[0022] (3) The lead-free and antimony-free solder alloy according to (1) or (2) above, wherein the alloy composition contains 0.0005 to 0.0045% of Ge by mass%.

(4) The lead-free and antimony-free solder alloy according to any one of (1) to (3) 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] (5) A solder ball comprising the lead-free and antimony-free solder alloy according to any one of (1) to (4) above.

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

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

(8) The solder ball according to (5) or (6) above, having a sphericity of 0.99 or more.

[0024] (9) A ball grid array formed using the solder ball according to any one of (5) to (8) above.

(10) A solder joint comprising the lead-free and antimony-free solder alloy according to any one of (1) to (4) above.

[0024a] 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,

0.005 to 0.090% of Ni, and

0.0005 to 0.0090% of Ge,

optionally 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%,

with the balance being Sn,

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

$0.005 \leq (Ag + Cu + Ni) \times Ge < 0.023$ relation (1)

$(Sn/Cu) \times (Ni \times Ge)/(Ni + Ge) < 0.49$ relation (2)

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

[0024b] In another 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,

0.005 to 0.090% of Ni,

0.0005 to 0.0090% of Ge, and

optionally 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%,

with the balance being Sn,

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

$0.003 < (Ag + Cu + Ni) \times Ge < 0.023$ relation (1)

$0.57 \leq (Sn/Cu) \times (Ni \times Ge)/(Ni + Ge) < 0.89$ relation (2)

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

Description of Embodiments

[0025] The present invention is described in more detail below. In the present description, "%" relating to the solder alloy composition refers to "mass%" unless otherwise specified.

[0026] 1. Alloy Composition

(1) 0.1 to 4.5% of Ag

Ag is an element that improves the strength of the solder alloy by precipitating minute $Ag_3Sn$ at the grain boundaries. If the Ag content is less than 0.1%, the effect of adding Ag is not sufficiently exhibited. In terms of the lower limit, the Ag content is 0.1% or more, preferably 0.5% or more, more preferably 1.0% or more, even more preferably 1.2% or more, and particularly preferably 2.0% or more, and most preferably 2.5% or more. On the other hand, if the Ag content is too large, coarse $Ag_3Sn$ is precipitated, whereby the strength deteriorates. In terms of the upper limit, the Ag content is 4.5% or less, preferably 4.0% or less, more preferably 3.5% or less, even more preferably 3.2% or less, and particularly preferably 3.0% or less.

[0027] (2) 0.20 to 0.85% of Cu

Cu is an element that can suppress Cu leaching and enable precipitation strengthening by $Cu_6Sn_5$. If the Cu content is less than 0.20%, since the precipitated amount of $Cu_6Sn_5$ is small and a brittle SnNi compound is precipitated, the solder alloy itself becomes brittle. In

# 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,

0.005 to 0.090% of Ni, ~~and~~

0.0005 to 0.0090% of Ge, and

optionally 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%,

with the balance being Sn,

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

$0.005 \leq (Ag + Cu + Ni) \times Ge < 0.023$ relation (1)

$(Sn/Cu) \times (Ni \times Ge)/(Ni + Ge) < 0.49$ relation (2)

wherein Ag, Cu, Ni, 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,

0.005 to 0.090% of Ni, ~~and~~

0.0005 to 0.0090% of Ge, and

optionally 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%,

with the balance being Sn,

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

$0.003 < (Ag + Cu + Ni) \times Ge < 0.023$ relation (1)

$0.57 \leq (Sn/Cu) \times (Ni \times Ge)/(Ni + Ge) < 0.89$ relation (2)

wherein Ag, Cu, Ni, 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 claim 1 or 2, wherein, by mass%,
the alloy composition comprises 0.0005 to 0.0045% of Ge.

~~4. The lead-free and antimony-free solder alloy according to any one of claims 1 to 3, wherein, by mass%,~~
~~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%.~~

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

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

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

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

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

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