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(54) Method of using an alloy type thermal fuse, and alloy type thermal fuse

(57) An In-Sn alloy of 85 to 52% In provides advantages that dispersion of an operating temperature can be sufficiently eliminated, and that a high yield can be ensured by adequate ductility, but has a defect which is fatal to a DC fuse, or in which troubles due to long-term DC application such as long-term DC application breakage occurs. In view of this fact, when an alloy type thermal fuse in which an In-Sn alloy is used as a fuse element is used under DC application, stability under long-term DC application that is a condition severer than that under AC application is imposed on the alloy type thermal fuse, whereby the fuse can be rationally used. An AC electronic/electrical appliance is protected against overheating by an AC-only alloy type thermal fuse in which a fuse element is made of an In-Sn alloy, and which has a predetermined operating temperature, and a DC electronic/electrical appliance is protected against overheating of a same temperature by a DC alloy type thermal fuse in which the alloy composition of a fuse element is different from that of the AC-only alloy type thermal fuse.

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Description

Background of the Invention

1. Field of the Invention

[0001] The present invention relates to a method of, in the case where an alloy type thermal fuse in which an In-Sn alloy is used as a fuse element is used under DC application, rationally using the alloy type thermal fuse while imposing a condition of stability under long-term DC application which is severer than that under AC application.

2. Description of Related Art

[0002] In an alloy type thermal fuse, a fusible alloy having a predetermined melting point is used as a fuse element, and a flux is applied to the fuse element. Such an alloy type thermal fuse is disposed so as to be thermally contacted with an electronic/electrical appliance. The fuse element is melted by heat generation due to abnormality of the electronic/electrical appliance, and the molten alloy is divided and spheroidized because of the surface tension under the coexistence with the molten flux. When the temperature of the appliance is lowered as a result of the division and spheroidization, the divided molten alloys are solidified, whereby interruption of the power application is completed.

[0003] Recently, the use of lead-free materials is being advanced in electronic/electrical appliances. In the case where an electronic/electrical appliance contains lead, when the appliance is scrapped, lead leaks out of the scrap to adversely affect the ecological system. Therefore, the use of, for example, lead-free solder is being advanced.

[0004] Also in alloy type thermal fuses, the use of a lead-free fuse element is being advanced.

[0005] The operating temperatures of alloy type thermal fuses which are widely used belong to a range of 120 to 150°C.

[0006] Conventionally, it is proposed that an In-Sn alloy is used as a lead-free fuse element of an alloy type thermal fuse having an operating temperature of 120 to 150°C (for example, see Document Nos. 1, 2 and 3).

[0007] [Document No. 1] Japanese Patent Application Laying-Open No. 11-25829

[0008] [Document No. 2] Japanese Patent Application Laying-Open No. 2002-25402

[0009] [Document No. 2] Japanese Patent Application Laying-Open No. 2003-13167

[0010] Fig. 1 is a temperature phase diagram of an In-Sn alloy. In the range of 85 to 52% In (15 to 48% Sn), the solidus temperature is in a range of about 120 to 150°C, the solid-liquid coexisting width between β phase of a solid solution and L phase of a melt is very narrow or 3 to 4°C, and hence it is expected that dispersion of the operating temperature can be reduced.

[0011] According to results of intensive studies by the inventors on an alloy type thermal fuse in which an In-Sn alloy is used as a fuse element, however, it was unexpectedly found that, when a DC current is applied to the fuse for a long term, a trouble due to the long-term DC application occurs, or for example a shear fracture of the fuse element occurs at a temperature which is lower than the melting point of the fuse element. It was ascertained that this phenomenon does not occur under AC application, and is inherent in DC application.

[0012] An example of such long-term DC application breakage will be described. A wire member of a diameter of 500 μmϕ was obtained by drawing an In-Sn alloy of 74% In and 26% Sn. Cylindrical thermal fuses (50 fuses) in which the wire member is used as a fuse element were placed in a thermostatic bath of a temperature which is lower than the operating temperature by 35°C. A DC current of 5 A was supplied to the fuses for 3,000 hours. As a result, although the fuse elements were lower than the melting point and in a solid state, a shear fracture at a middle of each fuse element occurred in about 50% of the specimens.

[0013] By contrast, when an AC current (having a peak value of $\sqrt{2} \times 5$ A) in which the RMS value is equal to the value of the DC current was applied for 3,000 hours, no abnormality was observed.

[0014] In Fig. 1, phase transformation from (γ + β) mixed phase to β phase occurs along the curve ab in the range of 85 to 52% In. However, it was ascertained that no breakage occurs in a temperature rise from the ordinary temperature at a timing before DC application to 100°C. It is apparent that the above-mentioned long-term DC application breakage is not based on such phase transformation.

[0015] When a current flows through a conductor, a circumferential magnetic field is produced so that a force of attracting the current toward the center of the conductor acts between the circumferential magnetic field and the conductor current. Although remaining a matter of speculation, the cause of the long-term DC application breakage of a fuse element is supposed that the DC application causes the whole length of the fuse element to be subjected to a central compressive force by the function of the electromagnetic force, an axial compression stress due to the Poisson's ratio therefore acts on the fuse element, and the fuse element of an In-Sn alloy which is soft because of the large amount of In is broken by shear in a plane where a shear stress due to the axial compressive force acts.

[0016] As a reason that the shear breakage is caused under DC application but not under AC application, the following breakage mechanism can be assumed. Under AC application, when the angular frequency is indicated by o, the shear stress in the inclined plane is an alternating force having a frequency of 2ω. During a period when the alternating stress becomes zero, strains between crystals are restored. By contrast, under DC application, there is no frequency and no alternate restoring force, and therefore strains between crystals are accumulated. Finally, the fuse element is broken by shear.

[0017] For example, a thermoprotector is used in a protection circuit of a battery pack to protect the circuit against abnormal heat generation in an FET, or in an AC adapter to prevent overheating of transistors, coils, and a transformer from occurring. In such a case, a thermoprotector is requested to have an operating temperature of 120 to 150°C.

[0018] Although an alloy type thermal fuse in which an In-Sn alloy is used as a fuse element satisfies the operating temperature condition of a thermoprotector, such an alloy type thermal fuse is hardly used as a thermoprotector because of the above-mentioned troubles due to long-term DC application such as the destructiveness caused by long-term DC application.

[0019] By contrast, alloy type thermal fuses in which an In-Sn alloy of 85 to 52% In is used as a fuse element show a narrow dispersion range of the operating temperature, and have adequate ductility, so that breakage during a drawing process can be eliminated and a high yield can be ensured. Therefore, such an alloy type thermal fuse is very useful as a thermoprotector for an AC electronic/electrical appliance. The term of an AC electronic/electrical appliance means an appliance in which an AC current flows through an alloy type thermal fuse for protecting the appliance, and that of a DC electronic/electrical appliance means an appliance in which a DC current flows through an alloy type thermal fuse for protecting the appliance.

Summary of the Invention

[0020] An In-Sn alloy of 85 to 52% In provides the advantages that dispersion of an operating temperature can be sufficiently eliminated, and that a high yield can be ensured by adequate ductility, but has a defect which is fatal to a DC fuse, or in which troubles due to long-term DC application such as long-term DC application breakage occur. In view of this fact, it is an object of the invention to rationally use an alloy type thermal fuse in which an In-Sn alloy is used as a fuse element, and on which, when the fuse is used under DC application, stability under long-term DC application that is a condition severer than that under AC application is imposed.

[0021] The method of using an alloy type thermal fuse according to the invention is characterized in that an AC electronic/electrical appliance is protected against overheating by an AC-only alloy type thermal fuse in which a fuse element is made of an In-Sn alloy of (In% + Sn%) > 93.4% and In% > 48.5%, and which has an operating temperature of 120 to 150°C, and a DC electronic/electrical appliance is protected against overheating of a same temperature by a DC alloy type thermal fuse in which an alloy composition of a fuse element is different from an alloy composition of the AC-only alloy type thermal fuse.

[0022] The method of using an alloy type thermal fuse according to the invention is characterized in that, in the above method, the fuse element of the DC alloy type thermal fuse has an alloy composition in which 20% ≦ Bi ≦ 56.5%, 43% < Sn ≦ 70%, and 0.5% ≦ In ≦ 10%.

[0023] The method of using an alloy type thermal fuse according to the invention is characterized in that, in the above method, the fuse element of the DC alloy type thermal fuse has an alloy composition in which 20% ≦ Bi ≦ 56.5%, 43% < Sn ≦ 70%, and 0.5% ≦ In ≦ 10%, and 0.01 to 7 weight parts of at least one selected from the group consisting of Ag, Au, Cu, Ni, Pd, Pt, Sb, Ga, Ge, and P are added to 100 weight parts of Bi + Sn + In in the alloy composition.

[0024] The method of using an alloy type thermal fuse according to the invention is characterized in that an AC-only alloy type thermal fuse in which a fuse element is made of an In-Sn alloy of (In% + Sn%) > 93.4% and In% > 48.5%, and which has an operating temperature of 120 to 150°C is used for protecting only an AC electronic/electrical appliance among AC/DC electronic/electrical appliances, against overheating.

[0025] The method of using an alloy type thermal fuse according to the invention is characterized in that, in the above method, the fuse element of the AC-only alloy type thermal fuse has an alloy composition in which 52% ≦ In ≦ 85% and balance Sn.

[0026] The method of using an alloy type thermal fuse according to the invention is characterized in that, in the above method, the fuse element of the AC-only alloy type thermal fuse has an alloy composition in which 52% ≦ In ≦ 85% and balance Sn, and 0.01 to 7 weight parts of at least one selected from the group consisting of Ag, Au, Ni, Pd, Pt, and Sb are added to 100 weight parts of In + Sn in the alloy composition.

[0027] The method of using an alloy type thermal fuse according to the invention is characterized in that, in the above method, a heating element for fusing off the fuse element is additionally disposed on each of the alloy type thermal fuses.

[0028] In the method of using an alloy type thermal fuse according to the invention, an operating temperature of the AC-only alloy type thermal fuse is substantially equal to an operating temperature of the DC alloy type thermal fuse [including cases where the operating temperatures coincide with each other in a range of a tolerance (± values) of the operating temperatures, and where the operating temperatures coincide with each other in a range from +0°C to -7°C of the nominal operating temperature].

[0029] The alloy type thermal fuse according to the invention is an AC-only alloy type thermal fuse which is to be used in the method of using an alloy type thermal fuse, and in which a fuse element is made of an In-Sn alloy, and instructions for AC-use only or inhibition of DC-use are indicated directly or indirectly. In this case, the direct indication can be conducted by, for example, printing on the body of the alloy type thermal fuse, and the indirect indication can be conducted in the form of written description in an instruction manual, specifications, a catalog, or the like.

[0030] Under long-term DC application, an alloy type thermal fuse in which an In-Sn alloy, or particularly a binary In-Sn alloy of 85 to 52% In (15 to 48% Sn) is used as a fuse element is broken because of the application. In view of the fact, an alloy type thermal fuse in which the In-Sn alloy is used as a fuse element is used as an AC-only fuse, or an alloy type thermal fuse in which the In-Sn alloy is used as a fuse element is used as an AC-only fuse, and an alloy type thermal fuse which uses a fuse element having another alloy composition and exhibiting excellent stability under long-term DC application is used as a DC fuse. Therefore, it is possible to use safely and rationally an alloy type thermal fuse in which an In-Sn alloy of 85 to 52% In is used as a fuse element.

[0031] In the case where an alloy type thermal fuse is used as a thermoprotector for a battery pack of a secondary battery used as a power source for a notebook personal computer, a portable telephone, or the like, such as a lithium-ion secondary battery or a lithium polymer secondary battery, or for an AC adapter, the use of an alloy type thermal fuse in which an In-Sn alloy of 85 to 52% In is used is inhibited, and an alloy type thermal fuse which uses a fuse element having another alloy composition and exhibiting excellent stability under long-term DC application is used as a fuse dedicated to the thermoprotector for the battery pack or the AC adapter, whereby the reliability of thermal protection of the notebook personal computer, the portable telephone, or the like can be improved.

[0032] Moreover, an In-Sn alloy of 85 to 52% In has a narrow solid-liquid coexisting width and adequate ductility. Therefore, an alloy type thermal fuse in which the alloy is used as a fuse element has advantages that dispersion of the operating temperature can be reduced to a very low level, and that a wire drawing process can be conducted at a high yield. When the alloy type thermal fuse is used as an AC-only fuse, the fuse can benefit from the advantages.

<u>Brief Description of the Drawings</u>

[0033]

Fig. 1 is a temperature phase diagram of an In-Sn alloy;
Fig. 2 is a view showing an example of the alloy type thermal fuse to be used in the invention;
Fig. 3 is a view showing another example of the alloy type thermal fuse to be used in the invention;
Fig. 4 is a view showing a further example of the alloy type thermal fuse to be used in the invention;
Fig. 5 is a view showing a still further example of the alloy type thermal fuse to be used in the invention; and
Fig. 6 is a view showing a still further example of the alloy type thermal fuse to be used in the invention.

Detailed Description of the Preferred Embodiment

[0034] Fig. 1 is a temperature phase diagram of an In-Sn alloy of a fuse element of an alloy type thermal fuse which is to be used in the invention. In the fuse, the range of 85 to 52% In is used.

[0035] In this range, melting is advanced in the sequence of phase changes of β solid solution → coexisting phase of β solid solution and liquid solution L → liquid solution L, and the fuse element is divided and spheroidized in the coexisting region. Specifically, when the temperature of the fuse element exceeds the solidus temperature, a synergistic effect with the activating action of molten flux causes the coexisting region to wettingly spread over lead conductors and electrodes of the alloy type thermal fuse, and the fuse element is divided while being spheroidized because of the surface tension. Therefore, the operating temperature of the alloy type thermal fuse is a temperature between the solidus and liquidus temperatures. Since the temperature width is as small as about 3°C, dispersion of the operating temperature can be reduced.

[0036] Alloy type thermal fuses which are frequently used have an operating temperature of 120 to 150°C. The range of 85 to 52% In in the In-Sn alloy satisfies the operating temperature.

[0037] A fuse element can be produced by steps of mixing materials, producing a billet, and drawing into a wire. First, Sn and In ingots are weighed so as to attain a predetermined compound ratio, and then charged into a melting furnace. The molten alloy is poured into a mold to produce a billet. The billet is shaped into a stock wire by an extruder, and the stock wire is drawn by a dice to form a wire of a predetermined diameter. The wire is cut into pieces of a predetermined length, thereby obtaining a fuse element.

[0038] In pure In, the ductility is so high that a drawing process is hardly conducted. By contrast, an In-Sn alloy of 85 to 52% In has adequate ductility, and hence can be easily drawn at a high yield into a thin wire of 500 μmϕ or smaller.

[0039] Conventionally, alloy type thermal fuses made of the same alloy are used as both AC and DC fuses with making no distinction therebetween. Examples of the rating of such a fuse are AC 3.5 A × AC 50 V and DC 3.5 A × DC 50 V at an operating temperature of 126 ± 2°C, AC 3 A × AC 50 V and DC 3 A × DC 50 V at an operating temperature of 130 ± 2°C, and AC 4 A × AC 50 V and DC 4 A × DC 50 V at an operating temperature of 145 ± 2°C.

[0040] As described above, however, an alloy type thermal fuse in which an In-Sn alloy of 85 to 52% In is used as a fuse element has problems in the use as both AC and DC fuses because of troubles due to long-term DC application such as long-term DC application breakage.

[0041] As a cause of long-term DC application breakage, as described above, it is assumed that such breakage is produced by an electromagnetic force. This electromagnetic force will be considered.

[0042] When the current density of a fuse element is indicated by i, the magnetic field H in a place of a radius r is given by H = ir/2. When a radial compressive force in the place is indicated by f, the following expression holds:

[Ex. 1]

$$2\pi r f = \int_r^{d/2} H \cdot 2\pi r \Delta r$$

(where d is the outer diameter of the fuse element). Therefore, f is given by:

$$f = [(d/2)^3 - r^3]i^2/(6r).$$

As a result, it is assumed that, as the place is nearer to the center of the fuse element, the compressive force f is larger, and the softness of the fuse element causes creep fracture to occur therein.

[0043] The long-term DC application breakage in a fuse element of an In-Sn alloy of 85 to 52% In is a phenomenon inherent in DC application, and does not occur in AC application as described above. Actually, an AC current having an RMS value that is equal to a DC current which caused long-term DC application breakage was applied to a fuse element. Even after elapse of a time period which is largely longer than the time period of the occurrence of the long-term DC application breakage, no fracture was observed.

[0044] In a fuse element of an In-Sn alloy of 85 to 52% In, long-term DC application breakage is caused by a phenomenon that stress deformation easily occurs in the alloy composition. In a heat cycle in which a large thermal stress change occurs, the sectional area or the length tends to be changed by repetitive stress changes to increase the resistance. When such resistance increase occurs, the temperature of the fuse element is raised by Joule's heat. The temperature rise is indicated by ΔT. Therefore, the alloy type thermal fuse operates before the temperature of the fuse reaches the allowable temperature of the appliance, i.e., at a temperature which is lower than the allowable temperature by the temperature rise ΔT. When the temperature rise ΔT is large, a serious operation error may occur.

[0045] Therefore, it is effective to add 0.01 to 7 weight parts of at least one selected from the group consisting of Ag, Au, Ni, Pd, Pt, and Sb to 100 weight parts of the In-Sn alloy in which 52% ≦ In ≦ 85% and balance Sn. The reason why 0.01 weight parts or more of at least one selected from the group consisting of Ag, Au, Ni, Pd, Pt, and Sb are added is as follows. An intermetallic compound of In or Sn and at least one of Ag, Au, Ni, Pd, Pt, and Sb is produced. Slippage between crystals is caused to hardly occur by the wedge effect due to the intermetallic compound, whereby deformation of the fuse element under the heat cycle is suppressed to reduce the resistance change. The reason of the addition of 7 weight parts or less is as follows. The rise of the liquidus temperature and the increase of the solid-liquid coexisting temperature width become excessive, and dispersion of the operating temperature in the range of 120 to 150°C is hardly reduced.

[0046] The invention may be implemented in the following form. An alloy type thermal fuse that uses a fuse element of an In-Sn alloy of 52% ≦ In ≦ 85% and balance Sn, or that uses a fuse element of an alloy in which 0.01 to 7 weight parts of at least one selected from the group consisting of Ag, Au, Ni, Pd, Pt, and Sb are added to 100 weight parts of the alloy composition is inhibited from being used as a DC fuse, and is used as an AC-only fuse.

[0047] Alternatively, the invention may be implemented in the following form. An alloy type thermal fuse that uses a fuse element of an In-Sn alloy of 52% ≦ In ≦ 85% and balance Sn, or that uses a fuse element of an alloy in which 0.01 to 7 weight parts of at least one selected from the group consisting of Ag, Au, Ni, Pd, Pt, and Sb are added to 100 weight parts of the alloy composition is inhibited from being used as a DC fuse, and is used as an AC-only fuse, and an alloy type thermal fuse using a fuse element having an alloy composition which can satisfactorily eliminate troubles due to long-term DC application such as long-term DC application breakage is used as a DC fuse. Evaluation of the long-term DC application breakage may be conducted by a criterion in which, when a fuse passes a test of an application of DC 5A for 3,000 hours at a temperature which is lower by 35°C than the operating temperature, the fuse is judged acceptable.

[0048] As an alloy which can satisfy the conditions, it is possible to use a composition of 20% ≦ Bi ≦ 56.5%, 43% < Sn ≦ 70%, and 0.5% ≦ In ≦ 10%, or a composition in which 0.01 to 7 weight parts of at least one selected from the group consisting of Ag, Au, Cu, Ni, Pd, Pt, Sb, Ga, Ge, and P are added to 100 weight parts of a composition of 20% ≦ Bi ≦ 56.5%, 43% < Sn ≦ 70%, and 0.5% ≦ In ≦ 10%.

[0049] In the alloy composition, the amount of Sn (43% < Sn ≦ 70%) and that of Bi (20% ≦ Bi ≦ 56.5%) provide ductility which enables the alloy composition to be subjected to a drawing process, and these amounts and the amount of In (0.5% ≦ In ≦ 10%) cause the melting point to include the range of 120 to 150°C. When In enters a mixture of a Bi phase (α phase) and an Sn phase (γ phase) which little allows solid solution of Sn or In, the α phase and an In-Sn intermetallic compound phase which are hard and brittle separate out, and the difference in mechanical characteristics between the phases is increased to impair the workability, so that, as the amount of In is larger, the wire drawing process is more difficult. Therefore, the amount of In is limited to 10% or less.

[0050] The addition of 0.01 to 7 weight parts of at least one selected from the group consisting of Ag, Au, Cu, Ni, Pd, Pt, Sb, Ga, Ge, and P is conducted because the specific resistance of the alloy is reduced, and the crystal structure is miniaturized to reduce the heterophase interface in the alloy, thereby dispersing working strain and stress. When the addition amount is less than 0.01 weight parts, the effects are hardly attained. When the addition amount is larger than 7 weight parts, it is difficult to set the operating temperature of the alloy type thermal fuse to be within the range of 120 to 150°C.

[0051] In the invention, the fuse element can be used with remaining to have a circular section shape obtained as a result of a drawing process, or with being further subjected to a compression process to be flattened. In the case of a round wire, the outer diameter of the fuse element is 200 to 1,050 μmϕ.

[0052] The invention may be implemented in the form of thermal fuses shown in Figs. 2 to 6. Alternatively, the invention may be implemented in the form in which a thermal fuse element is connected in series to a semiconductor device, a capacitor, or a resistor, a flux is applied to the element, the flux-applied fuse element is placed in the vicinity of the semiconductor device, the capacitor, or the resistor, and the fuse element is sealed together with the semiconductor device, the capacitor, or the resistor by means of resin mold, a case, or the like.

[0053] Fig. 2 shows an alloy type thermal fuse of the cylindrical case type. A low-melting fusible alloy piece 2 is connected between a pair of lead wires 1, 1. A flux 3 is applied to the low-melting fusible alloy piece 2. The flux-applied low-melting fusible alloy piece is passed through an insulating tube 4 which is excellent in heat resistance and thermal conductivity, for example, a ceramic tube. Gaps between the ends of the insulating tube 4 and the lead wires 1 are sealingly closed by a cold-setting sealing agent 5 such as an epoxy resin.

[0054] Fig. 3 shows a tape-like alloy type thermal fuse. Strip lead conductors 1, 1 having a thickness of 100 to 200 μm are fixed by an adhesive agent or fusion bonding to a plastic base film 41 having a thickness of 100 to 300 μm. A fuse element 2 having a diameter of 250 to 500 μmϕ is connected between the strip lead conductors. A flux 3 is applied to the fuse element 2. The flux-applied fuse element is sealed by means of fixation of a plastic cover film 42 having a thickness of 100 to 300 μm by an adhesive agent or fusion bonding.

[0055] Fig. 4 shows a fuse of the radial case type. A fuse element 2 is bonded between tip ends of parallel lead conductors 1, 1 by welding. A flux 3 is applied to the fuse element 2. The flux-applied fuse element is enclosed by an insulating case 4 in which one end is opened, for example, a ceramic case. The opening of the insulating case 4 is sealingly closed by a sealing agent 5 such as an epoxy resin.

[0056] Fig. 5 shows a fuse of the substrate type. A pair of film electrodes 1, 1 are formed on an insulating substrate 4 such as a ceramic substrate by printing of conductive paste (for example, silver paste). Lead conductors 11 are connected respectively to the electrodes 1 by welding or the like. A fuse element 2 is bonded between the electrodes 1, 1 by welding. A flux 3 is applied to the fuse element 2. The flux-applied fuse element is covered by a sealing agent 5 such as an epoxy resin.

[0057] Fig. 6 shows a fuse of the radial resin dipping type. A fuse element 2 is bonded between tip ends of parallel lead conductors 1, 1 by welding. A flux 3 is applied to the fuse element 2. The flux-applied fuse element is dipped into a resin solution to seal the element by an insulative sealing agent such as an epoxy resin 5.

[0058] The invention may be implemented in the following form. A heating element is additionally disposed on each of the alloy type thermal fuses, and a film resistor is additionally disposed by, for example, applying and baking resistance paste (e.g., paste of metal oxide powder such as ruthenium oxide). In a normal state, a circuit current is flown through a fuse element formed as a series path of a circuit, and the film resistor is not formed as a part of the circuit or the circuit current is not flown through the film resistor. When a precursor causing abnormal heat generation of an appliance is detected, the film resistor is energized to generate heat in response to a signal indicative of the detection, and the fuse element is fused off by the heat generation, thereby interrupting the circuit current. In this case, the circuit current is flown through the fuse element in a normal state. When the current is a DC current, therefore, the above-mentioned troubles due to long-term DC application such as long-term DC application breakage become problematic. Therefore, the use of the thermal fuse which has the heating element, and in which the fuse element made of the In-Sn alloy is used is inhibited, and the thermal fuse which has the heating element, and which uses the fuse element made of the Bi-Sn-In alloy is used as the fuse element is used.

[0059] As the flux, a flux having a melting point which is lower than that of the fuse element is generally used. For example, useful is a flux containing 90 to 60 weight parts of rosin, 10 to 40 weight parts of stearic acid, and 0 to 3 weight parts of an activating agent. In this case, as the rosin, a natural rosin, a modified rosin (for example, a hydrogenated rosin, an inhomogeneous rosin, or a polymerized rosin), or a purified rosin thereof can be used. As the activating agent, hydrochloride of diethylamine, hydrobromide of diethylamine, an organic acid such as adipic acid can be used.

[0060] In the following example and comparative example, as alloy type thermal fuses, fuses of the cylindrical case type shown in Fig. 2 were used. In each of the fuses, lead conductors are connected to the ends of a fuse element having a diameter of 600 μmϕ and a length of 3.5 mm, a rosin-based flux to which 1 wt.% of adipic acid is added is applied to the fuse element, the flux-applied fuse element is passed through a ceramic tube having an outer diameter of 2.5 mmϕ, a thickness of 0.5 mm, and a length of 9 mm, and gaps between the ends of the ceramic tube and the lead conductors are sealingly closed by a cold-setting epoxy resin.

[0061] The operating temperature of the alloy type thermal fuse element was measured in the following manner. Fifty specimens were used. The specimens were immersed into an oil bath in which the temperature was raised at a rate of 1°C/min., while supplying a current of 0.1 A to the specimens, and the temperature of the oil when the current supply was interrupted by blowing-out was measured.

[0062] The long-term DC application aging was evaluated in the following manner. Fifty specimens were used. The specimens were placed in a thermostatic bath in which the temperature is lower than the operating temperature by 35°C. A DC current of 5 A was applied to the specimens. After the application, the presence or absence of breakage of the fuse element, or a failure due to the long-term DC application was checked by an X-ray observation apparatus. The case where breakage does not occur in all of the specimens was judged acceptable.

[0063] The operating temperature after the long-term DC application aging test was measured in the following manner. The specimens were immersed into an oil bath in which the temperature was raised at a rate of 1°C/min., while supplying a current of 0.1 A to the specimens. The temperature of the oil when the current supply was interrupted by blowing-out was measured.

[0064] In order to ascertain that breakage due to long-term DC application is inherent in DC, fifty specimens were used, the specimens were placed in a thermostatic bath in which the temperature is equal to that described above, an AC current (a peak value of $\sqrt{2} \times 5$ A) in which the RMS value is equal to DC 5 A was applied for 3,000 hours, and, after the application, the presence or absence of breakage of the fuse element was checked in a test of troubles due to long-term DC application by means of an X-ray apparatus (long-term application aging test).

[0065] With respect to the drawability of a fuse element, the specimens were drawn into a wire of 300 μmϕ in diameter while the draw-down ratio per dice was 6.5%, and the drawing speed was 45 m/min.

[Example 1]

[0066] Cylindrical thermal fuses in which a fuse element is made of an In-Sn alloy of 74% In and 26% Sn were used as AC fuses, and cylindrical thermal fuses in which a fuse element is made of a Bi-Sn-In alloy of 50% Bi, 45% Sn, and 5% In were used as DC fuses.

[0067] The operating temperature of the former fuses is 129.2 ± 1°C, and that of the latter fuses is 129.7 ± 1°C. Namely, the operating temperatures are substantially identical with each other.

[0068] In fifty AC fuses, the fuse elements of 28 fuses were broken in the long-term DC application aging test. With respect to the long-term DC application aging, therefore, the fuses were evaluated as unacceptable. In the DC fuses, none of the fuse elements was broken in the long-term DC application aging test. With respect to the long-term DC application aging, therefore, the fuses were evaluated as acceptable.

[0069] The operating temperatures of fifty specimens after the long-term DC application aging test were measured. As a result, no substantial change with respect to those before the aging test was observed. The operation performance was able to be stably maintained.

[0070] The wire drawing process on the elements of the DC fuses was more difficult than that on the elements of the AC fuses. However, none of the fuse elements was broken.

[0071] In the long-term AC application aging test, none of the fuse elements of both the AC and DC fuses was broken.

[0072] From the example, the followings are apparent. The phenomenon that, under long-term DC application, an alloy type thermal fuse in which a binary In-Sn alloy of 85 to 52% In is used as a fuse element is broken because of the application is inherent in DC application. When an alloy type thermal fuse in which the In-Sn alloy is used as a fuse element is used as an AC-only fuse, and an alloy type thermal fuse in which a Bi-Sn-In alloy is used as a fuse element is used as a DC fuse, it is possible to protect safely and rationally an electronic/electrical appliance under both AC and DC applications by alloy type thermal fuses of an operating temperature of 120 to 150°C.

[Comparative Example]

[0073] Cylindrical thermal fuses in which a fuse element is made of an In-Sn alloy of 74% In and 26% Sn were used as both AC and DC fuses in the same manner as the conventional art.

[0074] In the comparative example, it can be predicted that, during a long-term use, DC application breakage occurs in the DC fuses. Therefore, it is impossible to safely protect a DC electronic/electrical appliance.

Claims

1. A method of using an alloy type thermal fuse wherein an AC electronic/electrical appliance is protected against overheating by an AC-only alloy type thermal fuse in which a fuse element is made of an In-Sn alloy of (In% + Sn%) > 93.4% and In% > 48.5%, and which has an operating temperature of 120 to 150°C, and a DC electronic/electrical appliance is

protected against overheating of a same temperature by a DC alloy type thermal fuse in which an alloy composition of a fuse element is different from an alloy composition of said AC-only alloy type thermal fuse.

2. A method of using an alloy type thermal fuse according to claim 1, wherein said fuse element of said AC-only alloy type thermal fuse has an alloy composition in which 52% ≦ In ≦ 85% and balance Sn.

3. A method of using an alloy type thermal fuse according to claim 1, wherein said fuse element of said AC-only alloy type thermal fuse has an alloy composition in which 52% ≦ In ≦ 85% and balance Sn, and 0.01 to 7 weight parts of at least one selected from the group consisting of Ag, Au, Ni, Pd, Pt, and Sb are added to 100 weight parts of In + Sn in the alloy composition.

4. A method of using an alloy type thermal fuse according to any one of claims 1 to 3, wherein said fuse element of said DC alloy type thermal fuse has an alloy composition in which 20% ≦ Bi ≦ 56.5%, 43% < Sn ≦ 70%, and 0.5% ≦ In ≦ 10%.

5. A method of using an alloy type thermal fuse according to any one of claims 1 to 3, wherein said fuse element of said DC alloy type thermal fuse has an alloy composition in which 20% ≦ Bi ≦ 56.5%, 43% < Sn ≦ 70%, and 0.5% ≦ In ≦ 10%, and 0.01 to 7 weight parts of at least one selected from the group consisting of Ag, Au, Cu, Ni, Pd, Pt, Sb, Ga, Ge, and P are added to 100 weight parts of Bi + Sn + In in the alloy composition.

6. A method of using an alloy type thermal fuse wherein an AC-only alloy type thermal fuse in which a fuse element is made of an In-Sn alloy of (In% + Sn%) > 93.4% and In% > 48.5%, and which has an operating temperature of 120 to 150°C is used for protecting only an AC electronic/electrical appliance among AC/DC electronic/electrical appliances, against overheating.

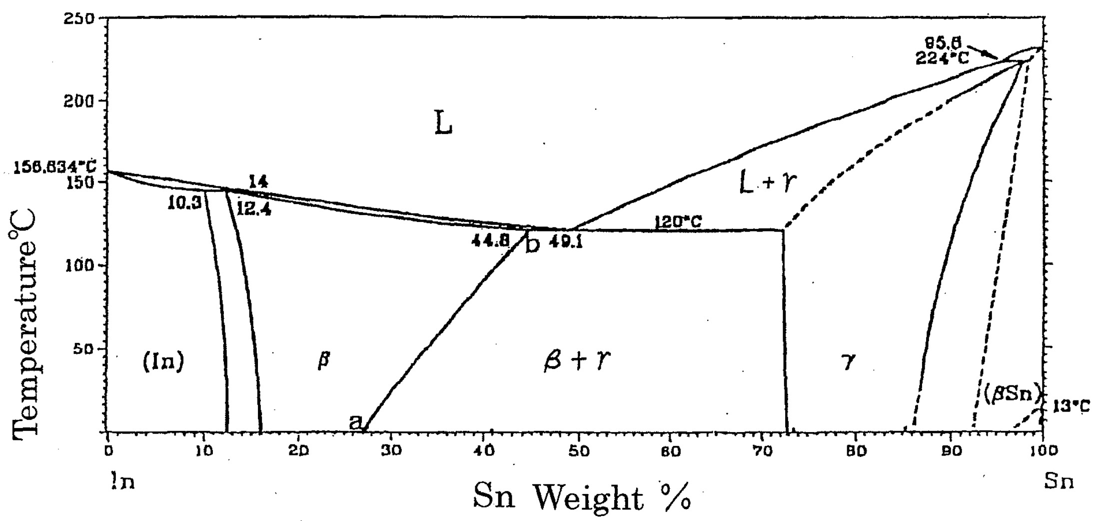
7. A method of using an alloy type thermal fuse according to claim 6, wherein said fuse element of said AC-only alloy type thermal fuse has an alloy composition in which 52% ≦ In ≦ 85% and balance Sn.

8. A method of using an alloy type thermal fuse according to claim 6, wherein said fuse element of said AC-only alloy type thermal fuse has an alloy composition in which 52% ≦ In ≦ 85% and balance Sn, and 0.01 to 7 weight parts of at least one selected from the group consisting of Ag, Au, Ni, Pd, Pt, and Sb are added to 100 weight parts of In + Sn in the alloy composition.

9. A method of using an alloy type thermal fuse according to any one of claims 1 to 8, wherein a heating element for fusing off said fuse element is additionally disposed on each of said alloy type thermal fuse.

10. An alloy type thermal fuse wherein said alloy type thermal fuse is an AC-only alloy type thermal fuse which is to be used in a method of using an alloy type thermal fuse according to any one of claims 1 to 9, and in which a fuse element is made of an In-Sn alloy, and instructions for AC-use only or inhibition of DC-use is indicated directly or indirectly.

Fig. 1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150
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10.3
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b
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L + γ
95.6
224°C
(In)
β
β + γ
γ
(βSn)
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a
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10
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30
40
50
60
70
80
90
100
In
Sn
Sn Weight %

Fig. 2

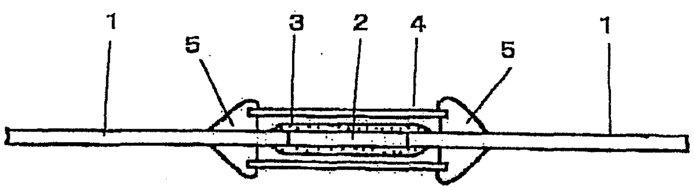
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Fig. 3

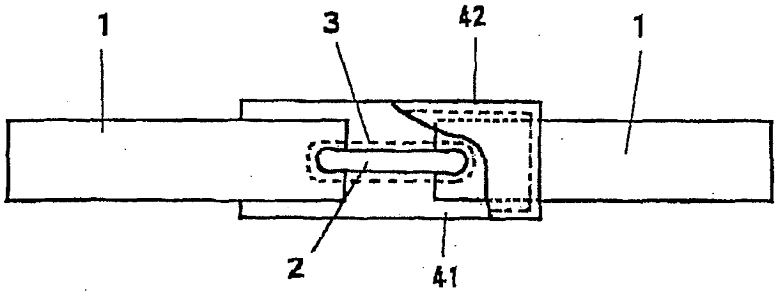


Fig. 4

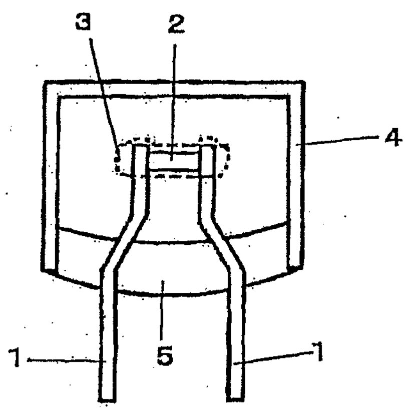


Fig. 5

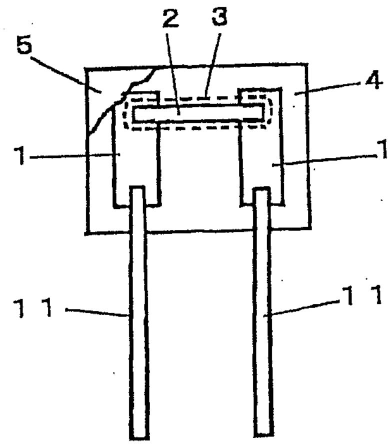
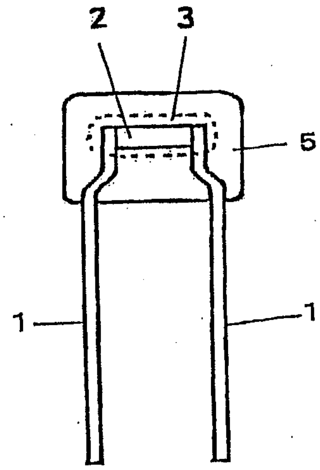


Fig. 6



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EUROPEAN SEARCH REPORT

Application Number
EP 05 10 2375

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	EP 1 383 149 A (UCHIHASHI ESTEC CO., LTD) 21 January 2004 (2004-01-21) * the whole document * -----	1-3	H01H37/76

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
H01H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	8 July 2005	Janssens De Vroom, P

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CATEGORY OF CITED DOCUMENTS

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