strength and drawability. An upper limit of the Bi content is 5.0% or less, preferably 4.0% or less, more preferably 3.0% or less, further preferably 2.0% or less, and particularly preferably 1.0% or less.

[0035] (7) 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. Even when unavoidable impurity is contained, it does not affect the above-described effects.

[0036] (8) Co: 0.100% or less

Co is an optional element having the effects of suppressing growth of the intermetallic compound and refining the alloy structure. An upper limit of the Co content is preferably 0.100% or less, more preferably 0.050% or less, and further preferably 0.010% or less. Although a lower limit of the Co content is not particularly limited, from the viewpoint of refining the alloy structure, the lower limit is preferably 0.001% or more, more preferably 0.003% or more, further preferably 0.005% or more, still further preferably 0.006% or more, particularly preferably 0.007% or more, and most preferably 0.008% or more.

[0037] (9) Other Optional Elements

In addition to the above-described elements, the solder alloy according to the present invention may contain at least one of Zr, Fe, Ge, Ga, P, As, Pb, Zn, Mg, Cr, Ti, Mn, Mo, Pt, Pd, Au, Al, and Si: 0.1% or less in total. In particular, concerning Fe, it has an effect of suppressing growth of an intermetallic compound that precipitates at a joint interface, so that, by containing Fe in the solder alloy of the present invention, the effects of Ni can be further improved. Even when a content of these elements is 0.1% or less, a coarse compound does not precipitate, and the above-described effects of the present invention can be exerted. A total content of these elements is preferably 0.1% or less, more preferably 0.09% or less, further preferably 0.05% or less, and particularly preferably 0.015% or less. A content of each element is preferably 0.0003 to 0.02% although not particularly limited. Among these, like Ni, Fe blocks diffusion of Cu to Sn after soldering, and suppresses growth of an intermetallic compound that precipitates at a joint interface. Further, by suppressing coarsening of the intermetallic compound that precipitates at the joint interface, Fe can strengthen the joint interface.

[0038] (10) Relations (1) to (4)

$113 \leq Sn/Cu \leq 165$ Relation (1)

$0.06 \leq Ag \times Ni \leq 0.19$ Relation (2)

$0.10 \leq Bi/(In+Sb) \leq 0.32$ Relation (3)

according to an alloy composition of the solder alloy.

Examples

[0048] Solder alloys consisting of the alloy compositions described in Tables 1 to 3 were prepared, and the liquidus-line temperature was measured as evaluation 1, the denseness of the solder structure was evaluated as evaluation 2, the drawability was evaluated as evaluation 3, the tensile strength was evaluated as evaluation 4, and homogeneous refinement of a joint interface was evaluated as evaluation 5.

[0049] - Evaluation 1: Liquidus-line Temperature

The respective solder alloys described in Tables 1 to 3 were produced, and their liquidus-line temperatures were measured. The liquidus-line temperatures were measured by a method using DSC similar to the solidus temperature measuring method of JIS Z 3198-1. A case where the liquidus-line temperature was 200 to 218°C was evaluated as "excellent," a case where the liquidus-line temperature was more than 218°C and 220°C or less was evaluated as "good," a case where the liquidus-line temperature was more than 220°C was evaluated as "poor," and a case where the liquidus-line temperature was less than 200°C was also evaluated as "poor."

[0050] - Evaluation 2: Denseness of Solder Structure

Solder alloys having the alloy compositions described in Tables 1 to 3 were casted into a predetermined mold, and obtained solder alloys were molded by resin and ground, portions where the solder alloys were ground by about half were photographed at a magnification of 1000 with an FE-SEM. From the taken photograph, the denseness of Ag_3Sn and refinement of InSb were evaluated by cross-section observation and mapping composition analysis using EDS. Each compound was identified by mapping composition analysis, and a largest crystal grain was visually selected. For this crystal grain, two parallel tangent lines were drawn so that a distance between them became largest, and this distance was defined as a maximum crystal grain size. A case where the maximum crystal grain size of Ag_3Sn was 5 μm or more and 10 μm or less was evaluated as "excellent," a case where the maximum crystal grain size was more than 10 μm and 15 μm or less was evaluated as "good," and a case where the maximum crystal grain size was less than 5 μm and a case where the maximum crystal grain size was more than 15 μm were evaluated as "poor." A case where the maximum crystal grain size of InSb was 5 μm or less was evaluated as "excellent," a case where the maximum crystal grain size was more than 5 μm and 10 μm or less was evaluated as "good," and a case where the maximum crystal grain size was more than 10 μm was evaluated as "poor." In the evaluation 2, a case where both of

Ag_3Sn and InSb were evaluated as “excellent” was evaluated as “excellent,” and a case where either one was evaluated as “excellent” and the other was evaluated as “good” was evaluated as “good,” and a case where either one was evaluated as “poor” was evaluated as “poor.”

[0051] - Evaluation 3, 4: Drawability, Tensile Strength

The drawability and the tensile strength were measured according to JIS Z 3198-2. Each solder alloy described in Tables 1 to 3 was casted into a mold, and a test piece with a gauge length of 30 mm and a diameter of 8 mm was fabricated. The fabricated test piece was drawn with a stroke of 6 mm/min at a room temperature by Type 5966 manufactured by Instron, and a strength when the test piece ruptured was measured. The drawability was measured from a proportion of a sectional area S_1 of a ruptured portion of the test piece to a sectional area S_0 before the test. A case where the tensile strength was 65 MPa or more was evaluated as “excellent,” a case where the tensile strength was 60 MPa or more and less than 65 MPa was evaluated as “good,” and a case where the tensile strength was less than 60 MPa was evaluated as “poor.” A case where the drawability was 50% or more was evaluated as “good,” and a case where the drawability was less than 50% was evaluated as “poor.”

Evaluation results are shown in Tables 1 to 3.

[0052] - Evaluation 5: Homogeneous Refinement of Joint Interface

A solder ball with ϕ0.6 mm was prepared from each solder alloy described in Tables 1 to 3. After this solder ball was mounted onto a Cu pad, reflow soldering was performed at 245°C, and accordingly, a solder bump was formed. By measuring a thickness of an intermetallic compound (IMC) from a sectional SEM photograph imaging a section of a joint interface between the solder bump and the Cu pad, homogeneous refinement of the joint interface was evaluated. When the joint interface is homogeneously refined, the intermetallic compound layer becomes thin, so that, in evaluation 5, homogeneous refinement was evaluated based on a thickness of the intermetallic compound. The sectional SEM photograph was analyzed by image analysis software (Scandium made by SEIKA CORPORATION), and a thickness of the intermetallic compound layer was measured. A case where the thickness of the intermetallic compound was 1.5 μm or less was evaluated as “excellent,” a case where the thickness was more than 1.5 μm and 2.5 μm or less was evaluated as “good,” and a case where the thickness was more than 2.5 μm was evaluated as “poor.”

Evaluation results are shown in Tables 1 to 3.

CLAIMS

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

Ag: 1.0 to 3.8%,

Cu: 0.4 to 0.8%,

Sb: 0.03 to 2.90%,

In: 1.1 to 4.2%,

Ni: 0.01 to 0.14%,

Bi: 0.1 to 5.0%, with the balance being Sn.

2. The solder alloy according to claim 1, further containing, by mass%, Co: 0.1% or less,

wherein the alloy composition satisfies the following relation (3):

$0.10 \leq Bi/(In+Sb) \leq 0.32$ Relation (3)

wherein Bi, In, and Sb in the relation (3) above each represent the contents (mass%) thereof in the alloy composition.

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

wherein the alloy composition satisfies at least one of the following relations (1) and (4):

$113 \leq Sn/Cu \leq 165$ Relation (1)

$0.432 \leq (In+Sb)/(Ag+In+Bi) \leq 0.999$ Relation (4)

wherein Sn, Cu, Ag, Bi, In, and Sb in the relations (1) and (4) above each represent the contents (mass%) thereof in the alloy composition.

4. The solder alloy according to any one of claims 1 to 3, further containing, by mass%, at least one of Zr, Fe, Ge, Ga, P, As, Pb, Zn, Mg, Cr, Ti, Mn, Mo, Pt, Pd, Au, Al, and Si: 0.1% or less in total,

wherein the alloy composition satisfies the following relation (2):

$0.06 \leq Ag \times Ni \leq 0.19$ Relation (2)

wherein Ag and Ni in the relation (2) above each represent the contents (mass%) thereof in the alloy composition.

5. The solder alloy according to claim 1, further containing, by mass%, Co: 0.1% or less, and at least one of Zr, As, Pb, Zn, Mg, Ti, Pt, Pd, Au, Al, and Si: 0.1% or less in total.

6. The solder alloy according to claim 5,

wherein the alloy composition satisfies the following relation (3):

$0.10 \leq Bi/(In+Sb) \leq 0.32$ Relation (3)

wherein Bi, In, and Sb in the relation (3) above each represent the contents (mass%) thereof in the alloy composition.

7. The solder alloy according to any one of claims 1 to 3,

wherein the alloy composition satisfies the following relation (2):

$0.06 \leq Ag \times Ni \leq 0.19$ Relation (2)

wherein Ag and Ni in the relation (2) above each represent the contents (mass%) thereof in the alloy composition.

8. A solder ball consisting of the solder alloy according to any one of claims 1 to 7.

9. A solder preform consisting of the solder alloy according to any one of claims 1 to 7.

10. A solder paste comprising a solder powder consisting of the solder alloy according to any one of claims 1 to 7.

11. A solder joint comprising the solder alloy according to any one of claims 1 to 7.