



US 20080240975A1

(19) **United States**

(12) **Patent Application Publication**
Cho et al.

(10) **Pub. No.: US 2008/0240975 A1**

(43) **Pub. Date: Oct. 2, 2008**

(54) **AG-BASED ALLOY WIRE FOR
SEMICONDUCTOR PACKAGE**

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(21) Appl. No.: **12/051,371**

(22) Filed: **Mar. 19, 2008**

(30) **Foreign Application Priority Data**

Mar. 30, 2007 (KR) 1020070031998

Publication Classification

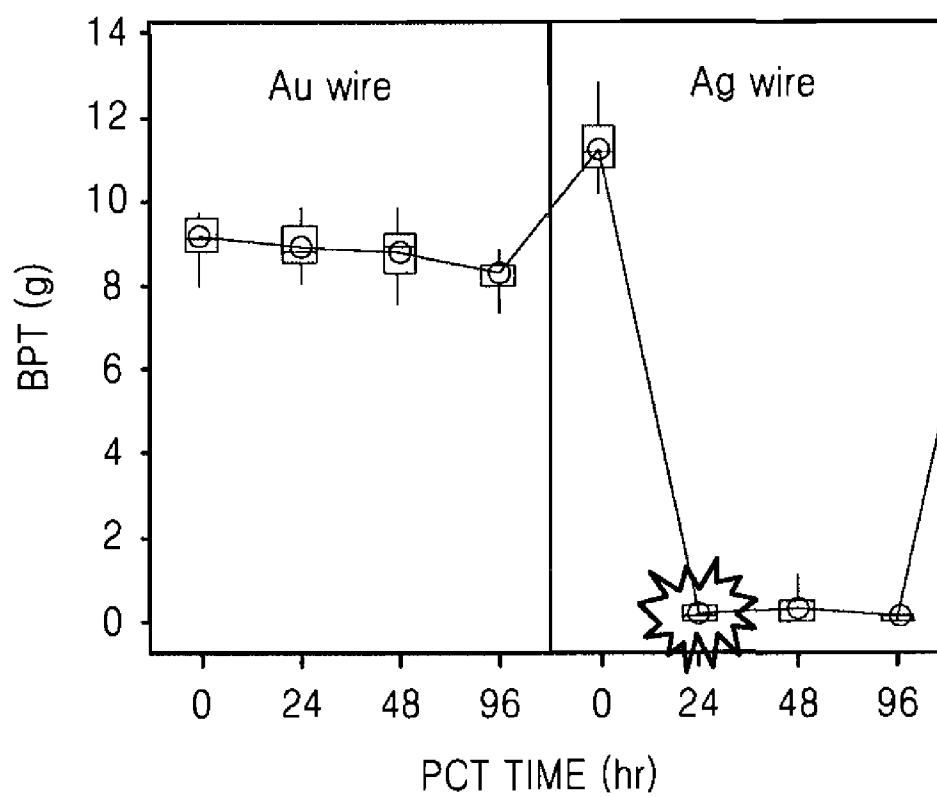
(51) **Int. Cl.**
C22C 5/06 (2006.01)
C22C 5/08 (2006.01)

(52) **U.S. Cl.** **420/503; 420/501; 420/502; 420/505**

(57) **ABSTRACT**

An Ag-based alloy wire for a semiconductor package is highly reliable and can be fabricated with low costs. The Ag-based alloy wire includes 0.05~5 wt % of at least one kind of a first additive ingredient selected from the group consisting of platinum (Pt), palladium (Pd), rhodium (Rh), osmium (Os), gold (Au), and nickel (Ni), and Ag as a remainder.

FIG. 1



AG-BASED ALLOY WIRE FOR SEMICONDUCTOR PACKAGE

CROSS-REFERENCE TO RELATED PATENT APPLICATION

[0001] This application claims the benefit of Korean Patent Application No. 10-2007-0031998, filed on Mar. 30, 2007, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a semiconductor package, and more particularly to a silver (Ag)-based alloy wire for wire bonding.

[0004] 2. Description of the Related Art

[0005] In semiconductor packages, semiconductor chips can be electrically connected to a package substrate using wire bonding. In conventional semiconductor packages, an aluminum pad of a semiconductor chip and a package substrate are bonded using gold (Au) wires. Au has been widely used because of its high chemical stability and high electrical conductivity. However, in order to meet the continuous demand to decrease the manufacturing costs in the semiconductor industry and address the cost increase of gold price, a new wire that replaces the Au wire is required.

[0006] For example, Japanese Patent Application Laid-open Nos. 1998-326803, 1999-67811, 1999-67812, and 2000-150562 disclose Au—Ag alloy wires. However, such Au—Ag alloy wires still include Au at high composite rates, which limits the cost reduction.

[0007] An Ag wire that is cheap by 30 to 50% of the conventional Au wire may be regarded as another example. However, the Ag wire has a reliability problem when bonded to the aluminum (Al) pad. Particularly as illustrated in FIG. 1, when performing a high humidity reliability test, a bonding surface of the Ag wire and the Al pad are most likely corroded or a chip crack occurs so that a bonding strength is significantly decreased. The high humidity reliability test is generally carried out using a pressure cooker test (PCT). The bonding strength of the Au wire is scarcely changed even after 96 hours in the PCT, but that of the Ag wire reaches nearly zero even after 24 hours in the PCT.

[0008] Moreover, the Ag wire has a drawback of a poor plasticity, which degrades product yield. Therefore, fabrication of the Ag wires requires many heat annealing operations, which increases the manufacturing costs.

SUMMARY OF THE INVENTION

[0009] The present invention provides an Ag-based alloy wire for a semiconductor package, which is highly reliable and requires low fabricating costs.

[0010] According to an aspect of the present invention, there is provided an Ag-based alloy wire for a semiconductor package, comprising 0.05~5 wt % of at least one kind of a first additive ingredient selected from the group consisting of platinum (Pt), palladium (Pd), rhodium (Rh), osmium (Os), gold (Au), and nickel (Ni), and Ag as a remainder.

[0011] According to another aspect of the present invention, there is provided an Ag-based alloy wire for a semiconductor package, comprising 3 wtppm~5 wt % of at least one kind of a second additive ingredient selected from the group consisting of copper (Cu), beryllium (Be), calcium (Ca),

magnesium (Mg), barium (Ba), lanthanum (La), cerium (Ce), and yttrium (Y), and Ag as a remainder.

[0012] According to another aspect of the present invention, there is provided an Ag-based alloy wire for a semiconductor package, comprising 0.05~5 wt % of the first additive ingredient, 3 wtppm~5 wt % of the second additive ingredient, and Ag as a remainder.

[0013] The term wt % or wtppm refers to a ratio of weight of ingredients to total weight of a wire in terms of % or ppm.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The above and other features and advantages of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings in which:

[0015] FIG. 1 is a graph illustrating the high humidity reliability between an Au wire and an Ag wire in a pressure cooker test (PCT).

DETAILED DESCRIPTION OF THE INVENTION

[0016] The present invention will now be described more fully with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown. The invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the concept of the invention to those skilled in the art.

[0017] A wire for a semiconductor package according to embodiments of the present invention is used for bonding a semiconductor chip to a package substrate. Thus, the wire for the semiconductor package according to embodiments of the present invention may be referred to as a bonding wire.

[0018] An Ag-based alloy wire according to embodiments of the present invention may be formed by alloying a predetermined quantity of additive ingredients into pure Ag. However, although not specially mentioned, the Ag-based alloy wire possibly includes unavoidable impurities in addition to Ag and the additive ingredients. This is because, even pure Ag may include a minute quantity of impurities when refining it, and a minute quantity of impurities may be included to the Ag alloy when alloying it. However, because the quantity of unavoidable impurities is negligible and irregular as compared with the additive ingredients, the unavoidable impurities are not generally observed. Therefore, the scope of the present invention is not limited to whether impurities are unavoidably included or not.

[0019] The Ag-based alloy wire according to an embodiment of the present invention may include at least one kind of a first additive ingredient selected from the group consisting of platinum (Pt), palladium (Pd), rhodium (Rh), osmium (Os), gold (Au), and nickel (Ni), and the remainder may be Ag. For example, the Ag-based alloy wire may be formed of the first additive ingredient in a content of 0.05~5 wt % and Ag as the remainder.

[0020] The first additive ingredient improves the high humidity reliability of the Ag-based alloy wire. The first additive ingredient can inhibit an oxide film formation and a galvanic corrosion in the bonding surface between the Ag-based alloy wire and a pad of a semiconductor chip. Thus, the occurrence of a chip crack in the bonding surface can be prevented, and a bonding strength can be improved.

[0021] However, if the amount of the first additive ingredient is less than 0.05 wt %, the high humidity reliability of the semiconductor package including the Ag-based alloy wire may be insufficiently improved. For example, the chip crack may occur in the bonding surface between the Ag-based alloy wire and the pad, thereby decreasing the bonding strength between them. Furthermore, if the amount of the first additive ingredient is greater than 5 wt %, an electrical resistance of the Ag-based alloy wire is increased and a free air ball of the Ag-based alloy wire is hardened in the bonding surface, which might create a chip crack. Accordingly, the reliability of the electrical connection of the wire and the semiconductor chip can be greatly decreased.

[0022] The Ag-based alloy wire according to another embodiment of the present invention may include at least one kind of a second additive ingredient selected from the group consisting of copper (Cu), beryllium (Be), calcium (Ca), magnesium (Mg), barium (Ba), lanthanum (La), cerium (Ce) and yttrium (Y), and Ag as a remainder.

[0023] For example, the second additive ingredient may include Cu in the content of 0.1~5 wt %. As another example, the second additive ingredient may include 3~100 wtpm of at least one material selected from the group consisting of Be, Ca, Mg, Ba, La, Ce, and Y. Alternatively, the second additive ingredient may include Cu in the content of 0.1~5 wt %, and 3~100 wtpm of at least one material selected from the group consisting of Be, Ca, Mg, Ba, La, Ce, and Y.

[0024] The second additive ingredient may contribute to further improving the workability and the tensile strength rather than the high humidity reliability of the Ag-based alloy wire. Therefore, the number of heat annealing operations when fabricating the Ag-based alloy wire can be greatly decreased as compared with the conventional technique, which in turn greatly decreases the fabricating costs.

[0025] If the content of Cu is less than 0.1 wt %, the improvement of the workability may be negligible. Also, if the content of Cu is greater than 5 wt %, the electrical resistance of the Ag-based alloy wire is increased, and a chip crack occurs, which decreases the bonding strength.

[0026] If the content of Be, Ca, Mg, Ba, La, Ce and Y is less than 3 wtppm, the improvement of the workability may be negligible. Also, if the content of Be, Ca, Mg, Ba, La, Ce, and Y is greater than 100 wtppm, solidified dimples are formed when the free air balls are formed in the bonding surface so that the bonding strength may be greatly decreased.

[0027] The Ag-based alloy wire according to another embodiment of the present invention may include both the above-stated first additive ingredient and the second additive ingredient, and the remainder may be Ag. In this case, the high humidity reliability and the workability of the Ag-based alloy wire can be improved.

[0028] Hereinafter, effects of the additive ingredients on the characteristics of the Ag-based alloy wire will be described in more detail with reference to exemplary embodiments and comparative examples.

TABLE 1

		First additive ingredient (wt %)														Second additive ingredient (wtppm)												Others (wt ppm)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
		Ag	Pd	Pt	Rh	Os	Au	Ni	Cu	Ca	Be	Mg	Ba	La	Ce	Y	Cd	Si	Ti	Al	Fe	Co	Nb	Mo	Sn	Zn	Pb	Bi	As	Sb	Se	Te	Ge	Br	I	Ag	Cu	Ca	Be	Mg	Ba	La	Ce	Y	Cd	Si	Ti	Al	Fe	Co	Nb	Mo	Sn	Zn	Pb	Bi	As	Sb	Se	Te	Ge	Br	I																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
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TABLE 1-continued

		First additive ingredient (wt %)							Second additive ingredient (wtppm)							Others (wt ppm)			
		Ag	Pd	Pt	Rh	Os	Au	Ni	Cu	Ca	Be	Mg	Ba	La	Ce	Y	Cd	Si	Ti
Comparison	36	Bal.	0.5			0.1			0.1										
	37	Bal.	0.5										10	10					
	38	Bal.	0.5								5								
	39	Bal.							0.5		5								
	40	Bal.	0.5						0.5										
	41	Bal.	0.5						0.5		5								
	1	Bal.															10		
	2	Bal.																10	
	3	Bal.																	10

TABLE 2

Classification		Bonding Strength (BPT)			Tensile						
		Before PCT	After PCT	Reliability	Strength (g)	Electrical Resistivity	Workability	Hardness (Hv)	Shelf Life (day)	Chip Crack	Dimple
Exemplary Embodiment	1	10.5	1.5	X	14.3	1.7	1.51	63	32	None (X)	None (X)
	2	10.7	9.5	⊙	16.2	1.8	0.13	64	128	None (X)	None (X)
	3	10.8	9.8	⊙	17.0	1.8	0.10	64	256	None (X)	None (X)
	4	1	10.2	⊙	17.5	2.9	0.09	65	256	None (X)	None (X)
	5	5	10.9	⊙	18.2	4.5	0.10	66	256	None (X)	None (X)
	6	10	6.3	○	21.6	10.8	1.56	70	256	Produced(O)	None (X)
	7	13.7	9.4	○	25.8	35.7	5.8	93	256	Produced(O)	None (X)
	8	11.2	9.3	⊙	16.8	1.8	0.18	64	256	None (X)	None (X)
	9	11.4	9.4	⊙	17.5	2.7	0.17	64	256	None (X)	None (X)
	10	11.5	9.4	⊙	17.4	2.8	0.21	65	256	None (X)	None (X)
	11	11.6	9.3	⊙	17.7	2.9	0.31	64	256	None (X)	None (X)
	12	11.4	9.1	⊙	17.2	1.8	0.25	64	256	None (X)	None (X)
	13	9.5	2.1	X	14.5	1.7	0.25	64	32	None (X)	None (X)
	14	11.3	9.5	⊙	17.2	1.8	0.25	64	256	None (X)	None (X)
	15	12.3	9.6	⊙	18.0	2.8	0.30	64	256	None (X)	None (X)
	16	12.5	9.6	⊙	18.5	4.7	1.32	66	256	None (X)	None (X)
	17	10.5	1.5	X	14.3	1.7	1.68	63	32	None (X)	None (X)
	18	11.2	2.6	X	15.3	1.8	0.03	65	128	None (X)	None (X)
	19	11.3	2.6	X	15.5	2.7	0.03	66	128	None (X)	None (X)
	20	12.1	2.4	X	16.4	4.3	0.04	67	128	None (X)	None (X)
	21	12.8	2.6	X	17.7	10.5	0.06	74	128	Produced(O)	None (X)
	22	10.3	2.5	X	14.5	1.7	0.89	63	128	None (X)	None (X)
	23	11.4	2.4	X	15.8	1.7	0.05	64	128	None (X)	None (X)
	24	12.6	2.1	X	17.8	1.7	0.04	65	128	None (X)	None (X)
	25	12.9	1.9	X	18.1	1.7	0.07	66	128	None (X)	None (X)
	26	12.9	1.5	X	18.2	1.8	1.74	71	128	Produced(O)	Produced(O)
	27	12.6	2.6	X	17.5	1.7	0.05	65	128	None (X)	None (X)
	28	12.6	2.4	X	17.4	1.7	0.06	65	128	None (X)	None (X)
	29	12.4	2.8	X	17.2	1.7	0.05	65	128	None (X)	None (X)
	30	12.5	3.1	X	17.4	1.7	0.04	65	128	None (X)	None (X)
	31	12.4	2.8	X	17.2	1.7	0.05	64	128	None (X)	None (X)
	32	12.5	2.6	X	16.7	1.7	0.07	65	128	None (X)	None (X)
	33	11.6	9.4	⊙	16.9	1.8	0.09	64	256	None (X)	None (X)
	34	12.6	10.2	⊙	17.0	1.8	0.06	64	256	None (X)	None (X)
	35	12.8	10.0	⊙	17.5	1.8	0.05	65	256	None (X)	None (X)
	36	12.2	9.9	⊙	16.7	1.9	0.05	64	256	None (X)	None (X)
	37	12.7	10.2	⊙	17.4	1.9	0.06	65	256	None (X)	None (X)
	38	12.6	10.2	⊙	17.5	1.9	0.05	64	256	None (X)	None (X)
	39	12.8	10.3	⊙	17.8	1.9	0.03	64	256	None (X)	None (X)
	40	11.8	9.6	⊙	17.2	1.9	0.04	64	256	None (X)	None (X)
	41	12.5	10.1	⊙	18.2	1.9	0.03	64	256	None (X)	None (X)
Comparison	1	11.8	2.1	X	20.4	4.7	4.7	81	32	Produced(0)	Produced(0)
	2	12.6	1.8	X	20.8	3.8	3.8	83	32	Produced(0)	Produced(0)
	3	12.4	1.3	X	19.9	4.2	4.2	81	32	Produced(0)	Produced(0)

[0029] Table 1 shows the Ag-based alloy wire according to the contents of the additive ingredients. Experimental embodiments 1 through 16 show Ag-based alloy wires each of which contains one kind of the first additive ingredient, and experimental embodiments 17 through 32 show Ag-based

alloy wires each containing one kind of the second additive ingredient. Experimental embodiments 33 through 41 show Ag-based alloy wires each of which contains either at least two kinds of the first additive ingredient or at least two kinds of the second additive ingredient, or each of which contains

both the first additive ingredient and the second additive ingredient. Comparative examples 1 through 3 denoted the Ag-based alloy wires each of which contains another additive ingredient exclusive of the first additive ingredient and the second additive ingredient.

[0030] Table 2 shows the experimental result with respect to the characteristics of the Ag-based alloy wires displayed in Table 1. In Table 2, the high humidity reliability is indicated by a bonding strength (BPT value) in the pressure cooker test (PCT). The Ag-based alloy wire had a diameter of about 30 μm , and the PCT was carried out at a temperature of 121° C. for about 96 hours. With regard to the reliability of the bonding strength, $\odot$ denotes a highly favourable state, $\bigcirc$ denotes a good state, Δ denotes a normal state, and $\times$ denotes a bad state. The workability was measured by the number of disconnections per 1 km of the Ag-based alloy wire, and thus the smaller number indicates better characteristics. The shelf life test shows the daily hours elapsed for forming an oxide film to a thickness of 100 nm on the Ag-based, and thus the greater number indicates better characteristics.

[0031] Referring to Tables 1 and 2, the experimental embodiments 1 through 7 show the effects of the content of palladium (Pd), that is, the first additive ingredient, on the characteristics of the Ag-based alloy wire. In the experimental embodiments 2 through 5, where the content of Pd was 0.05–5 wt %, the reliability of the Ag-based alloy wire was excellent, and the workability was better than that of the comparative examples 1 through 3. However, in the experimental embodiment 1, where the content of Pd was 0.01 wt %, the bonding strength was poor and the shelf life period decreased. Also, cracks occur in the experimental embodiments 6 and 7, where the content of Pd was respectively 10 and 30 wt %.

[0032] The experimental embodiments 8 through 16 show the effects of the content of one kind of the first additive ingredient including Pt, Rh, Os, Au, and Ni on the characteristics of the Ag-based alloy wire. In the experimental embodiments 8 through 12, and 14 through 16, where the content of the first additive component was 0.5–5 wt %, the reliability of the Ag-based alloy wire was excellent, and the workability was better than that of the comparative examples 1 through 3. Meantime, in the experimental embodiment 13, where the content of Ni was 0.01 wt %, the bonding strength was poor.

[0033] Consequently, it is concluded from the above experimental results that the first additive ingredient including Pd, Pt, Rh, Os, Au, and Ni similarly affects the characteristics of the Ag-based alloy wire. Accordingly, the experimental results with respect to Pd and Ni may be similarly applied to Pt, Rh, Os, and Au.

[0034] The experimental embodiments 17 through 21 show the effects of Cu, that is, the second additive ingredient, on the characteristics of the Ag-based alloy wire. In the experimental embodiments 18 through 20, where the content of Cu was 0.1–5 wt %, the workability was greatly improved over those of the comparative examples 1 through 3 and, moreover, was slightly improved over those of the experimental embodiments 1 through 16. However, the experimental embodiment 17, where the content of Cu was 0.05 wt %, showed a negligible improvement of the workability. Also, the experimental embodiment 21, where the content of Cu was 10 wt %, showed an increase of the electrical resistivity and the occurrence of chip cracks.

[0035] The experimental embodiments 22 through 26 show the effects of Ca, that is, the second additive ingredient exert-

ing on the characteristics of the Ag-based alloy wire. In the experimental embodiments 23 through 25, where the content of Ca was 3–100 wtppm, the workability that was greatly improved over those of the comparative examples 1 through 3, moreover, was slightly improved over those of the experimental embodiments 1 through 16. However, the experimental embodiment 22, where the content of Ca was 1 wtppm, showed an increase of the electrical resistivity and the occurrence of chip cracks. In the experimental embodiment 26, where the content of Ca was 500 wt %, chip cracks occurred, and the dimple was produced in the free air ball.

[0036] The experimental embodiments 27 through 32 show the effects of the content of the second additive ingredient including Be, Mg, Ba, La, Ce, and Y on the characteristics of the Ag-based alloy wire. The experimental embodiments 27 through 32, where the content of one of Be, Mg, Ba, La, Ce, and Y was 10 wt %, showed that workability greatly improved over those of the comparative examples 1 through 3 and, moreover, was slightly improved over those of the experimental embodiments 1 through 16.

[0037] Thus, from the above experimental result, it can be noted that Be, Ca, Mg, Ba, La, Ce, and Y of the second additive ingredient have similar characteristics. Accordingly, the experimental result with respect to Ca may be similarly applied to Be, Mg, Ba, La, Ce, and Y.

[0038] The experimental embodiments 33 through 41 show the effects of at least two kinds of the first additive ingredient, at least two kinds of the second additive ingredient, or mixing of the first additive ingredient and the second additive ingredient on the characteristics of the Ag-based alloy wire. The experimental embodiments 33 through 41 satisfied the preferable content of each of the first additive ingredient and the second additive ingredient from the results of the experimental embodiments 1 through 32. In this case, both the bonding strength and the workability were further improved than those of the comparative examples 1 through 3. Therefore, both the first additive ingredient and the second additive ingredient can be commonly included without adversely affecting each other in the Ag-based alloy wire.

[0039] An Ag-based alloy wire according to the present invention can increase an electrical conductivity while significantly decreasing a unit cost as compared with a typically used Au wire.

[0040] Also, the Ag-based alloy wire according to the present invention has a bonding strength further increased over that of a typically used Ag wire, thereby having increased reliability. Moreover, the workability of the Ag-based alloy wire is increased, which thereby decreases the fabricating costs of the Ag-based alloy wire.

[0041] While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the following claims.

What is claimed is:

1. An Ag-based alloy wire for a semiconductor package, comprising 0.05–5 wt % of at least one kind of a first additive ingredient selected from the group consisting of platinum (Pt), palladium (Pd), rhodium (Rh), osmium (Os), gold (Au), and nickel (Ni), and Ag as a remainder.

2. The Ag-based alloy wire of claim 1, wherein the first additive ingredient comprises 0.05–5 wt % of palladium (Pd).

3. An Ag-based alloy wire for a semiconductor package comprising, 3 wtppm~5 wt % of at least one kind of a second additive ingredient selected from the group consisting of copper (Cu), beryllium (Be), calcium (Ca), magnesium (Mg), barium (Ba), lanthanum (La), cerium (Ce), and yttrium (Y), and Ag as a remainder.

4. The Ag-based alloy wire of claim 3, wherein the second additive ingredient comprises 0.1~5 wt % of copper (Cu).

5. The Ag-based alloy wire of claim 3, wherein the second additive ingredient comprises 3~100 wtppm of at least one selected from the group consisting of beryllium (Be), calcium (Ca), magnesium (Mg), barium (Ba), lanthanum (La), cerium (Ce), and yttrium (Y).

6. An Ag-based alloy wire for a semiconductor package, comprising 0.05~5 wt % of at least one kind of a first additive

ingredient selected from the group consisting of platinum (Pt), palladium (Pd), rhodium (Rh), osmium (Os), gold (Au), and nickel (Ni), 3 wtppm~5 wt % of at least one kind of a second additive ingredient selected from the group consisting of copper (Cu), beryllium (Be), calcium (Ca), magnesium (Mg), barium (Ba), lanthanum (La), cerium (Ce), and yttrium (Y), and Ag as a remainder.

7. The Ag-based alloy wire of claim 6, wherein the second additive ingredient comprises 0.1~5 wt % of copper (Cu) or 3~100 wtppm of at least one selected from the group consisting of beryllium (Be), calcium (Ca), magnesium (Mg), barium (Ba), lanthanum (La), cerium (Ce), and yttrium (Y).

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