Specification

[Title of the Invention]

Aluminum Ribbon for Ultrasonic Bonding

[Technical Field]

[0001]

The present invention relates to an aluminum ribbon for connecting a semiconductor device to a lead from a printed circuit board within an electronic component or a semiconductor package by means of the ultrasonic bonding method.

[Background Technology]

[0002]

In the manufacture of a semiconductor device, a bonding method wherein a tape-shaped conductive body having a roughly rectangular cross section (hereinafter referred to as " ribbon") is widely used in order to electrically connect a connecting electrode (bonding pad) installed on a semiconductor chip with an externally drawn-out connector (lead) installed in a semiconductor package.

This method makes use of a ultrasonic wire bonding method wherein an aluminum conductive wire is used: in particular, by imparting a load and a ultrasonic vibration to the aluminum ribbon the oxide film which is naturally formed over the surface of the aluminum ribbon in a thickness of about 1 nanometer (nm) is broken, whereby the metallic atoms such as aluminum atoms (Al) are exposed through the surface, whereupon plastic flow takes place in the interface between the bonding pad made of aluminum (Al) or nickel (Ni) or the like

and the aluminum ribbon to trigger a growth of a new interface closely binding these two bodies at atom-to-atom level.

[0003]

This practically useful aluminum ribbon has been manufactured in methods which are generally employed for creating extremely thin tapes, such as the ones described below.

A first method comprises preparing a thin plate of an aluminum alloy by rolling, cutting the plate into strips having a predetermined width and a predetermined length by a cutter machine such as rotary cutter, or a press machine, further rolling the aluminum alloy thin strips into thinner tapes, and finally shaping the tapes into aluminum ribbons of predetermined dimensions.

A second method comprises thinning an aluminum alloy plate to a predetermined final thickness (this thickness is one twenty-fifth or so of the width) by rolling to obtain a tape preform, and cutting off the side edges of the tape preform by a slitter or a press machine to obtain an aluminum ribbon of a predetermined final width.

[0004]

However, with the above methods for forming extremely thin tapes, a machine oil is used during the rolling operations, and in general a film of the machine oil remains in an amount less than the detection limit, unevenly distributed over the aluminum ribbon, and this phenomenon has imparted an instability to the bonding conditions applied as the aluminum ribbon is used as a ultrasonic bonding ribbon. To solve this problem, a trial was made to clean the surface of the bonding ribbon with an acid by means of chemical etching; however, the chemical etching caused microscopic irregularity in the surfaces of the bonding ribbon, and this irregularity caused instability in the bonding conditions for the ultrasonic

bonding operation.

[0005]

Also, an aluminum ribbon made of an aluminum alloy with aluminum content of 99 mass % or higher consisting of additive element(s) and the remnant, the latter being aluminum, is liable to experience material defects such as blushing during the processing prior to the rolling operation, since such aluminum ribbon is harder than the conventional aluminum (Al) plates with aluminum content of 99.99 mass % made for ultrasonic bonding. For this reason, the cut faces and the sheared edges of such aluminum ribbon are apt to create pointy protrusions or burrs, and these remain at the ribbon edge faces and are apt to crash against the guides and tools during the bonding operation and are broken into flakes to adhere to the surfaces of the rollers which in turn impart irregularities to the surfaces of the bonding ribbons. The aluminum ribbons, none the less, were subjected to the ultrasonic bonding with the hardness of the aluminum ribbons being maintained unchanged from the time of the rolling stage, and since a larger amount of energy is needed during the bonding, the disadvantages were that the bonding conditions were unstable and the resulting bonding strength tends to be low.

[0006]

It has been hitherto thought that the reason for such instable bonding conditions is the following. Namely, the surfaces of the bonding pads and the bonding ribbons are microscopically not flat, and the thickness of the aluminum oxide, which is about 1 nanometer (nm) is microscopically not uniform, so that the position at which the bonding ribbon gets in contact with the bonding pad at an early stage of the bonding and the area of such contact are not microscopically constant.

On account of this, various shapes of bonding ribbon have bee contrived for the purpose of stabilizing the bonding

conditions for the bonding ribbons and obtaining stabilized bonding strength (fusion strength) (see Publication-in-patent 1 and Publication-in-patent 2).

[0007]

For example, in Publication-in-patent 1 "an electric current passage component shaped substantially in a plate form" in appearance is disclosed. Also, it is described that "the shape of the connection strap may not be the afore-mentioned substantially plate form, or a substantially belt form, or a rectangular form as seen from above. For example, elliptical, flattened elliptical (track-like and oval), and a trapezoidal are acceptable too. Or it is also possible to use a modified shape from these or use some of these in an appropriate combination." However, the connection strap described in Publication-in-patent 1 has a connecting part in a shape of a flat plane, so that the position and the area of the microscopic region at which the early stage bonding is effected are not constant and hence this does not materially solve the problem of instability in the bonding conditions, which is that the bonding strength is not constant.

[0008]

On the other hand, Publication-in-patent 2 discloses a bonding ribbon whose appearance is characterized in that " there are provided on one of the faces for bonding a plurality of projected bosses whose tops are substantially included in a flat plane" . This leads to a thought that by reducing the areas of the tops of the plurality of the projected bosses the friction between the ribbon and the ribbon-recipient matter becomes easier to occur, so that it becomes possible to break the oxide film formed on the surface with ease. In this method, by virtue of the fact that an early stage plastic flow is more easily caused, it is thought that it is possible, with a comparatively smaller load and smaller ultrasonic wave energy, to secure a creation of more strengthened bonding than

in the case of a ribbon whose bonding faces are flat.

[0009]

However, in the case of an aluminum ribbon for connecting semiconductor devices by ultrasonic bonding, it is necessary to effect ultrasonic bonding on one to several items within one second, and this pace is maintained under the same condition until several hundreds of thousands of items are done. Therefore, even if a bonding face is formed with a plurality of embossed tops to contact the recipient face, as in the case of Publication-in-patent 2, no sooner is a bonding effected at one locality to break the oxide film in the microscopic area to allow a plastic flow to commence than the balance of the bonding condition of the entire body is lost and it becomes impossible to continue the bonding for hundreds of thousands of times under the same condition.

As is the case with this example, with a conventional method whereby merely the external shape of the bonding ribbon is modified, it is difficult to obtain a bonding of a uniform quality throughout the hundreds of times of bonding at the same locality in a microscopic area, and it was impossible to obtain a highly strengthened and durable bonding.

[0010]

However, when an ultrasonic bonding was conducted using the above-mentioned bonding ribbon wherein the ribbon was caused to loop as it spanned from the first bond to the second bond, a problem took place in which the aluminum ribbon, which had been mirror-finished, was inadvertently broken during the loop formation. This phenomenon took place only when the loop height was very high or the loop length was very long or the like, but this had posed a problem which cries for a solution in the days when the shape of the loop is variously being diversified.

Also, the inventors had tried, as a manner for improving the bonding characteristics of an aluminum ribbon, to arrange the grain size and the surface roughness, as described in Publication-in-patent 3.

Prior technical publications

Publication-in-patents

[0011]

Publication-in-patent 1:
Japanese Patent Application Publication No. 2002-313851

Publication-in-patent 2:
Japanese Patent Application Publication No. 2007-194270

Publication-in-patent 3:
Japanese Patent No. 4212641

Summary of the Invention

Problems the invention seeks to solve:

[0012]

It is therefore an object of the invention to propose a bonding ribbon which can guarantee a uniform fusing over the entire joint area throughout hundreds of thousands of continuous ultrasonic bonding cycles and which can realize an improved bonding strength and which also can avoid being broken while it is looped, unlike the state of the art bonding ribbons based on conventional technology.

[Means to solve the problems]

[0013]

As one of the means for solving the problems described above, the aluminum ribbon for ultrasonic bonding, according to the present invention, is an improvement from the aluminum ribbon disclosed in Publication-in-patent 3, and is an aluminum ribbon for ultrasonic bonding formed of an aluminum alloy with aluminum content of 99 mass % or higher, the alloy being made from additive elements and the balance aluminum, and this ribbon is characterized in that it is in a shape of an extremely thin tape which is obtained by rolling a wire taken from a multi-stage wire drawing, that an average grain size within the cross section of this ribbon is 5 - 200 micrometers (μm), that the surface(s) of this extremely thin tape is mirror-finished to an extent that the surface roughness R_z is 2 micrometers (μm) or smaller, and that the ribbon has been subjected to an immersion treatment or a gas-exposure treatment wherein the liquid or gas comprises a substance having a vapor pressure higher than water such as a water-soluble hydrocarbons solvent, an alcoholic solvent, a ketone solvent, or an ether type solvent.

[0014]

The alcoholic solvent is preferably selected from ethanol, methanol, butanol, n-propyl alcohol, phenol, ethylene glycol, tridecanol and grycelin. Of them, ethanol, methanol and n-propyl alcohol are more preferred for the reason that they have such lower molecular weights that they are highly capable of extracting the water existing in the aluminum ribbon (Boehmite, bayerite, gibbsite and the like are thought to be bonded to the oxide film surface of the aluminum ribbon).

[0015]

The kenone solvent is preferably selected from acetone and methyl ethyl ketone.

[0016]

The ether type solvent is preferably selected from among methyl n-propyl ether, diethylene glycol monoethyl ether, diethylene glycol monobutyl ether, diethylene glycol dimethyl ether, diethylene glycol diethyl ether, propylene glycol monoethyl ether, propylene glycol monobutyl ether, dipropylene glycol mono ethyl ether, dipropylene glycol dimethyl ether, and dipropylene glycol mono butyl ether.

[0017]

The hydrocarbons solvent is preferably ethylamine or ethyl acetate.

[Effects of the Invention]

[0018]

By using one of the organic solvents as prescribed above to treat the mirror-finished bonding ribbon, the water picked up from the air by the aluminum existing in the surface of the bonding ribbon and the water brought to the aluminum during the wire drawing process, after the aluminum is touched by the air and thus oxidized, are extracted by the organic solvent, and therefore such water does not form an hydroxide of aluminum [AlO(OH)] in the ribbon surface, and thus it is possible to realize a bonding wire which has as high a durable bonding strength and as high a loop forming capability as a pure gold bonding wire. Furthermore, if a solvent which has a vapor pressure higher than that of water, such as a water-soluble hydrocarbons solvent, an alcoholic solvent, a ketone solvent, and an ether type solvent, is used to wet the bonding ribbon, the contaminant matters originating from the water are effaced from the bonding ribbon so that the resulting loop-formation capability of the ribbon becomes even greater.

[Examples of embodiment of the invention]

[0019]

If a solvent which has a vapor pressure higher than that of water, such as a water-soluble hydrocarbons solvent, an alcoholic solvent, a ketone solvent, and an ether type solvent, is used to wet the bonding ribbon, the contaminant matters originating from the water are effaced from the bonding ribbon so that the resulting loop-formation capability of the ribbon becomes even greater. An organic solvent has a tendency that the smaller the number of carbon atoms, the less the amount of carbon residue left by the evaporation, so that ethanol, methanol and n-propyl alcohol are especially preferred. On the other hand, the greater the number of carbon atoms the less does the solvent decompose and evaporate by heat and thus is more stable, but lower in reactivity for water removal. On account of this fact, if an organic solvent having a large number of carbon atoms is left in a high concentration and in a large amount on an aluminum ribbon, it is not advantageous in that the expected performance of the aluminum ribbon is not obtained.

The organic solvents prescribed by the present invention evaporate easily upon warming or heating, so that it is possible to wet an aluminum ribbon with such solvents by exposing the ribbon to an atmosphere filled with the vapor of such solvents.

[0020]

In another aspect, with regard to the quality of the inventive aluminum ribbon, especially the grain size is arranged such that the irregularity in the bonding strength, which has been a problem in the conventional art, has become smaller, and it is no longer necessary to maintain the output of the ultrasonic wave at a high level, and it is now possible to obtain a bonding of durable strength even when the output of the ultrasonic wave is at a low level, and the defective bonding which used to occur unexpectedly and for which the cause is unknown has completely ceased to take place. Also, by using the bonding

ribbon of the present invention, it was found that it is possible to avoid the occurrence of a microscopic void in the fusion interface, so that it has become possible to secure stable fusion area and realize a durable ultrasonic bonding even between narrowly pitched pads.

[0021]

Thereupon, the inventors researched into the effect that the crystalline structure of the aluminum ribbon causes on the fusion mechanism at the time of bonding.

The internal crystalline structure of the extremely thin tape as is obtained by rolling a wire taken from a multi-stage wire drawing is of a processed fibrous texture having a crystal grain size of one micrometer (μm) or smaller, and it is impossible to observe the crystal grain of an aluminum ribbon through an ordinary microscope. The processed fibrous texture does not undergo a plastic flow when this extremely thin tape is subjected to a low temperature thermal treatment for removal of strain. When an aluminum ribbon of this kind of crystalline structure is tried to be fused upon a bonding pad by means of a tremulous vibration caused by ultrasonic wave, a large energy is required to cause the bonding owing to the fact that the aluminum ribbon retains the hard internal structure it acquired as of the time it is rolled out, and the resulting bonding strength is low. This phenomenon is caused by the fact that although the propagation velocity of the ultrasonic wave in the processed fibrous texture is high, this medium is so hard that the fusion interface does not undergo a speedy plastic flow.

[0022]

However, when the extremely thin tape as is obtained by rolling a wire taken from a multi-stage wire drawing is subjected to a thermal treatment at an appropriate temperature, it is possible to control the hardness of the

aluminum ribbon to a low level such that the fusion interface of the aluminum ribbon undergoes a sufficient plastic alteration by the energy it receives as of the bonding. Also, by homogenizing the crystal grain size, it is possible to efface the microscopic defects such as internal strain whereby the propagation of the ultrasonic wave and the load become uniform and the irregularity in the bonding (fusing) strength throughout the bonding operation is reduced. [The irregularity in the bonding strength indicates a reduction in the bonding strength after a dependability test (HAST).]

The inventors invented during the research a controlling procedure for the crystalline structure of the aluminum ribbon and discovered the optimum range for the grain size, which were reproduced and reconfirmed. With such a crystalline structure, the alteration in the fusion interface caused by load, which contributes to the bonding strength, and the removal of the surface oxide film at the fusion interface caused by the ultrasonic wave are deemed well balanced. The effect which the crystalline structure of the aluminum ribbon has on the fusion structure at the time of ultrasonic bonding was found to be nearly equal to that described in Publication-in-patent 3.

[0023]

A thermal condition that brings about an effect of creating a region where the grain size is generally uniform is dependent on the kind of material the aluminum ribbon is made of as well as its dimension so that there is no fixed optimum condition. In the case of a common aluminum ribbon which is made of an aluminum alloy with the aluminum content of 99 mass % or higher consisting of additive element(s) plus the aluminum remnant, when the ribbon thickness is 1 mm, the experience indicates that a thermal condition of 250 - 400 degrees centigrade for a duration of 30 - 90 minutes brings about in the aluminum ribbon a separation of grains of such a size as is prescribed in the present invention. When the ribbon thickness is smaller than 1 mm, the appropriate thermal

treatment temperature ought to be lower and its time duration ought to be shorter; for example, when the ribbon thickness is 10 micrometers (μm), the thermal treatment temperature generally should be 200 - 250 degrees centigrade and the thermal treatment time should be 10 - 60 minutes. Incidentally the atmosphere for the thermal treatment can be the natural atmosphere. However, it is possible to use a warmed or heated artificial atmosphere.

When the thermal treatment temperature is 180 degrees centigrade or lower, the grain structure of the aluminum ribbon made of an aluminum alloy with the aluminum content of 99 mass % or higher remains as that of a processed fibrous texture, no matter how long the thermal treatment is continued, so that the average grain size across the cross section of the aluminum ribbon fails to increase to 5 micrometers (μm), which is not good. In this particular region, the hardness of the ribbon itself is so high that the plastic flow in the fusion interface becomes insufficient. Also, under such a thermal condition whereby the average grain size becomes smaller than 5 micrometers (μm), part of the grains that fail to undergo recrystallization remain, so that the flow of the recrystallized part and that of the not-recrystallized part in the ribbon interface which take place at the time of ultrasonic bonding do not match, and this causes an irregularity in the bonding strength.

[0024]

Also, when the thermal treatment temperature exceeds 450 degrees centigrade, the grains of the aluminum alloy with the aluminum content equal to or higher than 99 mass % undergo sharp increase in size, and it becomes difficult to homogenize the texture. Incidentally, in this situation, the average value of the grain size is over 200 micrometers (μm) in the case of a ribbon thickness of 1 mm, and as such the aluminum ribbon itself is liable to deform and the ultrasonic wave is hard to propagate inside such ribbon body, which leads to an imbalance

in the flow caused by the ultrasonic wave propagation and the load, which is not a favorable thing.

Also, in general, a preferable range of the thickness of an aluminum ribbon is 10 micrometers (μm) to 1 mm, from the viewpoint of optimum balance between the ultrasonic wave and the load.

[0025]

In this invention, so long as the average value of the grain size of an aluminum ribbon is 5 to 200 micrometers (μm), it is possible to obtain grains having an aspect ratio (width/thickness) of 0.5 – 10 and having a characteristic to cause an improved bonding strength, and further it is possible to obtain a more stabilized result at the time when the aluminum ribbon is severed after it is second-bonded by ultrasonic wave. The manner in which the aspect ratio is measured is such that the ribbon is looked at in the direction of its length and the measurement of the grain width is divided by that of the grain thickness.

[0026]

A preferable ratio of width to thickness of an aluminum ribbon is 7 to 16. The widths and thicknesses of typical aluminum ribbons are as indicated in Table 1 below.

[0027]

On the other hand, it is known that an aluminum ribbon undergoes a formation of oxide film of a thickness of 1 nanometer (nm) or so in the aluminum surface by the oxygen in the atmosphere even at a room temperature. Heretofore, this oxide film was considered too thin to have any influence on the bonding strength, but when the surface of the aluminum ribbon has microscopic irregularity, the amount of aluminum oxide is increased by as much as the increase in the surface area caused

by the irregularity. Since aluminum oxide does not contribute to bonding, the change in the amount of the oxide in the interface may cause departure from uniform bonding strength distribution during ultrasonic bonding operation. It is suspected that, in the conventional practices, because a phenomenon was observed wherein the HAST strength after the ultrasonic bonding did not stabilize even though the aluminum ribbons of the same appearance were used throughout the bonding operation, the attempt was made to stabilize the bonding strength by increasing the output of the ultrasonic wave.

[0028]

The present inventors came to know that it was possible to stabilize the bonding strength even at a lower ultrasonic wave output provided that the average value of the grain size of the aluminum ribbon was in the range of 5 - 200 micrometers (μm), by means of mirror-polishing the surface of the aluminum ribbon and eliminating the moisture completely from the surface of the aluminum ribbon with certain organic solvents, and then reducing the amount of oxide existing excessively due to the irregularity in the bonding interface.

The more mirror-polished an aluminum ribbon is the more desirable it is, for the surface area where oxide is produced is smaller; and a criterion is that the surface roughness R_z is 2 micrometers (μm) or smaller. In a ultrasonic bonding of an aluminum ribbon, a wave of a frequency so high as 10 to 120 Hz is used so that, so long as the average value of the grain size of the aluminum ribbon is 5 to 200 micrometers (μm) and the surface roughness R_z is 2 micrometers (μm) or smaller, it is possible to avoid formation of microscopic voids and obtain a stabilized bonding strength since an Al alloy with the aluminum content of 99 mass % or higher is soft. More preferably, the surface roughness R_z is 1.6 micrometers (μm) or smaller.

[0029]

It also happens that even when the aluminum ribbon is mirror-polished, the frictional resistance between the aluminum ribbon and the bonding tool can increase so high that the aluminum ribbon is disrupted during the loop formation. This is suspected to happen because some contaminant material originating from the moisture is remaining. Therefore, the present invention seeks to remove the contaminant material originating from the moisture from the bonding ribbon by dispersing and diluting the contaminant material with the organic solvent such as a water-soluble hydrocarbons solvent, an alcoholic solvent, a ketone solvent, and an ether type solvent, with which the bonding ribbon is wetted. On this occasion, as the organic solvent used has a vapor pressure higher than that of water, the evaporation rapidity of the organic solvent is high enough so that the organic solvent carries away the contaminant material originating from the moisture before the material thickens in the organic solvent on the ribbon surface. Especially if an alcoholic solvent is used, it is thought that the surface of the aluminum ribbon is further passivated on account of the fact that aluminum is liable to form alcoholate. In particular, ethanol, methanol and n-propyl alcohol are preferable for these do not leave carbon residue as they evaporate. By the way, if a halide such as aluminum halide exists in the alcohol, the halide works as a catalyst to expedite the formation of alcoholate. Also, it is possible to prepare a solvent by suitably mixing an alcoholic solvent with a hydrocarbons solvent, a ketone solvent, and an ether type solvent. For example, ethanol, which has a higher ability to remove water than methanol, can be used as a 3% ethanol-acetone mixture solvent.

[0030]

Now, the aluminum ribbon in accordance with the present invention is an aluminum alloy with the aluminum content of 99 mass % or higher consisting of additive(s) and the balance

aluminum.

The elements that are acceptable as the additives in the present invention include nickel (Ni), silicon (Si), magnesium (Mg), cupper (Cu), boron (B), indium (In), lithium (Li), beryllium (Be), calcium (Ca), strontium (Sr), yttrium (Y), Lanthanum (La), cerium (Ce), Neodymium (Nd), and bismuth (Bi). Elements that work better upon the grain size of the aluminum ribbon are nickel (Ni), silicon (Si), magnesium (Mg) and cupper (Cu). So long as the aluminum content is not lower than 99 mass %, the aluminum alloy containing at least one of these acceptable additives in a total amount of 5 - 700 mass ppm can develop uniform grain size distribution through a thermal treatment at 200 - 400 degrees centigrade.

The balance aluminum in the aluminum alloy with the aluminum content of 99 mass % or higher would contain unavoidable impurities. Possible influences the unavoidable impurities may have upon the aluminum (Al) element are not certain so that the unavoidable impurities should preferably exist as little as possible. In order to realize a situation dependably wherein uniform distribution of grain size of the aluminum ribbon develops, a mass of aluminum (Al) of a purity 99.99 mass % or higher is preferably used to make the mother alloy. With such aluminum (Al) having a purity of 99.99 mass % or higher, a uniform distribution of the grain size having an average value of 5 - 200 micrometers (μm) can develop upon a thermal treatment at 200 - 100 degrees centigrade, irrespective of the kind and quantities of the additives used in combination. It is needless to say that a better result is possible if aluminum (Al) having a purity of 99.999 mass % or higher is used as the mother alloy.

[0031]

Especially if an aluminum ribbon made of an aluminum (Al) alloy including nickel as an additive element in an amount of 10 - 300 mass ppm and, as the balance, aluminum (Al) having a

purity of 99.99 mass % or higher is used, it is possible to stabilize the bond strength at a high level while keeping the ultrasonic wave output at a low level.

[0032]

It is possible to define a favorable example of an aluminum ribbon as follows. The additive element(s) consist(s) of at least one of nickel (Ni), silicon (Si), magnesium (Mg) and cupper (Cu) in an overall amount of 5 - 700 mass ppm.

[0033]

It is especially preferable if the additive element consists only of nickel (Ni) in an amount of 10 - 300 mass ppm.

[0034]

Preferably, the balance aluminum consists of aluminum (Al) having a purity of 99.99 mass % or higher and impurities in an amount of less than 0.01 mass %, and more preferably the balance aluminum consists of aluminum having a purity of 99.999 mass % or higher and impurities in an amount of less than 0.001 mass %.

For the reason of easiness in controlling the grain size of the aluminum ribbon, it is preferable that the aluminum alloy with the aluminum content of 99 mass % or higher contains nickel (Ni) as an additive element in an amount of 10 - 300 mass ppm and that the balance comprises aluminum (Al) of a purity of 99.99 mass % or higher, and it is specially preferable that the balance comprises aluminum (Al) of a purity of 99.999 mass % or higher.

[0035]

Also, as a round wire is rolled into an extremely thin tape, it is preferable that this rolling is done in one or two strokes. If

the number of rolling strokes is three or greater, it was experienced that the resulting aluminum (Al) ribbon when bonded lacked stability in the bonding strength. It is thought that this instability in the bonding strength after bonding is caused by the ununiformity in the grain size, which results from the fact that the internal stress is increased in the rolled body as the rolled body is further compressed, and thereby there occur localities where the grains do not expand during the heat treatment after the rolling. For this reason, the case in which the rolling consisted of only one stroke had the result wherein the ununiformity in the grain size was the smallest. The effect of the aluminum ribbon obtained according to Publication-in-patent is preserved as it is in the present invention.

[0036]

Incidentally, even if a new active surface, that is not the ones that may have been caused to show up by a multiple step drawing, shows up in the surface of the aluminum ribbon as a result of one-stroke rolling, that new active surface is immediately covered with an aluminum oxide film of about one nanometer (nm) as the result of aluminum being oxidized by the oxygen in the atmosphere. Such aluminum oxide film does not stick to itself so that it is possible to form a multiple layer wound coil of the aluminum ribbon. If the bonding strength obtainable from the aluminum ribbon in the form of multiple layer wound coil, is stabilized, it becomes possible to operate the ultrasonic bonding continuously without human attendance.

Embodiments

[0037]

Now, the embodiments of the present invention shall be explained.

Using bonding wires having a predetermined wire diameter and made of alloys of compositions as shown in Table 1 (99.999 mass %-pure aluminum (Al) was used as the raw material, but when 99.99 mass %-pure aluminum (Al) was used the result was similar), as the starting material, bonding ribbons of Examples 1 - 20 and Comparative Examples 1 - 5 as listed in Table 1 were prepared. These bonding ribbons had been subjected to one-stroke thermal rolling in a compressive rolling machine (not shown), and these had been immersed in a high purity ethanol solution for two seconds either before or after a thermal treatment at temperatures shown in Table 1.

[0038]

The bonding ribbons of Examples 1 - 20 and Comparative Examples 1 - 5 obtained in the manner as described above, respectively, were subjected to ultrasonic bonding under the conditions described below including that the bonding pad consisted of an aluminum (Al) plate of a purity of 99.99 mass %. A total of 500 reels were repeatedly bonded for each Example and the number of wire disruption that occurred during the bonding was counted. The result is shown in Table 1.

[0039]

The ratio of the strength after the dependability test to that before the same test was measured in the following manner.

The bonding was conducted by using Al Ribbon Bonder 3600R (a product of Orthodyne Electronics Corporation), under conditions such that the collapsed Al ribbon bonded on the Al pad has a width of 1.05 times as large as that of the ribbon before collapsing.

The bonding strength was measured by a shear test using a multi-purpose Dage PC-4000 Bond Tester (a product of Nordson Corporation), which measured the shear strength from a side face of the ribbon bonded. By way of the test for the integrity

of the bonding, a pad to which bonding was done was exposed to a heat of 150 degrees centigrade for 1000 hours, and thereafter the shear strength was measured. The value of the shear strength after the integrity test was divided by the value of the shear strength before the integrity test and the result was defined as the after-integrity-test strength ratio, and this provided the basis for the dependability rating.

[0040]

The dependability rating was classified as follows: if the after-integrity-test strength ratio was 0.9 or greater, a rating represented by ◎ is given; if it was 0.7 or greater but smaller than 0.9, the rating represented by ○ is given; and if it was smaller than 0.7, the rating represented by × is given.

[0041]

[Table 1]

		alloy composition (mass ppm)					Total of impurities	solvent (to dip in for 2 sec at room temperature)	Dipped before or after heat treatment?	Number of disruption per 500 reels	heat treatment temperature after rolling (degrees C)	properties of the bonding ribbon				after-integrity-test strength ratio	rating
		Al	Ni	Mg	Si	Cu						surface roughness Rz (micrometer)	average value of grain size (micrometer)	thickness (micrometer)	aspect ratio		
Examples	1	balance	60				60	pure ethanol	after	0	280	1	10	200	10	0.90	◎
	2	balance		50			50	pure methanol	after	0	220	1	10	10	10	0.91	◎
	3	balance			30		30	3%-ethanol + acetone	after	0	240	0.5	10	50	10	0.90	◎
	4	balance				15	15	pure methyl ethyl ketone	after	0	280	0.5	10	200	6	0.86	○
	5	balance	20	20	20	20	80	pure methyl n-propyl ether	after	0	290	0.5	10	300	10	0.84	○
	6	balance	150				150	pure ethylamine	after	0	220	1.5	10	15	9	0.82	○
	7	balance		250			250	pure ethylene glycol	after	0	250	1.5	10	60	10	0.83	○
	8	balance			350		350	pure propylene glycol monoethyl ether	after	0	220	1.5	10	40	11	0.84	○
	9	balance				450	450	pure grycelin	after	0	285	1.5	10	250	12	0.79	○
	10	balance		250		300	550	pure tridecanol	after	0	220	1.8	10	20	13	0.90	○
	11	balance	200	200	250		650	pure phenol	before	0	280	1.8	10	200	14	0.79	○
	12	balance	60				60	pure n-propyl alcohol	before	0	300	1.8	10	400	9	0.89	○
	13	balance		50			50	pure ethylene glycol	before	0	230	1	10	70	10	0.79	○
	14	balance			30		30	pure acetone	before	0	290	1	10	350	11	0.89	○
	15	balance				15	15	pure diethylene glycol monoethyl ether	before	0	210	1	10	10	12	0.82	○
	16	balance	20	20	20	20	80	pure ethyl acetate	before	0	220	0.5	10	30	13	0.78	○
	17	balance	150				150	pure butanol	before	0	215	0.5	10	12	20	0.78	○
	18	balance		250			250	pure dipropylene glycol mono butyl ether	before	0	290	0.5	10	400	4	0.77	○
	19	balance			350		350	pure dipropylene glycol dimethyl ether	before	0	300	1.5	10	400	11	0.76	○
	20	balance				450	450	3%-ethanol + ethyl acetate	before	0	300	1.8	10	400	13	0.82	○
Comparative Examples	1	balance		250		300	550	no wetting	after	8	no heat treatment	0.5		5	19	0.63	×
	2	balance	200	200	250		650	pure water	after	13	no heat treatment	1.5		5	3	0.56	×
	3	balance	60				60	tap water	after	12	no heat treatment	1.8		7	10	0.57	×
	4	balance		50			50	water solution of acetic acid	before	16	360	3.0		3000	10	0.57	×
	5	balance			30		30	water solution of ammonium nitric acid	before	19	360	1		300	10	0.58	×

"pure" means special class or Cica class 1, used in such circumstances where special class does not exist.

Estimation classification (after-integrity-test strength ratio)
0.9≦: ◎; 0.7≦: ○; <0.7: ×

[0042]

The conditions under which the ultrasonic bonding was conducted are as follows:

The loop lengths and the loop heights of the bonding ribbons listed in Table 1 were set to be 50 mm and 30mm, respectively, and thus the frictional resistance that the ribbons receive from the passages and tools were controlled to be greater than they normally are.

The ultrasonic bonding was conducted upon a (5 mm thick) plate of aluminum (Al) having a purity of 99.99 mass %, by using a fully automatic Ribbon Bonder 3600R (a product of Orthodyne Electronics Corporation). The bonding conditions included that the frequency was 80 kHz, and the load and the ultrasonic level were such that the collapsed Al ribbon had a width which was 1.1 times greater than was before bonding. The total number of ribbon reels bonded in each example was 500. The bonding tool and the bonding guide used were ones made by Orthodyne Electronics Corporation., which conformed to each ribbon size.

In each Example a heat treatment was conducted at the respective temperature described in Table 1, whereas, in contrast to this, in each Comparative Example either no heat treatment was conducted or a heat treatment at 380 degrees centigrade was conducted.

[0043]

The number of disruptions of the ribbon during bonding was counted each time the bonding machine was brought to a halt by an occurrence of ribbon disruption. It was ascertained each time the machine came to a halt that the cause of the halt had been nothing but the ribbon disruption.

[0044]

The average grain size was calculated in the following manner.

An Al ribbon was clad entirely in a resin and this body was polished until a cross section of the ribbon was exposed, and, by means of chemical etching, the crystallization treatment was applied to the cross section, and then the cross section was observed and taken picture of through a metallographical microscope (with an objective lens of 4500 magnification); in a photo thus taken three straight lines were drawn in the direction of the ribbon thickness, and the thickness (micrometer) was divided by the number of the grains that were crossed by each straight line, and the results were averaged to obtain the average grain size.

[0045]

Each of the aluminum ribbons of Examples and Comparative Examples had a face to couple with an electrode by fusion, and this coupling face took a shape akin to a collection of bonding wires arranged at even intervals, and the fusion mechanism adopted was nearly the same as a conventionally practiced one.

Incidentally, after the test conducted to obtain the after-integrity-test strength ratio, the aluminum ribbons were detached by dissolution and the coupling faces were observed, and it was found that in Examples 1 - 20 the coupling faces had uniform coupling trace.

What is claimed is:

[Claim 1]

An aluminum ribbon for ultrasonic bonding made of an aluminum alloy with aluminum content of 99 mass % or higher, the alloy being made from additive elements and the balance aluminum, characterized in that said ribbon is in a shape of an extremely thin tape which is obtained by rolling a wire taken from a multi-stage wire drawing, that an average grain size within a cross section of this ribbon is 5 - 200 micrometers (μm), that the surface of this extremely thin tape is mirror-finished to an extent that the surface roughness R_z is 2 micrometers (μm) or smaller, and that the ribbon has been subjected to a liquid immersion treatment or a gas exposure treatment wherein the liquid or gas is a substance having a vapor pressure higher than water and is selected from water-soluble hydrocarbons solvents, alcoholic solvents, ketone solvents, and ether type solvents.

[Claim 2]

An aluminum ribbon for ultrasonic bonding as claimed in Claim 1, wherein said alcoholic solvents are ethanol, methanol, butanol, n-propyl alcohol, phenol, ethylene glycol, tridecanol and grycelin.

[Claim 3]

An aluminum ribbon for ultrasonic bonding as claimed in Claim 1, wherein said alcoholic solvents are ethanol, methanol, and n-propyl alcohol.

[Claim 4]

An aluminum ribbon for ultrasonic bonding as claimed in Claim 1, wherein said ketone solvents are acetone and methyl

ethyl ketone.

[Claim 5]

An aluminum ribbon for ultrasonic bonding as claimed in Claim 1, wherein said ether type solvents are methyl n-propyl ether, diethylene glycol monoethyl ether, diethylene glycol monobutyl ether, diethylene glycol dimethyl ether, diethylene glycol diethyl ether, propylene glycol monoethyl ether, propylene glycol monobutyl ether, dipropylene glycol mono ethyl ether, dipropylene glycol dimethyl ether, and dipropylene glycol mono butyl ether.

[Claim 6]

An aluminum ribbon for ultrasonic bonding as claimed in Claim 1, wherein said hydrocarbons solvents are ethylamine and ethyl acetate.