DESCRIPTION

Title of Invention:

SOLDER ALLOY, SOLDER PASTE, SOLDER BALL, SOLDER PREFORM, SOLDER JOINT, VEHICLE-MOUNTED ELECTRONIC CIRCUIT, ECU ELECTRONIC CIRCUIT, VEHICLE-MOUNTED ELECTRONIC CIRCUIT DEVICE, AND ECU ELECTRONIC CIRCUIT DEVICE

Technical Field

[0001] The present invention relates to a solder alloy, a solder paste, a solder ball, a solder preform, a solder joint, a vehicle-mounted electronic circuit, an ECU electronic circuit, a vehicle-mounted electronic circuit device, and an ECU electronic circuit device.

Background Art

[0002] A vehicle-mounted electronic circuit used for devices for electrically controlling an engine, a power steering, a brake, and the like is mounted on an automobile. Vehicle-mounted electronic circuits are very important safety components for automobile travel. In particular, a vehicle-mounted electronic circuit called an engine control unit (ECU), which is an electronic circuit that controls an automobile with a computer for improving fuel efficiency, needs to be capable of operating in a stable state without failure for a long period of time. This ECU is generally installed near an engine and is used under quite severe environmental conditions.

[0003] The vicinity of the engine in which such a vehicle-mounted electronic circuit is installed reaches a very high temperature of 125℃ or higher when the engine is running. On the other hand, for example, when the running of the engine is stopped, the outside air temperature becomes a low temperature of -40℃ or lower in winter in cold regions such as North America and Siberia. Therefore, the vehicle-mounted electronic circuit is exposed to a heat cycle environment of at least -40℃ to +125℃ by repeated operation

and stop of the engine.

[0004] The vehicle-mounted electronic circuit is an electronic circuit in which electronic components are soldered to a printed circuit board. The linear thermal expansion coefficient of the electronic components and the linear thermal expansion coefficient of the printed circuit board are greatly different. And, when the vehicle-mounted electronic circuit is exposed to a heat cycle environment, the electronic components and the printed circuit board repeat thermal expansion and contraction, respectively. By this repetition, a constant thermal displacement is repeatedly generated at a soldered portion (hereinafter, referred to as "solder joint") joining the electronic components and the printed circuit board. Therefore, in the heat cycle environment, stress continues to be applied to the solder joint, and the solder joint eventually fractures.

[0005] Even when the solder joint fractures not completely but partially, the resistance value of the electronic circuit increases, which may cause malfunction. A malfunction of an ECU mounted on an automobile can lead to a serious accident. As described above, in order to avoid the ECU malfunction, it is particularly important to improve heat cycle resistance.

[0006] Therefore, for example, Patent Document 1 discloses an Sn-Ag-Cu-Bi-Sb-Fe-Co solder alloy as a solder alloy having heat cycle resistance. This solder alloy has excellent thermal conductivity and reduced liberation in addition to heat cycle resistance. In addition, Patent Document 1 discloses that In may be contained as an optional element.

Citation List

Patent Document

[0007] Patent Document 1: Japanese Patent Publication No. 7323855 B

Summary of Invention

Technical Problem

[0008] The solder alloy described in Patent Document 1 is an excellent invention capable

of achieving a good balance between heat cycle resistance and thermal conductivity. However, in recent years, since warming has progressed and the highest temperature has increased, the severity of the use environment has further increased. On the other hand, although cold regions are also influenced by warming, the temperature may still fall below -40℃, as they have in the past. Consequently, besides the solder alloy described in Patent Document 1, a solder alloy specialized for improving heat cycle resistance is required.

[0009] Here, it is considered that the heat cycle resistance is improved by suppressing fracture of the solder joint. It is considered that tensile stress and compressive stress are alternately and repeatedly applied to the solder joint due to a difference in thermal expansion coefficients between the solder alloy and the electrode that constitute the solder joint in an area where temperature variations are significant. Accordingly, the solder joint fractures when being continuously exposed to a severe use environment.

[0010] Conventionally, various searches for compositions have been performed in order to improve heat cycle resistance from such a viewpoint. For example, in Patent Document 1, in order to meet the demand for a solder alloy having high versatility, a single alloy composition that satisfies both the heat cycle resistance and thermal conductivity has been searched.

[0011] However, it is desirable that fracture of the solder joint is suppressed even when the solder joint is continuously exposed to a severe environment as described above. For this purpose, it is necessary to have such properties that at least the fracture of the solder joint before the cycle test is suppressed. In addition, such properties preferably do not depend on the electrode or the like constituting the solder joint, and are properties specific to the solder alloy.

[0012] For example, the tensile strength of the solder alloy may be cited as a property for suppressing deformation of the solder alloy. When the tensile strength is high, deformation of the solder alloy constituting the solder joint is suppressed. Therefore, it is considered that fracture of the solder joint can be suppressed.

[0013] In addition, conventionally, as evaluation of wettability of molten solder, for example, a test using a meniscograph method has been performed. However, a copper plate is usually used in the test using the meniscograph. For this reason, the evaluation of wettability depends on the surface properties of the copper plate, and the wetting time and wetting force have been used as indices of wettability. Since this method is greatly affected by the surface properties of the base material, it is difficult to strictly evaluate the wettability. Therefore, surface tension using droplets of molten solder may be used as means for evaluating wettability specific to a solder alloy. This makes it possible to evaluate the wettability specific to the solder alloy without depending on the surface properties of the copper plate or the like.

[0014] Furthermore, even in a use environment in which external stress is applied to the solder joint separately from internal stress depending on a material constituting the solder joint such as heat cycle resistance, the solder joint should not fracture over a long period of time.

[0015] As described above, fracture of the solder joint should be suppressed even in an environment where internal stress or external stress is constantly applied. In the study of suppressing the fracture of the solder joint, attention should be paid not only to external stress but also to the fact that improvements in the properties of the solder alloy itself can suppress fracture even when internal stress is applied.

[0016] Therefore, an object of the present invention is to provide a solder alloy, a solder paste, a solder ball, a solder preform, a solder joint, a vehicle-mounted electronic circuit, an ECU electronic circuit, a vehicle-mounted electronic circuit device, and an ECU electronic circuit device, each of which has high tensile strength, low surface tension of molten solder, and high shear strength and thus has excellent reliability.

Solution to Problem

[0017] The present inventors have paid attention to properties of a solder alloy contributing to heat cycle resistance in the Sn-Ag-Cu-Bi-Sb-Fe-Co solder alloy disclosed

in Patent Document 1, and studied an alloy composition exhibiting high tensile strength and low surface tension. In the above solder alloy, when the Bi content is high, embrittlement of the solder alloy may occur due to segregation of Bi, and thus it is necessary to reduce the Bi content.

[0018] However, since the tensile strength tends to decrease when the Bi content is low, it is necessary to increase the Sb content to compensate for this. In the above solder alloy, since the Bi content is reduced and at the same time, the Sb content is increased, further improvement of the tensile strength of both elements of Bi and Sb cannot be expected. In addition, Co and Fe contribute to refinement of the alloy structure, but coarse compounds are precipitated when Co and Fe are added in an excessive amount, and thus the tensile strength is conversely reduced.

[0019] Here, the tensile strength needs to be synergistically improved by solid solution strengthening and precipitation strengthening of the solder alloy. The present inventors have paid attention to the fact that it is necessary to add an element contributing to solid solution strengthening and precipitation strengthening in addition to Bi and Sb among the above solder alloys described in Patent Document 1. As such an element, the present inventors have focused on In exemplified as an additive element in Patent Document 1.

[0020] In the Sn-Ag-Cu-Bi-Sb-Fe-Co solder alloy, about 0.5 mass% of In dissolves in Sn, but when the In content exceeds this amount, In precipitates as InSb because In is more reactive than Sn. Along with this, the precipitation amount of SnSb decreases. And, when Sb is consumed by precipitation of InSb, Ag_3In, Ag_2In, $AgIn_2$, and the like are precipitated. However, as described above, Patent Document 1 discloses that the In content that can be contained in the Sn-Ag-Cu-Bi-Sb-Fe-Co solder alloy is 0.1 mass% or less. Therefore, in the solder alloy described in Patent Document 1, the In content is low, and solid solution strengthening by In is insufficient. Therefore, in the Sn-Ag-Cu-Bi-Sb-Fe-Co-In solder alloy described in Patent Document 1, further improvement in tensile strength is not expected.

[0021] Bi improves wettability but does not form a compound, so that a low melting point

phase is likely to be formed and reliability may be impaired. The same applies to In. However, In preferentially forms a compound with Sb and Ag. When the In content is less than the total content of Sb and Ag, In is consumed as a compound, and the In content dissolved in Sn is optimized, so that In hardly forms a low melting point phase. When the Ag content (Ag_3In [Ag and In are 3:1], Ag_2In [Ag and In are 2:1]), and the Sb content (InSb [In and Sb are 1:1]) are less than the In content, the In content is more than the amount dissolved in Sn, and there is a concern that In forms a low melting point phase.

[0022] Here, Bi improves wettability but does not form a compound, and therefore when the Bi content is high, a low melting point phase is likely to be formed and reliability may be impaired. In also tends to form a low melting point phase, and thus, there is a possibility that reliability is impaired similarly to Bi.

[0023] However, In is different from Bi, and preferentially forms a compound with Sb and Ag as described above. Specifically, as described above, when the In content is less than the total content of Sb and Ag, In is consumed as a compound, and the In content dissolved in Sn is optimized, so that In hardly forms a low melting point phase. When the Ag content (Ag_3In [Ag and In are 3:1], Ag_2In [Ag and In are 2:1]), and the Sb content (InSb [In and Sb are 1:1]) are less than the In content, the In content is more than the amount dissolved in Sn, and there is a concern that In forms a low melting point phase. Further, excessive addition of In promotes phase transformation of the βSn phase to $InSn_4$, and therefore there is a concern about fracture of the solder joint due to deformation of the solder alloy.

[0024] As described above, in the Sn-Ag-Cu-Bi-Sb-Fe-Co solder alloy, it is necessary to reduce the Bi content as in the conventional case and to contain more In than in the conventional case. On the other hand, when the In content is too high, the problems described above occur. Therefore, the In content needs to fall within an appropriate range.

[0025] Furthermore, Ag, Cu, Fe, and Co also form compounds with Sn. For this reason, it is presumed that when various compounds are formed in the molten solder together with

Sb and In, the surface tension of the molten solder decreases and the wettability is improved. As described above, in the solder alloy according to the present invention, it has been found that the tensile strength of the solder alloy is improved, and at the same time, the surface tension of the molten solder itself is reduced, and the shear strength is further improved by studying the content of each constituent element in detail, and the present invention has been completed. It is to be noted that, in the present invention, the electronic circuit has been exemplified, but the present invention is not limited thereto as long as it is an application that needs to simultaneously exhibit these effects.

The present invention obtained from these findings is as follows.

[0026] (0) A solder alloy consisting of, by mass%, Ag: 3.0 to 4.0%, Cu: 0.1 to 1.0%, Bi: 0.1 to 1.5%, Sb: 3.0 to 6.0%, In: 0.2 to 6.0%, Fe: 0.020 to 0.040%, and Co: 0.001 to 0.020%, with the balance being Sn.

(1) A solder alloy having an alloy composition consisting of, by mass%, Ag: 3.0 to 4.0%, Cu: 0.1 to 1.0%, Bi: 0.1 to 1.5%, Sb: 3.0 to 6.0%, In: 0.2 to 6.0%, Fe: 0.020 to 0.040%, and Co: 0.001 to 0.020%, with the balance being Sn.

[0027] (2) The solder alloy according to (0) or (1) above, wherein, by mass%, the alloy composition (solder alloy) further contains at least one of Ge, Ga, As, Pd, Mn, Zn, Zr, and Mg: 0.1% or less in total.

[0028] (3) The solder alloy according to any one of (0) to (2) above, wherein the alloy composition (solder alloy) satisfies the following Relations (1) and (2):

$$0.0049 \leqq Ag \times Cu \times Bi \times Sb \times In \times Fe \times Co \leqq 0.0148 \quad (1)$$

$$49.4 \leqq Ag \times Sb \times In \leqq 88.3 \quad (2)$$

wherein Ag, Cu, Bi, Sb, In, Fe, and Co in the Relations (1) and (2) each represent the content in mass% thereof in the solder alloy.

[0029] (4) A solder paste having a solder powder consisting of the solder alloy according to any one of (0) to (2).

[0030] (5) A solder ball consisting of the solder alloy according to any one of (0) to (2) above.

[0031] (6) A solder preform consisting of the solder alloy according to any one of (0) to (2) above.

[0032] (7) A solder joint having the solder alloy according to any one of (0) to (2) above.

[0033] (8) A vehicle-mounted electronic circuit having the solder alloy according to any one of (0) to (2) above.

[0034] (9) An ECU electronic circuit having the solder alloy according to any one of (0) to (2) above.

[0035] (10) A vehicle-mounted electronic circuit device comprising the vehicle-mounted electronic circuit according to (8) above.

[0036] (11) An ECU electronic circuit device comprising the ECU electronic circuit according to (9) above.

Brief Description of Drawings

[0037] [FIG. 1] FIG. 1 is an SEM photograph of a cross section after a tensile strength test at a magnification of 1000, and FIG. 1(a) shows Comparative Example 9, FIG. 1(b) shows Example 12, and FIG. 1(c) shows Example 14.

[FIG. 2] FIG. 2 is an SEM photograph of FIG. 1 at a magnification of 3000, FIG. 2(a) shows Comparative Example 9, FIG. 2(b) shows Example 12, and FIG. 2(c) shows Example 14.

Description of Embodiments

[0038] The present invention is described in more detail below. In this description, "%" relating to the solder alloy composition refers to "mass%" unless otherwise specified.

[0039] 1. Solder Alloy

(1) Ag: 3.0 to 4.0%

Ag contributes to the improvement of wettability, and at the same time, also contributes to the improvement of shear strength since the toughness of the solder alloy is improved by forming a network structure of Ag_3Sn. When the Ag content is more than

4.0%, coarse Ag_3Sn is formed, and the toughness of the solder alloy decreases, so that the shear strength deteriorates. In terms of the upper limit, the Ag content is 4.0% or less, preferably 3.8% or less, and more preferably 3.6% or less.

[0040] On the other hand, when the Ag content is less than 3.0%, the network structure of Ag_3Sn is not formed, and the toughness decreases, thereby deteriorating the shear strength. In terms of the lower limit, the Ag content is 3.0% or more, preferably 3.1% or more, more preferably 3.2% or more, further preferably 3.3% or more, and particularly preferably 3.4% or more.

The preferred range of Ag is 3.2 to 3.6%.

[0041] (2) Cu: 0.1 to 1.0%

Cu can reduce the surface tension, improve the tensile strength by precipitation strengthening, and further increase the shear strength by forming a thin intermetallic compound at a joint interface. When the Cu content is more than 1.0%, a thick intermetallic compound is formed at the joint interface, so that the shear strength deteriorates. In terms of the upper limit, the Cu content is 1.0% or less, preferably 0.9% or less, more preferably 0.8% or less, and further preferably 0.7% or less.

[0042] On the other hand, when the Cu content is less than 0.1%, the compound with Sn is not sufficiently precipitated and the surface tension is poor, and accordingly, the tensile strength and the shear strength are also poor. In terms of the lower limit, the Cu content is 0.1% or more, preferably 0.3% or more, more preferably 0.5% or more, and further preferably 0.6% or more.

The preferred range of Cu is 0.5 to 0.9%.

[0043] (3) Bi: 0.1 to 1.5%

Bi can reduce the surface tension and improve the wettability by lowering the melting point, and can improve the tensile strength by solid solution strengthening. In addition, Bi can improve the tensile strength and at the same time, can improve the shear strength. When the Bi content is more than 1.5%, Bi segregates and the solder alloy becomes brittle, so that the shear strength is poor. In terms of the upper limit, the Bi

content is 1.5% or less, preferably 1.2% or less, more preferably 1.0% or less, further preferably 0.9% or less, and particularly preferably 0.8% or less.

[0044] On the other hand, when the Bi content is less than 0.1%, the solid solution amount of Bi becomes insufficient, and the tensile strength is poor. In addition, since the Bi content is low, the effect of improving wettability is not exhibited. Furthermore, when the Bi content is low, embrittlement is suppressed, but as the tensile strength deteriorates, the shear strength also deteriorates. In terms of the lower limit, the Bi content is 0.1% or more, preferably 0.3% or more, more preferably 0.4% or more, further preferably 0.5% or more, particularly preferably 0.6% or more, and most preferably 0.7% or more.

The preferred range of Bi is 0.5 to 1.5%.

[0045] (4) Sb: 3.0 to 6.0%

Sb contributes to precipitation strengthening of the solder alloy by forming SnSb. Along with this, the shear strength is also improved. When the Sb content is more than 6.0%, a coarse SnSb compound is precipitated and the fluidity of the molten solder is inhibited, so that the surface tension increases and the wettability deteriorates. In addition, the segregation of Sb causes embrittlement of the solder alloy, so that the shear strength deteriorates. In terms of the upper limit, the Sb content is 6.0% or less, preferably 5.5% or less, more preferably 5.0% or less, and further preferably 4.5% or less.

[0046] On the other hand, when the Sb content is less than 3.0%, precipitation strengthening is not exhibited, and solid solution strengthening is also insufficient, so that the tensile strength deteriorates. Along with this, the shear strength is also deteriorated. In terms of the lower limit, the Sb content is 3.0% or more, preferably 3.1% or more, more preferably 3.5% or more, and further preferably 4.0% or more.

The preferred range of Sb is 3.1 to 6.0%.

[0047] (5) In: 0.2 to 6.0%

In contributes to improvement of tensile strength by solid solution strengthening by dissolving in Sn and precipitation strengthening by precipitation of InSb, Ag_3In, and the like. In addition, since In is contained in the solder alloy, the surface tension

decreases due to a decrease in the melting point, which contributes to an improvement in wettability. As described above, In contributes to precipitation of various compounds, but the precipitated compounds exhibit fine precipitation behavior, so that high wettability is maintained. Furthermore, In contributes to improvement of shear strength by controlling phase transformation of Sn.

[0048] In the Sn-Ag-Cu-Bi-Sb-Fe-Co solder alloy, In dissolves in Sn up to 0.5%, and InSb is formed due to the reactivity of In at 0.5% or more. When Sb more than the solid solubility limit is consumed by InSb and further In is contained more than the solid solubility limit, Ag_3In, Ag_2In, or the like is formed. As described above, In can achieve solid solution strengthening and precipitation strengthening, and thus contributes to improvement in tensile strength.

[0049] When the In content is more than 6.0%, the Sn phase undergoes phase transformation from βSn to γSn, so that the solder alloy is deformed and the shear strength deteriorates. In terms of the upper limit, the In content is 6.0% or less, preferably 5.5% or less, more preferably 5.0% or less, and further preferably 4.0% or less.

[0050] On the other hand, when the In content is less than 0.2%, the solid solution strengthening becomes insufficient, and the tensile strength and the shear strength are deteriorated. In addition, since the In content is low, the effect of improving wettability is not exhibited. In terms of the lower limit, the In content is 0.2% or more, preferably 1.0% or more, more preferably 2.0% or more, and further preferably 3.0% or more.

The preferred range of In is 3.0 to 6.0%.

[0051] (6) Fe: 0.020 to 0.040%

Since Fe functions as a solidification nucleus during solidification of the molten solder, the alloy structure becomes fine, and the toughness of the solder alloy is improved, so that the shear strength is improved. When the Fe content is more than 0.040%, a coarse SnFe compound is precipitated and the fluidity of the molten solder is inhibited, so that the surface tension increases and the wettability is impaired. In terms of the upper limit, the Fe content is 0.040% or less, preferably 0.035% or less, and more preferably

0.030% or less.

[0052] On the other hand, when the Fe content is less than 0.020%, the alloy structure does not become fine, and the toughness of the solder alloy decreases, so that the shear strength deteriorates. In terms of the lower limit, the Fe content is 0.020% or more, and preferably 0.025% or more.

The preferred range of Fe is 0.020 to 0.030%.

[0053] (6) Co: 0.001 to 0.020%

Since Co, similarly to Fe, functions as a solidification nucleus during solidification of the molten solder, the alloy structure becomes fine, and the toughness of the solder alloy is improved, so that the shear strength is improved. When the Co content is more than 0.020%, the liquidus-line temperature increases, and in addition, a coarse SnCo compound is precipitated, so that the surface tension deteriorates. In terms of the upper limit, the Co content is 0.020% or less, preferably 0.015% or less, more preferably 0.012% or less, further preferably 0.010% or less, and particularly preferably 0.009% or less.

[0054] On the other hand, when the Co content is less than 0.001%, the alloy structure does not become fine, and the toughness of the solder alloy decreases, so that the shear strength deteriorates. In terms of the lower limit, the Co content is 0.001% or more, preferably 0.003% or more, more preferably 0.005% or more, further preferably 0.006% or more, and particularly preferably 0.008% or more.

The preferred range of Co is 0.006 to 0.010%.

[0055] (7) Relations (1) and (2):

$$0.0049 \leqq Ag \times Cu \times Bi \times Sb \times In \times Fe \times Co \leqq 0.0148 \quad (1)$$

$$49.4 \leqq Ag \times Sb \times In \leqq 88.3 \quad (2)$$

wherein Ag, Cu, Bi, Sb, In, Fe, and Co in the Relations (1) and (2) each represent the content in mass% thereof in the solder alloy.

[0056] The elements constituting the solder alloy according to the present invention have a liquidus-line temperature and a solidus-line temperature comparable to those of the

conventional solder alloy, and the surface tension is reduced, contributing to improvement of tensile strength and shear strength. Therefore, when the Relation (1) is satisfied, these effects can be further improved with a single composition. In addition, the Relation (2) is composed of an element that contributes to solid solution strengthening and precipitation strengthening, and at the same time, improves wettability by reducing surface tension by formation of a compound. Since the Relation (1) and the Relation (2) are preferred aspects of the present invention, even in the case of an alloy composition that does not satisfy these Relations, a practically acceptable effect can be obtained as long as the content of each constituent element is appropriate as described above. For alloy compositions that simultaneously satisfy these Relations, all evaluations in the present invention reach the highest level.

[0057] In terms of the upper limit of Relation (1), it is preferably 0.0148 or less, more preferably 0.0145 or less, still more preferably 0.0143 or less, particularly preferably 0.0140 or less, and most preferably 0.0136 or less, 0.0129 or less, 0.0124 or less, 0.0119 or less, 0.0114 or less, 0.0113 or less, or 0.0112 or less. In terms of the lower limit of Relation (1), it is preferably 0.0049 or more, more preferably 0.0050 or more, still more preferably 0.0059 or more, particularly preferably 0.0065 or more, and most preferably 0.0069 or more, 0.0071 or more, 0.0083 or more, 0.0085 or more, 0.0086 or more, 0.0095 or more, or 0.0105 or more.

A further preferred range for Relation (1) is 0.0050 to 0.0119. The above upper and lower limits can each define a further preferred range for Relation (1).

[0058] In terms of the upper limit of Relation (2), it is preferably 88.3 or less, more preferably 85.0 or less, still more preferably 81.0 or less, and even more preferably 80.0 or less. In terms of the lower limit of Relation (2), it is preferably 49.4 or more, more preferably 51.0 or more, still more preferably 68.0 or more, and particularly preferably 75.0 or more.

A further preferred range for Relation (2) is 51.0 to 85.0. The above upper and lower limits can each define a further preferred range for Relation (1).

[0059] In the calculation of the Relation (1) and the Relation (2), the numerical values as shown in Tables 1 and 2, which are measured values of the alloy composition, have been used. For the values calculated by the Relation (1) and the Relation (2), the Relation (1) calculates up to 4 decimal places, and the Relation (2) calculates up to 1 decimal place. This calculation rule is used in this application and further, is intended to be used as well for calculations relating to further compositions as described in other documents and the like, since all compositions must be handled in the same way.

[0060] (8) At least one of Ge, Ga, As, Pd, Mn, Zn, Zr, and Mg of 0.1% or less in total, by mass%

The solder alloy according to the present invention may contain any element as long as the effect of the present invention is not impaired. When the total content of these optional elements is 0.1% or less, the effect of the present invention is maintained.

[0061] (9) Balance: Sn

The balance of the solder alloy according to the present invention is Sn. In addition to the above-described elements, unavoidable impurity may be contained. The balance of the solder alloy according to the present invention may consist of Sn and unavoidable impurities. Even when unavoidable impurity is contained, it does not affect the above-described effects. It is to be noted that Ni is preferable not to be contained since Ni promotes liberation of the compound precipitated on the joint interface of the solder joint.

[0062] The value of surface tension evaluated in the present invention is static surface tension and is evaluated using a pendant drop method. In the pendant drop method adopted in the present invention, liquid is extruded from the tip of a tube (needle), and the surface tension is calculated from the shape of a droplet formed at the tip of the needle. In the conventional method for determining the contact angle with Cu, the measured value varies depending on the surface properties of Cu or the like, and therefore the surface tension of the solder alloy itself has not been measured. However, in the present invention, the wettability of the solder alloy itself can be evaluated by measuring the

surface tension of the solder alloy itself that does not depend on the material and surface properties of the electrode. In the solder alloy according to the present invention, the electrode or the like can be sufficiently wetted when the surface tension is 0.515 N/m or less, and the electrode or the like is wetted without any problem when the surface tension is more than 0.515 and 0.535 N/m or less. When the surface tension is more than 0.535 N/m, the wettability is poor.

[0063] 2. Solder Paste

A solder paste according to the present invention is a mixture of a solder powder consisting of the alloy composition described above and a flux. A flux to be used in the present invention is not particularly limited as long as soldering by an ordinary method is possible. Therefore, a flux appropriately blended with rosin, an organic acid, an activator, as well as a solvent, all of which are commonly used, may be employed. Blending ratios of the metal powder component and the flux component in the present invention are preferably the metal powder component: 70 to 90 mass%, the flux component: 10 to 30 mass%, although not particularly limited.

[0064] 3. Solder Ball

The solder alloy according to the present invention can be used as a solder ball. In the case of using the solder alloy according to the present invention as a solder ball, a solder ball can be manufactured using a dropping method which is a common method in the art. In addition, a solder joint can be manufactured by processing a solder ball using a common method in the art, such as mounting and joining one solder ball on one electrode coated with flux. A particle size of the solder ball is preferably 1 μm or more, more preferably 10 μm or more, still more preferably 20 μm or more, and particularly preferably 30 μm or more. In terms of the upper limit, the particle size of the solder ball is preferably 3000 μm or less, more preferably 1000 μm or less, still more preferably 800 μm or less, and particularly preferably 600 μm or less.

[0065] 4. Solder Preform

The solder alloy according to the present invention can be used as a solder preform.

The shape of the preform include a washer, a ring, a pellet, a disk, a ribbon, and a wire.

[0066] 5. Solder Joint

A solder joint according to the present invention is preferably used to join at least two or more of members to be joined. The members to be joined are not particularly limited as long as they are electrically connected by using the solder alloy according to the present invention, and examples thereof include elements, boards, electronic components, printed circuit boards, insulated boards, heat sinks, lead frames, semiconductors using electrode terminals and the like, power modules, inverter products, and the like.

[0067] The joining method using the solder alloy according to the present invention may be performed according to a conventional method using, for example, a reflow method. The melting temperature of the solder alloy in the case of performing flow soldering may be a temperature approximately 20°C higher than the liquidus-line temperature. In addition, when joining is performed using the solder alloy according to the present invention, the alloy structure can be further refined in consideration of the cooling rate during solidification. For example, the solder joint is cooled at a cooling rate of 2 to 3°C /s or more. The other joining conditions can be appropriately adjusted according to the alloy composition of the solder alloy.

[0068] 6. Vehicle-Mounted Electronic Circuit, ECU Electronic Circuit, Vehicle-Mounted Electronic Circuit Device, ECU Electronic Circuit Device

The solder alloy according to the present invention may be used for soldering of an electronic circuit mounted on an automobile.

[0069] Examples of the electronic component constituting such an electronic circuit include a chip resistor, a multiple resistance component, QFP, QFN, a power transistor, a diode, a capacitor, etc. The electronic circuit incorporating these electronic components is provided on a board and constitutes an electronic circuit device.

[0070] In the present invention, a board constituting such an electronic circuit device, for example, a printed wiring board is not particularly limited. The material thereof is also

not particularly limited, but a heat-resistant plastic board (for example, FR-4 having a high Tg and a low CTE) is exemplified. The printed circuit board is preferably a printed circuit board in which the Cu land surface is treated with an organic matter (OSP : Organic Surface Protection) such as amine or imidazole.

[0071] 7. Other

As the solder alloy according to the present invention, by using a low α-ray material as a raw material, a low α-ray alloy can be produced. Such a low α-ray alloy can prevent a soft error when used for forming solder bumps around a memory.

Examples

[0072] The present invention will be described based on the following examples, however, the present invention is not limited to the following examples.

In order to verify the effect of the present invention, the solder alloys described in Tables 2 and 3 were used to evaluate (1) Solidus-line Temperature and Liquidus-line Temperature, (2) Surface Tension, (3) Tensile Strength, and (4) Shear Strength.

[0073] (1) Solidus-line Temperature and Liquidus-line Temperature

For the solder alloys having the respective alloy compositions shown in Table 1 and Table 2, the respective temperatures were determined from the DSC curve. The DSC curve was obtained with a DSC (model number: Q2000) manufactured by Seiko Instruments Inc., by raising the temperature at 5℃/min in the atmosphere. The liquidus-line temperature was determined from the obtained DSC curve and taken as the melting temperature. In addition, the solidus-line temperature was also evaluated from the DSC curve. When the solidus-line temperature was 206℃ or higher and the liquidus-line temperature was lower than 230℃, it was judged as “Excellent”. When the solidus-line temperature was less than 206℃ and at the same time, the liquidus-line temperature was less than 230℃, or when the solidus-line temperature was 206℃ or more and at the same time, the liquidus-line temperature was 230℃ or more and less than 240℃, it was judged as “Good”. When the liquidus-line temperature was 240℃ or more, it was judged as

“Poor”.

[0074] (2) Surface Tension

Solder alloys having respective alloy compositions shown in Tables 1 and 2 were measured by the pendant drop method in the nitrogen atmosphere (oxygen concentration: 2000 ppm or less) at 250℃ using a contact angle meter (manufactured by Kyowa Interface Science Co., Ltd., model number DM-700). The formed surface tension was determined using an image processing solid-liquid interface analysis system, DropMaster 500 manufactured by Kyowa Interface Science Co., Ltd. When the surface tension was 0.515 N/m or less, it was determined as “Excellent”, when the surface tension was more than 0.515 N/m and 0.535 N/m or less, it was determined as “Good”, and when the surface tension was more than 0.535 N/m, it was determined as “Poor”.

[0075] (3) Tensile Strength

The tensile strength was measured according to JISZ3198-2. For each solder alloy described in Table 1 and Table 2, a test piece having a gauge length of 30 mm and a diameter of 8 mm was prepared by casting the solder alloy into a mold. The prepared test piece was pulled with a stroke of 6 mm/min at room temperature by Type5966 manufactured by Instron Corporation, and the strength when the test piece was fractured was measured. In addition, the reduction of area was determined from the ratio of the cross-sectional area S1 of the fractured portion of the test piece to the cross-sectional area S0 before the test. When the tensile strength was 40 MPa or more, it was evaluated as “Excellent”, when the tensile strength was 35 MPa or more and less than 40 MPa, it was evaluated as “Good”, and when the tensile strength was less than 35 MPa, it was evaluated as “Poor”.

[0076] (4) Shear Strength

(4-1) Preparation of Paste

Powders of the respective solder alloys shown in Tables 1 and 2 were prepared by an atomization method. This alloy powder was mixed with a flux (“GLV” manufactured by SENJU METAL INDUSTRY CO., LTD.) containing rosin, a solvent, a thixotropic

agent, an organic acid, and the like to prepare a solder paste. The alloy powder of the solder paste was 88 mass%, and the flux was 12 mass%. This solder paste was paste-printed on a Cu land of a six-layer printed circuit board (FR-4, Cu-OSP) with a 150 μm metal mask, and then 3216 chip resistors were mounted with a mounter. Thereafter, under heating conditions of a maximum temperature of 245℃ and a retention time of 40 seconds, reflowing was performed by melting in a reflow atmosphere of N_2 (oxygen concentration: 2000 ppm or less), and soldering was performed to prepare a test board.

[0077] (4-2) Measurement of Shear Strength

The shear strength test was performed on the above test board using a joint strength tester STR-5100 under the conditions of a test speed of 6 mm/min and a test height of 100 μm at 25℃. When the shear strength was 90 MPa or more, it was judged as “Excellent”, when the shear strength was 85 MPa or more and less than 90 MPa, it was judged as “Good”, and when the shear strength was less than 85 MPa, it was judged as “Poor”.

[0078]

[Table 1]

	Alloy Composition (mass%)									Relation (1)	Relation (2)	Evaluation 1	Evaluation 2	Evaluation 3	Evaluation 4	Overall Evaluation
	Sn	Ag	Cu	Bi	Sb	In	Fe	Co	Others			Solidus-line Liquidus-line	Wettability Evaluation: Surface Tension (Pendant Drop Method)	Tensile Strength	Shear Strength	
Example 1	Bal.	3.0	0.7	0.6	4.0	5.0	0.025	0.007		0.0044	60.0	Excellent	Good	Excellent	Excellent	Good
Example 2	Bal.	3.2	0.7	1.0	5.0	5.0	0.025	0.008		0.0112	80.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 3	Bal.	3.6	0.7	1.0	4.5	5.0	0.025	0.008		0.0113	81.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 4	Bal.	4.0	0.7	1.0	5.0	5.0	0.025	0.008		0.0140	100.0	Excellent	Excellent	Excellent	Good	Good
Example 5	Bal.	3.4	0.1	1.0	5.0	5.0	0.025	0.008		0.0017	85.0	Excellent	Excellent	Good	Good	Good
Example 6	Bal.	3.4	0.5	1.0	5.0	5.0	0.025	0.008		0.0085	85.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 7	Bal.	3.4	0.8	1.0	5.0	5.0	0.025	0.008		0.0136	85.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 8	Bal.	3.4	1.0	1.0	5.0	5.0	0.025	0.008		0.0170	85.0	Excellent	Excellent	Good	Good	Good
Example 9	Bal.	3.4	0.7	0.1	5.0	5.0	0.025	0.008		0.0012	85.0	Excellent	Good	Good	Good	Good
Example 10	Bal.	3.4	0.7	0.3	5.0	5.0	0.025	0.008		0.0036	85.0	Excellent	Good	Good	Good	Good
Example 11	Bal.	3.4	0.7	0.5	4.0	5.0	0.025	0.008		0.0048	68.0	Excellent	Excellent	Excellent	Good	Good
Example 12	Bal.	3.4	0.7	0.7	5.0	3.0	0.025	0.008		0.0050	51.0	Excellent	Excellent	Excellent	Excellent	Excellent

Table 1-continued

	Alloy Composition (mass%)									Relation (1)	Relation (2)	Evaluation 1	Evaluation 2	Evaluation 3	Evaluation 4	Overall Evaluation
	Sn	Ag	Cu	Bi	Sb	In	Fe	Co	Others			Solidus-line Liquidus-line	Wettability Evaluation: Surface Tension (Pendant Drop Method)	Tensile Strength	Shear Strength	
Example 13	Bal.	3.4	0.7	0.7	5.0	5.0	0.025	0.008		0.0083	85.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 14	Bal.	3.4	0.7	1.0	5.0	5.0	0.025	0.008		0.0119	85.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 15	Bal.	3.4	0.7	1.2	5.0	3.0	0.025	0.008		0.0086	51.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 16	Bal.	3.4	0.7	1.2	5.0	4.0	0.025	0.008		0.0114	68.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 17	Bal.	3.4	0.7	1.2	5.0	5.0	0.025	0.008		0.0143	85.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 18	Bal.	3.4	0.7	1.5	5.0	5.0	0.025	0.008		0.0179	85.0	Good	Excellent	Excellent	Good	Good
Example 19	Bal.	3.4	0.7	1.0	3.1	4.0	0.025	0.008		0.0059	42.2	Good	Excellent	Excellent	Good	Good
Example 20	Bal.	3.4	0.7	1.0	4.0	5.0	0.025	0.008		0.0095	68.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 21	Bal.	3.4	0.7	1.0	6.0	5.0	0.025	0.008		0.0143	102.0	Excellent	Good	Excellent	Good	Good
Example 22	Bal.	3.4	0.7	1.0	5.0	0.2	0.025	0.008		0.0005	3.4	Excellent	Excellent	Good	Good	Good
Example 23	Bal.	3.4	0.7	1.0	5.0	1.0	0.025	0.008		0.0024	17.0	Excellent	Excellent	Good	Good	Good
Example 24	Bal.	3.4	0.7	1.0	5.0	2.0	0.025	0.008		0.0048	34.0	Excellent	Excellent	Excellent	Good	Good
Example 25	Bal.	3.4	0.7	1.0	5.0	3.0	0.025	0.008		0.0071	51.0	Excellent	Excellent	Excellent	Excellent	Excellent

Table 1-continued

	Alloy Composition (mass%)									Relation (1)	Relation (2)	Evaluation 1	Evaluation 2	Evaluation 3	Evaluation 4	Overall Evaluation
	Sn	Ag	Cu	Bi	Sb	In	Fe	Co	Others			Solidus-line Liquidus-line	Wettability Evaluation: Surface Tension (Pendant Drop Method)	Tensile Strength	Shear Strength	
Example 26	Bal.	3.4	0.7	1.0	5.0	4.0	0.025	0.008		0.0095	68.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 27	Bal.	3.4	0.7	1.0	5.0	6.0	0.025	0.008		0.0143	102.0	Excellent	Excellent	Excellent	Good	Good
Example 28	Bal.	3.4	0.7	1.0	5.0	5.0	0.020	0.008		0.0095	85.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 29	Bal.	3.4	0.7	1.0	5.0	5.0	0.040	0.008		0.0190	85.0	Excellent	Good	Excellent	Good	Good
Example 30	Bal.	3.4	0.7	1.0	5.0	5.0	0.025	0.001		0.0015	85.0	Excellent	Excellent	Excellent	Good	Good
Example 31	Bal.	3.4	0.7	1.0	5.0	5.0	0.025	0.020		0.0298	85.0	Excellent	Good	Excellent	Good	Good
Example 32	Bal.	3.4	0.7	1.0	4.0	5.0	0.025	0.008	Ge:0.01	0.0095	68.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 33	Bal.	3.4	0.7	1.0	4.0	5.0	0.025	0.008	Ga:0.01	0.0095	68.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 34	Bal.	3.4	0.7	1.0	4.0	5.0	0.025	0.008	As:0.01	0.0095	68.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 35	Bal.	3.4	0.7	1.0	4.0	5.0	0.025	0.008	Pd:0.01	0.0095	68.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 36	Bal.	3.4	0.7	1.0	4.0	5.0	0.025	0.008	Mn:0.01	0.0095	68.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 37	Bal.	3.4	0.7	1.0	4.0	5.0	0.025	0.008	Zn:0.01	0.0095	68.0	Excellent	Excellent	Excellent	Excellent	Excellent

[0079]

[Table 2]

	Alloy Composition (mass%)									Relation (1)	Relation (2)	Evaluation 1	Evaluation 2	Evaluation 3	Evaluation 4	Overall Evaluation
	Sn	Ag	Cu	Bi	Sb	In	Fe	Co	Others			Solidus-line Liquidus-line	Wettability Evaluation: Surface Tension (Pendant Drop Method)	Tensile Strength	Shear Strength	
Example 38	Bal.	3.4	0.7	1.0	4.0	5.0	0.025	0.008	Zr:0.01	0.0095	68.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 39	Bal.	3.4	0.7	1.0	4.0	5.0	0.025	0.008	Mg:0.01	0.0095	68.0	Excellent	Excellent	Excellent	Excellent	Excellent
Example 40	Bal.	3.4	0.7	1.0	4.0	5.0	0.025	0.008	Ge:0.01, Ga:0.01, As:0.01, Pd:0.01, Mn:0.01 ,Zn:0.01, Zr:0.01, Mg:0.01	0.0095	68.0	Excellent	Excellent	Excellent	Excellent	Excellent
Comparative Example 1	Bal.	2.9	0.7	1.0	4.0	4.0	0.025	0.008		0.0065	46.4	Excellent	Poor	Excellent	Poor	Poor
Comparative Example 2	Bal.	4.1	0.7	1.0	4.5	5.0	0.025	0.008		0.0129	92.3	Excellent	Excellent	Excellent	Poor	Poor
Comparative Example 3	Bal.	3.4	0.04	1.0	4.0	5.0	0.025	0.008		0.0005	68.0	Excellent	Good	Poor	Poor	Poor
Comparative Example 4	Bal.	3.4	1.1	1.0	4.0	5.0	0.025	0.008		0.0150	68.0	Excellent	Good	Good	Poor	Poor
Comparative Example 5	Bal.	3.4	0.7	0.04	4.0	5.0	0.025	0.008		0.0004	68.0	Excellent	Poor	Poor	Poor	Poor
Comparative Example 6	Bal.	3.4	0.7	1.6	4.0	5.0	0.025	0.008		0.0152	68.0	Good	Excellent	Excellent	Poor	Poor
Comparative Example 7	Bal.	3.4	0.7	1.0	2.9	5.0	0.025	0.008		0.0069	49.3	Good	Excellent	Poor	Poor	Poor
Comparative Example 8	Bal.	3.4	0.7	1.0	6.1	5.0	0.025	0.008		0.0145	103.7	Excellent	Poor	Good	Poor	Poor

* Underlined indicates that it falls outside the scope of the present invention.

Table 2-continued

	Alloy Composition (mass%)									Relation (1)	Relation (2)	Evaluation 1	Evaluation 2	Evaluation 3	Evaluation 4	Overall Evaluation
	Sn	Ag	Cu	Bi	Sb	In	Fe	Co	Others			Solidus-line Liquidus-line	Wettability Evaluation: Surface Tension (Pendant Drop Method)	Tensile Strength	Shear Strength	
Comparative Example 9	Bal.	3.4	0.7	1.0	3.0	0.008	0.025	0.009		0.0000	0.1	Excellent	Poor	Poor	Poor	Poor
Comparative Example 10	Bal.	3.4	0.7	1.0	4.0	6.5	0.025	0.008		0.0124	88.4	Good	Excellent	Excellent	Poor	Poor
Comparative Example 11	Bal.	3.4	0.7	1.0	4.0	5.0	0.010	0.008		0.0038	68.0	Excellent	Excellent	Excellent	Poor	Poor
Comparative Example 12	Bal.	3.4	0.7	1.0	4.0	5.0	0.050	0.008		0.0190	68.0	Good	Poor	Excellent	Good	Poor
Comparative Example 13	Bal.	3.4	0.7	1.0	4.0	5.0	0.025	0.0004		0.0005	68.0	Excellent	Excellent	Excellent	Poor	Poor
Comparative Example 14	Bal.	3.4	0.7	1.0	4.0	5.0	0.025	0.025		0.0298	68.0	Poor	Poor	Excellent	Good	Poor

* Underlined indicates that it falls outside the scope of the present invention.

[0080] As is apparent from Tables 1 and 2, in Examples 1 to 40, the contents of Ag, Cu, Bi, Sb, In, Fe, and Co, all of which are essential elements, were within the scope of the present invention, and therefore all the evaluation determinations were judged as "Good" or "Excellent". In particular, all of Examples 2, 3, 6, 7, 12 to 17, 20, 25, 26, 28, and 32 to 40 satisfying Relations (1) and (2) had "Excellent" in all the evaluation determinations, and showed superior results among Examples.

[0081] On the other hand, in Comparative Example 1 and Comparative Example 2, the Ag content was inappropriate, and thus the shear strength was poor. In Comparative Example 3, the Cu content was low, and thus the surface tension, the tensile strength, and the shear strength were poor. In Comparative Example 4, the Cu content was high, and thus the shear strength was poor.

[0082] In Comparative Example 5, the Bi content was low, and thus the surface tension, the tensile strength, and the shear strength were poor. In Comparative Example 6, the Bi content was high, and thus the shear strength was poor. In Comparative Example 7, the Sb content was low, and thus the tensile strength and the shear strength were poor. In Comparative Example 8, the Sb content was high, and thus the surface tension and the shear strength were poor.

[0083] In Comparative Example 9, the In content was low, and thus the surface tension, the tensile strength, and the shear strength were poor. In Comparative Example 10, the In content was high, and thus the shear strength was poor. In Comparative Example 11, the Fe content was low, and thus the surface tension was poor. In Comparative Example 13, the Co content was low, and thus the shear strength was poor. In Comparative Example 14, the Co content was high, the liquidus-line temperature increased, and thus high surface tension was exhibited.

[0084] The results of observing the cross section after the tensile strength test are shown in FIGS. 1 and 2. FIG. 1 is an SEM photograph of a cross section after a tensile strength test at a magnification of 1000, and FIG. 1(a) shows Comparative Example 9, FIG. 1(b) shows Example 12, and FIG. 1(c) shows Example 14. FIG. 2 is an SEM photograph of

FIG. 1 at a magnification of 3000, FIG. 2(a) shows Comparative Example 9, FIG. 2(b) shows Example 12, and FIG. 2(c) shows Example 14. As is apparent from FIGS. 1 and 2, it was found that InSb, Ag_2In, and Ag_3In were precipitated in Example 12 and Example 14. In addition, in Example 14, it was found that Cu_6Sn_5 was precipitated in addition to InSb, Ag_2In, and Ag_3In.

[0085] Table 3 below shows the results of wettability evaluated in the present Example and the evaluation results using the meniscograph method which has been conventionally performed for Examples and Comparative Examples optionally selected from Table 1 and Table 2.

[0086] The meniscograph method was evaluated as follows.

(1) Preparation of Test Plate

A flux ("ES-1100" manufactured by SENJU METAL INDUSTRY CO., LTD.) was applied to a copper plate (width 10 mm × length 30 mm × thickness 0.3 mm). The copper plate coated with the flux was thermally treated at 120℃ for 15 minutes in the air atmosphere to obtain a test plate. In this manner, five test plates were prepared for each of Examples and Comparative Examples shown in Table 3.

[0087] (2) Evaluation Method

Each of the obtained test plates was immersed in a solder bath into which a molten solder having an alloy composition shown in Table 3 was introduced to obtain a zero crossing time (sec). Here, using Solder Checker SAT-5100 (manufactured by RHESCA) as a test apparatus, evaluation was performed as follows. Solder wettability was evaluated by an average value of zero crossing times (sec) of five test plates of each Example and each Comparative Example. The test conditions were set as follows.

[0088] Immersion Speed into Solder Bath: 10 mm/sec

Immersion Depth into Solder Bath: 4 mm

Immersion Time into Solder Bath: 10 sec

Solder Bath Temperature: 255℃

The shorter the average value of the zero crossing time (sec), the faster the wetting

speed and the better the solder wettability.

[0089] (3) Criterion

When the average value of the zero crossing time (sec) was 1.2 seconds or less, it was judged as “Excellent”, when it was more than 1.2 seconds and 1.3 seconds or less, it was judged as “Good”, and when it was more than 1.3 seconds, it was judged as “Poor”.

[0090]

[Table 3]

	Alloy Composition (mass%)								Evaluation 2	Wettability Evaluation (Meniscograph Method)
	Sn	Ag	Cu	Bi	Sb	In	Fe	Co	Wettability Evaluation: Surface Tension (Pendant Drop Method)	
Example 1	Bal.	3.0	0.7	0.6	4.0	5.0	0.025	0.007	Good	Excellent
Example 2	Bal.	3.2	0.7	1.0	5.0	5.0	0.025	0.008	Excellent	Excellent
Example 9	Bal.	3.4	0.7	0.1	5.0	5.0	0.025	0.008	Good	Good
Example 10	Bal.	3.4	0.7	0.3	5.0	5.0	0.025	0.008	Good	Excellent
Comparative Example 5	Bal.	3.4	0.7	0.04	4.0	5.0	0.025	0.008	Poor	Poor

* Underlined indicates that it falls outside the scope of the present invention.

[0091] As is apparent from Table 3, it was found that the evaluation results obtained by the meniscograph method and those obtained by the pendant drop method evaluated in the Examples do not necessarily coincide. In addition, even when an alloy composition had an evaluation result of “Excellent” in the meniscograph method, the alloy composition had an evaluation result of “Good” in the pendant drop method. Consequently, it was found that, in the pendant drop method evaluated in the Examples, the wettability of the molten solder itself can be directly evaluated, thereby enabling more accurate evaluation of the wettability.

CLAIMS

1. A solder alloy having an alloy composition consisting of, by mass%,

Ag: 3.0 to 4.0%,

Cu: 0.1 to 1.0%,

Bi: 0.1 to 1.5%,

Sb: 3.0 to 6.0%,

In: 0.2 to 6.0%,

Fe: 0.020 to 0.040%, and

Co: 0.001 to 0.020%, with the balance being Sn.

2. The solder alloy according to claim 1,

wherein, by mass%,

the alloy composition further contains at least one of Ge, Ga, As, Pd, Mn, Zn, Zr, and Mg: 0.1% or less in total.

3. The solder alloy according to claim 1 or 2,

wherein the alloy composition satisfies the following Relations (1) and (2):

$$0.0049 \leqq Ag \times Cu \times Bi \times Sb \times In \times Fe \times Co \leqq 0.0148 \quad (1)$$

$$49.4 \leqq Ag \times Sb \times In \leqq 88.3 \quad (2)$$

wherein Ag, Cu, Bi, Sb, In, Fe, and Co in the Relations (1) and (2) each represent the content in mass% thereof in the solder alloy.

4. A solder paste having a solder powder consisting of the solder alloy according to claim 1 or 2.

5. A solder ball consisting of the solder alloy according to claim 1 or 2.

6. A solder preform consisting of the solder alloy according to claim 1 or 2.

7. A solder joint having the solder alloy according to claim 1 or 2.

8. A vehicle-mounted electronic circuit having the solder alloy according to claim 1 or 2.

9. An ECU electronic circuit having the solder alloy according to claim 1 or 2.

10. A vehicle-mounted electronic circuit device comprising the vehicle-mounted electronic circuit according to claim 8.

11. An ECU electronic circuit device comprising the ECU electronic circuit according to claim 9.