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(54) Electrode wire for solar battery

Elektrodendraht für eine Solarbatterie

Fil d'électrode pour batterie solaire

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Description

TECHNICAL FIELD

[0001] The present invention relates to an electrode wire to be used as a connection lead wire for a solar cell.

BACKGROUND ART

[0002] A solar cell includes a semiconductor substrate of a silicon semiconductor having PN junctions, and a connection lead wire soldered to a solder band provided across a plurality of linear front surface electrodes disposed on a front surface of the semiconductor substrate. For use, a plurality of such solar cells are generally connected in series to provide desired electromotive force. For the serial connection, one surface (a lower surface) of a connection lead wire is soldered to a front surface electrode of one solar cell, and the other surface (an upper surface) of the connection lead wire is soldered to a relatively large rear surface electrode of an adjacent solar cell.

[0003] Conventionally used as a material for the connection lead wire is an electrode wire which includes a core material of a flattened copper wire prepared by rolling a tough pitch copper wire having a round cross section, and hot-dip solder plating layers formed on surfaces of the core material. The formation of the hot-dip solder plating layers is achieved by employing a hot-dip plating method for plating the flattened copper wire. That is, the surfaces of the flattened copper wire are cleaned with an acid or the like, and the flattened copper wire is dipped in a molten solder bath, whereby the solder plating layers are formed on the surfaces of the core material of the flattened copper wire. The hot-dip solder plating layers each have a mound shape bulged from lateral edges to a middle portion of the core material by surface tension occurring when the molten solder adhering to the core material is solidified.

[0004] When the electrode wire is soldered to the semiconductor substrate, the heating temperature is strictly controlled at a lower temperature around the melting point of the solder. This is because there is a difference in thermal expansion coefficient between copper for the core material of the electrode wire and silicon as an exemplary material for the semiconductor substrate. That is, the electrode wire is soldered at a lower temperature in order to minimize a thermal stress which may otherwise cause cracks in the expensive semiconductor substrate.

[0005] In a conventional case, the semiconductor substrate has a thickness of about 300μm. In recent years, however, the semiconductor substrate tends to halve as reduced thickness for cost reduction. A semiconductor substrate recently used has a thickness of about 250μm. Therefore, the electrode wire employing the conventional flattened wire as the core material is liable to cause cracks in the semiconductor substrate during the soldering. For prevention of the cracking, an electrically conductive material having a smaller difference in thermal expansion from the semiconductor substrate material has recently been employed for the core material. In JP-A-60-15937 (Patent Document 1), for example, a clad material is proposed as the electrically conductive material, which includes an interlayer of Invar or an alloy of Fe and Ni (having a typical composition of Fe-36%Ni) and copper layers disposed on opposite surfaces of the interlayer. Besides Invar, Kovar (registered trade mark) or an Fe-Ni-Co alloy is employed as the lower thermal expansion alloy.

[0006] In JP-A-59-204547 (Patent Document 2) and JP-A-59-204548 (Patent Document 3), aluminum-copper based clad materials each including a chromium layer or a zinc layer formed in a bonding interface between an aluminum or aluminum alloy material and a copper or copper alloy material are proposed as a lead frame material for a semiconductor device, though they are used in a field different from the field of the solar cells.

Patent Document 1: Japanese Unexamined Patent Publication No. 60-15937 (1985)
Patent Document 2 : Japanese Unexamined Patent publication NO. 59-204547 (1984)
Patent Document 3 : Japanese Unexamined Patent publication No. 59-204548 (1984)

JP-A-2001352014 discloses electrode wires being metal foils (metal terminals) of a semiconductor chip. Further, there is provided a bus-bar electrode collecting electricity from collector electrodes. The bus-bar electrode is made of a silver-plated copper foil and does not have a hot-dip solder plating layer. The copper foil of the silver-plated copper foil forming the bus-bar electrode is worked in a shape of a foil.

"Data Book of Wrought Copper and Copper Alloy Products" by Japan Copper and Brass Association discloses general characteristics of oxygen-free copper and, in particular, relations between annealing temperature and proof strength, as shown in Figs 5.4-3 and 5.4-4.

DISCLOSURE OF THE INVENTION

Problems to be solved by the invention

[0007] The electrode wire (which is sometimes referred to as "clad electrode wire") employing the clad material as the core material as disclosed in Patent Document 1 indeed alleviates the thermal stress occurring in the semiconductor substrate, but has an increased average electric resistance to reduce the power generation efficiency of the solar cell, because the interlayer is made of an alloy material such as the Fe-Ni alloy or the Fe-Ni-Co alloy which has a relatively high volume resistivity.

[0008] The aluminum-copper based clad materials of Patent Documents 2 and 3 are used in an application field different from the application field of the solar cell electrode wire. In addition, aluminum is exposed on one surface of such a clad material, making it impossible to form the hot-dip solder plating layer on the surface.

[0009] In view of the aforementioned problems, it is an object of the present invention to provide an electrode wire for a solar cell, which is usable as an alternative to the conventional clad electrode wire and less liable to cause cracks in a solar cell semiconductor substrate during soldering, and yet has excellent electrical conductivity.

Means for solving the problems

[0010] An inventive electrode wire according to the independent claim 1 or 2.

[0011] The electrode wire can be easily handled in a hot-dip solder plating process and the subsequent processes without excessive deformation thereof. In addition, when the electrode wire is soldered to the semiconductor substrate, thermal stress occurring in the semiconductor substrate during solidification can be alleviated by plastic self-deformation of the electrode wire arising from the thermal stress. Therefore, the cracking is unlikely to occur in the semiconductor substrate. Since the volume resistivity is not greater than 2.3$\mu\Omega\cdot$cm, the electrode wire is excellent in electrical conductivity and power generation efficiency.

[0012] In the electrode wire, the core material is preferably composed of an annealed pure copper material having an oxygen content of not greater than 20ppm. With the use of the annealed material, the production costs can be significantly reduced as compared with the conventional clad electrode wire. In contrast to the clad electrode wire employing the clad material as the core material, the electrode wire employing a single layer material as the core material are sometimes referred to as "single layer electrode wire".

[0013] Instead of the single layer core material, a clad core material may be used which includes an interlayer and a first surface layer and a second surface layer disposed on opposite surfaces of the interlayer. By employing proper materials for the clad core material, the average volume resistivity and the average proof strength are easily set within the aforesaid ranges, whereby various types of clad electrode wires can be provided. In this case, where the first and second surface layers are composed of the same material and have the same thickness, the electrode wire is prevented from being thermally deformed in the soldering, thereby improving efficiency of the soldering operation.

[0014] The first surface layer and the second surface layer are preferably composed of pure Cu or a Cu alloy mainly comprising Cu, and the interlayer is preferably composed of pure Al or an Al alloy mainly comprising Al. These materials are easily available at lower costs, making it possible to provide the inventive clad electrode wire at lower costs. If the percentage of the thickness is less than 10%, it is difficult to ensure the proof strength in the aforesaid range. If the percentage of the thickness is greater than 50%, it is difficult to ensure the volume resistivity in the aforesaid range.

[0015] In the single layer electrode wire and the clad electrode wire according to the present invention, the core materials preferably each have a recessed portion arranged along a longitudinal direction of the core material for storing molten solder and the hot-dip solder plating layer located in the recessed portion. With the provision of the hot-dip solder storing recessed portion, the middle portion of the molten solder supplied in the recessed portion is less liable to bulge when being solidified, so that the hot-dip solder plating layer is flattened. This improves the solderability of the electrode wire to ensure excellent bondability.

[0016] An opening width of the hot-dip solder storing recessed portion as measured transversely of the core material is preferably not less than 90% of the width of the core material. Where the opening width of the recessed portion is not less than 90% of the width of the core material, the molten solder supplied in the hot-dip solder storing recessed portion is easily flattened across the width of the core material when being solidified. This improves the solderability.

[0017] A solar cell employing the inventive electrode wire includes a semiconductor substrate of a semiconductor having PN junctions and a connection lead wire soldered to a plurality of front surface electrodes disposed on a front surface of the semiconductor substrate, wherein the connection lead wire is the single layer electrode wire or the clad electrode wire described above. Where the electrode wire having the hot-dip solder storing recessed portion is used as the connection lead wire, the connection lead wire is soldered with the hot-dip solder plating layer filled in the recessed portion. In the solar cell, the solar cell semiconductor substrate is less liable to be cracked, because the connection lead wire has the features, actions and effects provided by the electrode wire. Further, the solar cell is excellent in electrical conductivity and hence in power generation efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

Fig. 1 is a cross sectional view of a single layer electrode wire according to a first embodiment of the present invention;
Fig. 2 is a cross sectional view of a clad electrode wire according to a second embodiment of the present invention;
Fig. 3 is a cross sectional view of a clad electrode wire having a hot-dip solder storing recessed portion according to the present invention;
Fig. 4 is a cross sectional view of another clad electrode wire having a hot-dip solder storing recessed portion according to the present invention; and
Fig. 5 is a schematic perspective view of a solar cell employing inventive electrode wires.

DESCRIPTION OF REFERENCE CHARACTERS

[0019]

1, 1A, 1B: Electrode wires
2, 2A: Core materials
3A, 3B, 3C: Hot-dip solder plating layers
4: Interlayer
5A, 5B: Copper layers (first surface layer and second surface layer)
6, 6A: Hot-dip solder storing recessed portions

BEST MODE FOR CARRYING OUT THE INVENTION

[0020] Fig. 1 is a single layer electrode wire 1 according to a first embodiment. The electrode wire 1 includes a core material 2 having an elongate plate shape, and hot-dip solder plating layers 3A, 3B disposed on a front surface and a rear surface of the core material 2. The core material 2 is composed of a lower proof strength metal having a volume resistivity of not greater than 2.3$\mu\Omega\cdot$cm and a proof strength of not less than 19.6MPa and not greater than 85MPa, more preferably not less than 19.6MPa and not greater than 49MPa. The hot-dip solder plating layers are inevitably also formed on side surfaces of the core material, but not shown in Fig. 1. This is ditto in the figures illustrating other embodiments to be described later.

[0021] Any of various metal materials, such as pure copper and pure silver, having excellent electrical conductivity and solderability may be used for the core material 2, but pure copper is preferred in terms of material costs. The copper.material preferably has the highest possible purity, preferably a purity of 99.9 mass% or higher. Among other impurities, oxygen functions to increase the proof strength even if a very small amount of oxygen is present in the copper material. Therefore, the oxygen content is preferably the lowest possible level, and copper materials, such as oxygen free copper (OFHC) and copper refined by vacuum melting method, having an oxygen content of not greater than 20ppm are preferred.

[0022] Fig. 2 is a clad electrode wire 1A according to a second embodiment. The electrode wire 1A includes a core material 2A of a clad material having an elongate plate shape, and hot-dip solder plating layers 3A, 3B disposed on a front surface and a rear surface of the core material 2A. The core material 2A includes an interlayer 4 of an aluminum material, and a first surface layer 5A and a second surface layer 5B of a copper material disposed on opposite surfaces of the interlayer 4. The core material 2A has an average volume resistivity of not greater than 2.3$\mu\Omega\cdot$cm and an' average proof strength of not less than 19.6MPa and not greater than 85MPa, preferably not less than 19.6MPa and not greater than 49MPa. Where only one surface of the electrode wire is to be soldered to electrodes on a semiconductor substrate, it is sufficient to provide the copper layer on only one of the surfaces of the interlayer 4.

[0023] The aluminum material is preferably pure aluminum having an Al content of not less than about 99.0 mass%, more preferably not less than 99.9 mass%, or an aluminum alloy having the aforesaid Al content. Examples of the aluminum material include those specified by JIS 1050, 1060, 1085, 1080, 1070, 1N99 and 1N90. On the other hand, the copper material is preferably pure copper having a Cu content of not less than about 99.0 mass%, more preferably not less than 99.9 mass%, or a copper alloy having the aforesaid Cu content. Particularly, pure copper having an oxygen content of not greater than 20ppm has a lower proof strength and is preferred.

[0024] The interlayer 4 preferably has a thickness which is not less than 10% and not greater than 50% of the entire thickness of the core material 2A. A thickness less than 10% of the thickness of the core material is undesirable, because the clad material will have an average proof strength of greater than 85MPa. On the other hand, a thickness greater than 50% of the thickness of the core material is also undesirable, because the clad material will have an average volume resistivity of greater than 2.3$\mu\Omega\cdot$cm. The first and second surface layers 5A, 5B preferably have the same thickness. Where the first and second surface layers 5A, 5B have the same thickness, the electrode wire is prevented from being thermally deformed in soldering.

[0025] Usable as the core material 2 of the single layer electrode wire 1 are an elongate plate formed as having flattened opposite surfaces by rolling a wire of a round section, and an elongate plate prepared by slitting a rolled single layer sheet into a plurality of elongate plates. On the other hand, the core material of the aforesaid clad electrode wire is prepared by slitting a clad sheet having the same sectional construction into a plurality of elongate plates. The clad sheet is easily prepared by stacking an aluminum sheet and copper sheets for the respective layers, then rolling the resulting stack between a pair of cold or warm press rolls, and annealing the resulting press-bonded material at about 200°C to about 500°C for several tens seconds to several minutes for diffusion.

[0026] When the raw materials are worked to form the core material 2, 2A, the core material experiences work hardening, thereby having an increased proof strength. Therefore, it is desirable to sufficiently anneal the core material for softening so as to adjust the proof strength in the range of not less than 19.6MPa and not greater than 85MPa. Since the electrode wire typically has a thickness of about 100μm to about 300μm, the annealing is sufficiently performed at about 500°C for the Cu/Al/Cu clad material or at about 900°C for the Cu single layer material, respectively, for about one minute.

[0027] The annealing for softening may be performed on the core material prepared by slitting the rolled single layer sheet or the clad sheet into elongate plates and cutting the elongate plates to a proper length. Alternatively, the aforesaid sheet may be first annealed for softening (also for diffusion in this case), and then slit and cut to form the core material. Where the proof strength of the elongate plate is set at a level not less than about 19.6MPa and not greater than about 49MPa, the former method is more preferred. On the other hand, where the proof strength of the elongate plate is set at a level greater than about 49MPa and not greater than about 85MPa, the latter method is employed, which is advantageous for mass production.

[0028] The elongate plate prepared in the aforesaid manner, i.e. , the core material, is thereafter dipped in a plating bath regulated at a hot-dip solder plating temperature, whereby the hot-dip solder plating layers 3A, 3B are formed on the surfaces of the core material. A solder alloy for the hot-dip solder plating layers 3A, 3B will be described later. The hot-dip solder plating temperature is regulated at a temperature higher by about 50°C to about 100°C than the melting point of the solder alloy. By thus adjusting the temperature at the higher level, an annealing effect can be provided. Therefore, where the annealing is performed before the slitting, the hot-dip solder plating temperature is preferably set at the higher level.

[0029] The core material 2, 2A of the single layer electrode wire 1 or the clad electrode wire 1A has a simple rectangular sectional shape as shown in Fig. 1 or 2. However, the clad core material 2A, for example, is preferably configured such as to have a saucer-like cross section, as shown in Fig. 3, having a recessed flat center portion provided on one side (a lower side in this figure) of the cross section. The recessed portion is defined as a hot-dip solder storing recessed portion 6. The recessed portion preferably has a depth of not less than about 10μm and not greater than about 30μm at the deepest part thereof, and a width (an opening width on the lower surface) which is not less than about 90% of the width of the core material 2A. The upper limit of the width is not particularly limited, but the recessed portion may be open across the entire width of the lower surface.

[0030] In the case of an electrode wire 1B having the aforesaid hot-dip solder storing recessed portion 6, the molten solder is supplied into the recessed portion 6 to substantially fill the recessed portion 6 when the core material 2A is plated with solder by hot-dip plating. Thus, a hot-dip solder plating layer 3C is formed in the recessed portion 6 as having a generally flat surface. Since the surface of the hot-dip solder plating layer 3C is generally flat, the solderability is improved.

[0031] In order to substantially fill the recessedportion 6 with the supplied molten solder, the molten solder bath temperature and the plating speed for the hot-dip solder plating are properly controlled, or an excess part of the molten solder bulged from the opening of the recessed portion 6 after the core material 2A is dipped in the molten solder bath is blown off by hot air or scraped away by a proper scraping member.

[0032] The hot-dip solder storing recessed portion 6 is easily formed by working the elongate plate-shaped core material by a proper method such as a plastic working method or a bending method. For example, the working of the elongate plate material is easily achieved by passing the elongate plate material between die rolls which are spaced from each other to define a space having a saucer-shaped cross section. Alternatively, when the material sheet is slit into the elongate plates, the lateral edges of the elongate plates may be bent by controlling the distance between rotary cutters of a slitter and/or the rotation speed of the rotary cutters.

[0033] In the embodiment described above, the core material 2A of the electrode wire 1B has a saucer-like cross section such that the recessed portion 6 has the flat center bottom portion, but the sectional shape is not limited to the saucer-like sectional shape. For example, as shown in Fig. 4, the core material 2A may have an entirely curved cross section. In this case, the hot-dip solder storing recessed portion 6A has a curved bottom surface. The simple saucer-like or curved sectional shape of the core material can be provided by easy working, and is advantageous for industrial productivity.

[0034] In the embodiment described above, the clad core material 2A is used as the core material having the hot-dip solder storing recessed portion, but the rolled single layer core material may be used. As in the case of the single layer electrode wire, the annealing of the rolled single layer core material or the clad core material for softening may be performed after the elongate plate is prepared by the slitting and cutting of the rolled single layer sheet or the clad sheet and formed with the recessed portion. Alternatively, the sheet may be first annealed for softening, followed by the slitting and cutting of the sheet and the formation of the recessed portion. Where the latter method is employed, the hot-dip solder plating temperature is preferable set at a higher level to provide the annealing effect in the hot-dip solder plating.

[0035] Examples of the solder material for the hot-dip solder plating layers 3A, 3B, 3C include Sn-Pb alloys, Sn-(0.5 to 5 mass%)Ag alloys, Sn-(0.5 to 5 mass%)Ag-(0.3 to 1.0 mass%)Cu alloys, Sn-(0.3 to 1.0 mass%)Cu alloys, Sn-(1.0 t.o 5.0 mass%)Ag-(5 to 8 mass%)In alloys, Sn-(1.0 to 5.0 mass%)Ag-(40 to 50 mass%)Bi alloys, Sn-(40 to 50 mass%)Bi alloys and Sn-(1.0 to 5.0 mass%) Ag-(40 to 50 mass%) Bi- (5 to 8 mass%) In alloys, which each have a melt ing point of about 130°C to about 300°C. Since Pb is liable to pose a hazard to human bodies and pollute natural environment, lead-free solder materials such as the Sn-Ag alloys, the Sn-Ag-Cu alloys, the Sn-Cu alloys, the Sn-Ag-In alloys and the Sn-Ag-Bi alloys are preferred from the viewpoint of the prevention of the pollution. For prevention of oxidation of the molten solder, one or two or more of about 50ppm to about 200ppm of P, several ppm to several tens ppm of Ga, several ppm to several tens ppm of Gd and several ppm to several tens ppm of Ge may be added to any of the aforesaid solder materials. The hot-dip solder plating layer may have a multi-layer structure formed by using various pure metals such as Sn, Ag and Cu and/or alloys of any of these metals. In this case, the thicknesses of the respective layers are adjusted so that a solder resulting from the melting of the hot-dip solder plating layer has an intended alloy composition. The multi-layer structure can be easily formed by sequentially performing predetermined plating processes.

[0036] Next, a solar cell employing any of the electrode wires of the aforesaid embodiments as a connection lead wire will be described with reference to the drawing.

[0037] Fig. 5 illustrates a solar cell including connection lead wires 13 each prepared by using the electrode wire having the hot-dip solder storing recessed portion. The solar cell includes a semiconductor substrate 11 of a silicon semiconductor having PN junctions, and connection lead wires 13 each soldered to a plurality of linear front surface electrodes 12 disposed on a front surface of the semiconductor substrate 11. Rear surface electrodes each having a larger area of about 40 mm^2 to about 80mm^2 are disposed on a rear surface of the semiconductor substrate 11.

[0038] Before the soldering of the connection lead wires 13, solder bands are formed on the semiconductor substrate 11 as extending perpendicularly to the linear front surface electrodes 12 so as to be electrically connected to the liner front surface electrodes 12. The connection lead wires 13 are placed on the semiconductor substrate 11 so that the hot-dip solder plating layers disposed in the hot-dip solder storing recessed portions of the connection lead wires are respectively brought into contact with the solder bands. Then, the solder bands on the semiconductor substrate 11 and the hot-dip solder plating layers of the connection lead wires 13 are melted together, whereby the connection lead wires 13 are soldered to the front surface of the semiconductor substrate 11. Thus, the connection lead wires 13 of the electrode wires are bonded to the semiconductor substrate 11. Since the rear surface electrodes each have a relatively large exposure area (of about 40 mm^2 to about 80mm^2), the connection lead wires are easily soldered to rear surface electrodes of an adjacent solar cell as compared with the soldering to the front surface electrodes.

[0039] In the solar cell, the electrode wires are plastically deformed by thermal stress during the soldering, so that thermal stress occurring in the semiconductor substrate is alleviated. Therefore, cracking is unlikely to occur in the semiconductor substrate. In addition, the electrode wires each have a lower volume resistivity and, hence, are excellent in electrical conductivity. Therefore, the power generation efficiency is improved. Further, the electrode wires are each formed with the hot-dip solder storing recessed portion, and the hot-dip solder plating layer having a flat surface is located in the recessed portion. Therefore, the electrode wires are excellent in solderability, so that the connection lead wires 13 are firmly bonded to the semiconductor substrate 11. Accordingly, the connection lead wires are less liable to be disconnected from the semiconductor substrate, and excellent in durability.

Examples

Example A

[0040] Various clad materials were each prepared by press-bonding surface layers of oxygen-free copper (Cu: 99.97 mass%, 0: 15ppm) to opposite surfaces of an interlayer of aluminum (specified by JIS 1N90, Al: 99.90 mass%) or Invar (Fe-36.5 mass% Ni) and annealing the resulting stack for diffusion. The clad materials (core materials) each had a thickness of 160μm, and the ratio of the thickness of the interlayer to the thickness of the clad material is shown in Table 1. The clad materials were each slit to form elongate plates each having a width of 2mm, and the elongate plates were each cut to a length of 150mm, whereby a plurality of core materials were prepared. The core materials were annealed at 500°C for one minute for softening. Further, a plurality of core materials were prepared in substantially the same manner as described above by employing a rolled sheet of the oxygen-free copper, and some of the core materials were annealed for softening. Further, core materials were prepared by cutting a flattened copper wire (having a thickness of 160μm and a width of about 2mm) of tough pitch copper (Cu: 99.94 mass%, O: 33ppm) to the same length as the above-mentioned without the annealing.

[0041] A tensile test was performed by a method specified by JIS Z2241, in which the core materials were each stretched longitudinally thereof to measure the proof strength thereof. Further, the volume resistivity of each of the core materials was measured by a method specified by JIS H0505. The results of the measurement are also shown in Table 1.

[0042] After the surfaces of the core materials were cleaned with acetone, the core materials were quickly dipped in a molten solder plating bath (solder composition: Sn-3.5 mass% Ag, melting point: 220°C, bath temperature: 300°C), whereby hot-dip soldier plating layers were formed on surfaces of the core materials. The hot-dip solder plating layers of the electrode wires thus prepared each had an average thickness of about 40μm.

[0043] The electrode wires thus prepared were each kept in contact with a solder band of a solar cell silicon substrate (having a thickness of 200μm) at 260°C for one minute, thereby soldered to the substrate. The solder band was preliminarily formed on a front surface of the silicon substrate as extending across a plurality of front surface electrodes dispose on the substrate. After the soldering, whether or not the silicon substrate was cracked was checked. The results of the check are also shown in Table 1.

[0044] As shown in Table 1, the electrode wires (Sample Nos. 1, 2 and 4) of the examples, whether they are of the single layer type or of the clad type, each had a proof strength of not higher than 49MPa. Therefore, the thin silicon substrates each having a thickness of 200μm were free from cracking. In the case of the electrode wire of Sample No. 7 prepared by working the oxygen-free copper and not annealed for softening, the proof strength was higher on the order of 147MPa, so that the silicon substrate was cracked. In the case of the electrode wires of the examples, it was confirmed that the volume resistivity was lower as compared with the prior art clad electrode wire (Sample No. 5) having the Invar interlayer and the electrical conductivity was excellent.

Table 1

Sample No.	Core material Structure & materials	Interlayer Thickness ratio	Annealing for softening Done: ○ Not done : ×	Proof strength MPa	Volume resistivity μΩ · cm	Cracking of silicon substrate Present : × Absent: ○
*1	Cu/Al/Cu	20%	○	38.2	2.0	○
*2	Cu/Al/Cu	33%	○	36.3	2.2	○
*4	Cu single layer	-	○	41.2	1.8	○
5	Cu/Invar/Cu	33%	○	98	2.3	○
6	Flattened copper wire	-	×	98	1.8	×
7	Cu single layer	-	×	147	1.8	×
(Note) Cu: Oxygen-free copper, Material for flattened copper wire: Tough pitch copper Sample Nos. prefixed with *: Examples, Sample No 7: Comparative example Sample Nos. 5. 6: Prior art examples						

Example B

[0045] Various clad materials were each prepared by press-bonding surface layers of oxygen-free copper (Cu: 99.97 mass%, O: 15ppm) to opposite surfaces of an interlayer of aluminum (specified by JIS 1N90, Al: 99.90 mass%) or Invar (Fe-36.5 mass% Ni) and annealing the resulting stack for diffusion. The clad materials (core materials) each had a thickness of 200μm, and the ratio of the thickness of the interlayer to the thickness of the clad material is shown in Table 2. The clad materials were annealed at 500°C for one minute for softening. Then, the clad materials were each slit to form elongate plates each having a width of 2mm, and the elongate plates were each cut to a length of 150mm, whereby a plurality of core materials were prepared. Further, a plurality of core materials were prepared by annealing a rolled sheet of the oxygen-free copper for softening in the same manner as described above and then slitting the annealed sheet.

[0046] After the surfaces of the core materials were cleaned with acetone, some of the core materials, in each core material group were quickly dipped in a molten solder plating bath (solder composition: Sn-3.5 mass% Ag, melting point: 220°C, bath temperature: 300°C), whereby hot-dip solder plating layers were formed on surfaces of the core materials. The hot-dip solder plating layers of the electrode wires thus prepared each had an average thickness of about 40μm.

[0047] The other core materials in each core material group were quickly dipped in a salt bath (bath temperature : 300°C) containing potassium nitrate and sodium nitrite as major components under the same conditions as in the dipping in the molten solder plating bath. Thus, the other core materials were subjected to a heat treatment under the same conditions as in the dipping of the core materials for the formation of the hot-dip solder plating layers. The core materials dipped in the salt bath were rinsed with water to remove the salts from the surfaces thereof, and then the proof strength and the volume resistivity were measured in the same manner as in Example A. The results of the measurement are also shown in Table 2.

[0048] As in Example A, the electrode wires were each soldered to a solar cell silicon substrate (having a thickness of 200μm). After the soldering, whether or not the silicon substrate was cracked was checked. The results of the check are also shown in Table 2.

[0049] As shown in Table 2, the electrode wires (Sample Nos. 11, 12 and 14) of examples, whether they are of the single layer type or of the clad type, each had a proof strength of not higher than 85MPa. Therefore, the thin silicon substrates each having a thickness of 200μm were free from cracking. Further, it was confirmed that the volume resistivity was 2.2μΩ·cm or lower and the electrical conductivity was excellent.

Table 2

Sample No.	Core material Structure & materials	Interlayer Thickness ratio	Annealing for softening Done : ○ Not done : ×	Proof strength MPa	Volume resistivity μΩ · cm	Cracking of silicon substrate Present: × Absent : ○
*11	Cu/Al/Cu	20%	○	85	2.0	○
*12	Cu/Al/Cu	30%	○	72	2.2	○
*14	Cu single layer	-	○	85	1.8	○
(Note) Cu: Oxygen-free copper Sample Nos. prefixed with *: Examples, Sample Nos. 11, 12, 14; Comparative examples						

Claims

1. An electrode wire (1) for a connection lead wire to be soldered to a plurality of front surface electrodes (12) disposed on a front surface of a semiconductor substrate for a solar cell and/or rear surface electrodes disposed on a rear surface of the semiconductor substrate for the solar cell, comprising a core material (2) having a volume resistivity of not greater than 2.3 μΩ·cm and a hot-dip solder plating layer (3A, 3B) disposed on a surface of the core material (2), **characterized in that**

   the core material (2) is composed of an annealed pure copper material having an oxygen content of not greater than 20ppm, a thickness of 160 μm, a width of 2 mm, and has a proof strength of 41.2 MPa, this core material is quickly dipped in a molten solder plating bath with solder composition Sn-3.5 mass% Ag, melting point 220°C, bath temperature 300°C, whereby hot-dip solder plating layers were formed having an average thickness of about 40 μm,
   the semiconductor substrate is composed of a silicon semiconductor, and
   the thickness of the semiconductor substrate is 200 μm.

2. An electrode wire (1A, 1B) for a connection lead wire to be soldered to a plurality of front surface electrodes (12) disposed on a front surface of a semiconductor substrate for a solar cell and/or rear surface electrodes disposed on a rear surface of the semiconductor substrate for the solar cell, comprising a core material (2A) made of a clad material including an interlayer (4), and a first surface layer (5A) and a second surface layer (5B) disposed on opposite surfaces of the interlayer (4), and a hot-dip solder plating layer (3A, 3B, 3C) disposed on a surface of the core material (2A), the core material (2A) having a volume resistivity of not greater than 2.3 μΩ·cm, **characterized in that**

   the first surface layer (5A) and the second surface layer (5B) are composed of pure Cu or a Cu alloy mainly comprising Cu, and the core material (2A) has a thickness of 160 μm, a width of 2 mm and a proof strength of 36.3 MPa or 38.2 MPa, this core material is quickly dipped in a molten solder plating bath with solder composition Sn-3.5 mass% Ag, melting point 220°C, bath temperature 300°C, whereby hot-dip solder plating layers were formed having an average thickness of about 40 μm, the interlayer (4) is composed of pure Al or an Al alloy mainly comprising Al and having a thickness ratio of 20% or 33%,
   the semiconductor substrate is composed of a silicon semiconductor, and
   the thickness of the semiconductor substrate is 200 μm.

3. A solar cell electrode wire (1A, 1B) according to claim 2, wherein the first surface layer (5A) and the second surface layer (5B) are composed of the same material and have the same thickness.

4. A solar cell electrode wire (1A, 1B) according to any one of claims 1 to 3, wherein the core material has a recessed portion (6, 6A) arranged along a longitudinal direction of the core material (2, 2A) for storing molten solder and the hot-dip solder plating layer (3C) is located in the recessed portion (6, 6A).

5. A solar cell electrode wire according to claim 4, wherein an opening width of the recessed portion (6, 6A) as measured transversely of the core material (2, 2A) is not less than 90% of a width of the core material (2, 2A).

Patentansprüche

1. Elektrodendraht (1) für einen Anschlussleitungsdraht, der an eine Vielzahl von Vorderseitenoberflächenelektroden (12), die auf einer Vorderseitenoberfläche eines Halbleitersubstrats für eine Solarzelle angeordnet sind, und/oder Rückseitenoberflächenelektroden, die auf einer Rückseitenoberfläche des Halbleitersubstrats für die Solarzelle angeordnet sind, zu löten ist, umfassend ein Kernmaterial (2) mit einem spezifischen Durchgangswiderstand von nicht größer als 2,3 $\mu\Omega\cdot$cm und eine Schmelztauch-Lötmittelüberzugsschicht (3A, 3B), die auf einer Oberfläche des Kernmaterials (2) angeordnet ist, **dadurch gekennzeichnet, dass**

das Kernmaterial (2) aus einem geglühten reinen Kupfermaterial mit einem Sauerstoffgehalt von nicht größer als 20ppm, einer Dicke von 160 μm, einer Breite von 2 mm besteht und eine Fließfestigkeit von 41.2 MPa hat, dieses Kernmaterial schnell in ein Überzugsbad mit geschmolzenem Lötmittel mit einer Lötmittelzusammensetzung Sn-3.5 Massenanteil Ag, einem Schmelzpunkt 220°C, einer Badtemperatur 300°C eingetaucht wird, wodurch Schmelztauch-Lötmittelüberzugsschichten mit einer Durchschnittsdicke von etwa 40 μm ausgebildet wurden,
das Halbleitersubstrat aus einem Siliziumsubstrat besteht, und
die Dicke des Halbleitersubstrats 200 μm ist.

2. Elektrodendraht (1A, 1B) für einen Anschlussleitungsdraht, der an eine Vielzahl von Vorderseitenoberflächenelektroden (12), die auf einer Vorderseitenoberfläche eines Halbleitersubstrats für eine Solarzelle angeordnet sind, und/oder Rückseitenoberflächenelektroden, die auf einer Rückseitenoberfläche des Halbleitersubstrats für die Solarzelle angeordnet sind, zu löten ist, umfassend ein Kernmaterial (2A), das hergestellt ist aus einem Mantelmaterial einschließlich einer Zwischenschicht (4) und einer ersten Oberflächenschicht (5A) und einer zweiten Oberflächenschicht (5B), die auf entgegengesetzten Oberflächen der Zwischenschicht (4) angeordnet sind, und eine Schmelztauch-Lötmittelüberzugsschicht (3A, 3B, 3C), die auf einer Oberfläche des Kernmaterials (2A) angeordnet ist, wobei das Kernmaterial einen spezifischen Durchgangswiderstand von nicht größer als 2,3 $\mu\Omega\cdot$cm hat, **dadurch gekennzeichnet, dass**

die erste Oberflächenschicht (5A) und die zweite Oberflächenschicht (5B) aus reinem CU oder einer CU-Legierung mit hauptsächlich CU bestehen, und das Kernmaterial (2A) eine Dicke von 160 μm, eine Breite von 2 mm und eine Fließfestigkeit von 36.3 MPa oder 38.2 MPa hat, dieses Kernmaterial schnell in ein Überzugsbad mit geschmolzenem Lötmittel mit einer Lötmittelzusammensetzung Sn-3.5 Massenanteil Ag, einem Schmelzpunkt 220°C, einer Badtemperatur 300°C eingetaucht wird, wodurch Schmelztauch-Lötmittelüberzugsschichten mit einer Durchschnittsdicke von etwa 40 μm ausgebildet wurden, die Zwischenschicht (4) aus reinem Al oder einer Al-Legierung mit hauptsächlich Al besteht und ein Dickenverhältnis von 20 % oder 33 % hat,
das Halbleitersubstrat aus einem Siliziumsubstrat besteht, und
die Dicke des Halbleitersubstrats 200 μm ist.

3. Solarzellen-Elektrodendraht (1A, 1B) nach Anspruch 2, wobei die erste Oberflächenschicht (5A) und die zweite Oberflächenschicht (5B) aus demselben Material bestehen und dieselbe Dicke haben.

4. Solarzellen-Elektrodendraht (1A, 1B) nach einem der Ansprüche 1 bis 3, wobei das Kernmaterial einen rückgesetzten Teilbereich (6, 6A) hat, der entlang einer Längsrichtung des Kernmaterials (2, 2A) angeordnet ist, um geschmolzenes Lötmittel unterzubringen, und die Schmelztauch-Lötmittelüberzugsschicht (3C) in dem rückgesetzten Teilbereich (6, 6A) angeordnet ist.

5. Solarzellen-Elektrodendraht nach Anspruch 4, wobei eine Öffnungsweite des rückgesetzten Teilbereichs (6, 6A), wenn sie quer vom Kernmaterial (2, 2A) gemessen wird, nicht kleiner als 90% einer Breite des Kernmaterials (2, 2A) ist.

Revendications

1. Fil d'électrode (1) pour un fil conducteur de connexion devant être brasé sur une pluralité d'électrodes de surface avant (12) disposées sur une surface avant d'un substrat semi-conducteur pour une cellule solaire et/ou sur une pluralité d'électrodes de surface arrière disposées sur une surface arrière d'un substrat semi-conducteur pour la cellule solaire, comprenant un matériau central (2) ayant une résistivité volumique n'excédant pas 2,3 μΩ cm et une couche de placage brasée par immersion à chaud (3A, 3B) disposée sur une surface du matériau central (2), **caractérisé en ce que**

   le matériau central (2) est composé d'un matériau de cuivre pur recuit ayant un contenu en oxygène n'excédant pas 20ppm, une épaisseur de 160 μm, une largeur de 2 mm, et qui présente une limite d'élasticité de 41,2 MPa, ce matériau central est immergé rapidement dans un bain de placage par brasure en fusion avec une composition de brasure Sn-3,5 % en masse d'Ag, un point de fusion 220°C, une température de bain 300°, moyennant quoi des couches de placage brasé par immersion à chaud sont formées qui présentent une épaisseur moyenne d'environ 40μm,
   le substrat semi-conducteur est composé d'un semi-conducteur en silicium, et
   l'épaisseur du substrat semi-conducteur est de 200 μm.

2. Fil d'électrode (1A, 1B) pour un fil conducteur de connexion devant être brasé sur une pluralité d'électrodes de surface avant (12) disposées sur une surface avant d'un substrat semi-conducteur pour une cellule solaire et/ou sur une pluralité d'électrodes de surface arrière disposées sur une surface arrière d'un substrat semi-conducteur pour la cellule solaire, comprenant un matériau central (2A) constitué d'un matériau de placage incluant une couche intermédiaire (4) et une première couche superficielle (5A) et une seconde couche superficielle (5B) disposées sur des surfaces opposées de la couche intermédiaire (4), et une couche de placage brasé par immersion à chaud (3A, 3B, 3C) disposée sur une surface du matériau central (2A), le matériau central (2A) ayant une résistivité volumique n'excédant pas 2,3 μΩ cm, **caractérisé en ce que**

   la première couche superficielle (5A) et la seconde couche superficielle (5B) sont composées de Cu pur ou d'un alliage de Cu comprenant principalement du Cu, et le matériau central (2A) présente une épaisseur de 160 μm, une largeur de 2 mm et une limite d'élasticité de 36,3 MPa ou 38,2 MPa, ce matériau central est rapidement immergé dans un bain de placage par brasure en fusion avec une composition de brasure Sn-3,5 % en masse d'Ag, un point de fusion 220°C, une température de bain 300°C,
   moyennant quoi des couches de placage par immersion à chaud sont formées qui présentent une épaisseur moyenne d'environ 40 μm, la couche intermédiaire (4) est composée d'Al pur ou d'un alliage d'Al comprenant principalement de l'Al et ayant une rapport d'épaisseur de 20% ou de 33%,
   le substrat semi-conducteur est composé d'un semi-conducteur en silicium et
   l'épaisseur du substrat semi-conducteur est de 200 μm.

3. Fil d'électrode de cellule solaire (1A, 1B) suivant la revendication 2, dans lequel la première couche superficielle (5A) et la seconde couche superficielle (5B) sont composées du même matériau et présentent la même épaisseur.

4. Fil d'électrode de cellule solaire (1A, 1B) suivant une des revendications 1 à 3, dans lequel le matériau central présente une partie en retrait (6, 6A) disposée le long d'un sens longitudinal du matériau central (2, 2A) pour stocker de la brasure fondue et la couche de placage brasé par immersion à chaud (3C) se situe dans la partie en retrait (6, 6A).

5. Fil d'électrode de cellule solaire suivant la revendication 4, dans lequel une largeur d'ouverture de la partie en retrait (6, 6A), telle que mesurée transversalement, du matériau central (2, 2A) n'est pas inférieure à 90% d'une largeur du matériau central (2, 2A).

Fig. 1

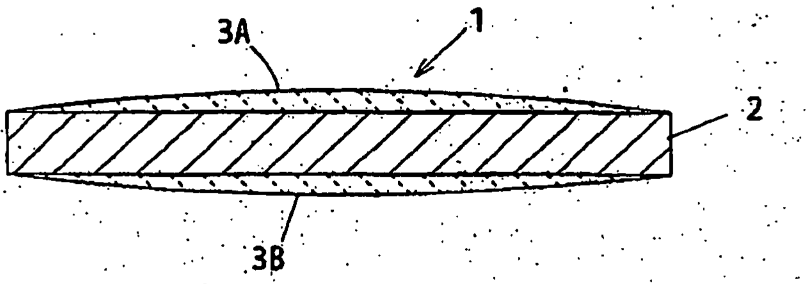


Fig. 2

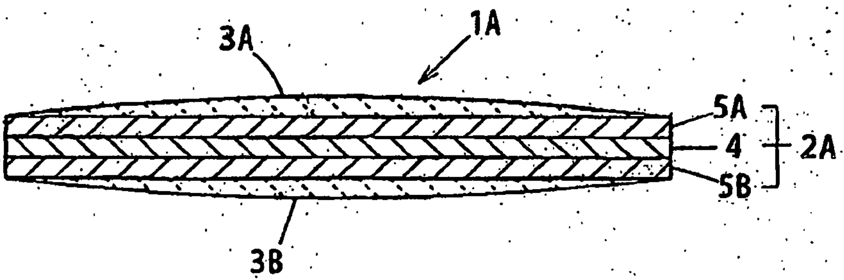


Fig. 3

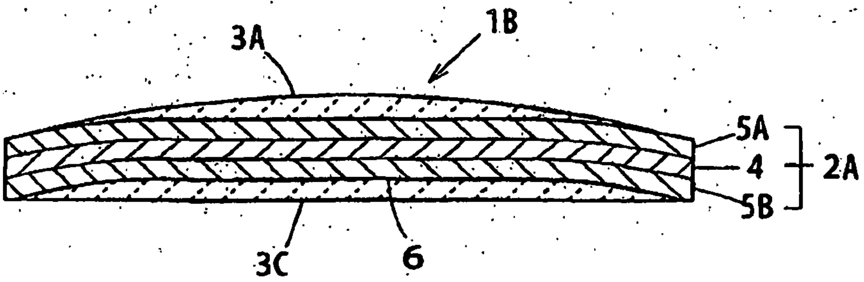


Fig. 4

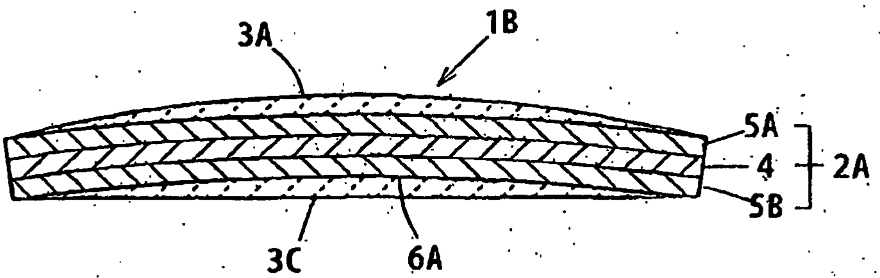
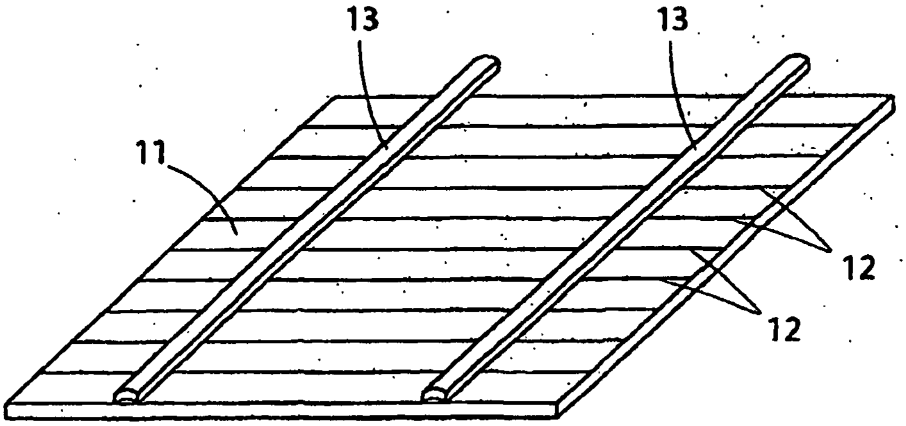


Fig. 5



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