fracture of solder joints by adding In to a Sn-Ag-Cu solder alloy. Although Patent Document 1 refers to resistance to thermal fatigue, it does not contain sufficient discussion of the effects when electrical conduction takes place for a long period in a high current density environment at a high temperature. Thus, the environment of operation of CPUs is not faithfully reproduced in Patent Document 1.

【0009】

The specific solder alloys which are investigated in Patent Document 1 are ones having alloy compositions containing 0.5% In. These alloy compositions have an extremely low In content, which makes it impossible to confirm whether resistance to thermal fatigue is sufficiently improved by the addition of In. It is not verified at all whether these alloy compositions can avoid electromigration and various kinds of problems caused thereby when electrical conduction takes place for a long period in a high current density environment at a high temperature. Accordingly, the solder alloy disclosed in Patent Document 1 cannot be said to solve the problem of increased electromigration due to the increase in current density in recent years.

【0010】

~~The problem~~ Embodiments of the present invention ~~is~~seek to provide a lead-free solder alloy which can suppress an increase in the interconnection resistance of solder joints by suppressing of the growth of void due to electromigration in a high temperature, high current density environment.

【0011】

The present inventors performed detail investigation of the composition of a Sn-Ag-Cu-In solder alloy from the standpoint of suppressing the occurrence of electromigration. Namely, the present inventors considered that when Sn atoms migrated toward the anode side along with the flow of electrons to leave lattice vacancies in the cathode side, In atoms might fill the lattice vacancies and could suppress the growth of the lattice vacancies. As a result, the present inventors found that an In content of 1.0 - 13.0 % in a Sn-Ag-Cu-In solder alloy can effectively suppress the formation of lattice vacancies and the growth of void due to electromigration~~, and they thereby completed the present invention~~.

Means for solving Problem

【0012】

~~In order to solve the above-mentioned problem, a lead-free solder alloy as set forth in claim 1 is~~ According to a first aspect of the present invention, there is provided a lead-free solder alloy having an alloy composition consisting essentially of, in mass percent, In: 1.0 - 13.0 %, Ag: 0.1 - 4.0 %, Cu: 0.3 - 1.0 %, and a remainder of Sn.

【0013】

~~The lead-free solder alloy as set forth in claim 2 is the lead-free solder alloy according to the claim 1 wherein the~~ Preferably, the Ag content of the lead-free solder alloy is 0.3 - 3.0 % by mass.

【0014】

~~The lead-free solder alloy as set forth in claim 3 is the lead-free solder alloy according to the claim 1 containing,~~ Preferably, the alloy composition contains, in mass percent, In: 2.0 - 13.0 %, Ag: 0.3 - 3.0 %, and Cu: 0.5 - 0.7 %.

【0015】

~~The lead-free solder alloy as set forth in claim 4 is the lead-free solder alloy according to the claim 1 containing,~~ Preferably, the alloy composition contains, in mass percent, In: 5.0 - 10.0 %, Ag: 0.1 - 1.5 %, and Cu: 0.3 - 1.0 %.

【0016】

~~A~~According to a second aspect of the present invention, there is provided a solder joint ~~as set forth in claim 5 is~~ made from the lead-free solder alloy ~~according to any one of the claims 1 through 4~~ as defined in the first aspect.

【0017】

~~The solder joint as set forth in claim 6 is the solder joint according to claim 5 wherein~~ Preferably, a percent increase in the resistance after 2500 hours of conduction in the air at 165° C with a current density of 0.12 $mA/\mu m^2$ is at most 30% compared to the resistance before the start of conduction and is at most 5% compared to the resistance at 500 hours after the start of conduction.

【0018】

~~A~~According to a third aspect of the present invention, there is provided a method of suppressing electromigration of a solder joint during electrical conduction ~~as set forth in claim 7~~ comprises forming a solder joint using the lead-free solder alloy ~~according to any one of the claims 1 through 4~~ as defined in the first aspect.

Effects of the Invention

【0019】

Thereby, the lead-free solder alloy according to embodiments of the invention contains 1.0 - 13.0 % of In in the Sn-In-Ag-Cu solder alloy so that the electromigration which is easily formed in such a lead-free solder alloy can be suppressed. Further, When In content is within a range of 5 through 10%, not only is it possible to effectively suppress the formation of electromigration, it is also possible to obtain excellent mechanical properties at high temperatures.

【0020】

Additionally, the solder joint according to embodiments of the invention is made from the above-mentioned lead-free solder alloy so that it is possible to suppress fracture of a solder joint due to electromigration in a high current density environment at a high temperature.

【0021】

Still further, the method of suppressing electromigration of a solder joint during electrical conduction according to embodiments of the invention can suppress the growth of void due to electromigration in the solder joint during electrical conduction.

Brief Explanation of the Drawings

【0022】

[Figure 1] Figure 1 is a graph schematically showing the relationship between the In concentration of a solder joint and the distance from the cathode side of the solder joint at the end of an EM test.

[Figure 2A] Figure 2A is a schematic vertical cross-sectional view of a FCLGA package used in an EM test.

[Figure 2B] Figure 2B is a schematic plan view of the FCLGA package used in an EM test.

[Figure 3] Figure 3 is a diagram schematically showing the flowing directions of electrons (e^-) in soldered joints which are subjected to an EM test.

[Figure 4] Figure 4 is a cross-sectional SEM photograph showing intermetallic compounds formed at the boundary between a solder joint made of a Sn-7In-1Ag-0.5Cu solder alloy and an electrode with a Ni/Au coating.