BONDING WIRE FOR SEMICONDUCTOR ELEMENT

The present invention relates to a bonding wire for connecting a semiconductor element and an external lead to each other.

In order to connect electrodes of a semiconductor element to external leads, there has conventionally been used a wire having a diameter of 25 to 50 μm and made of Au alloy containing a small amounts of Ca, Be, Ge or the like, that is, a bonding wire has been used.

When such a wire is used for connecting a semiconductor element and a lead frame to each other, such a method is employed that both components are pressure-bonded through ultrasonic waves, or for the electrodes of the semiconductor element, hot pressure bonding is effected after each tip thereof has been formed into a ball using an arc.

However, it has recently become possible to make ICs smaller in size and to make the degree of integration thereof higher, which has given rise to the problem that, due to an increase in the number of electrodes, the electrodes have occupied too large an area when using a conventional wire diameter. In order to solve this problem, it is necessary to use a wire of smaller diameter. However, when the wires at present available are made small in size, they are extremely liable to rupture during a wiring operation and in use. Such wire

cannot be used in practice.

For this reason, it has been considered that, for conventional wires, a wire diameter of about 20 μm is a minimum value.

There have been some attempts to make a wire diameter small, as disclosed in Japanese Patent Unexamined Publication Nos. 56-49534 and 56-49535 in which up to 30 wt. % Pt or up to 40 % Pd is added to Au to enhance the strength of the wire and to make the wire diameter small. However, if the content of the alloy elements exceeds a certain limit, the hardness of the ball will be increased and the load necessary for hot pressure bonding will be increased with the result that a silicon chip of an IC is apt to be damaged. Japanese Patent Unexamined Publication No. 60-15958 proposes an Au base alloy wire as a bonding wire having good hot pressure properties with respect to electrode wirings in which a different element is mixed into Al. This also suffers the same problem as above. Thus, there is a demand for a new bonding wire that is effective for making an IC which is small in size and which is densified in a higher degree without any special modification of the conventional IC and conventional bonding methods.

An object of the invention is to provide a bonding wire having a reliability substantially equal to that of a conventional wire, even if the wire diameter of the

bonding wire is smaller than that of the conventional wire. Another object of the invention is to provide a bonding wire for a semiconductor element, which wire can be formed to have an extremely small diameter as well as a sufficiently high strength with respect to the production thereof, and is improved with respect to rupture during the bonding thereof.

In the accompanying drawings:

Fig. 1 is a graph in which, regarding the rupture strength of a Cu-containing bonding wire according to the invention, there is shown the relationship between Cu content and heat treatment condition; and

Fig. 2 illustrates a method for measuring bonding strength.

The present invention provides a bonding wire for a semiconductor element consisting of more than 1 wt. % but less than 5 wt. % Cu, the balance being Au and incidental impurities.

The invention also provides a bonding wire for a semiconductor element consisting of more than 1 wt. % but less than 5 wt. % Cu, and at least one substance selected from the group consisting of Ca, Ge, Be, La and In in a proportion of 0.0003 to 0.01 wt. % in total, the balance being Au and incidental impurities.

The invention further provides a bonding wire for a semiconductor element consisting of more than 1 wt. % but less than 5 wt. % Cu, not less than 1 wt. % but less than

5 wt. % Pt, the balance being Au and incidental impurities.

The invention also provides a bonding wire for a semiconductor element consisting of more than 1 wt. % but less than 5 wt. % Cu, not less than 1 wt. % but less than 5 wt. % Pt, and at least one substance selected from the group consisting of Ca, Ge, Be, La and In in a proportion of 0.0003 to 0.01 wt. % in total, the balance being Au and incidental impurities.

In the bonding wire for a semiconductor element according to the invention, the reason why the proportion of Cu is more than 1 wt. % but less than 5 wt. % is that when Cu is completely incorporated into Au in the form of a solid-solution both the strength of the base wire and the bonding strength are enhanced, so that it becomes possible to produce a thin wire having a wire diameter of 20 micron or less (which was difficult to realize in the prior art), which wire has a rupture strength of 4 grams or more. With respect to this feature, the strength is increased as the proportion of Cu increases. However, if the Cu content exceeds 5 %, there occurs a problem with the anti-corrosion properties, resulting in degradation in reliability after a long time has elapsed. Also, when the content of Cu reaches 5%, the hardness of a ball formed during the bonding operation is increased, and the load needed for the hot pressure bonding is increased, with the result that a silicon chip is apt to be damaged.

If a large amount of impurity is contained in Au and Cu used as raw materials, the characteristics of the product will become unstable and this will become a cause of rupture during the production of a thin wire and during bonding operations. Thus, it is preferable to obtain a purity exceeding 99.9%.

It is considered that the reason why such effects may be obtained by the use of Cu is that solid-solution strengthening occurs and a superlattice is generated. Pt serves to promote the effects. Where Pt is used, the proportion of Pt is not less than 1 wt. % but less than 5 wt. %. If the Pt content is less than the lower limit, the effect cannot be obtained. If the Pt content is more than the upper limit, ductility ends to be decreased and hardness of the ball tends to be increased.

It is preferable to perform a heat treatment at 200 to 600°C for a suitable period of time in order to insure a suitable ductility and sufficient strength by relieving working strain occurring during the wire drawing operation.

A thin wire in an as-drawn state has inferior

ductility (elongation) and undesirable curls due to the working deformation, so that it is sometimes impossible to use it for practical applications. Thus, an annealing operation is usually performed on the wire. In general, the higher the temperature of the heat treatment and the longer the period thereof, the more the strength decreases and the more the ductility increases. However, the degree varies in accordance with the content of the alloy components. Therefore, it is necessary to select the heat treatment condition in accordance with the wire diameter and the composition. Also, recrystallization of the structure and grain growth proceed by the heat treatment. If the crystalline grain size approaches the wire diameter, both the strength and ductility are considerably degraded. It is therefore very important to select the heat treatment condition in the case of the thin diameter wire.

Fig. 1 is a graph showing a heat treatment condition for insuring a rupture strength of not less than 4 grams the case of a wire having a diameter of 10 μm and containing Cu. The solid line represents the case of 400°C treatment and the broken line represents the case of 200°C treatment.

Also, in particular, the addition of Ca, Be Ge, La and/or In, which have been added in the conventional gold bonding wire, is effective to enhance the bonding strength of the bonding wire according to the present invention. In order to attain this purpose, it is possible to add at

least one selected from these elements in a proportion of 0.0003 to 0.01 wt. % in total.

Regarding the bonding wire according to the present invention, Au alloy having a chemical composition in accordance with the invention is melted in a vacuum melting furnace etc. and is cast. Thereafter, the wire drawing operation, heat treatment etc. are effected to obtain a wire having a desired wire diameter.

Embodiments for clarifying the advantages of the invention will now be described.

By using a high purity Au having a purity of 99.99% and a high purity Cu having a purity of 99.9%, a material to which the elements shown in Table 1 were added was melted in a vacuum melting furnace. The material was then subjected to a wire drawing and a heat treatment to thereby obtain wires having diameters of 10, 12, 15, 19, 25 and 30 μm.

In a tensile test, a test piece having a gauge length of 100 mm was used. The bonding strength measurement was conducted in such a manner that the bonding wire 3 connected to both the Si chip 1 and the lead frame 2 as shown in Fig. 2 was tensioned in a direction indicated by the arrow so that the rupture strength was measured. The results for wire of the invention are shown in Table 1 with respect to rupture load, elongation and rupture strength of the wire after bonding together with the results of comparison materials.

As is apparent from Table 1, it is understood

that the wires according to the present invention are superior in rupture strength and bonding strength irrespective of their thin diameters. Also, it is apparent that if the bonding wires having the same diameter as that of the conventional bonding wires are used, the wire having a higher strength may be obtained in the case of the invention.

Table 1

Example of the invention	Chemical composition (wt%)							
	Au	Cu	Pt	Ca	Ge	Be	La	In
" 1	Balance	1.2	1					
" 2	Balance	2		0.0004				
" 3	Balance	2		0.0008		0.0014		0.0024
" 4	Balance	3						
" 5	Balance	4			0.0042			
" 6	Balance	4	2	0.0011	0.0042	0.0018	0.0014	0.0012
" 7	Balance	2	4			0.0028		
" 8	Balance	2		0.0004			0.0012	
" 9	Balance	2	3					
" 10	Balance	2	3			0.0062		
" 11	Balance	2				0.0028		

- cont'd -

Table 1 (cont'd)

" 12	Balance	2					0.0022		
" 13	Balance	2						0.0043	
" 14	Balance	3							
" 15	Balance	3		0.0008	0.0021		0.0013		
" 16	Balance	3			0.0033				
" 17	Balance	4							
Comparison material	Balance			0.0010				0.0025	
" 1	Balance			"				"	
" 2	Balance				0.0015	0.0008			
" 3	Balance				"	"			
" 4	Balance	0.7							
" 5	Balance	5.5							
" 6	Balance	1	6						

Table 1 (cont'd)

Wire diameter (μm)	Tensile test		Rupture strength after bonding (g)	Heat treatment condition
	Rupture strength	Elongation (%)		
10	4.4	4	2.8	200°C x 5 min.
10	4.3	6	2.3	"
10	4.2	5	3.6	400°C x 10 sec.
10	4.7	12	3.8	200°C x 15 min.
10	6.4	9	4.1	"
10	7.2	7	4.4	"
15	12.2	3	4.7	"
15	10.5	3	4.9	"
19	17.4	11	5.4	220°C x 15 min.
19	17.4	11	5.4	220°C x 15 min.
15	10.2	3	4.7	"

- cont'd -

Table 1 (cont'd)

25	19.3	8	6.7	"
30	24.4	5	10.2	"
15	13.2	4	6.8	450°C x 5 sec.
19	17.3	5	8.7	"
30	41.2	9	12.8	550°C x 2 sec.
30	46.8	12	11.3	"
25	7.4	7	3.6	200°C x 5 min.
10	1.2	4	1.0	"
25	8.1	6	4.3	"
12	2.1	5	1.3	"
10	2.8	2	1.1	200°C x 1 min.
25	19.7	11	*7.2	220°C x 10 min.
25	21.8	2	*9.6	220°C x 15 min.

* : Damage was observed in IC chip after bonding

As described above, the wire according to the invention is superior in rupture strength and bonding strength. In particular, even if the wire is thinned to 10 micron meters, the wire according to the invention insures a higher reliability than that of the conventional wire and is effective for making highly integrated LSI small in size.

CLAIMS

1. A bonding wire for a semiconductor element, consisting of more than 1 wt. % but less than 5 wt. % Cu, the balance being Au and incidental impurities.

2. A bonding wire for a semiconductor element, consisting of more than 1 wt. % but less than 5 wt. % Cu, and at least one substance selected from the group consisting of Ca, Ge, Be, La and In in a proportion of 0.0003 to 0.01 wt. % in total, the balance being Au and incidental impurities.

3. A bonding wire for a semiconductor element, consisting of more than 1 wt. % but less than 5 wt. % Cu, and not less than 1 wt. % but less than 5 wt. % Pt, the balance being Au and incidental impurities.

4. A bonding wire for a semiconductor element, consisting of more than 1 wt. % but less than 5 wt. % Cu, not less than 1 wt. % but less than 5 wt. % Pt, and at least one substance selected from the group consisting of Ca, Ge, Be, La and In in a proportion of 0.0003 to 0.01 wt. % in total, the balance being Au and incidental impurities.

5. A wire as claimed in any one of claims 1 to 4, having a diameter of not greater than 20 μm.

* C L M S *

6. A wire as claimed in any one of claims 1 to 4, having a rupture strength of not less than 4 gr.

7. A wire as claimed in any one of claims 1 to 4, having a diameter of not greater than 15 μm and a rupture strength of not less than 4 gr.

8. A bonding wire as claimed in any one of claims 1 to 4, substantially as described herein.

9. A method of connecting a semiconductor element to an article in which a bonding wire as claimed in any one of claims 1 to 8 is used.

10. An assembly produced by a method as claimed in claim 9.