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COATED COPPER WIRE FOR BONDING APPLICATIONS

The invention is related to a bonding wire, comprising a core with a surface, wherein
15 the core comprises copper as a main component, and a coating layer superimposed
over the surface of the core, wherein the coating layer comprises palladium as a main
component, wherein the core comprises silver and phosphorus as further components,
wherein the ratio between the silver content and the phosphorus content of the core is
in the range of 0.03 to 2.

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The invention further relates to a system for bonding an electronic device, comprising a
first bonding pad, a second bonding pad and a wire according to the invention, wherein
the inventive wire is connected to at least one of the bonding pads by means of wedge-
bonding.

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The invention further relates to a method for manufacturing a wire according to the in-
vention.

Bonding wires are used in the manufacture of semiconductor devices for electrically
30 interconnecting an integrated circuit and a printed circuit board during semiconductor
device fabrication. Further, bonding wires are used in power electronic applications to
electrically connect transistors, diodes and the like with pads or pins of the housing.
While bonding wires were made from gold in the beginning, nowadays less expensive
materials are used such as copper. While copper wire provides very good electric and
35 thermal conductivity, wedge-bonding of copper wire has its challenges. Moreover, cop-
per wires are susceptible to oxidation of the wire.

With respect to wire geometry, most common are bonding wires of circular cross-
section and bonding ribbons which have a more or less rectangular cross-section. Both

types of wire geometries have their advantages making them useful for specific applications. Thus, both types of geometry have their share in the market. For example, bonding ribbons have a larger contact area for a given cross-sectional area. However, bending of the ribbons is limited and orientation of the ribbon must be observed when bonding in order to arrive at acceptable electrical contact between the ribbon and the element to which it is bonded. Turning to bonding wires, these are more flexible to bending. However, bonding involves either soldering or larger deformation of the wire in the bonding process, which can cause harm or even destroy the bonding pad and underlying electric structures of the element, which is bonded thereto.

For the present invention, the term bonding wire comprises all shapes of cross-sections and all usual wire diameters, though bonding wires with circular cross-section and thin diameters are preferred.

Some recent developments were directed to bonding wires having a copper core and a protective coating layer. As core material, copper is chosen because of high electric conductivity. With regard to the coating layer, palladium is one of the possible choices. These coated bonding wires combine the advantages of the copper wire with less sensitivity to oxidation. Nevertheless, there is an ongoing need for further improving bonding wire technology with regard to the bonding wire itself and the bonding processes.

Accordingly, it is an object of the invention to provide improved bonding wires.

Thus, it is another object of the invention to provide a bonding wire, which has good processing properties and which has no specific needs when interconnecting, thus saving costs.

It is also an object of the invention to provide a bonding wire which has excellent electrical and thermal conductivity.

It is a further object of the invention to provide a bonding wire which exhibits an improved reliability.

It is a further object of the invention to provide a bonding wire which exhibits excellent bondability.

It is another object of the invention to provide a bonding wire which shows an improved bondability with respect to a wedge bonding and / or second bonding.

- 5 It is another object of the invention to provide a bonding wire which shows an improved bondability with respect to a second bonding being a wedge bonding, whilst the bonding performance for a first bonding being a ball bonding is at least sufficient.

- 10 It is another object of the invention to provide a bonding wire which has improved resistance to corrosion and/or oxidation.

- It is another object to provide a system for bonding an electronic device, to be used with standard chip and bonding technology, which system shows reduced failure rate at least with respect to a second bonding.

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It is another object to provide a method for manufacturing an inventive bonding wire, the method basically showing no increase in manufacturing costs compared with known methods.

- 20 Surprisingly, wires of the present invention have been found to solve at least one of the objects mentioned above. Further, a process for manufacturing these wires has been found which overcomes at least one of the challenges of manufacturing wires. Further, systems comprising the wires of the invention were found to be more reliable at the interface between the wire according to the invention and other electrical elements,
- 25 e.g., the printed circuit board, the pad/pin etc.

- A contribution to the solution of at least one of the above objects is provided by the subject matters of the category-forming claims, whereby the dependent sub-claims of the category-forming independent claims representing preferred aspects of the invention, the subject matter of which likewise makes a contribution to solving at least one of the objects mentioned above.
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A first aspect of the invention is a bonding wire, comprising:

a core with a surface,

- 35 wherein the core comprises copper as a main component, and

a coating layer superimposed over the surface of the core,
wherein the coating layer comprises palladium as a main component,
wherein the core comprises silver and phosphorus as further components,
wherein the ratio between the silver content and the phosphorus content of the
5 core is in the range of 0.03 to 2.

In a preferred embodiment, the ratio of silver content to phosphorous content is in the range of 0.05 to 2, most preferred in the range of 0.05 to 0.5.

10 If no other specific definition is provided, all contents or shares of components are presently given as shares in weight. In particular, shares given in percent are understood as weight-%, and shares given in ppm (parts per million) are understood as weight-ppm.

15 The term "superimposed" in the context of this invention is used to describe the relative position of a first item, e.g. a copper core, with respect to a second item, e.g. a coating layer. Possibly, further items, such as an intermediate layer, might be arranged between the first and the second item. Preferably, the second item is at least partially superimposed over the first item, e.g. for at least 30 %, 50 %, 70 % or for at least 90 %
20 with respect to the total surface of the first item. Most preferably, the second item is completely superimposed over the first item. The term "intermediate layer" in the context of this invention is a region of the wire, between the copper core and the coating layer. In this region, material as in the core as well as material as in the coating layer is present in combination.

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The wire is a bonding wire in particular for bonding in microelectronics. The wire is preferably a one-piece object.

A component is a "main component" if the share of this component exceeds all further
30 components of a referenced material. Preferably, a main component comprises at least 50% of the total weight of the material.

It has surprisingly turned out that controlling the ratio of silver content and copper content leads to a wire with improved properties of the bonding process. In particular, advantageous improvements in wedge-bonding performance have been found.
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These improvements are particularly significant if the phosphorus content of the core is in the range of 20 ppm to 300 ppm. In more preferred embodiments, the phosphorus content is in the range of 30 ppm to 200 ppm. It has turned out that such amount of phosphorous appear to be tolerable with respect to a Vickers hardness of the core, at the same time keeping benefits of the phosphorous content with respect to oxidation etc.

Additionally or alternatively, a silver content of the core is at least 5 ppm. In a preferred embodiment, the silver content is in the range of 5 ppm to 1000 ppm. In a most preferred embodiment, the silver content is in the range of 5 ppm to 100 ppm. Results of the present invention show that the presence of at least small amounts of silver is adding to beneficial mechanical properties like softness of the wire. This is particularly obvious if a defined ratio of silver and phosphorous in the wire core is kept.

Preferably, the copper content of the core is at least 99.98%. This allows for using common supplies of copper material for wire bonding without exceedingly high costs due to high purity specifications. Further preferably, a total of all metal impurities of the core, apart from silver, sums up to less than 30 ppm.

Generally preferred are embodiments wherein the coating layer has a thickness of less than 0.5 μm . If the coating layer is sufficiently thin, this provides for neglectable effects of the coating layer in the bonding process. The term "thickness" in the context of this invention is used to define the size of a layer in perpendicular direction to the longitudinal axis of the copper core, which layer is at least partially superimposed over the surface copper core.

Concerning the composition of the coating layer, the palladium content of the layer is at least 50%, more preferably at least 95%. Particularly preferably, the coating layer consists of pure palladium with less than 1% of other components. In case the coating layer has significant further components, those components are preferably noble metals.

The present invention is particularly related to thin bonding wires. The observed effects are specifically beneficial to thin wires, for example because of the sensitivity to oxida-

tion of such wires. In the present case, the term "thin wire" is defined as a wire having a diameter in the range of 8 μm to 80 μm .

Such thin wires mostly, but not necessarily have a cross-sectional view essentially in the shape of a circle. The term "a cross-sectional view" in the present context refers to a view of a cut through the wire, wherein the plane of the cut is perpendicular to the longitudinal extension of the wire. The cross-sectional view can be found at any position on the longitudinal extension of the wire. A "longest path" through the wire in a cross-section is the longest chord which can be laid through the cross-section of the wire within the plane of the cross-sectional view. A "shortest path" through the wire in a cross-section is the longest chord perpendicular to the longest path within the plane of the cross-sectional view defined above. If the wire has a perfect circular cross-section, then the longest path and the shortest path become indistinguishable and share the same value. The term "diameter" is the arithmetic mean of all geometric diameters of any plane and in any direction, wherein all planes are perpendicular to the longitudinal extension of the wire.

Generally preferred, a ratio of an elongation of the wire and a diameter of the wire is in the range of 0.25 $\%/\mu\text{m}$ to 0.75 $\%/\mu\text{m}$. The elongation E of the wire is given as a percentage value. If an initial length L of the wire is given and the wire is stretched to a length L' until it breaks, the elongation is defined by $E = (L' - L)/L$.

In a preferred embodiment of the invention, the wire meets the relation $0.0008 < E/(d \cdot \text{CP}) < 0.0375$, wherein E is the elongation of the wire measured in %, d is the diameter of the wire measured in μm and CP is the phosphorus content of the wire core measured in ppm. Such wire has an optimized phosphorous content dependent on the respective demands for its elongation and diameter. More preferably, the wire meets the relation $0.002 < E/(d \cdot \text{CP}) < 0.02$, and most preferably the wire meets the relation $0.003 < E/(d \cdot \text{CP}) < 0.015$.

In a yet further preferred embodiment of the invention, the wire meets the relation $0.000025 < E/(d \cdot \text{CAg}) < 0.15$, wherein E is the elongation of the wire measured in %, d is the diameter of the wire measured in μm and CAg is the silver content of the wire core measured in ppm. Such wire has an optimized silver content dependent on the respective demands for its elongation and diameter. More preferably, the wire meets

the relation $0.00025 < E/(d \cdot Ag) < 0.15$, and most preferably the wire meets the relation $0.005 < E/(d \cdot Ag) < 0.12$.

5 An inventive wire is preferably treated in an annealing step with a temperature of at least 370°C. Even more preferred, the temperature of the annealing step is at least 430°C, wherein higher annealing temperatures can provide for higher values for the elongation of the wire.

10 Concerning further parameters for annealing, in particular thin wires need not be exposed to the annealing temperature for long. In most cases annealing is done by pulling the wire through an annealing oven of a given length and with a defined temperature profile at a given speed. An exposure time of a thin wire to the annealing temperature is typically in the range of 0.1 second to 10 seconds.

15 For a wire according to a preferred embodiment, a hardness of the wire core is not higher than 120.00 Hv0.5. This limits the maximum forces applied on the bond pad which can occur during the automated bonding procedure. Such limitation is particularly helpful if mechanically sensitive structures are aligned below the bond pad. This is
20 particularly true if the bond pad consists of a soft material like aluminium or gold. The sensitive structure can, for example, comprise one or several layers of porous silicon dioxide, in particular with a dielectric constant of less than 2.5. Such porous and hence weak material is becoming increasingly common as it can help to increase the device performance. Therefore, the mechanical properties of the inventive bonding wire are
25 optimized to avoid cracking or other damaging of the weak layers.

The hardness of the wire core is ideally measured at the wire as a finished product, that means after all manufacturing steps like coating and annealing have been finished. In order to perform the hardness measurement, a metallography cross section of the
30 wire can be prepared in order to produce a flat surface. This can be done in the longitudinal direction, which is more common, or in the transversal direction.

Further advantageously, a specific resistivity of the inventive wire is in the range of 1.65 to 1.9 $\mu\text{Ohm} \cdot \text{cm}$, such conductivity being suitable for many applications. A more preferred resistivity of the wire is in the range of 1.8 to 1.9 $\mu\text{Ohm} \cdot \text{cm}$.
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A further aspect of the invention is a system for bonding an electronic device, comprising a first bonding pad, a second bonding pad and a wire according to the invention, wherein the wire is connected to at least one of the bonding pads by means of wedge-
5 bonding. This combination of an inventive wire in a system is preferred due to the fact that the wire has especially beneficial properties with respect to wedge bonding.

Generally preferred, a process window area for the at least one wedge bond has a value of at least 3500 mA*g in the case of a bonding a wire of 20 μm diameter bonded to
10 a gold bond pad.

The definition of a process window area for bonding wires is known in the art and is widely used to compare different wires. In principle, it is the product of a bonding window of an ultrasonic energy used in the bonding and a bonding window of a force used
15 in the bonding, wherein the resulting bond has to meet certain pull test specifications, e.g. a pull force of 3 grams, no non-stick on lead etc.. The actual value of the process window area of a given wire further depends on the wire diameter as well as the bond pad material. In order to give a specific definition of the properties of an inventive wire, the claimed process window value is based on a wire diameter of 20 μm = 0.8 mil,
20 wherein the bond pad consists of gold. The scope an inventive system is not limited to wires of this diameter and bond pads made of gold, but names this data only for definition purpose.

A yet further aspect of the invention is a method for connecting an electrical device,
25 comprising the steps

- a. providing a wire according to the invention;
 - b. bonding the wire to a first bond pad of the device by means of ball bonding or wedge bonding; and
 - 30 c. bonding the wire to a second bond pad of the device by means of wedge bonding;
- wherein steps b and c are performed without the use of a forming gas.

The wire according to the invention shows excellent properties with respect to oxidation
35 effects. This is specifically true if a complete encapsulation of the copper core with the

palladium coating layer is present in combination with a certain amount of phosphorous in the core material. The resulting properties allow for processing without using forming gas and hence lead to significant savings in costs and hazard precautions.

5 Forming gas is known in the art as a mixture of an inert gas like nitrogen with hydrogen, wherein the hydrogen content may provide for reduction reactions of oxidized wire material. In the sense of the invention, omitting of forming gas means that no reactive compound like hydrogen is used. Nevertheless, use of an inert gas like nitrogen can still be advantageous.

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A yet further aspect of the invention is a method for manufacturing a bonding wire according to the invention, comprising the steps

- 15 a. providing a copper core precursor with the demanded contents of phosphorus and silver;
- b. drawing the precursor until a final diameter of the wire core is reached;
- c. coating the copper core with the material of the coating layer, either before or after the step b of drawing the precursor;
- 20 d. annealing the coated and drawn wire at a defined temperature for a minimum time.

Concerning steps b to c, the manufacturing method is generally known in the art. It is pointed out that the coating layer might be applied by any known or suitable method like mechanical coating, electric plating, electroless plating, physical vapor deposition (PVD), chemical vapor deposition (CVD) and more. The coating can be done before or after the drawing of the wire, which may be dependent on properties of the respective coating and coating method. In particular, the coating might be performed at an intermediate step, with a drawing of the wire or precursor occurring before as well as after the coating step.

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As to step a, the phosphorous might be doped into the copper core as known in the art.

Concerning the silver content, the silver might be added to the copper in a specific production step of the core material. Alternatively, the silver content might be obtained by

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selection of available copper with a sufficient impurity specification. Though not necessarily present, silver is often contained in copper as an impurity, it being possible of provide the demanded core material without applying additional process steps, but by analytically controlling the raw material.

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As to step d, the annealing is performed in a controlled way as known in the art in order to achieve a softening of the wire and/or optimizing the crystal structure of the wire according to the respective demands. Preferably, the annealing is done dynamically while the wire is moved through an annealing oven and spooled onto a reel after having left
10 the oven.

DESCRIPTION OF THE FIGURES

The subject matter of the invention is exemplified in the figures. The figures, however,
15 are not intended to limit the scope of the invention or the claims in any way.

In Figure 1, a wire 1 is depicted.

20 Figure 2 shows a cross sectional view of wire 1. In the cross sectional view, a copper core 2 is in the middle of the cross sectional view. The copper core 2 is encompassed by a coating layer 3. On the limit of copper wire 2, a surface 15 of the copper core is located. On a line L through the center 23 of wire 1 the diameter of copper core 2 is shown as the end to end distance between the intersections of line L with the surface
25 15. The diameter of wire 1 is the end-to-end distance between the intersections of line L through the center 23 and the outer limit of wire 1. Besides, the thickness of coating layer 3 is depicted.

Figure 3 shows a process for manufacturing a wire according to the invention.

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Figure 4 depicts an electric device 10 comprising two elements 11 and a wire 1. The wire 1 electrically connects the two elements 11. The dashed lines mean further connections or circuitry which connect the elements 11 with external wiring of a packaging device surrounding the elements 11. The elements 11 can comprise bond pads, inte-
35 grated circuits, LEDs or the like.

Figure 5 shows a sketch of a wire pull test. To a substrate 20, a wire 1 is bonded in bonds 21 at an angle 19 of 45°. A pull hook 17 pulls wire 1. The angle 32, which is formed when the pull hook 17 pulls the wire 1, is 90°.

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TEST METHODS

All tests and measurements were conducted at $T = 20\text{ }^{\circ}\text{C}$ and a relative humidity of 50 %.

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ELECTRICAL CONDUCTIVITY

Both ends of a test specimen, i.e. a wire of 1.0 m in length, were connected to a power source providing a constant current of $I = 10\text{ mA}$. The voltage was recorded with a device for measuring voltage. This set-up was repeated with at least 4 test specimens.

15 The arithmetic mean of the four measurements was used for the calculations given below.

The resistance R was calculated according to $R = U / I$.

20 The specific resistivity ρ was calculated according to $\rho = (R \times A) / l$, wherein A is the mean cross-sectional area of the wire and l the length of the wire between the two measuring points of the device for measuring voltage.

The specific conductivity σ was calculated according to $\sigma = 1 / \rho$.

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WEDGE-WEDGE BONDING – PARAMETER DEFINITION

Bonding of a wire to a substrate plated with gold was performed at 20°C , wherein the bonding was applied to the gold surface. After forming a first wedge bond with an angle of 45° between the wire and the substrate, the wire was wedged with its second end to the substrate. The distance of the bonds between the two ends of the wire was in the range of from 5 to 20 mm. This distance was selected in order to assure the angle of 45° between the wire and the substrate. During wedge bonding, ultrasonic sound of a frequency in the range of 60 – 120 kHz was applied to the bondtool for 40 to 500 milliseconds.

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EXAMPLES

The invention is further exemplified by examples. These examples serve for exemplary elucidation of the invention and are not intended to limit the scope of the invention or the claims in any way.

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Example 1

A quantity of copper material of at least 99.99 % purity ("4N-copper") is molten in a crucible. Small amounts of silver (Ag) and phosphorous (P) are added to the melt and an even distribution of the added components in the copper melt is provided. The added amounts of silver and phosphorous are calculated to contribute to a share of 10 ppm Ag and 75 ppm P. Then a wire core precursor is cast from the melt.

The wire core precursor is then drawn in several drawing steps to form the wire core 2 with a diameter of 20 μm . The cross section of the wire core 2 is of essentially circular shape. It is to be understood that the wire diameter is not considered to be a highly exact value due to fluctuations in the shape of the cross section, a thickness of the coating layer or the like. If a wire is presently defined to have a diameter of e.g. 20 μm , the diameter is understood to be in the range of 19.5 to 20.5 μm .

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The wire core is then coated with a layer 3 consisting of Palladium (Pd) of at least 99% purity. The thickness of the coating layer 3 is in the range of 100 nm or less. Therefore, the coating layer is not significantly adding to the wire diameter.

The coated wire is then annealed in an annealing step in order to further adjust parameters like elongation, hardness, crystal structures and the like. The annealing is performed dynamically by running the wire through an annealing oven of a defined length and temperature with a defined speed. After leaving the oven, the wire is spooled on reels for packaging.

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In the present examples, the annealing time, which is the time during which a given piece of the moving wire remains in the heated oven, is about 0.76 s.

Table 1 and table 2 show data of several examples IW1 to IW5 of wires according to the invention. The exemplary inventive wires have been produced identically, let alone

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for exposure to different annealing temperatures in the annealing step. None of the further annealing parameters apart from the temperature have been changed.

Further, tables 1 and 2 show data of two samples of commercially purchased bonding wires Comp1 and Comp2. As the exact production process of these wires is not known, data of annealing temperatures is not available. All of the evaluated wires (inventive wires and comparative wires) have a diameter of 0.8 mil = 20 μm .

Sample	T (°C)	Ag (ppm)	P (ppm)	Ag/P	E (%)	BL(g)	EL/BL (1/g)	E/(d*CP) (1/ μm)	E/(d*CAg) (1/ μm)
IW1	450	9	76	0,1184	5,8	6,7	0,87	0,0038	0,03222
IW2	500	9	76	0,1184	11,7	6,3	1,86	0,0077	0,065
IW3	550	8	76	0,1053	13	6,2	2,10	0,0086	0,08125
IW4	600	10,1	75	0,1347	12,7	5,8	2,19	0,0085	0,06287
IW5	400	10,1	75	0,1347	0,7	10,5	0,07	0,0005	0,00347
Comp1	?	0,5	104	0,0048	10,9	6,2	1,76	0,0052	1,09
Comp2	?	10	<1	>10	12,7	6,2	2,05	>0,635	0,0635

(table 1)

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With: E Elongation (in %)
 BL Break load (in grams)
 T Annealing temperature (in degrees Celsius)
 d diameter (= 20 μm for all wires)
 15 CP Phosphorous concentration in ppm
 CAg Silver concentration in ppm

Sample	Stitch pull (g)	Stitch pull standard deviation(g)	Second bond window (USG)	Second bond (force)	Second bond window area	Wire Hardness (Hv0.5)	Ball shape	ball/ metal lift at as bonded
IW1	5,1	0,3	80-180	40-100	6000	No data	good	2,5
IW2	5	0,4	80-180	40-90	4000	116,2	good	5
IW3	4,8	0,3	80-180	40-90	4000	No data	fair	3,7
IW4	4,7	0,4	80-180	40-90	4000	No data	fair	2,4
IW5	4,9	0,4	80-180	40-90	4000	144,7	best	1,2
Comp1	4,4	0,4	120-170	40-100	3000	122,2	good	3,7
Comp2	4,9	0,5	80-180	40-100	6000	110,2	bad	7,4

(table 2)

Remarks:

- 5 The "ball shape" property is being visually evaluated and categorized into four classes (decreasing quality): best - good - fair – bad. It is the shape of the ball of a ball bonding performed under standard conditions which are the same for all of the evaluated wires.

10 The second bond window USG (= ultrasonic energy) value is generally preferred to have a lower starting point (lower value).

15 The evaluation of the data of table 1 and table 2 shows that the wires according to the invention have some outstanding properties whilst maintaining at least good quality throughout all of the evaluated properties.

20 In particular, the inventive wires generally show a high value of the second bond window area, i.e. 4000 or more. For the comparative examples, the wire Comp2 shows also a high second bond window area, but it has high standard deviation on the stitch pull value, which is disadvantageous for the process stability. Furthermore, the Comp2 sample has a significantly bad value of the ball shape. The wire Comp2 would not be chosen at least for ball bonding applications when compared to the inventive wires.

25 For the other comparative wire Comp1, the second bond window area is significantly lower than for any of the inventive wires. This makes the inventive wire particularly advantageous for second bond or wedge bond applications. Inventive wires can be a pre-

ferred choice for wedge-wedge-bonding applications, but also show excellent results for ball-wedge-bonding applications.

5 It is noted that the example IW5 has some striking properties, e.g. the elongation value and/or the wire hardness value. This owes to the fact that this wire has been annealed at a rather low temperature of 400 °C. Softening effects from the annealing process are comparably weak in this range. On the other hand, such wire can be advantageous in specific applications, e.g. when a particularly good ball shape or a high break load is demanded for.

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Nevertheless, in most applications higher elongation values and lower wire hardness are advantageous. In this and further respects, IW1 to IW4 are specifically preferred examples of inventive wires.

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Claims:

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1. A bonding wire, comprising:
a core (2) with a surface,
wherein the core (2) comprises copper as a main component, and
a coating layer (3) superimposed over the surface (15) of the core (2),
10 wherein the coating layer (3) comprises palladium as a main component,
wherein the core (2) comprises silver and phosphorus as further components,
wherein the ratio between the silver content and the phosphorus content of the
core (2) is in the range of 0.03 to 2.
- 15 2. Wire according to claim 1, wherein the phosphorus content is in the range of 20
ppm to 300 ppm.
3. Wire according to any of the preceding claims, wherein the silver content is at
least 5 ppm.
- 20 4. Wire according to any of the preceding claims, wherein the silver content is in
the range of 5 ppm to 1000 ppm.
5. Wire according to any of the preceding claims, wherein the copper content of
25 the core (2) is at least 99.98%.
6. Wire according to any of the preceding claims, wherein the coating layer (3) has
a thickness of less than 0.5 μm .
- 30 7. Wire according to any of the preceding claims, wherein the palladium content of
the coating layer (3) is at least 95%.
8. Wire according to any of the preceding claims, wherein the wire (1) has a diam-
eter in the range of 8 μm to 80 μm .

9. Wire according to any of the preceding claims, wherein a ratio of an elongation of the wire (1) and a diameter of the wire (1) is in the range of 0.25 %/ μm to 0.75 %/ μm .
- 5 10. Wire according to any of the preceding claims, wherein the wire meets the relation
 $0.0008 < E/(d \cdot \text{CP}) < 0.0375$, wherein E is an elongation of the wire (1) measured in %, d is a diameter of the wire measured in μm and CP is the phosphorus content of the wire core (2) measured in ppm.
- 10 11. Wire according to any of the preceding claims, wherein the wire meets the relation
 $0.000025 < E/(d \cdot \text{CAg}) < 0.15$, wherein E is an elongation of the wire measured in %, d is a diameter of the wire measured in μm and CAg is the silver content
15 of the wire core (2) measured in ppm.
12. Wire according to any of the preceding claims, wherein the wire (1) has been treated in an annealing step with a temperature of at least 370°C.
- 20 13. Wire according to any of the preceding claims, wherein a hardness of the wire core (2) is not greater than 120.00 Hv0.5.
14. Wire according to any of the preceding claims, wherein a specific resistivity of the wire (1) is in the range of 1.8 to 1.9 $\mu\text{Ohm} \cdot \text{cm}$
- 25 15. System for bonding an electronic device, comprising a first bonding pad (11), a second bonding pad (11) and a wire (1) according to any of the preceding claims, wherein the wire (1) is connected to at least one of the bonding pads (11) by means of wedge-bonding.
- 30 16. System according to claim 15, wherein the wire (1) is connected to both bonding pads (11) by means of wedge-bonding.

17. System according to claim 15 or 16, wherein a process window area for the at least one wedge bond has a value of at least 3500 mA*g in the case of bonding a wire of 20 µm diameter to a gold bond pad.
- 5 18. System according to any of claims 15 to 17, wherein a structure underlying one of the bonding pads (11) comprises at least one layer of porous silicon dioxide.
19. Method for connecting an electrical device, comprising the steps
- 10 a. providing a wire (1) according to any of claims 1 to 14;
- b. bonding the wire (1) to a first bond pad (11) of the device by means of ball bonding or wedge bonding; and
- c. bonding the wire (1) to a second bond pad (11) of the device by means of wedge bonding;
- wherein steps b and c are performed without the use of a forming gas.
- 15 20. Method for manufacturing a bonding wire according to any of claims 1 to 14, comprising the steps
- a. providing a copper core precursor with the demanded contents of phosphorus and silver;
- 20 b. drawing the precursor until a final diameter of the wire core (2) is reached;
- c. coating the copper core (2) with the material of the coating layer (3), either before or after the step b of drawing the precursor;
- d. annealing the coated and drawn wire (1) at a defined temperature for a minimum annealing time.
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