[MEANS FOR SOLVING THE PROBLEMS]

[0016]

According to a first aspect of the present invention, there is provided a lead-free solder for use in a semiconductor package, wherein the lead-free solder contains Ag of 2 mass % through 4.5 mass %, Cu of 0.25 mass % through 0.75 mass %, Bi of 3 mass % through 5 mass %, Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder, wherein after 1000 thermal cycles on the semiconductor package, with each thermal cycle comprises a temperature of -40°C for 10 minutes and followed by a temperature of 125°C for 10 minutes, a resistance value of the semiconductor package is less than double of the resistance value of the semiconductor package prior to the thermal cycles.

[0017]

Preferably, the lead-free solder contains Ag of 2 mass % through 4 mass %, Cu of 0.25 mass % through 0.75 mass %, Bi of 3 mass % through 5 mass %, Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder.

[0018]

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 0.02 mass % or more and less than 0.1 mass % and Sn as the remainder.

[0019]

According to a second aspect of the present invention, there is provided a lead-free solder, 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 as defined in the first aspect.

[0020]

According to a third aspect of the present invention, there is provided a lead-free solder ball for use in a semiconductor package,, wherein the lead-free solder ball contains Ag of 2 mass % through 4.5 mass %, Cu of 0.25 mass % through 0.75 mass %, Bi of 3 mass % through 5 mass %, Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder, wherein after 1000 thermal cycles on the semiconductor package, with each thermal cycle comprises a temperature of -40°C for 10 minutes and followed by a temperature of 125°C for 10 minutes, a resistance value of the semiconductor package is less than double of the resistance value of the semiconductor package prior to the thermal cycles.

[0021]

Preferably, the lead-free solder ball contains Ag of 2 mass % through 4 mass %, Cu of 0.25 mass % through 0.75 mass %, Bi of 3 mass % through 5 mass %, Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder.

[0022]

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 0.02 mass % or more and less than 0.1 mass % and Sn as the remainder.

[0023]

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 as defined in the third aspect.

[0024]

According to a fourth aspect of the present invention, there is provided a solder joint for use in a semiconductor package, wherein the lead-free solder containing Ag of 2 mass % through 4.5 mass %, Cu of 0.25 mass % through 0.75 mass %, Bi of 3 mass % through 5 mass %, Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder is used, wherein after 1000 thermal cycles on the semiconductor package, with each thermal cycle comprises a temperature of -40°C for 10 minutes and followed by a temperature of 125°C for 10 minutes, a resistance value of the semiconductor package is less than double of the resistance value of the semiconductor package prior to the thermal cycles.

[0025]

Preferably, the lead-free solder containing Ag of 2 mass % through 4 mass %, Cu of 0.25 mass % through 0.75 mass %, Bi of 3 mass % through 5 mass %, Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder is used.

[0026]

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 0.02 mass % or more and less than 0.1 mass % and Sn as the remainder is used.

[0027]

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 as defined in the fourth aspect.

[0028]

According to a fifth aspect of the present invention, there is provided a semiconductor circuit for use in a semiconductor package, wherein the lead-free solder containing Ag of 2 mass % through 4.5 mass %, Cu of 0.25 mass % through 0.75 mass %, Bi of 3 mass % through 5 mass %, Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder is used, wherein after 1000 thermal cycles on the semiconductor package, with each thermal cycle comprises a temperature of -40°C for 10 minutes and followed by a temperature of 125°C for 10 minutes, a resistance value of the semiconductor package is less than

double of the resistance value of the semiconductor package prior to the thermal cycles.

[0029]

Preferably, the lead-free solder containing Ag of 2 mass % through 4 mass %, Cu of 0.25 mass % through 0.75 mass %, Bi of 3 mass % through 5 mass %, Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder is used.

[0030]

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 0.02 mass % or more and less than 0.1 mass % and Sn as the remainder is used.

[0031]

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 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 for use in a semiconductor package, wherein the lead-free solder contains Ag of 2 mass % through 4.5 mass %; Cu of 0.25 mass % through 0.75 mass %; Bi of 3 mass % through 5 mass %; Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder, wherein after 1000 thermal cycles, with each thermal cycle comprises a temperature of -40°C for 10 minutes and followed by a temperature of 125°C for 10 minutes, a resistance value of the semiconductor package is less than double of the resistance value of the semiconductor package prior to the thermal cycles.

[Claim 2]

The lead-free solder according to Claim 1 wherein the lead-free solder contains Ag of 2 mass % through 4 mass %; Cu of 0.25 mass % through 0.75 mass %; Bi of 3 mass % through 5 mass %; Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder.

[Claim 3]

The lead-free solder according to Claim 1 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 0.02 mass % or more and less than 0.1 mass % and Sn as the remainder.

[Claim 4]

The lead-free solder 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 for use in a semiconductor package, wherein the lead-free solder ball contains Ag of 2 mass % through 4.5 mass %; Cu of 0.25 mass % through 0.75 mass %; Bi of 3 mass % through 5 mass %; Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder, wherein after 1000 thermal cycles, with each thermal cycle comprises a temperature of -40°C for 10 minutes and followed by a temperature of 125°C for 10 minutes, a resistance value of the semiconductor package is less than double of the resistance value of the semiconductor package prior to the thermal cycles.

[Claim 6]

The lead-free solder ball according to Claim 5 wherein the lead-free solder ball contains Ag of 2 mass % through 4 mass %; Cu of 0.25 mass % through 0.75 mass %; Bi of 3 mass % through 5 mass %; Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder.

[Claim 7]

The lead-free solder ball according to Claim 5 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 0.02 mass % or more and less than 0.1 mass % and Sn as the remainder.

[Claim 8]

Lead-free solder ball according to any one of Claims 5 through 7 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 for use in a semiconductor package, wherein the lead-free solder containing Ag of 2 mass % through 4.5 mass %; Cu of 0.25 mass % through 0.75 mass %; Bi of 3 mass % through 5 mass %; Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder is used, wherein after 1000 thermal cycles, with each thermal cycle comprises a temperature of -40°C for 10 minutes and followed by a temperature of 125°C for 10 minutes, a resistance value of the semiconductor package is less than double of the resistance value of the semiconductor package prior to the thermal cycles.

[Claim 10]

The solder joint according to Claim 9 wherein the lead-free solder containing Ag of 2 mass % through 4 mass %; Cu of 0.25 mass % through 0.75 mass %; Bi of 3 mass % through 5 mass %; Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder is used.

[Claim 11]

The solder joint according to Claim 9 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 0.02 mass % or more and less than 0.1 mass % and Sn as the remainder is used.

[Claim 12]

Solder joint according to any one of Claims 9 through 11 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 for use in a semiconductor package, wherein the lead-free solder containing Ag of 2 mass % through 4.5 mass %; Cu of 0.25 mass % through 0.75 mass %; Bi of 3 mass % through 5 mass %; Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder is used, wherein after 1000 thermal cycles on the semiconductor package, with each thermal cycle comprises a temperature of -40°C for 10 minutes and followed by a temperature of 125°C for 10 minutes, a resistance value of the semiconductor package is less than double of the resistance value of the semiconductor package prior to the thermal cycles.

[Claim 14]

The semiconductor circuit according to Claim 13 wherein the lead-free solder containing Ag of 2 mass % through 4 mass %; Cu of 0.25 mass % through 0.75 mass %; Bi of 3 mass % through 5 mass %; Ni of 0.01 mass % or more and less than 0.1 mass % and Sn as the remainder is used.

[Claim 15]

The semiconductor circuit according to Claim 13 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 0.02 mass % or more and less than 0.1 mass % and Sn as the remainder is used.

[Claim 16]

Semiconductor circuit according to any one of Claims 13 through 15 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.