

[Document Name] Description

[Title of the Invention] BALL BONDING-WIRE OF DILUTE ALLOYS OF PRECIOUS METAL IN SILVER

[Technical Field]

[0001]

The present invention relates to a noble metal thin silver alloy wire for bonding suitable for connecting an IC chip electrode and a substrate, such as an outer lead, used in a semiconductor device; and particularly relates to a noble metal thin silver alloy wire for ball bonding having excellent second bondability.

[Background Art]

[0002]

Conventionally, as a ball bonding wire for connecting an IC chip electrode and an outer lead in a semiconductor device, a pure gold wire comprising gold (Au) having a purity of 99.99 mass% or more and less than 100 mass ppm of other metal elements is often used because of its excellent connection reliability. One end of the pure gold wire is formed into a molten ball and then connected to an aluminum pad on an IC chip electrode by ultrasonic combined thermal compression bonding, while the other end is connected to an outer lead wire, etc., of a printed circuit board, lead frame, device, etc. The connected pure gold wire is then sealed with mold resin to form a semiconductor device. The aluminum pad is composed of pure aluminum (Al), Al-1 mass% Si alloy, Al-0.5 mass% Cu alloy, Al-1 mass% Si-0.5 mass% Cu alloy, or the like, and is generally formed by dry plating, such as vacuum deposition.

[0003]

For a long time, it has been considered to use a silver alloy as an alternative to such a pure gold wire. For example, JP2012-99577A ("Patent Document 1" described later) discloses an invention of "a bonding wire comprising silver (Ag) as a main component and at least one component selected from 10,000 to 90,000 mass ppm of gold (Au), 10,000 to 50,000 mass ppm of

palladium (Pd), 10,000 to 30,000 mass ppm of copper (Cu), and 10,000 to 20,000 mass ppm of nickel (Ni), and having a chlorine (Cl) content of less than 1 mass ppm." This invention is "aimed to provide an inexpensive bonding wire that has an excellent light reflectivity with a wavelength of 380 to 560 nm so as to improve the optical property of a light-emitting device, without coating the surface of the bonding wire with metal, and that has enhanced chemical stability (paragraph [0008] of Patent Document 1)."

[0004]

Compared to pure silver bonding wires, the silver alloy wire show some improvement in contamination by chlorine (Cl), sulfur (S), etc., in the atmosphere or in a specific environment, due to the interaction of chlorine resistance and sulfur resistance of palladium (Pd), etc. However, silver alloy wires in which the noble metal content of the alloying component is 6% or less (i.e., so-called noble metal thin silver alloy wires) have defects that the wire surface is more liable to be contaminated, and that sulfurization is still more likely to proceed, as compared to pure gold wires. This causes a problem that when such a noble metal thin silver alloy wire is allowed to stand for about 30 days even in a typical clean room in which bonding wires are used, sulfur (S) present in the air introduced from the outside forms silver sulfide (Ag_2S) on the wire surface, which disturbs excellent second bonding, thereby reducing the bonding strength to the outer lead by ultrasonic waves.

[0005]

Alternatively, in order to facilitate sliding with a bonding tool, a bonding wire that is "wire-drawn into a very fine wire with a diameter of about 10 to 50 μm using one of Au, Al, and Cu as a main element, and that is used such that it is attached to a wire bonder in a state where a predetermined length of the wire is wound in a spool (paragraph [0002] of JP6-151497A ("Patent Document 2" described later))" is known. This "bonding wire for a semiconductor device is characterized in

that the wire surface has a total organic carbon content of 50 to 1,500 $\mu\text{g}/\text{m}^2$ (claim 1 of Patent Document 2)," which is achieved, for example, by washing an ingot with acid after melting and casting. This method is described as follows: "As one method for producing a wire, the surface of which has a total organic carbon content of 50 to 1,500 $\mu\text{g}/\text{m}^2$, a wire produced through general steps, that is, melting, casting, wire drawing, annealing, and winding steps, the surface of which already has a total organic carbon of greater than 1,500 $\mu\text{g}/\text{m}^2$, is washed by acid . . . or the like so as to adjust the total organic carbon content of the surface within the range of 50 to 1,500 $\mu\text{g}/\text{m}^2$ (claim 2). The method may have a washing step before or after the annealing step in the general steps, and the method is characteristically easily implemented (paragraph [0010] of Patent Document 2)." Patent Document 2 also states as follows: "Examples of lubricant components include mineral-based lubricants, such as paraffin hydrocarbon, naphthene hydrocarbon, and aromatic hydrocarbon; synthetic oil-based lubricants, such as polyolefin, alkylbenzene, fatty acid, higher alcohol, fatty acid soap, polyglycol, polyphenyl ether, fatty acid diester, polyol ester, polyoxyethylene alkyl ether, sulfonate, amine, amine salts, silicone, phosphate ester, fluorocarbon, fluoropolyether, and fluoroglycol; natural oil-based lubricants, such as beef tallow, lard, palm oil, soybean oil, rapeseed oil, castor oil, and pine oil; any of which can be used. Moreover, a mixed system of these several components can also be used (paragraph [0012] of Patent Document 2)."

[0006]

However, this organic carbon is used as a lubricant component, but does not intend to block sulfur (S) components in the atmosphere. The noble metal thin silver alloy wire of the present invention is likely, but less likely than a pure silver wire having a purity of 99.9 mass% or more, to incorporate sulfur (S) components in the atmosphere. Hence, when the carbon

layer is thin, the silver (Ag) component is likely to bind to sulfur (S) components present in the atmosphere to form silver sulfide on the wire surface. Once solid silver sulfide (Ag_2S) is formed on the wire surface, the silver sulfide (Ag_2S) grows into the inside of the wire to form an uneven silver sulfide (Ag_2S) film, which makes the second bonding unstable, thereby causing a problem that the bonding interface of the second bond is not stable. Moreover, when the noble metal thin silver alloy wire is subjected to second bonding, the substrate, lead frame, device, etc., are generally heated to a high temperature (about 100°C to 250°C); thus, due to hot air of their surrounding environment, sulfur (S) derived from the wire and present in the bonding interface is more likely to bind to sulfur (S) components present in the atmosphere. This causes a problem that sulfurization of the bonding interface further proceeds even after the second bonding, so that the bonding interface is more easily peeled off. Furthermore, if the silver sulfide (Ag_2S) film further grows into the inside of the wire before bonding, the first bonding would also be adversely affected, such as chip cracking and junction defects.

[Prior Art Documents]

[Patent Documents]

[0007]

[Patent Document 1] JP2012-99577A

[Patent Document 2] JPHei6-151497A

[Summary of the Invention]

[Technical Problem]

[0008]

The present invention was made to solve the above problems of second bonding, and an object of the present invention is to provide a bonding wire for realizing a noble metal thin silver alloy wire that can prevent sulfurization of the noble metal thin silver alloy with sulfur in the atmosphere.

[Solution to problem]

[0009]

Focusing on the fact that the surface of a molten and cast noble metal thin silver alloy has less activity (chemical reactivity with sulfur (S) in the atmosphere) than a pure silver alloy, the present inventors intend to use a noble metal thin silver alloy, thereby decreasing the chemical reactivity between sulfur (S) in the atmosphere and the silver (Ag) component on the wire surface; to reduce the diameter of the surface to decrease the surface area, thereby reducing surface activity; to form an ultra-thin carbon layer on the entire surface of the noble metal thin silver alloy wire, thereby preventing sulfurization and oxidization of the noble metal thin silver alloy in the atmosphere, due to the reducing action of carbon (C) in the carbon layer; and to remove a silver sulfide (Ag_2S) film, etc., weakly bonded to the surface of the silver alloy wire from the bonding interface, even by low thermal energy of ultrasonic waves during the second bonding, which is less powerful than the heat of melting during the first bonding.

[0010]

The surface structure of the noble metal thin silver alloy wire for ball bonding for solving the problems of the present invention is characterized in that the noble metal thin silver alloy wire for ball bonding comprises 0.1 to 6 mass% of palladium (Pd) having a purity of 99.9 mass% or more and the balance silver (Ag) having a purity of 99.99 mass% or more, wherein the wire has a surface structure in which the wire surface comprising 3.0 to 4.8 mass% of the palladium (Pd) and the balance the silver (Ag) is a wire drawing surface that is a continuous casting surface having a diameter reduced by diamond dies, and the wire drawing surface is entirely covered with an organic carbon layer that has a total organic carbon (TOC) content of 50 to 3,000 $\mu\text{g}/\text{m}^2$ and that is derived from a water-soluble non-sulfur organic polymer having a boiling point lower than the melting point of the noble metal thin silver alloy.

[0011]

In the surface structure of the noble metal thin silver alloy wire of the present invention, the continuous casting surface is maintained as the wire surface, because the formation of a new active surface on the wire surface is prevented. Moreover, the continuous casting surface is wire-drawn through diamond dies, because diamond dies have good sliding properties for noble metal thin silver alloys, and the diameter is reduced while the continuous casting surface is maintained. For diameter reduction through diamond dies, it is necessary that at least the last wire drawing die is a diamond die. General diameter reduction is performed by wet-type continuous wire drawing in water or a shower. The surface of the noble metal thin silver alloy wire of the present invention is an inert wire drawing surface that is a continuous casting surface having a reduced diameter, and the surface is covered with an organic carbon layer, thereby preventing binding between sulfur (S) in the atmosphere and the silver (Ag) component on the wire surface.

[0012]

In the surface structure of the noble metal thin silver alloy wire of the present invention, the noble metal thin silver alloy comprises 0.1 to 6 mass% of palladium (Pd) having a purity of 99.9 mass% or more and the balance silver (Ag) having a purity of 99.99 mass% or more, because bondability to an aluminum pad and reliability life are taken into consideration. More specifically, this is because, unless the noble metal thin silver alloy wire itself has a certain degree of softness, chip damage is likely to occur when the molten ball is connected to a pure aluminum (Al) pad, an aluminum alloy pad, or the like. Another reason is that, also in the bonding interface of the first bond, sulfur (S) components are prevented from remaining in the bonding interface between silver (Ag) and aluminum (Al). Palladium (Pd) has the effects of preventing the formation of intermetallic compounds between a free air ball (FAB) and the aluminum pad in a nitrogen atmosphere during the first bonding,

and bonding a molten ball in a spherical shape. The content of the alloying element is 6 mass% or less, because when the content is greater than 6 mass%, the molten ball formed from the free air ball (FAB) becomes too hard, and chip damage is likely to occur. Moreover, the content of the alloying element is 0.1 mass% or more, because a very low amount of alloying element does not ensure resistance to sulfurization, and even when an organic carbon film is formed on the surface, the progress of sulfurization on the continuous casting surface cannot be prevented. Once a silver sulfide (Ag_2S) film is formed on the continuous casting surface of the noble metal thin silver alloy wire, even when a molten ball is formed and the organic carbon layer is thermally decomposed, the molten ball is hardened, and chip damage is likely to occur.

[0013]

The purity of the silver (Ag) component is 99.99 mass% or more, because the metal impurity content is less than 100 mass ppm so as to avoid internal oxidation of the metal impurities on the continuous casting surface of the noble metal thin silver alloy wire. The purity of the silver (Ag) component is preferably 99.999 mass% or more so as to form a good quality of noble metal thin silver alloy wire. Similarly, the purity of alloying elements, i.e., palladium (Pd), platinum (Pt), and gold (Au), is preferably 99.99 mass% or more so as to form a good quality of noble metal thin silver alloy wire.

[0014]

Among the alloying elements for the noble metal thin silver alloy wire of the present invention, palladium (Pd) is preferred. This is because sulfide formed on the surface of the noble metal thin silver alloy wire during the second bonding can be easily decomposed. Further, palladium (Pd) is highly effective to prevent the formation of intermetallic compounds of silver (Ag) and aluminum (Al) in the bonding interface during the first bonding, and to prevent degradation of the bonding interface due to intermetallic compounds of silver (Ag) and

aluminum (Al) under high-humidity and high-temperature conditions. Furthermore, the noble metal thin silver alloy of the present invention preferably comprises 0.1 to 5 mass% of palladium (Pd) having a purity of 99.99 mass% or more, 5 to 60 mass ppm of titanium (Ti), and the balance silver (Ag) having a purity of 99.99 mass% or more. This is because titanium (Ti) can inhibit the catalytic activity of palladium (Pd) during the formation of the molten ball. However, titanium (Ti) tends to harden the molten ball of the noble metal thin silver alloy; thus, the titanium content is preferably 5 to 60 mass ppm. [0015]

In the surface structure of the ball bonding noble metal thin silver alloy wire of the present invention, the wire drawing surface is entirely covered with an organic carbon layer having a total organic carbon (TOC) content of 50 to 3,000 $\mu\text{g}/\text{m}^2$, because the activity of the wire is reduced so as to prevent binding of the noble metal thin silver alloy wire to sulfur (S), etc., in the atmosphere. The organic carbon layer of the present invention is derived from a non-sulfur organic polymer compound that does not contain sulfur (S) as a constituent element. Since the melting point of the noble metal thin silver alloy wire is lower than that of a pure gold wire, the organic carbon layer is preferably derived from a water-soluble non-sulfur organic polymer having a boiling point lower than the melting point of the noble metal thin silver alloy, such as a non-ionic surfactant, an anionic surfactant, a cationic surfactant, or an amphoteric surfactant. Among surfactants, non-ionic surfactants are most preferable. For example, NCW-1001 (trade name available from Wako Pure Chemical Industries, Ltd.) can be used. The organic carbon layer is also preferably derived from a water-soluble alcohol having a boiling point lower than the melting point of the noble metal thin silver alloy, and is more preferably derived from ethanol, methanol, or isopropyl alcohol, all of which have a low total molecular weight.

[0016]

The wire drawing surface of the present invention is entirely covered with an organic carbon layer, because even if a part of the surface is not covered with an organic carbon layer, this part allows sulfur (S) in the atmosphere to bind to the surface of the noble metal thin silver alloy wire to thereby form a silver sulfide (Ag_2S) film.

Moreover, the thickness of the organic carbon layer is set so that the total organic carbon (TOC) content is 50 to 3,000 $\mu\text{g}/\text{m}^2$, because the diameter of a ball bonding wire is generally 15 to 25 μm , and the effective thickness of the organic carbon layer can be easily calculated from the total organic carbon (TOC) content. The total organic carbon (TOC) content can be controlled within the range of 50 to 3,000 $\mu\text{g}/\text{m}^2$ by washing with hot pure water or ultrasonic washing, or by immersion in a highly-diluted solution of an organic polymer compound; however, in terms of easy control, immersion in a highly-diluted solution is preferred. The upper limit is 3,000 $\mu\text{g}/\text{m}^2$, because the amount of carbon powder attached and deposited in the bonding tool is reduced. This is because, even though the melting point of the noble metal thin silver alloy wire of the present invention is lower than that of a pure gold bonding wire, carbon powder is attached and deposited in the bonding tool. Considering workability of the exchange frequency of the bonding tool, the upper limit is preferably 2,400 $\mu\text{g}/\text{m}^2$, and more preferably 1,800 $\mu\text{g}/\text{m}^2$.

[0017]

As long as the organic carbon layer was derived from, among water-soluble non-sulfur organic polymer compounds, a non-ionic surfactant or a water-soluble alcohol, such as ethanol, methanol, or isopropyl alcohol, even when the total organic carbon content of the surface was greater than 1,800 $\mu\text{g}/\text{m}^2$ but was less than 3,000 $\mu\text{g}/\text{m}^2$, there was no capillary clogging or clamper contamination caused by the deposition of carbon powder during a continuous bonding operation in which

the number of times of bonding was generally 500,000.

[Effects of the Invention]

[0018]

According to the ball bonding noble metal thin silver alloy wire of the present invention, the organic carbon layer formed on the inert continuous casting surface having a reduced diameter prevents the noble metal thin silver alloy wire from immediately binding to sulfur (S) in the atmosphere to form solid silver sulfide. Therefore, even if the ball bonding noble metal thin silver alloy wire of the present invention is allowed to stand at room temperature for a long period of time, no solid silver sulfide (Ag_2S) film by sulfur (S) components present in the atmosphere is formed on the wire surface. That is, the ball bonding noble metal thin silver alloy wire of the present invention has excellent bonding properties due to the component composition, as well as excellent second bondability due to ultrasonic waves; thus, the product life of the bonding wire before the start of use can be ensured. Furthermore, according to the noble metal thin silver alloy wire of the present invention, repeated bonding does not cause capillary contamination.

[Examples]

[0019]

Noble metal thin silver alloys having the component compositions shown in Table 1 (purity of noble metal components: silver (Ag): 99.999 mass% or more, each of the other alloy components: 99.99 mass% or more) were each uniformly molten and then continuously cast, thereby obtaining 5-mm-diameter thick wires. The thick wires were each subjected to wet continuous wire drawing through diamond dies, without acid washing, and conditioning heating was performed to obtain predetermined mechanical properties, thereby obtaining 20- μm -diameter wires in which the continuous casting surface remained. Subsequently, each wire was continuously immersed in a non-sulfur organic compound aqueous solution having each of the

concentrations shown in Table 2. Thus, the ball bonding noble metal thin silver alloy wires of the present invention (Example Products 1 to 15) were obtained.

Here, Example Product 9 shows that the organic carbon content when the bonding wire was immersed in an aqueous solution of ethanol having a concentration of 1% and then dried was 2,800 $\mu\text{g}/\text{m}^2$.

Example Product 15 was obtained by producing an Ag-3% Pd alloy bonding wire, and immersing the wire in a dilute solution of ethanol, followed by washing with hot pure water.

[0020]

[Table 1]

		Composition of dilute silver alloy				
		Ag	Pd (%)	Pt (%)	Au (%)	Ti (ppm)
Example Product	1	Balance	3.5			
	2	Balance		2		
	3	Balance			4	
	4	Balance	4.8			
	5	Balance		0.3		
	6	Balance			5.8	
	7	Balance	1		0.5	
	8	Balance		1.5	2.5	
	9	Balance	0.4	3.6	0.7	
	10	Balance	2.3			28
	11	Balance		4.6		14
	12	Balance			1.7	56
	13	Balance	0.7	1.2		42
	14	Balance		0.2	3.3	49
	15	Balance	3			
Comparative Product	16	Balance	2.5			
	17	Balance		4		
	18	Balance			0.07	

[0021]

The non-ionic surfactant shown in Table 2 is a liquid detergent for clothes (trade name: Natural, available from Bluebell Co., Ltd.). The anionic surfactant is PerSoft (registered trademark) (trade name available from NOF Corporation). The cationic surfactant is Nissancation

(registered trademark) (trade name available from NOF Corporation). The amphoteric surfactant is Nissananon (registered trademark) BD (trade name available from NOF Corporation).

[0022]

[Table 2]

		Type of water-soluble non-sulfur organic compounds (TOC ($\mu\text{g}/\text{m}^2$))						
		Ethanol	Methanol	Isopropyl alcohol	Non-ionic surfactant	Anionic surfactant	Cationic surfactant	Amphoteric surfactant
Example Product	1				500			
	2			200				
	3		1200					
	4	150			70			
	5		400					
	6							
	7	300		900				
	8							600
	9	2800 *						
	10				1300			
	11					2000		
	12			500			100	
	13	800						
	14		100					
	15	1500						
Comparative Product	16	1000						
	17				100			
	18							3500

[0023]

After the noble metal thin silver alloy wires were allowed to stand in a laboratory under a clean room environment (atmosphere with a temperature of 25°C and a humidity of 50%) for 30 days, the measurement of the thickness of silver sulfide (Ag_2S) films, the bondability test of the second bond, and the capillary clogging test were preformed. The results shown in Table 3 were obtained.

[0024]

[Table 3]

		Thickness of silver sulfide film after 30 days	Pull strength of second bond after 30 days (gF)	Result of capillary clogging test
Example Product	1	0	4.5	No clogging until 1,000,000 bonds
	2	0	4.0	No clogging until 1,000,000 bonds
	3	0	3.3	No clogging until 1,000,000 bonds
	4	0	3.5	No clogging until 1,000,000 bonds
	5	8	3.8	No clogging until 1,000,000 bonds
	6	0	3.3	No clogging until 1,000,000 bonds
	7	5	3.5	No clogging until 1,000,000 bonds
	8	0	3.9	No clogging until 1,000,000 bonds
	9	0	3.4	No clogging until 800,000 bonds
	10	0	3.8	No clogging until 1,000,000 bonds
	11	0	3.3	No clogging until 1,000,000 bonds
	12	5	3.2	No clogging until 1,000,000 bonds
	13	5	3.3	No clogging until 1,000,000 bonds
	14	0	3.5	No clogging until 1,000,000 bonds
	15	0	3.1	No clogging until 1,000,000 bonds
Comparative Product	16	0 *	3.2	No clogging until 1,000,000 bonds
	17	30	1.5	No clogging until 1,000,000 bonds
	18	40	1.0	No clogging until 250,000 bonds

[Comparative Examples]

[0025]

Noble-metal thin silver alloys having the component compositions shown in Table 1 were each uniformly molten, and then continuously cast, thereby obtaining 5-mm-diameter thick wires. The surface of the thick wires was washed or not washed with thin nitric acid. Thus, the ball bonding noble metal thin silver alloy wires of Comparative Examples (Comparative Products 16 to 18) were obtained in the same manner as in the Examples.

Here, Comparative Product 16 was obtained as follows: A bonding wire was produced by continuously casting an Ag-2.5% Pd alloy to obtain a 5-mm-diameter thick wire, and washing the surface of the wire with thin nitric acid, followed by continuous wire drawing. Then, the bonding wire was immersed in a highly-diluted solution of ethanol, and subjected to the tests on the same day, without being allowed to stand for 30 days.

Comparative Product 17 was obtained as follows: A

bonding wire was produced by continuously casting an Ag-4% Pt alloy to obtain a 5-mm-diameter thick wire, and the surface of the wire was washed with dilute nitric acid, followed by continuous wire drawing. Then, an organic carbon film derived from a non-ionic surfactant was formed on the bonding wire. After the bonding wire was allowed to stand for 30 days, the film thickness measurement and the tests were performed.

Comparative Product 18 was obtained by producing an Ag-0.07% Au alloy bonding wire having a gold (Au) content that was outside of the lower limit, and then forming an organic carbon film derived from an amphoteric surfactant having an organic carbon content that exceeded the upper limit.

[0026]

After the noble metal thin silver alloy wires (Comparative Products 17 and 18) were allowed to stand in a laboratory at room temperature for 30 days, the measurement of thickness of silver sulfide (Ag_2S) films, the bondability test of the second bond, and the capillary clogging test were performed. The results shown in Table 3 were obtained. However, Comparative Example 16 was not allowed to stand and was subjected to the film thickness measurement and the tests on the same day, as described above.

[Measurement of total organic carbon (TOC) content]

[0027]

The total organic carbon content was measured as follows: Each noble metal thin silver alloy wire (1,000 m) was weighed, and 200 g of 0.1 N-NaOH aqueous solution was added and boiled in a water bath for 30 minutes for extraction. After cooling, 2.5 ml of 8 N-HCl was added, and the mixture was slightly shaken, followed by bubbling with highly-purified air for 15 minutes. The resultant was supplied to an organic carbon analyzer (model: TOC-5000, produced by Shimadzu Corporation) to measure the organic carbon concentration. The total organic carbon mass was calculated from the organic carbon concentration, and divided by the surface area of the 20- μm -diameter noble metal

thin silver alloy wire. The resulting value was used as the total organic carbon content of the non-ionic surfactant on the surface.

[Measurement of thickness of silver sulfide (Ag_2S) film]

[0028]

The thickness of the silver sulfide (Ag_2S) films formed on the wire surface was measured by a film thickness measuring apparatus (Model: QC200, produced by ECI). The thickness of all of the silver sulfide (Ag_2S) films of Example Products 1 to 15 and Comparative Product 16 was 10 nm or less. In contrast, the film thickness of both Comparative Products 17 and 18 was 20 nm or more.

[Bondability test of second bond after 30 days]

[0029]

The bondability test of the second bond was preformed using a wire bonder (produced by Shinkawa Ltd.), and bonding strength was measured by a tension test under conditions that the loop length was 2 mm and the loop height was 200 μm , using a specific pull hook at a position 20% distant from the second bond point. Example Products 1 to 15 and Comparative Product 16 were excellent; however, Comparative Product 17, which was contrasted with Comparative Product 16, showed insufficient results. This is caused by the formation of silver sulfide (Ag_2S).

[Capillary clogging test]

[0030]

The capillary clogging test was performed in such a manner that bonding was started using a new capillary, and the number of times of bonding until the capillary clogged to disable bonding was measured. Table 3 shows the results.

[0031]

As is clear from the bondability test of the second bond after 30 days, all of Example Products 1 to 15, which were the ball bonding noble metal thin silver alloy wires of the present invention, and Comparative Product 16 had a breaking strength

of 4.0 weight g (gf) or more, and were excellent. In contrast, it is revealed that the ball bonding noble metal thin silver alloy wires of the Comparative Examples (Comparative Products 17 and 18) were insufficient.

[0032]

As is clear from the capillary clogging test, the ball bonding noble metal thin silver alloy wires and the like of the present invention (Example Products 1 to 8 and 10 to 15, and Comparative Products 16 and 17) showed no capillary clogging even after one million or more times of bonding, and were excellent. In contrast, it is revealed that the ball bonding noble metal thin silver alloy wire of the Comparative Example (particularly Comparative Product 18) showed capillary clogging after 250,000 times of bonding.

[0033]

As is clear from the above Examples and Comparative Examples, the Example Products of the present invention showed no capillary clogging, and had excellent bonding properties after they were allowed to stand in a laboratory at room temperature for 30 days. Specifically, it is revealed that although the comparative product had excellent second bonding properties immediately after the production of the bonding wire (Comparative Product 16), silver sulfide (Ag_2S) films were grown after 30 days, and second pull strength was extremely low (Comparative Products 17 and 18). In contrast, it is revealed that even after Example Products 1 to 15 of the present invention were allowed to stand for 30 days, almost no or no silver sulfide (Ag_2S) films were formed, and second pull strength was high. Furthermore, it is revealed that capillary clogging occurred faster as the TOC content was larger (Comparative Product 18), thereby impairing workability.

[Industrial Applicability]

[0034]

The ball bonding noble metal thin silver alloy wire of the present invention is used for general-purpose ICs, discrete

ICs, and memory ICs; IC packages for LEDs and IC packages for automobile semiconductors, which are used at high temperature and high humidity, but are required to be inexpensive; IC packages for defense, space, and airline industries, in which copper (Cu) bonding wires are less likely to be used; or medical applications and semiconductor applications, such as photocouplers.

[Document Name] Claims

[Claim 1]

A noble metal thin silver alloy wire for ball bonding comprising 0.1 to 6 mass% of palladium (Pd) having a purity of 99.9 mass% or more and the balance silver (Ag) having a purity of 99.99 mass% or more;

the wire having a surface structure in which the wire surface comprising 3.0 to 4.8 mass % of the palladium (Pd) and the balance the silver (Ag) is a wire drawing surface that is a continuous casting surface having a diameter reduced by diamond dies, and the wire drawing surface is entirely covered with an organic carbon layer that has a total organic carbon (TOC) content of 50 to 3,000 $\mu\text{g}/\text{m}^2$ and that is derived from a water-soluble non-sulfur organic polymer having a boiling point lower than the melting point of the noble metal thin silver alloy.

[Claim 2]

The noble metal thin silver alloy wire for ball bonding according to claim 1, wherein the palladium (Pd) has a purity of 99.99 mass% or more.

[Claim 3]

The noble metal thin silver alloy wire for ball bonding according to claim 1, wherein the noble metal thin silver alloy comprises 3.0 to 4.8 mass% of palladium (Pd) having a purity of 99.99 mass% or more, 5 to 60 mass ppm of titanium (Ti), and the balance silver (Ag) having a purity of 99.99 mass% or more.

[Claim 4]

The noble metal thin silver alloy wire for ball bonding according to claim 1, wherein the organic carbon layer is derived from a water-soluble alcohol that has a boiling point lower than the melting point of the noble metal thin silver alloy.

[Claim 5]

The noble metal thin silver alloy wire for ball bonding according to claim 1, wherein the organic carbon layer is

derived from ethanol, methanol, or isopropyl alcohol.