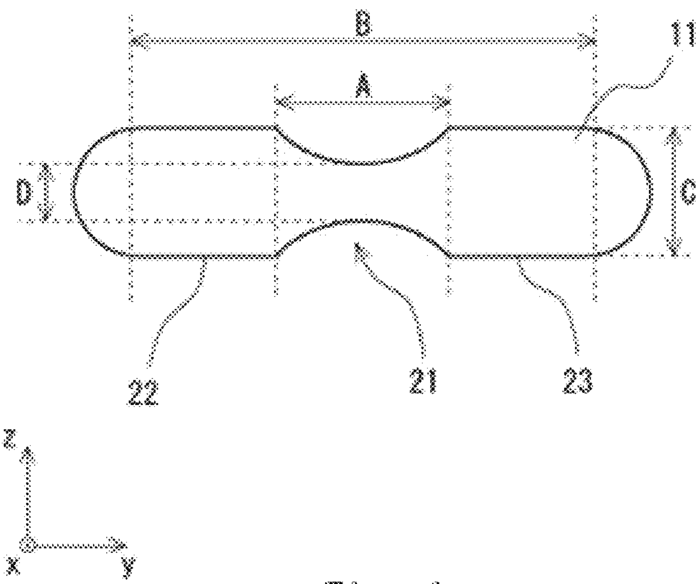


Fig. 4

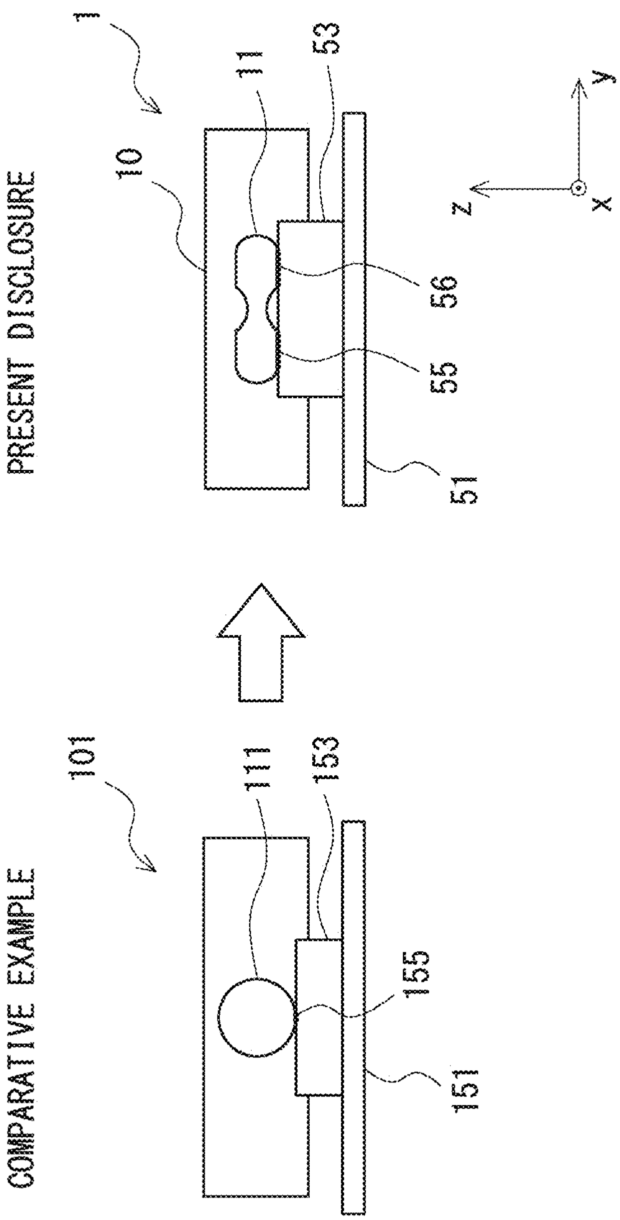
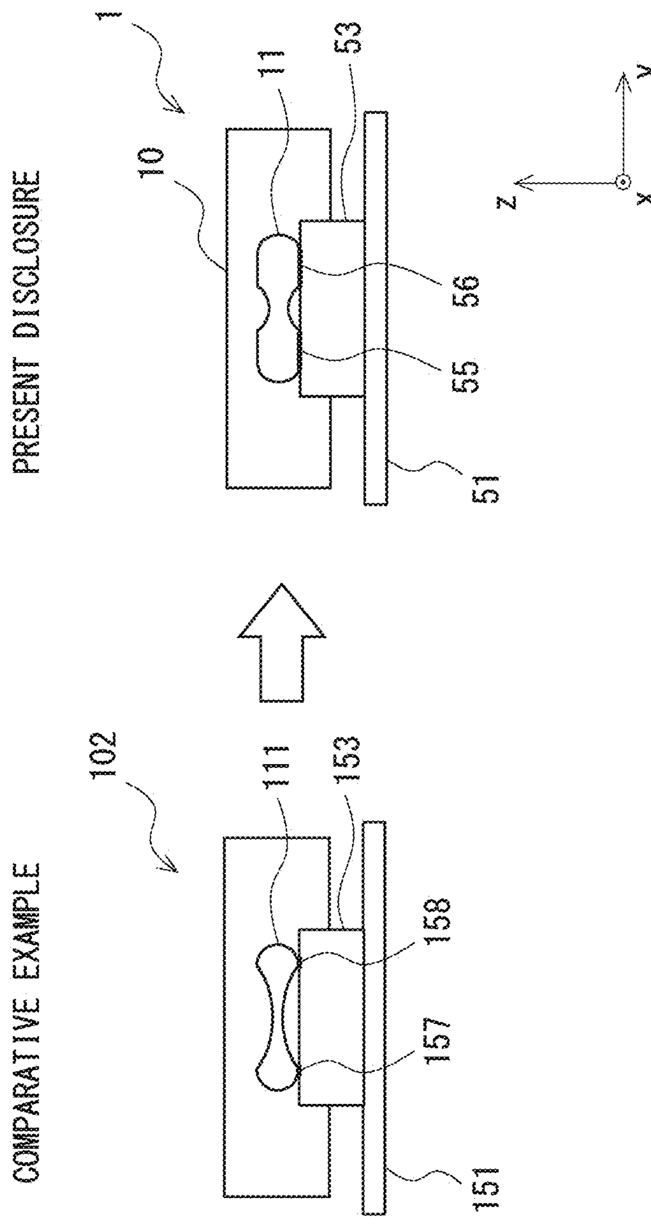

PRESENT DISCLOSURE
COMPARATIVE EXAMPLE
1
10
11
53
56
55
51
101
111
153
155
151
z
y
x

Fig. 5



PRESENT DISCLOSURE
1
10
11
53
56
55
51
z
y
x
COMPARATIVE EXAMPLE
102
111
153
158
157
151

Fig. 6

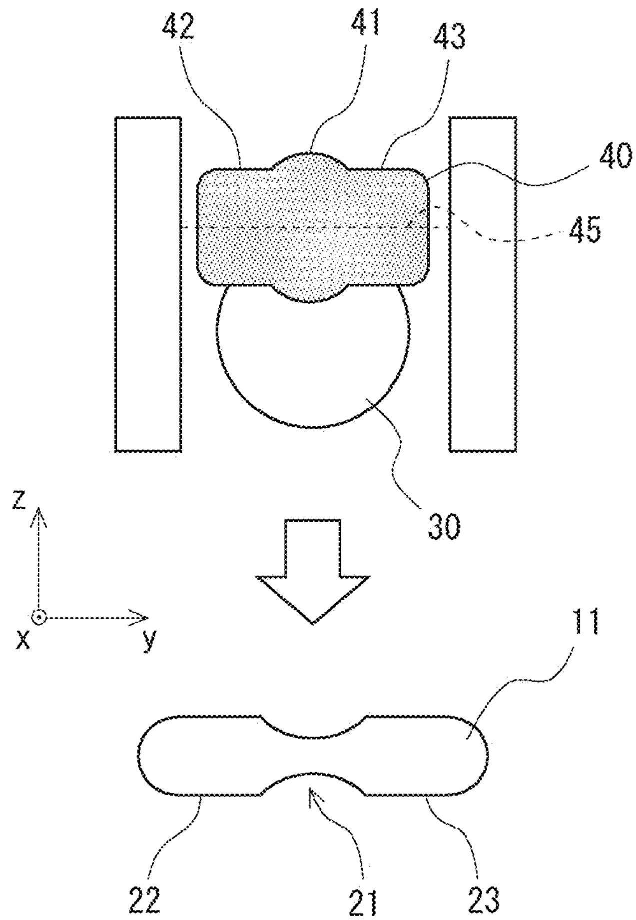


Fig. 7

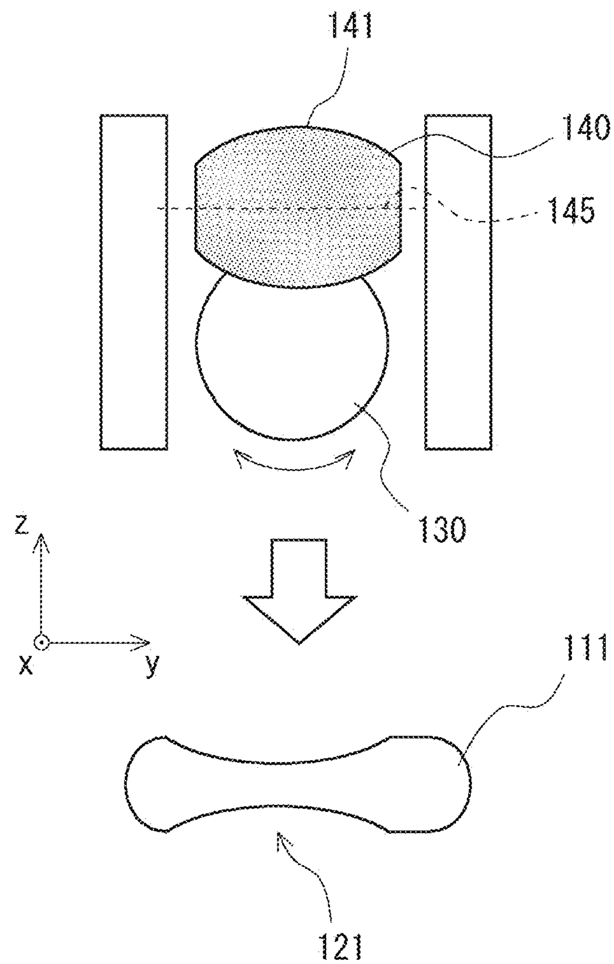


Fig. 8

SOLID ELECTROLYTIC CAPACITOR AND METHOD FOR MANUFACTURING SOLID ELECTROLYTIC CAPACITOR WITH IMPROVED ANODE LEAD-OUT WIRE

INCORPORATION BY REFERENCE

[0001] The present application is a divisional of U.S. Non-Provisional patent application Ser. No. 18/163,150, entitled "SOLID ELECTROLYTIC CAPACITOR AND METHOD FOR MANUFACTURING SOLID ELECTROLYTIC CAPACITOR WITH IMPROVED ANODE LEAD-OUT WIRE," and filed on Feb. 1, 2023. U.S. Non-Provisional patent application Ser. No. 18/163,150 claims priority to Japanese patent application No. 2022-26354, filed on Feb. 24, 2022. The entire contents of the above-listed applications are hereby incorporated by reference for all purposes.

BACKGROUND

[0002] The present disclosure relates to a solid electrolytic capacitor and a method for manufacturing the solid electrolytic capacitor.

[0003] In recent years, solid electrolytic capacitors have been widely used in various fields such as the field of electronic apparatuses. Japanese Unexamined Patent Application Publication No. 2004-7105 discloses a technique regarding a noise filter including a tantalum fine wire, a capacitance forming portion provided around the tantalum fine wire, and a conductor layer provided around the capacitance forming portion.

SUMMARY

[0004] The noise filter (a solid electrolytic capacitor) disclosed in Japanese Unexamined Patent Application Publication No. 2004-7105 includes a tantalum fine wire (an anode lead-out wire) having a cylindrical structure (i.e., a circular cross-sectional shape). However, the anode lead-out wire having a cylindrical structure may cause a welding failure to occur when the anode lead-out wire and a lead frame are welded together. Further, when the anode lead-out wire is thinned while its cylindrical structure is maintained or flattened in such a way that the anode lead-out wire has a flat cross section in order to reduce the thickness of the solid electrolytic capacitor, the anode lead-out wire may be bent when the anode lead-out wire is inserted into anode body powder, which causes a problem that manufacturing yield is degraded.

[0005] In view of the aforementioned problem, an object of the present disclosure is to provide a solid electrolytic capacitor capable of improving manufacturing yield and a method for manufacturing the solid electrolytic capacitor.

[0006] A solid electrolytic capacitor according to one aspect of the present disclosure includes: an anode lead-out wire; and a capacitor element in which the anode lead-out wire is embedded, in which a cross section of at least a part of the anode lead-out wire in a direction in which the anode lead-out wire is extended has a flat shape, and a recess provided in a central part, a first linear part that is extended outward from one side of the recess, and a second linear part that is extended outward from another side of the recess are formed in at least one of an upper surface and a lower surface of the anode lead-out wire having the flat shape.

[0007] A method for manufacturing a solid electrolytic capacitor according to one aspect of the present disclosure includes: a first process of forming a wire having a substantially circular cross section by holding the wire by first and second rollers that are disposed so as to be opposed to each other, thereby forming an anode lead-out wire having a flat cross section; and a second process of forming a capacitor element in which the anode lead-out wire is embedded. A protrusion provided in a central part, a third linear part that is extended outward from one side of the protrusion, and a fourth linear part that is extended outward from another side of the protrusion are provided in at least one of the first and second rollers. In at least one of an upper surface and a lower surface of the anode lead-out wire formed in the first process, a recess is formed in a central part, and a first linear part that is extended outward from one side of the recess is formed in one side of the recess and a second linear part that is extended outward from another side of the recess is formed in another side of the recess.

[0008] According to the present disclosure, it is possible to provide a solid electrolytic capacitor capable of improving manufacturing yield, and a method for manufacturing the solid electrolytic capacitor.

[0009] The above and other objects, features and advantages of the present disclosure will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not to be considered as limiting the present disclosure.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. **1** is a side view showing one example of a solid electrolytic capacitor according to an embodiment;

[0011] FIG. **2** is a partial cross-sectional view of a central part taken along the cutting line II-II of FIG. **1**;

[0012] FIG. **3** is a cross-sectional view of a capacitor element part of the solid electrolytic capacitor according to the embodiment;

[0013] FIG. **4** is a cross-sectional view showing a configuration example of an anode lead-out wire included in the solid electrolytic capacitor according to the embodiment;

[0014] FIG. **5** is a cross-sectional view for describing an effect of the present disclosure;

[0015] FIG. **6** is a cross-sectional view for describing an effect of the present disclosure;

[0016] FIG. **7** is a cross-sectional view for describing a method for manufacturing the anode lead-out wire according to the embodiment; and

[0017] FIG. **8** is a cross-sectional view for describing a method for manufacturing the anode lead-out wire according to related art.

DESCRIPTION OF EMBODIMENTS

[0018] Embodiments according to the present disclosure will be described hereinafter with reference to the drawings.

[0019] FIG. **1** is a side view showing one example of a solid electrolytic capacitor according to this embodiment. As shown in FIG. **1**, a solid electrolytic capacitor **1** according to this embodiment includes a capacitor element **10** and an anode lead-out wire **11**.

[0020] A part of the anode lead-out wire **11** is embedded in the capacitor element **10** and a part of the anode lead-out wire **11** that is exposed from the capacitor element **10** is connected to an anode lead frame **50**. Specifically, the anode lead frame **50** includes a pedestal part **51** that is extended in a horizontal direction (an x-axis direction) and an erected part **53** that is erected in a vertical direction (a z-axis direction) from the pedestal part **51**. Then, the anode lead-out wire **11** is connected to the top surface of the erected part **53**, whereby the anode lead-out wire **11** and the anode lead frame **50** are electrically connected to each other. For example, the anode lead-out wire **11** is connected to the erected part **53** by welding **54**. The pedestal part **51** is connected to a substrate (not shown). In some examples, the anode lead-out wire **11** penetrates the capacitor element **10**, and the anode lead-out wire forms a first anode lead-out wire **11***a* in one side of the anode lead-out wire exposed from the capacitor element **10** and forms a second anode lead-out wire **11***b* in another side thereof. Further, the first anode lead-out wire **11***a* may be welded to a first anode lead frame **50** erected from a substrate, and the second anode lead-out wire **11***b* may be welded **57** to a second anode lead frame **58** erected from the substrate.

[0021] A cathode body **15** (see FIG. **2**) of the capacitor element **10** is electrically connected to a cathode terminal **52** on a lower surface side (a negative side in the z-axis direction) of the capacitor element **10**. For example, the cathode body **15** is connected to the cathode terminal **52** using a conductive adhesive. The cathode terminal **52** is connected to a substrate (not shown).

[0022] The configuration example in FIG. **1** shows a configuration in which the anode lead-out wire **11** is embedded in the capacitor element **10** and the anode lead-out wire **11** is exposed from one side of the capacitor element **10** (two-terminal structure). However, in this embodiment, a configuration in which the anode lead-out wire **11** penetrates the capacitor element **10** and the anode lead-out wire **11** is exposed from both sides of the capacitor element **10** (three-terminal structure) may instead be employed.

[0023] FIG. **2** is a cross-sectional view for describing an internal structure of the capacitor element **10** and is a partial cross-sectional view of the central part taken along the cutting line II-II of FIG. **1**. As shown in FIG. **2**, the capacitor element **10** includes an anode body **12**, a dielectric layer **13**, a solid electrolyte layer **14**, and a cathode body **15**. The capacitor element **10** has a central part where the anode lead-out wire **11** is disposed.

[0024] The anode lead-out wire **11** is formed of, for example, metallic tantalum (Ta). The details of the anode lead-out wire **11** will be described later.

[0025] The anode body **12** covers the periphery of the anode lead-out wire **11** (covers a part of the anode lead-out wire **11** other than the part of the anode lead-out wire **11** exposed from the capacitor element **10**). The anode body **12** may be formed using metallic tantalum (Ta), which is a valve metal. The anode body **12** may be formed, for example, by inserting the anode lead-out wire **11** into a metallic tantalum powder (the anode body **12**) and then sintering it.

[0026] The dielectric layer **13** is formed on a surface of the anode body **12**. For example, the dielectric layer **13** can be formed by anodizing the surface of the anode body **12**. For example, when tantalum is used for the anode body **12**, a tantalum oxide film (the dielectric layer **13**) can be formed on the surface of the anode body **12** by anodizing the anode body **12**. For example, the thickness of the dielectric layer **13** can be appropriately adjusted by a voltage of the anodization.

[0027] The solid electrolyte layer **14** is formed on a surface of the dielectric layer **13**. For example, the solid electrolyte layer **14** can be formed using a conductive polymer. In order to form the solid electrolyte layer **14**, for example, chemical oxidation polymerization or electrolytic polymerization may be used. Alternatively, the solid electrolyte layer **14** may be formed by coating or impregnating a workpiece with a conductive polymer solution and drying it.

[0028] The solid electrolyte layer **14** may include, for example, a polymer composed of a monomer including at least one kind of pyrrole, thiophene, aniline, and derivative thereof. In addition, a sulfonic acid-based compound may be included as a dopant. In addition to the above conductive polymer, the solid electrolyte layer **14** may include an oxide material such as manganese dioxide and ruthenium oxide, and an organic semiconductor such as TCNQ (7,7,8,8-tetracyanoquinodimethane complex salt).

[0029] The cathode body **15** is formed on a surface of the solid electrolyte layer **14**. For example, the cathode body **15** may be formed of a graphite layer formed on the surface of the solid electrolyte layer **14** and a silver paste layer formed on the surface of the graphite layer. The cathode body **15** is connected to the cathode terminal **52** using a conductive adhesive on the lower surface side of the capacitor element **10** (the negative side in the z-axis direction).

[0030] FIG. **3** is a cross-sectional view of the capacitor element part of the solid electrolytic capacitor according to this embodiment, and is a cross-sectional view for describing the cross-sectional shape of the capacitor element **10** and the anode lead-out wire **11**. In FIG. **3**, the cathode terminal **52** is not shown.

[0031] As shown in FIG. **3**, the anode lead-out wire **11** is embedded in the capacitor element **10**. In this embodiment, the shape of the cross section of the capacitor element **10** (the cross section of the capacitor element **10** taken along the yz-plane) is a rectangular shape in which the longitudinal direction is extended in the horizontal direction (a y-axis direction). For example, the height of the capacitor element **10** (the length thereof in the z-axis direction) is preferably 2.0 mm or smaller. Further, in the solid electrolytic capacitor according to this embodiment, the capacitor element **10** may be encased in an exterior resin **16**. In this case, the height of the solid electrolytic capacitor including the exterior resin **16** is preferably 3.0 mm or smaller.

[0032] The shape of the cross section of the anode lead-out wire **11** that is vertical to the direction in which the anode lead-out wire **11** is extended (the x-axis direction) is flat. Further, a recess **21***a* provided in the central part, a first linear part **22***a* that is extended outward (a negative side in the y-axis direction) from one side of the recess **21***a*, and a second linear part **23***a* that is extended outward (a positive side in the y-axis direction) from the other side of the recess **21***a* are formed on the upper surface of the anode lead-out wire **11**. Likewise, a recess **21***b* provided in the central part, a first linear part **22***b* that is extended outward (the negative side in the y-axis direction) from one side of the recess **21***b*, and a second linear part **23***b* that is extended outward (the positive side in the y-axis direction) from the other side of the recess **21***b* are formed on the lower surface of the anode lead-out wire **11**. Further, both side parts of the anode lead-out wire **11** (both end parts in the y-axis direction) held between the upper surface and the lower surface of the anode lead-out wire **11** respectively include curved shapes **24** and

25 that bulge outward. In the following description, the recesses **21**a and **21**b may be collectively referred to as a recess **21**. The same holds true for the other components.

[0033] In the configuration example shown in FIG. **3**, a configuration in which the cross-sectional shape of the recesses **21**a and **21**b is a curved shape is shown. Alternatively, in this embodiment, the cross-sectional shape of the recesses **21**a and **21**b may be a shape other than the curved shape and is not particularly limited as long as it has a shape that is gradually deepened toward the central part of the recesses **21**a and **21**b. The cross-sectional shape of the recesses **21**a and **21**b may be a trapezoidal shape or a V shape. By making the cross-sectional shape of the recesses **21**a and **21**b have the shape of this kind, flowability of the anode body powder on the surface of the recesses **21**a and **21**b can be improved when the anode lead-out wire **11** is inserted into the anode body powder.

[0034] As shown in FIG. **4**, in this embodiment, when the distance between one side of the recess **21** of the anode lead-out wire **11** and the other side of the recess **21** thereof is denoted by A and the distance between the outer edge part of the first linear part **22** and the outer edge part of the second linear part **23** is denoted by B, the value of A/B may be 0.05 or larger and 0.95 or smaller, and preferably 0.1 or larger and 0.9 or smaller. More preferably, when the strength of the anode lead-out wire **11** itself is taken into account, in particular, the value of A/B is 0.2 or larger and 0.5 or smaller.

[0035] Further, in this embodiment, when the thickness of the anode lead-out wire **11** is denoted by C and the distance between the bottom of the recess **21**a on the upper surface and the bottom of the recess **21**b on the lower surface is denoted by D, the value of D/C may be 0.05 or larger and 0.95 or smaller, preferably 0.1 or larger and 0.9 or smaller. More preferably, when the strength of the anode lead-out wire **11** itself is taken into account, in particular, the value of D/C is 0.5 or larger and 0.8 or smaller.

[0036] In this embodiment, in both of the part of the anode lead-out wire **11** embedded in the capacitor element **10** and the part of the anode lead-out wire **11** that is exposed from the capacitor element **10**, the cross-sectional shape of the anode lead-out wire **11** may be the shape as shown in FIG. **4** (a shape including the recess **21**, the first linear part **22**, and the second linear part **23**).

[0037] Further, in this embodiment, in at least a part of the direction in which the anode lead-out wire **11** is extended (the x-axis direction), the cross-sectional shape of the anode lead-out wire **11** may be a shape as shown in FIG. **4** (a shape including the recess **21**, the first linear part **22**, and the second linear part **23**). Specifically, in a part of the anode lead-out wire **11** embedded in the capacitor element **10**, the cross-sectional shape of the anode lead-out wire **11** may be a shape as shown in FIG. **4**. In the other part of the anode lead-out wire **11**, the cross-sectional shape of the anode lead-out wire **11** may be another shape . . . . Further, in a part of the anode lead-out wire **11** that is exposed from the capacitor element **10**, the cross-sectional shape of the anode lead-out wire **11** may be a shape as shown in FIG. **4**. In the other part of the anode lead-out wire **11**, the cross-sectional shape of the anode lead-out wire **11** may be another shape.

[0038] In the configuration example shown in FIGS. **3** and **4**, a configuration in which the recesses **21**a and **21**b, the first linear parts **22**a and **22**b, and the second linear parts **23**a and **23**b are provided in both the upper surface and the lower surface of the anode lead-out wire **11** is shown. Alternatively, in this embodiment, the recess **21**, the first linear part **22**, and the second linear part **23** may be provided in only one of the upper surface and the lower surface of the anode lead-out wire **11**. In this case, the recess **21**, the first linear part **22**, and the second linear part **23** are preferably provided on a surface of the anode lead-out wire **11** where the anode lead-out wire **11** contacts the anode lead frame **50** (the erected part **53**).

[0039] As described above, in this embodiment, the cross-sectional shape of the anode lead-out wire **11** of the solid electrolytic capacitor is a flat shape. Then the recess **21**, the first linear part **22** that is extended outward from one side of the recess **21**, and the second linear part **23** that is extended outward from the other side of the recess **21** are formed in at least one of the upper surface and the lower surface of the anode lead-out wire **11**.

[0040] In this embodiment, the shape of the anode lead-out wire **11** is the one described above, whereby it is possible to prevent a welding failure from occurring when the anode lead-out wire is welded to the lead frame. It is also possible to prevent the anode lead-out wire from being bent when the anode lead-out wire is inserted into the anode body powder. Therefore, with the invention according to this embodiment, it is possible to provide a solid electrolytic capacitor capable of improving manufacturing yield, and a method for manufacturing the solid electrolytic capacitor.

[0041] FIGS. **5** and **6** are cross-sectional views for explaining effects of the present disclosure. As shown in the left view of FIG. **5**, in a solid electrolytic capacitor **101** according to a comparative example, an anode lead-out wire **111** has a cylindrical structure, that is, a cross-sectional shape of the anode lead-out wire **111** is circular. Thus, a contact part **155** where an erected part **153** erected from a pedestal part **151** (anode lead frame) contacts the anode lead-out wire **111** is a point, and thus the solid electrolytic capacitor **101** becomes unstable. Therefore, when a cathode body is adhered to a cathode terminal using a conductive adhesive, there is a case where the solid electrolytic capacitor **101** is inclined, which causes an adhesion failure, or a case in which a capacitor element is exposed from an exterior resin, which causes an exposure failure.

[0042] On the other hand, in the solid electrolytic capacitor **1** according to this embodiment, as shown in the right view of FIG. **5**, the anode lead-out wire **11** includes the first linear part **22** and the second linear part **23**. Thus, contact parts **55** and **56** where the erected part **53** contacts the anode lead-out wire **11** are linear, and thus the solid electrolytic capacitor **1** is stable. It is therefore possible to reduce occurrence of an adhesion failure or an exposure failure.

[0043] Further, as shown in the left view of FIG. **5**, in the solid electrolytic capacitor **101** according to the comparative example, the contact part **155** where the erected part **153** contacts the anode lead-out wire **111** is a point, and thus the electrical connection is made at this point. This causes a problem that the connection resistance between the anode lead-out wire **111** and the erected part **153** is increased.

[0044] On the other hand, in the solid electrolytic capacitor **1** according to this embodiment, as shown in the right view of FIG. **5**, the anode lead-out wire **11** includes the first linear part **22** and the second linear part **23**. Therefore, the contact parts **55** and **56** where the erected part **53** contacts the anode lead-out wire **11** are linear, and thus the connection is a surface contact. It is therefore possible to decrease the connection resistance between the anode lead-out wire **11** and the erected part **53**.

[0045] Further, as shown in a solid electrolytic capacitor **102** according to a comparative example in the left view of FIG. **6**, when an anode lead-out wire **111** is formed to have a flat shape and an anode lead-out wire **111** and an erected part **153** contact each other at two contact parts **157** and **158**, a spark may be generated at the time of welding (a spark may be generated in the configuration shown in FIG. **5** as well).

[0046] On the other hand, in the solid electrolytic capacitor **1** according to this embodiment, the anode lead-out wire **11** is welded to the erected part **53** in a state in which the first linear part **22** and the second linear part **23** of the anode lead-out wire **11** contact the erected part **53** (anode lead frame). That is, the anode lead-out wire **11** is welded in the state in which the erected part **53** and the anode lead-out wire **11** are in surface contact each other, whereby it is possible to prevent a spark from being generated at the time of welding.

[0047] When, for example, the value of A/B of the anode lead-out wire **11** according to this embodiment was set to be 0.1 or larger and 0.9 or smaller and the value of D/C thereof was set to be 0.1 or larger and 0.9 or smaller (see FIG. **4**), the spark generation percentage when the anode lead-out wire **11** was welded to the erected part **53** was 0% (0% in 20 samples). On the other hand, when the anode lead-out wire **111** shown in the left view of FIG. **6** was used, the spark generation percentage when the anode lead-out wire **111** was welded to the erected part **153** was 50% (50% in 20 samples).

[0048] Further, in a case in which the anode lead-out wire **111** is made to have a cylindrical structure (i.e., the cross-sectional shape thereof is circular), like in the solid electrolytic capacitor **101** according to the comparative example shown in FIG. **5**, when the diameter of the anode lead-out wire **111** is decreased in order to make the solid electrolytic capacitor thin, there is a case in which the anode lead-out wire **111** is bent when the anode lead-out wire **111** is inserted into the anode body powder. Further, in a case in which the cross-sectional shape of the anode lead-out wire is a simple flat shape, the anode lead-out wire tends to be bent. In this case, there is a case in which the anode lead-out wire **111** is bent when the anode lead-out wire is inserted into the anode body powder. On the other hand, in the solid electrolytic capacitor **1** according to this embodiment, the recess **21** is provided in at least one of the upper surface and the lower surface of the anode lead-out wire **11**, whereby the strength against bending of the anode lead-out wire **11** can be increased. It is therefore possible to prevent the anode lead-out wire **11** from being bent when the anode lead-out wire **11** is inserted into the anode body powder.

[0049] When, for example, the value of A/B of the anode lead-out wire **11** according to this embodiment was set to be 0.1 or larger and 0.9 or smaller and the value of D/C thereof was set to be 0.1 or larger and 0.9 or smaller (see FIG. **4**), the percentage that bending has occurred when the anode lead-out wire **11** was inserted into the anode body powder was 0% (0% in 100 samples). On the other hand, when the same demonstration has been conducted using a flat anode lead-out wire without the recess **21**, the percentage that bending has occurred when the anode lead-out wire is inserted into the anode body powder was 20% (20% in 100 samples).

[0050] Further, in the solid electrolytic capacitor **1** according to this embodiment, the recess **21** is provided in at least one of the upper surface and the lower surface of the anode lead-out wire **11**. Therefore, when the anode lead-out wire **11** is inserted into the anode body powder, a part of the anode body powder can be made to flow along the shape of the recess **21**. In this manner, by causing the anode body powder to flow in the vicinity of the surface of the anode lead-out wire **11**, it is possible to prevent the density of the anode body powder from being high. Therefore, an oxidant solution, a monomer liquid, and a conductive polymer solution are easily soaked into the anode body. Accordingly, the solid electrolyte **14** formed by polymerization reaction can be formed uniformly, whereby it is possible to prevent the ESR value from being increased.

[0051] For example, the equivalent series resistance (ESR) of the solid electrolytic capacitor according to this embodiment at an operation frequency of 100 kHz was 20 mΩ or smaller. Meanwhile, in the solid electrolytic capacitor using the anode lead-out wire having a flat shape where the recess **21** is not provided, the ESR at an operation frequency of 100 kHz was 30 mΩ, which is 1.5 times larger than that in this embodiment.

[0052] Next, a method for manufacturing the solid electrolytic capacitor according to this embodiment will be described.

[0053] When the solid electrolytic capacitor according to this embodiment is manufactured, first, an anode lead-out wire **11** having a flat cross section (the shape as shown in FIG. **4**) is formed. Then, a capacitor element **10** in which the anode lead-out wire **11** is embedded is formed. Specifically, after the anode lead-out wire **11** is inserted into an anode body powder (tantalum powder), it is sintered, whereby an anode body **12** (see FIG. **2**) is formed. After that, a dielectric layer **13** is electrochemically formed on a surface of the anode body **12**. The dielectric layer **13** may be formed, for example, by anodizing the surface of the anode body **12**.

[0054] After that, a solid electrolyte layer **14** is formed on a surface of the dielectric layer **13**. For example, the solid electrolyte layer **14** may be formed using a conductive polymer. In order to form the solid electrolyte layer **14**, for example, chemical oxidative polymerization, electrolytic polymerization or the like may be used. Alternatively, the solid electrolyte layer **14** may be formed by coating or impregnating a workpiece with a conductive polymer solution and drying it. Next, a cathode body **15** is formed on a surface of the solid electrolyte layer **14**. Then, the cathode body **15** is connected to a cathode terminal **52** using a conductive adhesive.

[0055] Next, a method for manufacturing the anode lead-out wire according to this embodiment will be described. FIG. **7** is a cross-sectional view for describing the method for manufacturing the anode lead-out wire according to this embodiment. The anode lead-out wire **11** according to this embodiment is manufactured by sending a wire **30**, which is a raw material of the anode lead-out wire **11**, in the x-axis direction while flattening the upper and lower surfaces of the wire **30**, by two rollers **40**. In FIG. **7**, a lower roller is not shown.

[0056] In this embodiment, a protrusion **41**, a third linear part **42** that is extended outward from one side of the protrusion **41**, and a fourth linear part **43** that is extended outward from the other side of the protrusion **41** are provided on a surface of the roller **40**. The roller **40** is rotated about a rotation axis **45**. By flattening the upper and lower surfaces of the wire **30** by the two rollers **40** having the aforementioned shape, the anode lead-out wire **11** as shown in FIG. **4** may be formed.

[0057] That is, the protrusion **41** of the roller **40** forms the recess **21** of the anode lead-out wire **11**, the third linear part **42** of the roller **40** forms the first linear part **22** of the anode lead-out wire **11**, and the fourth linear part **43** of the roller **40** forms the second linear part **23** of the anode lead-out wire **11**.

[0058] In this embodiment, the third linear part **42** and the fourth linear part **43** are provided on the both respective sides of the protrusion **41** of the surface of the roller **40**. It is therefore possible to prevent the position of the wire **30** from being deviated with respect to the roller **40** when the anode lead-out wire **11** is manufactured by flattening the upper and lower surfaces of the wire **30** by the two rollers **40**.

[0059] In the configuration example in FIG. **7**, a configuration example in which the cross-sectional shape of the protrusion **41** is a curved shape is shown. However, in this embodiment, the cross-sectional shape of the protrusion **41** may be a shape other than the curved shape and is not particularly limited as long as it has a shape that it is gradually elevated toward the central part of the protrusion **41**.

[0060] FIG. **8** is a cross-sectional view for describing a method for manufacturing the anode lead-out wire according to related art. In the related art, only a protrusion **141** having a curved shape is provided on a surface of a roller **140**. The roller **140** is rotated about a rotation axis **145**. In FIG. **8** as well, a lower roller is not shown.

[0061] In the related art shown in FIG. **8**, when an anode lead-out wire **111** is formed by flattening upper and lower surfaces of a wire **130** by the two rollers **140**, the wire **130** may be deviated to the right or left (the y-axis direction) (see the arrow in FIG. **8**). Therefore, as shown in the lower view of FIG. **8**, there is a case in which the position of a recess **121** formed in the formed anode lead-out wire **111** is deviated from the central part.

[0062] On the other hand, in this embodiment, as shown in FIG. **7**, the third linear part **42** and the fourth linear part **43** are provided on the both respective sides of the protrusion **41** of the surface of the roller **40**. Therefore, when the anode lead-out wire **11** is manufactured by flattening the upper and lower surfaces of the wire **30** by the two rollers **40**, the position of the wire **30** may be prevented from being deviated with respect to the roller **40**. It is therefore possible to prevent the position of the recess **21** formed in the anode lead-out wire **11** from being deviated from the central part.

[0063] In this embodiment, the protrusion **41**, the third linear part **42**, and the fourth linear part **43** may be provided in at least one of the upper and lower rollers **40**. That is, when the recess **21**, the first linear part **22**, and the second linear part **23** are formed in only one of the anode lead-out wire **11**, the protrusion **41**, the third linear part **42**, and the fourth linear part **43** are provided in only one of the two rollers **40**.

[0064] From the disclosure thus described, it will be obvious that the embodiments of the disclosure may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the disclosure, and all such modifications as would be obvious to one skilled in the art are intended for inclusion within the scope of the following claims.

What is claimed is:

1. A method for manufacturing a solid electrolytic capacitor comprising:

a first process of forming a wire having a substantially circular cross section by holding the wire by first and second rollers that are disposed so as to be opposed to each other, thereby forming an anode lead-out wire having a flat cross section; and

a second process of forming a capacitor element in which the anode lead-out wire is embedded, wherein:

a protrusion provided in a central part, a third linear part that is extended outward from one side of the protrusion, and a fourth linear part that is extended outward from another side of the protrusion are provided in at least one of the first and second rollers, and

in at least one of an upper surface and a lower surface of the anode lead-out wire formed in the first process, a recess is formed in a central part, and a first linear part that is extended outward from one side of the recess is formed in one side of the recess and a second linear part that is extended outward from another side of the recess is formed in another side of the recess.

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