[0006] Further, Patent Document 1 describes that an alloy structure becomes fine due to a synergistic effect of Sb and Ni, and ductility, shear strength, and heat cycle resistance are simultaneously exhibited. Moreover, Patent Document 1 discloses that Ge may be added as an element that suppresses oxidation of Sn and further improves wettability.

Citation List

Patent Document

[0007] Patent Document 1: Japanese Patent Publication No. 6477965

Summary

Technical Problem

[0008] As described above, the solder alloy described in Patent Document 1 is a very excellent solder alloy that can simultaneously exhibit ductility, shear strength, and heat cycle resistance with one alloy composition, and even more, can also improve suppression of oxidation and wettability. However, in the last several years, the board has been thinned due to the increase in the number of layers, and further, the package has been increased in size, so that defects caused by warpage of the board due to heating during solder bonding have occurred again.

[0009] Therefore, in a stage where the heating temperature rises from room temperature to reach the mounting peak temperature or in a stage where the board is cooled from the peak temperature, PKG (Package) such as BGA (Ball Grid Array) or LGA (Land Grid Array) mounted on the board is bent due to a difference in thermal expansion coefficient or rigidity of each material constituting the inside of PKG, and deviates from a position at the time of mounting. Along with this, a tear phenomenon occurs in which the electrode of the board and the electrode of the PKG are solidified in a state of being separated from each other more than the initial interval, and at that time, a minute gap is generated such that the molten portion of the solder alloy constituting the solder joint is torn. When only the tear phenomenon occurs, the solder joint maintains an electrically connected state, so that the function as the solder joint is exhibited.

[0010] However, when the tear phenomenon progresses, an open defect occurs in which the

been sufficiently studied.

[0015] An object of the present disclosure is to provide a solder alloy, a solder paste, a solder ball, and a solder joint which have a low melting point, are excellent in ductility, shear strength, and heat cycle resistance, further suppress the occurrence of open defects, and in addition, have reduced residual voids even at the time of joining in a large area.

Solution to Problem

[0016] The present inventors have paid attention to the Sn-Bi-Sb-Ni-Ge solder alloy disclosed in Patent Document 1 that exhibits an effect of improving the bonding quality by being compatible with the mounting process even as a liquid. In addition, as a result of studying the cause of the existence of an alloy composition that causes an open defect when warpage occurs in a thin board, it has been found that when the oxidation state of the surface of the molten solder alloy becomes unstable, an open defect occurs due to the progress of a tear phenomenon from a liquid phase portion in a case where the alloy is entirely in a liquid phase or in a mixed state of a solid phase and a liquid phase.

[0017] In view of these, in order to increase the stable oxide film on the surface of the molten solder alloy, it may be better to increase the Ge content. However, it has been found that at the time of a high content of Ge, open defects are curbed, but there is an alloy composition in which a large amount of voids are generated when a solder joint is formed using a paste printed over a wide area. This is presumed to be because when a thick oxide film of Ge is generated, the active component in the flux constituting the paste is preferentially consumed for the reduction of the oxide film, and as a result of the subsequent reduction of the electrode, a large amount of voids are generated at the bonding interface.

[0018] Therefore, the present inventors have found that it is necessary to accurately control the Ge content to be within a predetermined range by focusing on the Ge content. However, in the Sn-Bi-Sb-Ni-Ge solder alloy, it has been found that a sufficient effect cannot be obtained if only the Ge content is controlled.

[0019] In order to prevent the occurrence of open defects even when the Ge content is reduced, it has also been found that the occurrence of open defects can be suppressed due to the reduction

of the Ge content by precisely controlling the Bi and Ni contents in addition to Ge.

[0020] In obtaining this finding, the present inventors have focused on the point that when the surface state of the molten solder alloy is stable, the occurrence of open defects due to the progress of the tear phenomenon can be suppressed. Then, assuming that the droplet of the molten solder alloy is stably retained as long as the surface state is stabilized, the droplet retainability of the molten solder alloy was evaluated. As a result, it has also been found that a solder alloy having a droplet retainability, which is an index for stably retaining droplets, tends to be capable of suppressing the occurrence of open defects.

[0021] Furthermore, in order to sufficiently suppress voids that can be generated in a solder joint having a large area by Ge being contained to some extent, it has also been found that generation of voids can be sufficiently suppressed when the Sb content is within a predetermined range in addition to the Bi, Ni, and Ge contents. In addition, it has also been found that the Sn-Bi-Sb-Ni-Ge solder alloy exhibiting these effects has a low liquidus-line temperature and is also excellent in ductility, shear strength, and heat cycle resistance, similarly to the conventional solder alloy.

The present disclosure obtained by these findings is as follows.

[0022] (0) A solder alloy consisting of, by mass%, Bi: 35.0 to 68.0%, Sb: 0.1 to 2.0%, Ni: 0.010 to 0.050%, Ge: 0.007 to 0.090%, with the balance being Sn.

(1) A solder alloy having an alloy composition consisting of, by mass%, Bi: 35.0 to 68.0%, Sb: 0.1 to 2.0%, Ni: 0.010 to 0.050%, Ge: 0.007 to 0.090%, with the balance being Sn.

[0023] (2) The solder alloy according to (0) or (1) above, wherein the alloy composition (solder alloy) further comprises, by mass%, at least one of Co, As, Fe, Pd, Zr, Pb, Ce, and P: 0.1% or less in total.

[0024] (3) The solder alloy according to (0) or (1) above, wherein the alloy composition (solder alloy) further comprises, by mass%, at least one of Co, Ti, Al, Mn, As, Fe, Pd, Zn, Zr, Pb, In, Ce, P, and Ga: 0.1% or less in total.

[0025] (4, 8) The solder alloy according to any one of (0) to (3) above, wherein the alloy composition (solder alloy) satisfies the following Relations (1) and (2):

$0.0008 \leqq Bi \times Sb \times Ni \times Ge \leqq 0.0347$ Relation (1)

$34.7 \leqq (Bi \times Ni)/Ge \leqq 154.6$ Relation (2)

wherein Bi, Sb, Ni, and Ge in the Relations (1) and (2) above each represent the content as mass% thereof in the solder alloy.

[0026] (5) A solder paste comprising the solder alloy according to any one of (0) to (3).

[0027] (6) A solder ball consisting of the solder alloy according to any one of (0) to (3).

[0028] (7) A solder joint comprising the solder alloy according to any one of (0) to (3).

[0028a] In an aspect of the present disclosure, there is provided a solder alloy having an alloy composition consisting of, by mass%,

Bi: 35.0 to 68.0%,

Sb: 0.1 to 2.0%,

Ni: 0.010 to 0.050%,

Ge: 0.007 to 0.090%, with the balance being Sn.

[0028b] In another aspect of the present disclosure, there is provided a solder paste comprising the solder alloy as disclosed herein.

[0028c] In another aspect of the present disclosure, there is provided a solder ball comprising the solder alloy as disclosed herein.

[0028d] In another aspect of the present disclosure, there is provided a solder joint comprising the solder alloy as disclosed herein.

Brief Description of Drawings

[0029] FIG. 1 is a schematic view showing a method for evaluating droplet retainability, FIG. 1(a) is a schematic view showing a discharge state which is judged as “Excellent”, FIG. 1(b) is a schematic view showing a discharge state which is judged as “Good”, FIG. 1(c) is a schematic view showing a discharge state which is judged as “Poor”, and FIG. 1(d) is a view showing a discharge amount and time.

FIG. 2 is a schematic view showing a method for evaluating avoidance of an open defect of an LGA joint portion, FIG. 2(a) is a schematic view showing a state in which PKG is installed on a board, FIG. 2(b) is a schematic view showing a state in which PKG is brought

into contact with a solder paste printed on a board and the temperature is also raised, FIG. 2(c) is a schematic view showing a state in which PKG is raised upward by 40 μm from the state in FIG. 2(b) in an environment of 190℃, FIG. 2(d) is a schematic partial cross-sectional view showing a region in the vicinity of a joint portion of a solder joint before the PKG is raised upward by 40 μm in FIG. 2(c), FIG. 2(e) is a schematic partial cross-sectional view showing a region in the vicinity of a joint portion of a solder joint in FIG. 2(c), FIG. 2(f) is a schematic partial cross-sectional view showing a state of the solder joint in which no defect occurs from the middle of solidification to the completion of solidification, FIG. 2(g) is a schematic partial cross-sectional view showing a state of the solder joint in which a hot tear phenomenon occurs from the middle of solidification to the completion of solidification, and FIG. 2(h) is a schematic partial cross-sectional view showing a state of the solder joint in which an open defect occurs due to the progress of a tear phenomenon from the middle of solidification to the