

Description

ALUMINUM ALLOY BONDING WIRE

Technical Field

5 [0001]

The present invention relates to an aluminum alloy wire material to be used for bonding an electrode on a semiconductor element which is used under a high temperature environment to an external electrode with the use of an aluminum alloy thin wire and, particularly, to an aluminum alloy bonding wire which utilizes an effect attained by Al_3Sc particles which are age-precipitated from high purity aluminum in a semiconductor device used under a high temperature environment such as those used in aircrafts, electric vehicles, and ships.

Background Art

[0002]

For a bonding pad mounted to a semiconductor element such as silicon (Si), silicon carbide (SiC), and gallium nitride (GaN), a substrate of aluminum (Al), copper (Cu), and nickel (Ni), or the like is mostly used. The substrate is in some cases provided with noble metal plating of gold (Au), silver (Ag), or the like or nickel (Ni) plating for use. These substrates are collectively referred to as "aluminum pad" unless otherwise specified. For performing ultrasonic bonding of the aluminum pad to a lead frame or the like, an aluminum alloy thin wire using high purity

aluminum (Al) is used since the high purity aluminum exhibits high conductivity of the order of 60%. For the aluminum alloy thin wire, a round thin wire having a wire diameter of 50 to 500 μm is generally used, and a very thin wire having a wire diameter of less than 50 μm and ones having a wire diameter exceeding 500 μm are occasionally used. Also, a flat rectangular thin wire (tape) obtained by pressing any one of the thin wires is sometimes used as the aluminum alloy thin wire for the semiconductor device.

[0003]

Difficulty in ensuring high temperature reliability has been a problem with the case where the aluminum alloy thin wire using the high purity aluminum (Al) is used under a high temperature environment (atmosphere), particularly, as a wire material for aircrafts, automobiles, ships, and the like.

Accordingly, the following aluminum alloys which are obtained by dissolving scandium (Sc) into aluminum (Al) are known as wire materials having relatively small specific resistance, relatively high mechanical strength, and excellent heat resistance.

Japanese Unexamined Patent Publication No. 7-316705 (referred to as Patent Literature 1 below) discloses "a wire material characterized by comprising about 0.1 to 0.3 wt% of Sc with the balance being Al and about 0.05 wt% or less of impurities" and describes that "pure aluminum having purity of 99.95% or more is used, and about 0.1% to

0.3% of scandium (Sc) in terms of weight ratio to the entire alloy is added to the aluminum (paragraph 0012 of Patent Literature 1)" and "plastic working is performed with a rolling reduction of 50%, followed by a heat
5 treatment at 400°C to 500°C for about one hour (paragraph 0016 of Patent Literature 1)".

Also, Japanese Unexamined Patent Publication No. 2001-348637 (referred to as Patent Literature 2 below) discloses "an aluminum alloy material characterized by
10 comprising, in a pure Al matrix having purity of 99.95% or more, 0.05% to 0.3% of Sc and 0.1% to 0.4% of Zr in terms of weight ratio" (claim 1, etc.) and obtains "the one having conductivity of 60% IACS or more, tensile strength of 200 MPa or more, and residual tensile strength of 90% or
15 more at 280°C (paragraph 0011 of Patent Literature 2)" "by performing plastic working (cold working) which attains a reduction-of-area rate of 80% or more", followed by "a heat treatment at 300°C to 400°C x about 1 hr (paragraph 0024 of Patent Literature 2)".

20 [0004]

However, when the above-mentioned aluminum alloy thin wires are bonded to an aluminum pad electrode containing Al as a main component by the ultrasonic bonding, they have not been in practical use since chip is broken due to the
25 high mechanical strength. Particularly, in the case where the wire diameter of the wire is relatively large, i.e. from 50 to 500 μm , it has been difficult to avoid the

problem of chip breakage.

[0005]

On the other hand, it is considered that the applicable range of the aluminum alloy thin wire will be expanded more and more from now on since there is a demand for a semiconductor which is required to have heat resistance of 100°C to 200°C, particularly, for a power semiconductor which is used in air conditioners, solar power generation systems, hybrid cars, electric vehicles, and the like. Among operation conditions of the power semiconductor elements, a temperature is higher than that of ordinary semiconductor elements. For example, in the power semiconductor used in vehicles, the aluminum alloy thin wire is generally required to endure a temperature of 100°C to 150°C at the highest at a bonding part. The pure aluminum alloy thin wire which consists of the high purity aluminum (Al) which is readily softened under the temperature range has not been in practical use in the devices used under the high temperature environment.

Citation List

Patent Literatures

[0006]

Patent Literature 1: Japanese Unexamined Patent Publication No. 7-316705

Patent Literature 2: Japanese Unexamined Patent Publication No. 2001-348637

Summary of the Invention

Technical Problem

[0007]

An object of the invention of the present application is to provide an aluminum alloy wire material which is as soft as a pure aluminum alloy thin wire which consists of high purity aluminum (Al) during wiring on a semiconductor chip and is not softened under a high temperature condition after the wiring.

Solution to Problem

10 [0008]

In order to attain the object, the inventors contemplated utilization of the fact that scandium (Sc) hardly contributes to improvement of strength unless it is age-precipitated from a state in which scandium is dissolved into aluminum (Al).

More specifically, they confirmed that it is possible to suppress the age-hardening caused by Sc by: performing a solution treatment for forcedly dissolving all of fine Sc precipitates by an intermediate heat treatment of an aluminum (Al) alloy wire material comprising a predetermined amount of scandium (Sc); performing wire drawing up to a desired wire diameter; and performing a refining heat treatment at a temperature and under conditions where the fine precipitates of Sc are not generated.

Since the aluminum alloy wire material is soft and is subject to plastic deformation in the above-described

state, the aluminum alloy thin wire having the above-described composition, which is cold-drawn to attain a desired wire diameter, can be wired to form a predetermined circuit by ultrasonic bonding onto an aluminum pad in the same manner as in the case of using the pure aluminum alloy thin wire.

Also, it was confirmed that it is possible to attain the same effects by adding a certain amount of zirconium (Zr) in addition to scandium (Sc). The addition of zirconium exhibits the effects same as those exhibited by scandium (Sc) in the aluminum (Al) alloy wire material and has the effect of improving temporal stability relative to a temperature history of age hardening.

[0009]

As described above, when the aluminum alloy thin wire subjected to the solution heat treatment is subjected to the wiring and then to the aging heat treatment, mechanical strength is increased owing to the Al_3Sc particles precipitated from the aluminum (Al) matrix as described in Patent Literatures 1 and 2. Further, it was proved that coarsening of Sc particles hardly proceeds in repetitive use under high temperature environment since compatibility between the Al_3Sc particles and the aluminum (Al) matrix is excellent.

[0010]

One of the aluminum alloy wire materials of the present invention to be used for connection in

semiconductor devices used under high temperature environments is an aluminum alloy which has a composition comprising 0.15 to 0.5 mass% of scandium (Sc) with the balance being aluminum (Al) having purity of 99.99 mass% or more; has a recrystallized structure in an aluminum alloy matrix obtained by a forced solution treatment; and has Vickers hardness of 21 to 30 Hv.

[0011]

Another one of the aluminum alloy wire materials of the present invention to be used for connection in semiconductor devices used under high temperature environments is an aluminum alloy which has a composition comprising 0.15 to 0.5 mass% of scandium (Sc) and 0.01 to 0.2 mass% of zirconium (Zr) (provided that the amount of zirconium (Zr) is equal to or less than a half of the amount of scandium (Sc)) with the balance being aluminum (Al) having purity of 99.998 mass% or more; has a recrystallized structure in an aluminum alloy matrix obtained by a forced solution treatment; and has Vickers hardness of 21 to 30 Hv.

[0012]

The above-described two kinds of aluminum alloy wire materials of the present invention to be used for connection in semiconductor devices used under high temperature environments may be subjected to an aging heat treatment within a temperature range of 200°C to 450°C after wiring in advance of a post treatment and processing

to be performed after the wiring. Since the shape of the aluminum alloy wire material does not change after the wiring, semiconductor chip breakage does not occur even when the mechanical strength is increased. Further, since
5 a difference in thermal expansion coefficient between the aluminum alloy wiring material and the aluminum pad is small, crack which is otherwise caused by repetitive heat expansion and heat shrinkage does not proceed at a bonding interface.

10 [0013]

In the invention of the prevent application, when the purity of aluminum (Al) is 99.998 mass% or more, Vickers hardness which is almost the same as that of an aluminum alloy having purity of 99.999 mass% or more is attained.

15 Therefore, the higher the purity of aluminum, the more preferred the aluminum is.

[0014]

In the invention of the present application, the amount of scandium (Sc) to be added may preferably be 0.3
20 mass% or less since such an amount enables to forcedly dissolve scandium (Sc) so that scandium (Sc) is uniformly dispersed into the aluminum matrix. It is possible to determine whether or not the forced solid solution is uniform from a distribution of Al_3Sc particles precipitated
25 from the aluminum (Al) matrix. The a forced solution treatment may preferably be performed near 580°C to 630°C which is close to a melting point of aluminum (Al) for a

several hours.

[0015]

In the invention of the present application, the aluminum alloy wire material to be used for connection in semiconductor devices before the aging heat treatment may be subjected to a refining heat treatment after performing cold wire drawing to attain a desired wire diameter within a range of 50 to 500 μm . The aluminum alloy thin wire after the continuous wire drawing is subjected to the refining heat treatment with a constant tension being applied thereto. The constant tension is basically applied from an outlet of a final diamond dice to an entrance of a winding spool during the continuous wire drawing and is particularly maintained constant during the refining heat treatment step and the cooling step by preventing vibration caused in other process steps from transmitting to the aluminum alloy thin wire with the use of a dancer roller or the like, so that it is possible to impart predetermined heat energy to the aluminum alloy thin wire by the set heat treatment temperature and heat treatment interval.

The cold wire drawn structure attained by the cold wire drawing which is performed after the forced solution treatment becomes the recrystallized structure having mechanical properties suitable for wire bonding by the refining heat treatment.

Examples of the heating method for the refining heat treatment include heating in an electric furnace, electric

conduction heating, heating by light irradiation, water vapor heating, and the like. Since the refining heat treatment is performed for a several seconds to a several tens of seconds, the Al_3Sc particles are not precipitated from the aluminum (Al) matrix. Likewise, when the aluminum alloy wire material after the refining heat treatment is subjected to ultrasonic bonding to an aluminum pad, the aluminum alloy wiring material is not hardened and, therefore, does not cause chip breakage of a semiconductor element.

[0016]

As described above, the aluminum alloy wire material obtained by uniformly and forcedly dissolving scandium (Sc) into the aluminum matrix is free from the chip breakage like the pure aluminum and is capable of easily forming a loop to enable wiring on a semiconductor device.

Further, since the aging heat treatment is performed after the wiring, it is possible to exhibit mechanical strength as an Al-Sc binary alloy owing to the precipitation of Al_3Sc particles from the aluminum (Al) matrix. The aging heat treatment may be performed before resin sealing, for example, depending on resistance against a thermal history of the semiconductor device after wiring formation.

A material for the pad predominantly is aluminum (Al) or an aluminum (Al) alloy, but copper (Cu) or nickel (Ni) which has a high ultrasonic bonding property to the

aluminum alloy wire material may be used as the material,
and a noble metal such as gold (Au) may be coated on the
material.

Advantageous Effects of Invention

5 [0017]

Since the aluminum alloy wire material of the present
invention before wiring is soft as a pure aluminum thin
wire and enables flexible wiring, it is bonded to an
aluminum pad by ultrasonic bonding like a pure aluminum
10 alloy thin wire.

On the other hand, it is possible to enhance
mechanical strength of a wiring after the wiring owing to
the precipitation of Al_3Sc particles from the aluminum (Al)
matrix. Since the amount of scandium (Sc) is small, and
15 since compatibility between the precipitate and the
aluminum (Al) matrix is good, a crack which is otherwise
caused by mechanical strain is not generated from a bonding
interface even when the Al_3Sc particles are precipitated.
Further, the precipitated Al_3Sc particles are hardly
20 coarsened under repetitive high temperature environments in
a power semiconductor such as those of electric vehicles.
The effect is more favorably exhibited by a 5N aluminum
alloy thin wire than by a 4N aluminum alloy thin wire, but
the 4N8 purity aluminum alloy thin wire is preferred when
25 priority is placed on a price and is the aluminum alloy
wire material suitably used for power cycle semiconductors.

Brief Description of Drawing

[0018]

Fig. 1 is a diagram showing change ratios of shear strength values of an aluminum alloy thin wire of the present invention and a pure aluminum thin wire.

5 Description of Embodiments

[0019]

Hereinafter, embodiments of the present invention will be described.

[Example 1]

10 [0020]

Each of four types of Al-Sc alloys which was formed of aluminum (Al) having purity of 99.99 mass% and scandium (Sc) having purity of 99.9 mass%, namely, Al-0.15%Sc, Al-0.2%Sc, Al-0.3%Sc, and Al-0.5%Sc, was molten and then
15 subjected to continuous casting to obtain an aluminum alloy ingot having a diameter of 300 mm.

An aluminum alloy element wire having a diameter of 5 mm was produced by subjecting each of the ingots to rolling using grooved rollers and then to wire drawing. Next, the
20 element wire was subjected to a solution heat treatment of $630^{\circ}\text{C} \times 120 \text{ min}$, followed by quenching in water. After that, continuous wire drawing was performed in water by using a diamond dice to attain a diameter of 0.5 mm, and then a refining heat treatment of $620^{\circ}\text{C} \times 1 \text{ min}$ was
25 performed, followed by water cooling.

The samples were used as Example 1 (samples 1 to 4). Each of Example 1 was subjected to a measurement using a

microvickers hardness meter (Type MVK-G3 manufactured by Akashi Corporation). The measured hardness values are shown in Table 1.

One hundred wirings of each of Example 1 were bonded
5 by ultrasonic bonding to Al-1.0% Si film (thickness: 4 μ m)
on a Si chip (thickness: 0.5 mm) under the following
conditions.

[0021]

(Ultrasonic Bonding Conditions)

10 The aluminum alloy thin wire had a wire diameter of
0.5 mm, a loop length of 10 mm, and a loop height of 1.5
mm.

The ultrasonic bonding of the aluminum alloy thin
wire to the Si chip was performed by using an automatic
15 bonder (REB07 Type manufactured by Ultrasonic Engineering
Co., Ltd.).

Bonding conditions were as follows. The bonding was
performed at a frequency of 120 kHz with load and
ultrasonic conditions being arbitrarily adjusted in order
20 that a deformation width at a first bonding part was 1.3
times of the wire diameter, and the ultrasonic bonding
including first bonding and second bonding was performed
under the same conditions on the entire 100 wirings of each
of the samples. As a superhard tool and a bonding guide,
25 the ones which were manufactured by Ultrasonic Engineering
Co., Ltd. and fit to the wire size were used.
Next, the bonded aluminum alloy thin wires of Example 1

were subjected to an aging treatment under aging treatment conditions of 300°C for 2 hours.

Next, the bonded aluminum alloy thin wires of Example 1 were subjected to the following tests. Results of the tests are shown in Table 1.

[0022]

(Thermal Shock Test)

A small size cold impact device (TSE-11 manufactured by Espec Corp.) was used as a thermal shock testing device, and the test was repeated for 10000 times each of which was performed for 3 minutes at +200°C on a high temperature side and for 3 minutes at -50°C on a low temperature side.

As to a result of a damage applied to the wire bonding part by the thermal shock test, a degree of the damage was evaluated by the following shear strength test.

[0023]

(Shear Strength Test)

A shearing test was performed by using Type 2400 manufactured by Dage Japan Co., Ltd., and shear strength of the first bonding part was measured after performing the test for 1000 times, 2000 times, 5000 times, and 10000 times, respectively, to be compared with the initial strength measured before starting the test. Graphs of Example 1 (No. 4) and Conventional Example are shown in Fig. 1 for comparison.

As a ratio of the shear strength after the repetition to the initial shear strength, the sample in which the

number of reductions in shear strength to 20% (0.8) from the initial strength is less than twice a value of Conventional Example is indicated as x, and the sample in which the number is equal to or more than twice the value
5 of the conventional example is indicated as O. A test height was 5 μm , and a test speed was 500 $\mu\text{m}/\text{sec}$.

[0024]

(Chip Breakage Observation Test)

The Al-0.1%Si pad was molten by using a 20% NaOH
10 solution, and chip breakage of the sample after the bonding was observed by using an optical microscope (STM6, a measurement microscope manufactured by Olympus Corporation) at a magnification of $\times 100$. The observation was performed on 10 points. Generation of chip breakage is indicated by
15 $\times$ even when only one chip breakage was found, and no chip breakage is indicated by O.

[Example 2]

[0025]

Aluminum alloy thin wires each having a diameter of
20 0.5 mm were produced in the same manner as in Example 1 by using Al-0.2%Sc-0.1%Zr and Al-0.5%Sc-0.25%Zr alloys each of which was formed of aluminum (Al) having purity of 99.99 mass%, scandium (Sc) having purity of 99.9 mass%, and zirconium (Zr) having purity of 99.9 mass% to serve as
25 Example 2 (samples 5 and 6).

Next, the samples were subjected to ultrasonic bonding and an aging heat treatment under the conditions

same as those of Example 1.

The above-described tests were conducted on the samples under the conditions same as those of Example 1. Results of the tests are shown in Table 1.

5 [Example 3]

[0026]

Aluminum alloy thin wires having a diameter of 0.1 mm and a diameter of 0.3 mm, respectively, were produced in the same manner as in Example 1 by using an Al-0.3%Sc alloy
10 formed of aluminum (Al) having purity of 99.99 mass% and scandium (Sc) having purity of 99.9 mass% to serve as Example 3 (samples 7 and 8).

Next, the samples were subjected to ultrasonic bonding and an aging heat treatment under the conditions
15 same as those of Example 1.

The above-described tests were conducted on the samples under the conditions same as those of Example 1. Results of the tests are shown in Table 1.

[Example 4]

20 [0027]

An aluminum alloy thin wire having a diameter of 0.5 mm was produced in the same manner as in Example 1 by using an Al-0.15%Sc alloy formed of aluminum (Al) having purity of 99.998 mass% and scandium (Sc) having purity of 99.9
25 mass% to serve as Example 4 (sample 9).

Next, the samples were subjected to ultrasonic bonding and an aging heat treatment under the conditions

same as those of Example 1.

The above-described tests were conducted on the samples under the conditions same as those of Example 1. Results of the tests are shown in Table 1.

5 [Comparative Examples]

[0028]

Aluminum alloy thin wires each having a diameter of 0.5 mm were produced in the same manner as in Example 1 by using Al-0.1%Sc and Al-0.8%Sc alloys each of which was
10 formed of aluminum (Al) having purity of 99.99 mass% and scandium (Sc) having purity of 99.9 mass% to serve as Comparative Examples 1 and 2.

Next, the samples were subjected to ultrasonic bonding and an aging heat treatment under the conditions
15 same as those of Example 1.

The above-described tests were conducted on the samples under the conditions same as those of Example 1. Results of the tests are shown in Table 1.

[Conventional Example]

20 [0029]

An aluminum ingot having a diameter of 300 mm was obtained by melting high purity Al having purity of 99.995 mass% (5N) and then performing continuous casting, and the ingot was subjected to rolling using grooved rollers and
25 then to wire drawing to obtain an aluminum element wire having a diameter of 5 mm. The element wire was subjected to an intermediate heat treatment of 400°C × 60 min and

300°C × 1 min. After that, continuous wire drawing was performed to attain a diameter of 0.5 mm, and then a final heat treatment was performed at 330°C to obtain Conventional Example. This Conventional Example was subjected to the tests in the same manner as in Example 1, and results of the tests are shown in Table 1.

[Table 1]

Sample No.		Component (mass%)			Solution treatment temperature (°C)	Wire diameter (mm)	Refining temperature (°C)	Hardness after refining (Vc)	Chip breakage	Aging heat treatment	Hardness after aging heat treatment (Hv)	Heat shock test
		Sc	Zr	Al								
E x a m p l e s	1	0.15		Balance	630	0.5	620	22	○	300°C × 2hr	38	○
	2	0.2		Balance	630	0.5	620	23	○	300°C × 2hr	42	○
	3	0.3		Balance	630	0.5	620	25	○	300°C × 2hr	47	○
	4	0.5		Balance	630	0.5	620	27	○	300°C × 2hr	55	○
	5	0.2	0.1	Balance	630	0.5	620	27	○	300°C × 2hr	48	○
	6	0.5	0.25	Balance	630	0.5	620	30	○	300°C × 2hr	59	○
	7	0.3		Balance	630	0.1	620	25	○	300°C × 2hr	47	○
	8	0.3		Balance	630	0.3	620	25	○	300°C × 2hr	47	○
	9	0.15		Balance	630	0.5	620	21	○	300°C × 2hr	38	○
Comparative Example 1		0.1		Balance	630	0.5	620	22	○	300°C × 2hr	33	×
Comparative Example 2		0.8		Balance	630	0.5	620	32	×	300°C × 2hr	55	○
Conventional Example		Al-50ppm(5N)			—	0.5	330	20	○	—	—	×

(Note 1) Purity of each of the Al materials of Examples 1 to 3 (sample Nos. 1 to 8) and Comparative Examples 1 and 2 is 99.99 mass%, purity of the Al material of Example 5 (sample No. 9) is 99.998 mass%, and purity of the Al material of Conventional Example is 99.995 mass%.

(Note 2) cooling method after solutionizing examples: water cooling.

[0030]

From the test results of Table 1, it is confirmed that the Vickers hardness of each of the sample Nos. 1 to 4 of Example is suppressed to 27 at the maximum range of the Sc content which is 0.5 mass% to be free from chip breakage

though the Vickers hardness after refining is increased along with the increase in Sc content from 0.15 mass% to 0.5 mass%.

Also, since the hardness is greatly improved by the aging treatment performed after the wire bonding, the Vickers hardness reaches to 38 when the Sc content is the minimum which is 0.15 mass% to attain the favorable thermal shock test results.

[0031]

In contrast, in Comparative Examples 1 and 2 having the Sc contents of 0.1 mass% and 0.8 mass%, respectively, Comparative Example 1 attains the low Vickers hardness and did not cause chip breakage, but shows the poor hardness after the aging treatment and the poor thermal shock test result. In contrast, since Comparative Example 2 has the large Sc content, it shows the high hardness owing to the aging treatment performed after the bonding and attains favorable thermal shock test result, but entails chip breakage to be unusable due to the high hardness after refining.

[0032]

Further, the sample Nos. 7 and 8 in which the Sc content was changed to 0.3 mass% and the diameters of the aluminum alloy thin wires were changed to 0.1 mm and 0.3 mm attain the favorable results in the chip breakage during bonding and the thermal shock test performed after the bonding to prove that the effects do not change even when

the diameter of the aluminum alloy thin wire is changed.

[0033]

Also, from the samples 5 and 6 to which Zr was added in addition to Sc, it is confirmed that chip breakage is not caused owing to suppression of the hardness after refining heat treatment even when the addition of Zr causes the increase in hardness after refining heat treatment, while the hardness attained by the aging treatment performed after the bonding is remarkably improved to give the favorable thermal shock test results.

Zirconium (Zr) has the same age-hardening action as scandium (Sc) and an action of stabilizing deterioration of the age-hardened aluminum alloy thin wire caused by a temperature history such as exposure to a temperature change in use environment, and it is possible to treat zirconium (Zr) as scandium (Sc) in the case where the added amount of zirconium (Zr) is less than a half of the content of scandium (Sc).

[0034]

Further, as to the sample 9 in which the purity of the aluminum raw material is improved by one digit (99.998 mass%) and the Sc content is suppressed to the minimum value, it is confirmed that the hardness after aging treatment is maintained high, namely, to 38, though the hardness after refining is lowered, and the thermal shock test result is favorable.

[0035]

As to the shear strength test results, as is apparent from the graphs of Fig. 1 showing the shear strength ratios of the shear strength after repetition to the initial shear strength of the sample No. 4 of Example 1 and the aluminum thin wire having 5N purity, the number of reductions to 20% (0.8) from the initial value in Example 4 is 10000 or more, while the number is about 3000 in the aluminum thin wire having 5N purity of Conventional Example. Thus, it is confirmed that Example 4 has the thermal shock life which is three times of that of the high purity aluminum thin wire.

[0036]

From the above-described test results, the range of Sc of 0.15 to 0.5 mass% is suitable for the Al-Sc binary alloy formed of scandium (Sc) and aluminum (Al) to be used for a wiring of a semiconductor device. In the case of the Al-Sc-Zr ternary alloy formed of scandium (Sc), aluminum (Al), and zirconium (Zr), zirconium (Zr) has the effect as the third additive element within a small amount range lower than that of the above-specified content relative to 0.15 to 0.5 mass% of scandium (Sc) and is suitably used within the range of 0.01 to 0.25 mass%. However, since the influence exerted by Zr on the hardness is greater than that of Sc, the content of Zr is necessarily equal to or less than a half Sc.

As to the Vickers hardness after solution treatment, since it is possible to improve the thermal shock by the

aging treatment owing to the addition of Sc even when the hardness is less than 21 Hv shown in Table 1 from the viewpoint of chip breakage, the effective range of Vickers hardness is 18 to 30 Hv.

5 Industrial Applicability

[0037]

Since the present invention attains the suppression in reduction of shear strength even when a thermal shock test is repeatedly conducted, the invention is useful as a connection wire of a power semiconductor which is used in hybrid cars and electric vehicles as well as in trains, windmill power generation, industrial robots, and the like.

Claims

1. An aluminum wedge bonding wire to be used for connection in semiconductor devices characterized by being used under a high temperature environment, wherein the aluminum wedge bonding wire has a composition comprising 0.15 to 0.5 mass% of scandium (Sc) with the balance being aluminum (Al) having purity of 99.99 mass% or more in an Al-Sc binary alloy comprising scandium (Sc) and aluminum (Al), has a recrystallized structure in an aluminum alloy matrix obtained by a forced solution treatment, and has Vickers hardness before an aging heat treatment of 21 to 30 Hv.

2. An aluminum wedge bonding wire to be used for connection in semiconductor devices characterized by being used under a high temperature environment, wherein the aluminum wedge bonding wire has a composition comprising 0.15 to 0.5 mass% of scandium (Sc) with the balance being aluminum (Al) having purity of 99.99 mass% or more in an Al-Sc binary alloy comprising scandium (Sc) and aluminum (Al), has a recrystallized structure in an aluminum alloy matrix obtained by a forced solution treatment, and forms age-precipitated particles of Al_3Sc by an aging heat treatment.

3. An aluminum wedge bonding wire to be used for connection in semiconductor devices characterized by being used under a high temperature environment, which is an aluminum alloy having a composition comprising 0.15 to 0.5

mass% of scandium (Sc) and 0.01 to 0.2 mass% of zirconium (Zr) (provided that the amount of zirconium (Zr) is equal to or less than a half of the amount of scandium (Sc)) with the balance being aluminum (Al) having purity of 99.998 mass% or more in an Al-Sc-Zr ternary alloy comprising scandium (Sc), aluminum (Al), and zirconium (Zr), having a recrystallized structure in an aluminum alloy matrix obtained by a forced solution treatment, and Vickers hardness of 21 to 30 Hv.

4. An aluminum wedge bonding wire to be used for connection in semiconductor devices characterized by being used under a high temperature environment, which is an aluminum alloy having a composition comprising 0.15 to 0.5 mass% of scandium (Sc) and 0.01 to 0.2 mass% of zirconium (Zr) (provided that the amount of zirconium (Zr) is equal to or less than a half of the amount of scandium (Sc)) with the balance being aluminum (Al) having purity of 99.998 mass% or more in an Al-Sc-Zr ternary alloy comprising scandium (Sc), aluminum (Al), and zirconium (Zr), having a recrystallized structure in an aluminum alloy matrix obtained by a forced solution treatment, and forming age-precipitated particles of Al_3Sc by an aging heat treatment.

5. The aluminum wedge bonding wire to be used for connection in semiconductor devices according to any one of claims 1 to 4, characterized in that the purity of the aluminum (Al) of the aluminum alloy is 99.998 mass% or more.

6. The aluminum wedge bonding wire to be used for connection in semiconductor devices according to any one of claims 1 to 4, characterized in that the amount of the scandium (Sc) to be added is 0.1 to 0.3 mass%.

5 7. The aluminum wedge bonding wire to be used for connection in semiconductor devices according to any one of claims 1 to 4, characterized in that the recrystallized structure is a cold wire drawn structure which is formed by a refining heat treatment performed after continuous wire
10 drawing performed with water cooling after the forced solution treatment.

8. The aluminum wedge bonding wire to be used for connection in semiconductor devices according to any one of claims 1 to 4, characterized in that the aluminum alloy is
15 bonded by ultrasonic bonding.

9. The aluminum wedge bonding wire to be used for connection in semiconductor devices according to any one of claims 1 to 4, characterized in that the thin wire has a wire diameter of from 50 μm to less than 500 μm .

20 10. The aluminum wedge bonding wire to be used for connection in semiconductor devices according to any one of claims 1 to 4, characterized in that the high temperature environment is 80°C to 300°C.

25 11. The aluminum wedge bonding wire to be used for connection in semiconductor devices according to any one of claims 1 to 4, characterized in that the high temperature environment is 150°C to 250°C.

12. A process for bonding a semiconductor device used under a high temperature environment, characterized in that

wedge bonding is performed by using an Al-Sc binary alloy thin wire having a composition comprising 0.15 to 0.5 mass% of scandium (Sc) with the balance being aluminum (Al) having purity of 99.99 mass% or more as a thin wire which has a recrystallized structure in an aluminum alloy matrix which is forcedly dissolved by a solution treatment, and

an aging heat treatment is performed after the

10 bonding.

13. A process for bonding a semiconductor device used under a high temperature environment, characterized in that

wedge bonding is performed by using an Al-Sc-Zr ternary alloy thin wire having a composition comprising 0.15 to 0.5 mass% of scandium (Sc) and 0.01 to 0.2 mass% of zirconium (Zr) with the balance being aluminum (Al) having purity of 99.998 mass% or more as a thin wire which has a recrystallized structure in an aluminum alloy matrix which is forcedly dissolved by a solution treatment, and

20 an aging heat treatment is performed after the bonding.