considerably influence on thermal fatigue resistance of joined solder based on a repeat of heat and cold, which considerably affect reliability of an electronic circuit. Taking this into consideration, lead-free solder which considerably improves its thermal fatigue resistance has been proposed (see Patent Document 1).

[0012]

The above-mentioned evaluation properties are solder properties required in a case where an electronic circuit is mounted on consumer electronics but in any uses thereof, solderability (solder properties) such as the above-mentioned wettability and shear strength properties is required together with the thermal fatigue resistance. Here, the consumer electronics refer to a cellular phone, a multifunctional terminal (smart phone), a personal computer and the like, other than well-known household electric appliance.

[DOCUMENT FOR PRIOR ART]

[PATENT DOCUMENT]

[0013]

Patent Document 1: International Publication No. 2009/011341

[SUMMARY OF THE INVENTION]

[PROBLEM TO BE SOLVED BY THE INVENTION]

[0014]

By the way, the lead-free solder (solder alloy including Sn, Ag, Cu, Bi, Ni or the like) disclosed in the Patent Document 1 has realized thermal fatigue resistance which conventional ternary alloy solder (Sn-3Ag-0.5 Cu or the like) could not obtain, but further improvement on the solder properties such as wettability, shear strength properties and the like is also important improvement theme. Particularly, in an electronic circuit to be mounted on a cellular phone or the like, micro-miniaturization of circuit elements has been progressed and the cellular phone has been often dropped during its use so that wettability, the shear strength properties and the like have also formed important property improvement factors.

[0015]

Therefore, embodiments of the present invention seek to resolves such a conventional problem and ~~is~~ to provide lead-free solder, a lead-free solder ball, a solder joint using the lead-free solder and a semiconductor circuit having the solder joint, in which an attempt is made to further improve the solder properties such as the wettability, the shear strength properties and the like in addition to the thermal fatigue resistance.

[MEANS FOR SOLVING THE PROBLEMS]

[0016]

~~In order to resolve the above-mentioned problem,~~ According to a first aspect of the present invention, there is provided a lead-free solder ~~according to the invention, which is claimed in Claim 1, is characterized in that~~ wherein the lead-free solder contains Ag of 1.2 mass % through 4.5 mass %, Cu of 0.25 mass % through 0.75 mass %, Bi of 1 mass % through 5.8 mass %, Ni of 0.01 mass % through 0.15 mass % and Sn as the remainder.

[0017]

~~Lead-free solder claimed in Claim 2 is characterized in that~~ Preferably, the lead-free solder contains Ag of 2 mass % through 4 mass %, Cu of 0.3 mass % through 0.75 mass %, Bi of 1 mass % through 5 mass %, Ni of 0.02 mass % through 0.15 mass % and Sn as the remainder.

[0018]

~~Lead-free solder claimed in Claim 3 is characterized in that~~ Preferably, the lead-free solder contains Ag of 2.5 mass % through 3.5 mass %, Cu of 0.5 mass % through 0.75 mass %, Bi of 3 mass % through 5 mass %, Ni of 0.03 mass % through 0.12 mass % and Sn as the remainder.

[0019]

~~Lead-free~~ According to a second aspect of the present invention, there is provided a lead-free solder, ~~claimed in Claim 4 is characterized in that~~ wherein a total amount of 0.0005 mass % through 0.05 mass % of at least one selected from the group consisting of P and Ge is added to the lead-free solder ~~claimed in any one of Claims 1 through 3~~ as defined in the first aspect.

[0020]

~~Lead-free~~According to a third aspect of the present invention, there is provided a lead-free solder ball, ~~claimed in Claim 5 is characterized in that~~ wherein the lead-free solder ball contains Ag of 1.2 mass % through 4.5 mass %, Cu of 0.25 mass % through 0.75 mass %, Bi of 1 mass % through 5.8 mass %, Ni of 0.01 mass % through 0.15 mass % and Sn as the remainder.

[0021]

~~Lead-free solder ball claimed in Claim 6 is characterized in that~~ Preferably, the lead-free solder ball contains Ag of 2 mass % through 4 mass %, Cu of 0.3 mass % through 0.75 mass %, Bi of 1 mass % through 5 mass %, Ni of 0.02 mass % through 0.15 mass % and Sn as the remainder.

[0022]

~~Lead-free solder ball claimed in Claim 7 is characterized in that~~ Preferably, the lead-free solder ball contains Ag of 2.5 mass % through 3.5 mass %, Cu of 0.5 mass % through 0.75 mass %, Bi of 3 mass % through 5 mass %, Ni of 0.03 mass % through 0.12 mass % and Sn as the remainder.

[0023]

~~Lead-free solder ball claimed in Claim 8 is characterized in that~~ Preferably, a total amount of 0.0005 mass % through 0.05 mass % of at least one selected from the group consisting of P and Ge is added to the lead-free solder ball ~~claimed in any one of Claims 5 through 7~~ as defined in the third aspect.

[0024]

~~Solder~~ According to a fourth aspect of the present invention, there is provided a solder joint, ~~Joint claimed in Claim 9 is characterized in that~~ wherein the lead-free solder containing Ag of 1.2 mass % through 4.5 mass %, Cu of 0.25 mass % through 0.75 mass %, Bi of 1 mass % through 5.8 mass %, Ni of 0.01 mass % through 0.15 mass % and Sn as the remainder is used.

[0025]

~~Solder Joint claimed in Claim 10 is characterized in that~~ Preferably, the lead-free solder containing Ag of 2 mass % through 4 mass %, Cu of 0.3 mass % through 0.75 mass %, Bi of 1 mass % through 5 mass %, Ni of 0.02 mass % through 0.15 mass % and Sn as the remainder is used.

[0026]

~~Solder Joint claimed in Claim 11 is characterized in that~~ Preferably, the lead-free solder containing Ag of 2.5 mass % through 3.5 mass %, Cu of 0.5 mass % through 0.75 mass %, Bi of 3 mass % through 5 mass %, Ni of 0.03 mass % through 0.12 mass % and Sn as the remainder is used.

[0027]

~~Solder Joint claimed in Claim 12 is characterized in that~~ Preferably, the lead-free solder in which a total amount of 0.0005 mass % through 0.05 mass % of at least one selected from the group consisting of P and Ge is added to the lead-free solder composition ~~claimed in any one of Claims 9 through 11 is used~~ as defined in the fourth aspect.

[0028]

~~Semiconductor~~ According to a fifth aspect of the present invention, there is provided a semiconductor circuit, ~~claimed in Claim 13 is characterized in that~~ wherein the lead-free solder containing Ag of 1.2 mass % through 4.5 mass %, Cu of 0.25 mass % through 0.75 mass %, Bi of 1 mass % through 5.8 mass %, Ni of 0.01 mass % through 0.15 mass % and Sn as the remainder is used.

[0029]

~~Semiconductor circuit claimed in Claim 14 is characterized in that~~ Preferably, the lead-free solder containing Ag of 2 mass % through 4 mass %, Cu of 0.3 mass % through 0.75 mass %, Bi of 1 mass % through 5 mass %, Ni of 0.02 mass % through 0.15 mass % and Sn as the remainder is used.

[0030]

~~Semiconductor circuit claimed in Claim 15 is characterized in that~~ Preferably, the lead-free solder containing Ag of 2.5 mass % through 3.5 mass %, Cu of 0.5 mass % through 0.75 mass %, Bi of 3 mass % through 5 mass %, Ni of 0.03 mass % through 0.12 mass % and Sn as the remainder is used.

[0031]

~~Semiconductor circuit claimed in Claim 16 is characterized in that~~ Preferably, a total amount of 0.0005 mass % through 0.05 mass % of at least one selected from the group consisting of P and Ge is added to the lead-free solder ~~claimed in any one of Claims 13 through 15~~ as defined in the fifth aspect.

[EFFECT OF THE INVENTION]

[0032]

According to this invention, in a solder alloy containing Sn, Ag, Cu, Bi, Ni and the like, it is possible to further improve the common solder properties such as wettability, the shear strength properties and the like in addition to the thermal fatigue resistance.

[BRIEF DESCRIPTION OF DRAWINGS]

[0033]

[FIG. 1] FIG. 1 is a sectional view of a CSP package concept showing an important portion thereof.

[FIG. 2] FIG. 2 is a sectional view of a WL-CSP chip concept showing an important portion thereof.

[FIG. 3] FIG. 3 is a graph showing a relationship between content of Ag and thermal fatigue resistance or wettability in the lead-free solder according to this invention.

[FIG. 4] FIG. 4 is a graph showing a relationship between content of Cu and wettability or shear properties in the lead-free solder according to this invention.

[FIG. 5] FIG. 5 is a graph showing a relationship between content of Bi and thermal fatigue resistance in the lead-free solder according to this invention.

[FIG. 6] FIG. 6 is a graph showing a relationship between content of Ni and thermal fatigue resistance or wettability in the lead-free solder according to this invention.

[MODES FOR IMPLEMENTING THE INVENTION]

[EMBODIMENTS]

[0034]

The following will describe lead-free solder according to this invention

CLAIM

[Claim 1]

Lead-free solder ~~characterized in that~~ wherein the lead-free solder contains Ag of 1.2 mass % through 4.5 mass %; Cu of 0.25 mass % through 0.75 mass %; Bi of 1 mass % through 5.8 mass %; Ni of 0.01 mass % through 0.15 mass % and Sn as the remainder.

[Claim 2]

The lead-free solder according to Claim 1 ~~characterized in that~~ wherein the lead-free solder contains Ag of 2 mass % through 4 mass %; Cu of 0.3 mass % through 0.75 mass %; Bi of 1 mass % through 5 mass %; Ni of 0.02 mass % through 0.15 mass % and Sn as the remainder.

[Claim 3]

The lead-free solder according to Claim 1 ~~characterized in that~~ wherein the lead-free solder contains Ag of 2.5 mass % through 3.5 mass %; Cu of 0.5 mass % through 0.75 mass %; Bi of 3 mass % through 5 mass %; Ni of 0.03 mass % through 0.12 mass % and Sn as the remainder.

[Claim 4]

The lead-free solder ~~characterized in that~~ wherein a total amount of 0.0005 mass % through 0.05 mass % of at least one selected from the group consisting of P and Ge is added to the lead-free solder claimed in any one of Claims 1 through 3.

[Claim 5]

Lead-free solder ball ~~characterized in that~~ wherein the lead-free solder ball contains Ag of 1.2 mass % through 4.5 mass %; Cu of 0.25 mass % through 0.75 mass %; Bi of 1 mass % through 5.8 mass %; Ni of 0.01 mass % through 0.15 mass % and Sn as the remainder.

[Claim 6]

The lead-free solder ball according to Claim 5 ~~characterized in that~~ wherein the lead-free solder ball contains Ag of 2 mass % through 4 mass %; Cu of 0.3 mass % through 0.75 mass %; Bi of 1 mass % through 5 mass %; Ni of 0.02 mass % through 0.15 mass % and Sn as the remainder.

[Claim 7]

The lead-free solder ball according to Claim 5 ~~characterized in that~~ wherein the lead-free solder ball contains Ag of 2.5 mass % through 3.5 mass %; Cu of 0.5 mass % through 0.75 mass %; Bi of 3 mass % through 5 mass %; Ni of 0.03 mass % through 0.12 mass % and Sn as the remainder.

[Claim 8]

Lead-free solder ball according to any one of Claims 5 through 7 ~~characterized in that~~ wherein a total amount of 0.0005 mass % through 0.05 mass % of at least one selected from the group consisting of P and Ge is added to the lead-free solder.

[Claim 9]

Solder joint ~~characterized in that~~ wherein the lead-free solder containing Ag of 1.2 mass % through 4.5 mass %; Cu of 0.25 mass % through 0.75 mass %; Bi of 1 mass % through 5.8 mass %; Ni of 0.01 mass % through 0.15 mass % and Sn as the remainder is used.

[Claim 10]

The solder joint according to Claim 9 ~~characterized in that~~ wherein the lead-free solder containing Ag of 2 mass % through 4 mass %; Cu of 0.3 mass % through 0.75 mass %; Bi of 1 mass % through 5 mass %; Ni of 0.02 mass % through 0.15 mass % and Sn as the remainder is used.

[Claim 11]

The solder joint according to Claim 9 ~~characterized in that~~ wherein the lead-free solder containing Ag of 2.5 mass % through 3.5 mass %; Cu of 0.5 mass % through 0.75 mass %; Bi of 3 mass % through 5 mass %; Ni of 0.03 mass % through 0.12 mass % and Sn as the remainder is used.

[Claim 12]

Solder joint according to any one of Claims 9 through 11 ~~characterized in that~~ wherein the lead-free solder to which a total amount of 0.0005 mass % through 0.05 mass % of at least one selected from the group consisting of P and Ge is added is used to the lead-free solder.

[Claim 13]

Semiconductor circuit ~~characterized in that~~ wherein the lead-free solder containing Ag of 1.2 mass % through 4.5 mass %; Cu of 0.25 mass % through 0.75 mass %; Bi of 1 mass % through 5.8 mass %; Ni of 0.01 mass % through 0.15 mass % and Sn as the remainder is used.

[Claim 14]

The semiconductor circuit according to Claim 13 ~~characterized in that~~ wherein the lead-free solder containing Ag of 2 mass % through 4 mass %; Cu of 0.3 mass % through 0.75 mass %; Bi of 1 mass % through 5 mass %; Ni of 0.02 mass % through 0.15 mass % and Sn as the remainder is used.

[Claim 15]

The semiconductor circuit according to Claim 13 ~~characterized in that~~ wherein the lead-free solder containing Ag of 2.5 mass % through 3.5 mass %; Cu of 0.5 mass % through 0.75 mass %; Bi of 1 mass % through 4 mass %; Ni of 0.03 mass % through 0.12 mass % and Sn as the remainder is used.

[Claim 16]

Semiconductor circuit according to any one of Claims 13 through 15 ~~characterized in that~~ wherein the lead-free solder to which a total amount of 0.0005 mass % through 0.05 mass % of at least one selected from the group consisting of P and Ge is added is used to the lead-free solder.