compound of Cu and Sn, the minuteness of the compound is achieved by replacing a part of Cu with Ni. Furthermore, since the liquidus temperature of the solder alloy fluctuates greatly depending on the contents of Cu and Ni, the viscosity during melting was controlled in a way that ΔT did not become too large, and a study was conducted to suppress the growth of the Sn compound. As a result, it was also found that in the Sn-Ag-Cu-Bi-Ni-Ge solder alloy, ΔT is controlled to make intermetallic compounds formed at a bonded interface minute by containing Sn, Cu, and Ni contents in a well-balanced manner, so that the shear strength is improved.

[0020] As a result of the keen study conducted focusing on the above, it was found that Ni leaching is suppressed by adding Bi to the Sn-Ag-Cu-Ni-Ge solder alloy. Then, it was found that the total content of Ag, Cu, Bi, and Ni and the Ge content can satisfy the suppression of fusion failure at the same time by satisfying the prescribed relationship, as described above. Furthermore, it was also found that if Sn, Cu, and Ni are mixed in a well-balanced manner, shear strength is improved.

The present invention obtained from these finding is as follows.

[0021] (1) A lead-free and antimony-free solder alloy having an alloy composition consisting of, by mass%, 0.1 to 4.5% of Ag, 0.20 to 0.85% of Cu, 0.2 to 5.00% of Bi, 0.005 to 0.09% of Ni, and 0.0005 to 0.0090% of Ge with the balance being Sn,

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

$0.013 \leq (Ag + Cu + Ni + Bi) \times Ge \leq 0.027$ Relation (1)

$Sn \times Cu \times Ni \leq 5.0$ Relation (2)

wherein Ag, Cu, Ni, Bi, Ge, and Sn in the relations (1) and (2) each represent the contents (mass%) in the alloy composition.

[0022] (2) The lead-free and antimony-free solder alloy according to (1) above, wherein, by mass%, the alloy composition contains 0.0005 to 0.0045% of Ge.

In one aspect, there is provided a lead-free and antimony-free solder alloy having an alloy composition consisting of, by mass%,

0.1 to 4.5% of Ag,

0.20 to 0.85% of Cu,

0.2 to 5.00% of Bi,

0.005 to 0.09% of Ni, and

0.0005 to 0.0045% of Ge with the balance being Sn,

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

$0.029 \leq (Ag + Cu + Ni + Bi) \times Ge < 0.032$ relation (1)

$Sn \times Cu \times Ni \leq 5.0$ relation (2)

wherein Ag, Cu, Ni, Bi, Ge, and Sn in the relations (1) and (2) each represent the contents (mass%) thereof in the alloy composition.

(3) The lead-free and antimony-free solder alloy according to any one of (1) or (2) above, wherein the alloy composition contains one or more selected from the group consisting of Mn, Pd, P, Au, Pt, Cr, Fe, Co, V, Mo, and Nb each with an upper limit of 0.01% by mass%.

[0023] (4) A solder ball comprising the lead-free and antimony-free solder alloy according to any one of (1) to (3) above.

(5) The solder ball according to (4) above, having an average particle diameter of 1 to 1000 μm.

(6) The solder ball according to (4) or (5) above, having a sphericity of 0.95 or more.

(7) The solder ball according to (4) or (5) above, having a sphericity of 0.99 or more.

# CLAIMS

1. A lead-free and antimony-free solder alloy having an alloy composition consisting of, by mass%,

0.1 to 4.5% of Ag,

0.20 to 0.85% of Cu,

0.2 to 5.00% of Bi,

0.005 to 0.09% of Ni, and

0.0005 to 0.0090% of Ge with the balance being Sn,

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

$0.013 \leq (Ag + Cu + Ni + Bi) \times Ge \leq 0.027$ relation (1)

$Sn \times Cu \times Ni \leq 5.0$ relation (2)

wherein Ag, Cu, Ni, Bi, Ge, and Sn in the relations (1) and (2) each represent the contents (mass%) thereof in the alloy composition.

2. A lead-free and antimony-free solder alloy having an alloy composition consisting of, by mass%,

0.1 to 4.5% of Ag,

0.20 to 0.85% of Cu,

0.2 to 5.00% of Bi,

0.005 to 0.09% of Ni, and

0.0005 to 0.0045% of Ge with the balance being Sn,

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

$0.029 \leq (Ag + Cu + Ni + Bi) \times Ge < 0.032$ relation (1)

$Sn \times Cu \times Ni \leq 5.0$ relation (2)

wherein Ag, Cu, Ni, Bi, Ge, and Sn in the relations (1) and (2) each represent the contents (mass%) thereof in the alloy composition.

~~2~~3. The lead-free and antimony-free solder alloy according to claim 1, wherein, by mass%, the alloy composition comprises 0.0005 to 0.0045% of Ge.

~~3~~4. The lead-free and antimony-free solder alloy according to any one of claims 1 ~~or 2~~to 3, wherein the alloy composition comprises one or more selected from the group consisting of Mn, Pd, P, Au, Pt, Cr, Fe, Co, V, Mo, and Nb each with an upper limit of 0.01% by mass%.

~~4~~5. A solder ball comprising the lead-free and antimony-free solder alloy according to any one of claims 1 to ~~3~~4.

~~5~~6. The solder ball according to claim ~~4~~5, having an average particle diameter of 1 to 1000 μm.

~~6~~7. The solder ball according to claim ~~4~~ 5 or ~~5~~6, having a sphericity of 0.95 or more.

~~7~~8. The solder ball according to claim ~~4~~ 5 or ~~5~~6, having a sphericity of 0.99 or more.

~~8~~9. A ball grid array formed using the solder ball according to any one of claims ~~4~~ 5 to ~~7~~8.

~~9~~10. A solder joint comprising the lead-free and antimony-free solder alloy according to any one of claims 1 to ~~3~~4.