LINEAR PHOTOVOLTAIC CELL ASSEMBLY

TECHNICAL FIELD

[0001] The present invention belongs to the field of photovoltaic cells, and particularly relates to a linear photovoltaic cell assembly.

BACKGROUND ART

[0002] A photovoltaic cell is a device that converts light energy into electrical energy by utilizing the photovoltaic effect, and is a thin slice made of photoelectric semiconductor which is capable of generating electricity directly by absorbing light. The main application of photovoltaic cells is solar power generation, and they are therefore also called solar cells. Conventional solar cells use silicon wafers as the base material; owing to the structural form of the silicon wafer, the solar cell produced is a rigid planar structure. In recent years, with the development of thin-film cell technology, flexible cells have been widely studied because of their characteristics such as being bendable, light in weight, and wide in application range. A common flexible cell is formed by fabricating a thin-film cell material on a flexible transparent film, which can substantially reduce the product weight while providing a certain flexibility. With the development of technology, in order to convert sunlight into usable electric energy anytime and anywhere and to allow individuals to conveniently utilize solar energy, wearable devices have received extensive attention. Therefore, weavable fiber-shaped flexible solar cells have been proposed, also referred to as linear photovoltaic cells. A linear photovoltaic cell is formed by constructing a working electrode on a flexible linear substrate, depositing multiple functional layers and a counter electrode, and assembling them into a complete device to achieve photoelectric conversion. Compared with a flexible planar cell, a linear cell is not only lightweight and bendable, but can also withstand various three-dimensional deformations such as twisting and knotting, and thus has a wider application range.

[0003] However, since the transparent outer electrode of an existing linear photovoltaic cell needs to maintain good light transmittance, its thickness is usually very thin, often only on the order of nanometer scale, and it therefore has the problems of low strength and high resistivity. Consequently, transmitting charge from one end of the cell to the other end through the transparent outer electrode in an existing linear photovoltaic cell suffers from the problem of excessive resistance, which limits the length of the linear cell. In addition, the extremely thin transparent outer electrode has low strength, making it difficult, and even insufficiently robust, to connect to an external circuit.

SUMMARY OF THE INVENTION

[0004] An object of the present invention is to solve the problem that an existing linear photovoltaic cell suffers from excessive resistance when transmitting charge from one end of the cell to the other end through the transparent outer electrode.

[0005] The object of the present invention is achieved by the following technical solutions:

[0006] A linear photovoltaic cell assembly, the photovoltaic cell assembly comprising:

[0007] a first inner electrode, which is a linear electrical conductor;

[0008] a first functional photosensitive layer, which coats the first inner electrode;

[0009] a second inner electrode, which is a linear electrical conductor;

[0010] a second functional photosensitive layer, which coats the second inner electrode;

[0011] wherein the first functional photosensitive layer and the second functional photosensitive layer are arranged in parallel or twisted together and are electrically connected; the first functional photosensitive layer and the second functional photosensitive layer have a photovoltaic effect, and the output voltages generated thereby are of opposite polarity.

[0012] Preferably, the photovoltaic cell assembly further comprises a transparent outer electrode sleeved over the outer sides of the first functional photosensitive layer and the second functional photosensitive layer.

[0013] Preferably, the photovoltaic cell assembly further comprises a transparent protective layer sleeved on the outer side of the assembly.

[0014] Preferably, the photovoltaic cell assembly further comprises a connection electrode disposed on the outer sides of the first functional photosensitive layer and the second functional photosensitive layer.

[0015] Preferably, in the linear photovoltaic cell assembly, a plurality of sub-linear photovoltaic cells are arranged in parallel or twisted together, and their transparent outer electrodes are connected through the connection electrode.

[0016] Optionally, if the outer side of a part of the functional photosensitive layers has no transparent outer electrode, the connection electrode is directly connected to the functional photosensitive layer.

[0017] Preferably, the first functional photosensitive layer and the second functional photosensitive layer are each a heterojunction or homojunction formed of multiple layers of material, having a structure such as pn, np, pin, nip, nn+, pp+, nn-, or pp-, or a multilayer stack based on these structures, but the two types of functional photosensitive layers have output

voltages of opposite polarity under illumination.

[0018] Preferably, the structural form of the connection electrode includes: binding, winding or twisting with a conductive wire; a conductive snap ring; adhesion with a conductive tape; application of a conductive adhesive; and covering with a conductive film, etc.

[0019] Preferably, the material of the transparent outer electrode includes a transparent oxide thin film such as ITO or FTO, a transparent metal thin film such as a gold or silver film, and a nanomaterial thin film such as nano-silver, a conductive grid mesh, or a transparent carbon film, etc.

[0020] Preferably, the first inner electrode and the second inner electrode are solid-core or hollow-core conductive wires. Their form and material may be a metal wire/filament/strip such as an Au wire, Ag wire, Cu wire, Al wire, or Ti wire, a carbon fiber, a conductive fiber, etc., or may be a multilayer structure in which a conductive layer is coated on the surface of an insulating wire/filament/fiber/strip or an insulating tube, such as a polymer fiber, glass fiber, cotton thread, hemp thread, or plastic tube coated with a conductive layer.

[0021] Preferably, the linear photovoltaic cell assembly comprises a plurality of inner electrodes, and a functional photosensitive layer having a photovoltaic function is covered on the surface of each inner electrode, wherein the output voltage generated by the functional photosensitive layer on the surface of a part of the inner electrodes is of opposite polarity to the output voltage generated by the others.

[0022] Preferably, a plurality of the linear photovoltaic cell assemblies may be connected in series and in parallel to form a photovoltaic cell assembly of larger scale.

[0023] Compared with the prior art, the beneficial effects of the present invention are as follows:

[0024] The main difference between the present invention and a common linear photovoltaic cell assembly is as follows: in a common linear photovoltaic cell, the photocurrent generated by the functional photosensitive layer is transmitted out via the inner electrode and the transparent outer electrode; since the inner electrode only needs to satisfy flexibility and electrical conductivity, its diameter can be designed as required, and its resistance is therefore usually very small; however, the outer electrode must preferentially satisfy light transmittance, so its thickness is extremely thin and its resistance per unit length is relatively large, and the loss is large when the current is transmitted along the axial direction of the outer electrode of the linear cell, which affects the improvement of cell performance. In addition, because the transparent outer electrode is thin, it is extremely difficult to lead out and difficult to connect to an external circuit, or the connection is not robust. In the present invention, the positive and

negative charges at one end of two cells of different polarity recombine via the outer electrodes and the connection electrode, while the other ends are respectively led out from their own inner electrodes; the current path mainly passes through the inner electrodes, so the resistance is small, which can greatly reduce electric energy loss and is advantageous for improving cell efficiency. In addition, since the inner electrode usually has a certain size and strength, leading it out to the external circuit is simpler than the transparent outer electrode.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIG. 1 is a schematic structural diagram of Embodiment 1 of a linear photovoltaic cell assembly of the present invention;

[0026] FIG. 2 is a schematic structural diagram of a single-core photovoltaic cell;

[0027] FIG. 3 is a schematic structural diagram of Embodiment 2 of a linear photovoltaic cell assembly of the present invention;

[0028] FIG. 4 is a schematic structural diagram of a four-strand twisted photovoltaic cell assembly of the present invention;

[0029] wherein: 1 - first inner electrode; 2 - first functional photosensitive layer; 3 - first transparent outer electrode; 4 - second inner electrode; 5 - second functional photosensitive layer; 6 - second transparent outer electrode; 7 - connection electrode; 8 - transparent protective layer; 10 - inner electrode; 20 - functional photosensitive layer; 30 - transparent outer electrode; 80 - transparent outer protective layer; 201 - P layer; 202 - I layer; 203 - N layer; A1 - first inner electrode No. 1; A2 - first inner electrode No. 2; Am - first inner electrode No. m; B1 - second inner electrode No. 1; B2 - second inner electrode No. 2; Bn - second inner electrode No. n; 100 - type-A sub-cell; 200 - type-B sub-cell.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0030] The technical solution is further described below in conjunction with the drawings and specific embodiments to facilitate understanding of the content of the present invention.

[0031] The object of the present invention is achieved by the following technical solution:

[0032] As shown in FIG. 1, the present invention provides a linear photovoltaic cell assembly, the photovoltaic cell assembly comprising:

[0033] a first inner electrode 1, which is a linear electrical conductor;

[0034] a first functional photosensitive layer 2, which coats the first inner electrode 1;

[0035] a second inner electrode 4, which is a linear electrical conductor;

[0036] a second functional photosensitive layer 5, which coats the second inner electrode;

[0037] wherein the first functional photosensitive layer and the second functional photosensitive layer are arranged in parallel or twisted together and are electrically connected; the first functional photosensitive layer and the second functional photosensitive layer have a photovoltaic effect, and the output voltages generated thereby are of opposite polarity.

[0038] The photovoltaic cell assembly further comprises a first transparent outer electrode 3 sleeved on the first functional photosensitive layer 2, and a second transparent outer electrode 6 sleeved on the outer side of the second functional photosensitive layer 5. The transparent outer electrodes may be separately wrapped as shown in FIG. 1, or the first transparent outer electrode 3 and the second transparent outer electrode 6 may be merged into a single transparent outer electrode that simultaneously wraps the first functional photosensitive layer 2 and the second functional photosensitive layer 5.

[0039] The photovoltaic cell assembly further comprises a transparent protective layer 8 sleeved on the outer side of the transparent outer electrodes.

[0040] The photovoltaic cell assembly further comprises a connection electrode 7 disposed on the outer side of the first functional photosensitive layer 2 and the second functional photosensitive layer 5. As shown in FIG. 1, when the photovoltaic cell assembly further comprises the transparent outer electrodes 3 and 6, the connection electrode 7 may also be disposed on the outer side of the transparent outer electrodes.

[0041] As shown in FIG. 1, the present invention in fact adopts a side-by-side series-connection configuration. Two types of linear photovoltaic cells A and B are taken: for cell A, the first inner electrode 1 is the positive electrode and the first transparent outer electrode 3 is the negative electrode; for cell B, the second inner electrode 4 is the negative electrode and the second transparent outer electrode 6 is the positive electrode. Cells A and B are placed side by side, a connection electrode 7 is fabricated at an appropriate position between cells A and B, and finally a transparent protective layer 8 is fabricated. Its main working principle is as follows: when light strikes the photovoltaic cell assembly and passes through the transparent protective layer 8 and the transparent outer electrodes 4 and 6 to reach the functional photosensitive layers 2 and 5, a photovoltaic effect is produced in the functional photosensitive layers, forming electron-hole pairs, which respectively accumulate on the inner electrode and the transparent outer electrode to generate a voltage. For cell A, the holes flow toward the inner electrode 1 and the electrons flow toward the transparent outer electrode 3, so the inner electrode 1 is the positive electrode and the transparent outer electrode 3 is the negative electrode; for cell B, the

electrons flow toward the inner electrode 4 and the holes flow toward the transparent outer electrode 6, so its inner electrode 4 is the negative electrode and its transparent outer electrode 6 is the positive electrode. Since the connection electrode 7 connects the transparent outer electrodes 3 and 6 of the two cells, it is equivalent to connecting the negative electrode of cell A to the positive electrode of cell B, so that cells A and B form a series structure. In the cell assembly after series connection, the positive electrode is the inner electrode 1 of cell A and the negative electrode is the inner electrode 4 of cell B. When this cell assembly is to be used, it is only necessary to connect the two inner electrodes to the external circuit.

[0042] The main difference between the present invention and a common linear photovoltaic cell assembly is as follows: a common linear photovoltaic cell has the structure shown in FIG. 2, comprising an inner electrode 10, a functional photosensitive layer 20, a transparent outer electrode 30, and a transparent outer protective layer 80. The charge generated at a certain position in the functional photosensitive layer first reaches the inner electrode and the transparent outer electrode along the normal direction, then moves along the axial direction of the inner electrode and the transparent outer electrode, and is finally transmitted out at a lead-out at one end. Therefore, for a point far from the lead-out, the charge generated thereat must pass through a relatively long axial transmission path to be transmitted out, and since the transparent outer electrode is usually extremely thin owing to the requirement for light transmittance, its resistivity is relatively high. When the linear cell is relatively long, the axial resistance of the transparent outer electrode is very large, and the current transmission loss is extremely large. When the structure shown in FIG. 1 is adopted, the holes generated at a certain position in the functional photosensitive layer 2 of cell A first flow along the normal direction to the inner electrode 1 and then move along the axial direction of the inner electrode, while the generated electrons reach the transparent outer electrode 3 along the normal direction; the electrons generated at a certain position in the functional photosensitive layer 5 of cell B first flow along the normal direction to the inner electrode 4 and then move along the axial direction of the inner electrode, while the generated holes reach the transparent outer electrode 6 along the normal direction; since the transparent outer electrodes 3 and 6 of the relatively positioned cells A and B are very close and are connected by a connection electrode 7 at intervals, the electrons of the transparent outer electrode 3 of cell A need only pass through the short connection electrode 7 to be connected to the transparent outer electrode 6 of cell B and recombine with the holes on the transparent outer electrode of cell B. Thus, when this series-connected cell supplies power to the outside, the holes mainly flow via the inner electrode 1 of cell A and the electrons mainly flow via the inner electrode 4 of cell B. Since the inner electrode

only needs to satisfy flexibility and electrical conductivity, its thickness can be well designed, and its resistance is therefore usually very small. However, the outer electrode must preferentially satisfy light transmittance, so its thickness is extremely thin and its resistance per unit length is relatively large, and the loss is large when the current is transmitted along the axial direction of the outer electrode of the linear cell. Therefore, by adopting the method of the present invention, the positive and negative charges at one end of two cells of different polarity recombine via the outer electrodes and the connection electrode, while the other ends are respectively led out from their own inner electrodes; the current path mainly passes through the inner electrodes, so the resistance is small, which is advantageous for improving cell efficiency. In addition, since the inner electrode usually has a certain size and strength, leading it out to the external circuit is simpler than the transparent outer electrode.

[0043] FIG. 1 shows one of the simplest examples of the present invention; each inner electrode together with the corresponding functional photosensitive layer and transparent outer electrode may be regarded as one sub linear photovoltaic cell. In specific implementation, the sub linear photovoltaic cells need to be adjusted according to actual needs, including the number, diameter and length of the sub linear photovoltaic cells, the material and fabrication method of each layer in each sub linear photovoltaic cell, the arrangement of the sub linear photovoltaic cells, the form and fabrication method of the connection electrode, and the lead-out manner of the inner electrodes.

[0044] As for the number of sub linear photovoltaic cells, FIG. 1 shows a form having one type-A and one type-B sub linear photovoltaic cell each. In practical applications, as two types of cells having opposite output polarity, each may comprise one or more sub linear photovoltaic cells. That is, the numbers of the two portions of sub linear photovoltaic cells having different polarity may be 1:1, one-to-many, or many-to-many. Regardless of how many sub linear photovoltaic cells the photovoltaic cell assembly contains, a part of the sub linear photovoltaic cells therein must have an output voltage polarity opposite to that of another part of the sub linear photovoltaic cells. The transparent outer electrodes of these sub linear photovoltaic cells are connected via the connection electrode; or, if certain linear cells have no transparent outer electrode, the connection electrode is directly connected to the photosensitive functional layer. The numbers of the two portions of sub linear photovoltaic cells having different polarity may be 1:1, one-to-many, or many-to-many, the ratio thereof being determined by the total photocurrent of the two types of sub linear photovoltaic cells. To achieve high efficiency of the photovoltaic assembly, the ratio should ensure that the total photocurrents generated by the two

types of sub linear photovoltaic cells are close to each other. A plurality of sub linear photovoltaic cells having the same polarity should have similar output voltages to ensure that there is no large attenuation of the parallel voltage after connection.

[0045] The sub linear photovoltaic cells inside may be arranged in parallel side by side as shown in FIG. 2 or FIG. 3, or may be in a two-strand (1:1) or multi-strand (one-to-many or many-to-many) twisted manner.

[0046] The materials of the inner electrode, functional photosensitive layer and transparent outer electrode of the sub linear photovoltaic cells inside may be the same or different, but the outermost layer of a single sub linear photovoltaic cell should not undergo any reaction that damages cell performance with the outermost layer of the other sub linear photovoltaic cells or with the connection electrode.

[0047] The inner electrode may be of a solid structure or a hollow structure. It may be entirely of conductive material or of a multilayer structure; if it is a multilayer structure, its outer surface must be ensured to be a conductive layer. Common inner electrodes include metal wires/filaments/strips such as Au wires, Ag wires, Cu wires, Al wires, and Ti wires, carbon fibers, conductive fibers, etc., or may be a multilayer structure in which a conductive layer is coated on the surface of an insulating wire/filament/fiber/strip or insulating tube, such as a polymer fiber, glass fiber, cotton thread, hemp thread, nylon thread, or plastic tube coated with a conductive layer. The length of the inner electrode determines the length of the linear cell and the assembly.

[0048] The inner electrode of the sub linear photovoltaic cell in the photovoltaic cell assembly may be led out from one end or from both ends. When led out from one end, it may be led out from the same end or from different ends.

[0049] The functional photosensitive layer is usually a heterojunction or homojunction formed of multiple layers of material, having a structure such as pn, np, pin, nip, nn+, pp+, nn-, or pp-, or a multilayer stack based on these structures, but the two types of functional photosensitive layers have output voltages of opposite polarity under illumination. Each semiconductor material layer may be any of the various materials used in current thin-film photovoltaic cells: group IV semiconductor materials such as silicon-based and selenium-based semiconductors, group III-V semiconductor materials such as GaAs, InP, and AlSb, group II-VI semiconductor materials such as CdSe, CdTe, CdS, ZnTe, ZnS, and CdZnTe, group I-III-VI compound materials such as CIGS, CuInSe2, CuGaSe2, and AgInS2, iodide materials such as PbI2, perovskite-type materials such as FAPbI3, MAPbI3, SnPbI3, CsPbI3, and Cs2AgBiBr6, dye-

sensitized cell materials, organic compound cell materials, and so on. Sometimes, in order to improve the cell conversion efficiency, it is also necessary to optimize the semiconductor junction interface and the interface layer between the semiconductor layer and the inner and outer electrodes, and to add a transport layer/modification layer, so that the functional photosensitive layer maintains good energy-level matching with the inner and outer electrode layers, ensuring that the charges can be well led out. The functional photosensitive layer 20 shown in FIG. 2 comprises a P layer 201, an I layer 202, and an N layer 203, and is a typical pin structure; its contact layer with the inner electrode is the p layer, so the inner electrode 10 is the positive electrode and the transparent outer electrode 30 is the negative electrode. If the linear cell of FIG. 2 is used as a sub linear photovoltaic cell of the linear photovoltaic cell assembly shown in FIG. 1, it corresponds to cell A of the linear photovoltaic cell assembly. The holes generated by the photosensitive layer flow toward the first inner electrode 1, and the electrons flow toward the first transparent outer electrode 3. For cell B, an opposite nip cell is fabricated, so that its electrons flow toward the second inner electrode 4 and its holes flow toward the second transparent outer electrode 6. Cells A and B are placed side by side, and then a connection electrode 7 is fabricated on their surface. The connection electrode 7 connects the outer electrodes of cell A and cell B, so that the electrons flowing out of the outer electrode of cell A can recombine with the holes of the outer electrode of cell B. Thus, the holes of cell A are transmitted out axially via the inner electrode of cell A, the electrons of the outer electrode of cell A recombine with the holes of the outer electrode of cell B via the connection electrode, and the electrons of cell B are transmitted out axially via the inner electrode of cell B. Therefore, the inner electrodes of cells A and B form the positive and negative electrodes of the entire cell assembly, cells A and B form a series structure, the voltages add up, and the currents are equal. Finally, a transparent protective layer is fabricated on the surface of the entire cell assembly.

[0050] As required, cell A is not necessarily of a pin structure and cell B is not necessarily of a nip structure; they may be one of the semiconductor junctions such as pn, np, pin, nip, nn+, pp+, nn-, or pp-. Cells A and B may also be organic-molecule donor-acceptor type cells. The photosensitive functional layers of cells A and B may also be stacks composed of these structures. Regardless of the form of the photosensitive layer structure, it is ultimately only required that the output polarities of cells A and B be opposite, without being limited to the material and structure of the functional photosensitive layers.

[0051] A transparent outer electrode is covered on the outside of the photosensitive functional layer. The transparent outer electrode has excellent electrical conductivity and good light

transmittance. The material of the transparent outer electrode includes a transparent oxide thin film such as ITO or FTO, a transparent metal thin film such as a gold or silver film, and a nanomaterial thin film such as nano-silver, a conductive grid mesh, or a transparent carbon film, etc. The transparent outer electrode is in good conductive contact with the functional photosensitive layer and is mainly used to extract the charges of the functional photosensitive layer.

[0052] As required, the transparent outer electrodes of cell A and cell B may also be omitted. When the transparent outer electrode of a certain sub linear photovoltaic cell is omitted, the connection electrode then also assumes the charge-extraction capability of the transparent electrode, in which case the connection electrode 7 should be arranged more densely so as to be able to extract charges from the sub linear photovoltaic cell to a greater extent.

[0053] The purpose of the connection electrode is to connect the outermost layers of the respective sub linear photovoltaic cells, ensuring that sub linear photovoltaic cells of the same polarity form a parallel structure and sub linear photovoltaic cells of different polarity form a series structure. Therefore, its form is not limited: it may be connecting conductive rings arranged at intervals as shown in FIG. 1, may be a continuously wound conductive wire, may be multi-twisted together with the sub linear photovoltaic cells, or may be another conductive material such as conductive tape adhesion, conductive adhesive application, or conductive film covering.

[0054] The connection electrode may be transparent or opaque. If it is opaque, the connection electrode should be extremely thin and maintain a certain interval so as to avoid blocking too much light.

[0055] For convenience of fabrication, the fabricated inner electrodes covered with the photosensitive functional layer may also be arranged in parallel or twisted together, and then a transparent outer electrode is uniformly fabricated on the outside thereof; in this case the transparent outer electrode can serve the function of the connection electrode, and the connection electrode may be reduced or omitted as required.

[0056] A transparent protective layer is wrapped on the outside of the entire linear photovoltaic assembly. The transparent protective layer is an insulating material which should also have good light transmittance, waterproofness, oxidation resistance, corrosion resistance, and wear resistance, and is mainly used to protect the surface of the cell. Common transparent protective layers include glass coatings, organic coatings, and thin films, etc.

[0057] Owing to the flexibility of the linear cells, it is sometimes somewhat difficult to arrange

the sub linear photovoltaic cells in parallel; in this case, the sub linear photovoltaic cells and the connection electrode in the form of a conductive wire may be mutually wound and twisted together.

[0058] In specific implementation, the present invention needs to be adjusted according to actual needs, mainly the number, diameter and length of the sub linear photovoltaic cells, the material and fabrication method of each layer in each sub linear photovoltaic cell, the arrangement of the sub linear photovoltaic cells, the form and fabrication method of the connection electrode, and the manner of leading out the inner electrodes. However, in any form, two types of cells A and B having different polarity must be formed inside the assembly to form a series structure.

[0059] The inner electrode is a solid-core or hollow-core conductive wire, which may be a metal wire such as an Au wire, Ag wire, Cu wire, or Al wire, or a conductive fiber such as a carbon fiber or a conductive tube, etc. For cell A, a pin-type cell is fabricated on the surface of its inner electrode, in which the i layer is the photosensitive layer, usually any of the various materials used in current thin-film cells, such as group IV semiconductor materials such as silicon-based and selenium-based, group III-V semiconductor materials such as GaAs, group II-VI semiconductor materials such as CdTe, compound materials such as CIGS, iodide materials, perovskite-type materials, dye-sensitized cell materials, and organic compound cell materials, etc., while the p layer is a hole transport layer and the n layer is an electron transport layer, so that the holes generated by the photosensitive layer flow toward the inner electrode A1 and the electrons flow toward the transparent outer electrode A3. For cell B, an opposite nip cell is fabricated, so that its electrons flow toward the inner electrode B1 and its holes flow toward the transparent outer electrode B3. Cells A and B are placed side by side, and then a connection electrode is fabricated on their surface. The connection electrode connects the outer electrodes of cell A and cell B, so that the electrons flowing out of the outer electrode of cell A can recombine with the holes of the outer electrode of cell B. Thus, the holes of cell A are transmitted out axially via the inner electrode of cell A, the electrons of the outer electrode of cell A recombine with the holes of the outer electrode of cell B via the connection electrode, and the electrons of cell B are transmitted out axially via the inner electrode of cell B. Therefore, the inner electrodes of cells A and B form the positive and negative electrodes of the entire cell assembly, cells A and B form a series structure, the voltages add up, and the currents are equal. Finally, a transparent protective layer is fabricated on the surface of the entire cell assembly.

[0060] As required, cell A is not necessarily of a pin structure and cell B is not necessarily of a

nip structure; they may be of a pn structure, an np structure, or an organic-molecule donor-acceptor type cell. It is only required that the output polarities of cells A and B be opposite, without being limited to the material and structure of the functional photosensitive layers.

[0061] The connection electrode 7 may generally adopt the following manners: binding or winding with a conductive wire at intervals, snapping with a conductive snap ring, adhering with a conductive tape, or applying a conductive adhesive; or, after fixing A and B side by side, adding a conductive film, conductive adhesive, or the like at the place where they are in close contact on their side.

[0062] As required, the transparent outer electrodes of cell A and cell B may also be omitted. When the transparent outer electrode of a certain sub-cell is omitted, the connection electrode then also assumes the charge-extraction capability of the transparent electrode, in which case the connection electrode 7 should be arranged more densely so as to be able to extract charges from the sub-cell to a greater extent.

[0063] Since cell A and cell B form a series structure, their voltages add up and the currents are equal. To ensure the performance of the entire cell assembly, it should be ensured that the photo-generated currents of cell A and cell B are the same. However, since the film-layer structures of cells A and B are different, the performances of the two types of cells often differ; to solve this problem, a one-to-many or many-to-many structure may be adopted. As shown in FIG. 3, cell A comprises first inner electrode No. 1 A1, first inner electrode No. 2 A2, and up to first inner electrode No. m Am; cell B comprises second inner electrode No. 1 B1, second inner electrode No. 2 B2, and up to second inner electrode No. n Bn. The fabrication processes and constituent materials of these sub linear photovoltaic cells may be similar or different, but their ratio should be optimized when they are combined into the photovoltaic cell assembly. The photovoltaic voltages of the m type-A sub linear photovoltaic cells are UA1, UA2, ..., UAm, respectively, and the currents are IA1, IA2, ..., IAm. The photovoltaic voltages of the n type-B sub linear photovoltaic cells are UB1, UB2, ..., UBn, respectively, and the currents are IB1, IB2, ..., IBn. Since sub linear photovoltaic cells of the same type are equivalent to being connected in parallel, it should be ensured that the photo-generated voltages of the sub linear photovoltaic cells of the same type are relatively close, i.e., UA = UA1 = UA2 = ... = UAm and UB = UB1 = UB2 = ... = UBn, and their respective currents add up, i.e., IA = IA1 + IA2 + ... + IAm and IB = IB1 + IB2 + ... + IBn. Theoretically, since the two types of sub linear photovoltaic cells are equivalent to being connected in series after being combined into the photovoltaic cell assembly, the voltage of the photovoltaic cell assembly is Ucell = UA + UB, and the current of

the cell assembly is the smaller of IA and IB, i.e., Icell = min(IA, IB). In practice, however, for a photovoltaic cell, when the method of the present invention is not adopted, since the resistance of the transparent electrode is relatively large, the charges generated by the photosensitive functional layer cannot be sufficiently led out, and the voltage and current of the sub-cell are relatively small. After the assembly is formed by adopting the present method, the charges generated by the photosensitive functional layer can be better led out, and the voltage and current of the system increase rather than being a simple superposition.

[0064] In the plurality of sub linear cells shown in FIG. 1 and FIG. 3, cells A and B are all arranged in parallel in a row. In fact, owing to the flexibility of the linear cells, it is sometimes somewhat difficult to arrange the sub-cells side by side; in this case, a winding or twisted-wire structure may also be adopted. FIG. 4 shows an example of a four-strand twisted structure, comprising two type-A sub-cells 100 and two type-B sub-cells 200, with the four linear sub-cells twisted together. A transparent conductive mesh is wrapped on the outside of the entire four linear sub-cells as the connection electrode 7, and a transparent protective layer 8 is wrapped on the outside of the connection electrode 7. When connecting to an external circuit, first inner electrode No. 1 A1 and first inner electrode No. 2 A2 are combined and connected to form the positive electrode; second inner electrode No. 1 B1 and second inner electrode No. 2 B2 are combined and connected to form the negative electrode. In FIG. 4, the inner electrodes of the type-A and type-B sub-cells are led out from the same end; in fact, they may also be led out from both ends as required, to facilitate connection to the external circuit.

[0065] As a practical application of the present invention, the inventor fabricated a linear photovoltaic assembly comprising two sub linear photovoltaic cells. The fabrication method is as follows: a Cu wire of 200 μm was taken, and after surface treatment, a p-type transport layer PEDOT:PSS, an i-type semiconductor layer of perovskite MAPbI3, and an n-type transport layer PCBM were fabricated in sequence, and finally a nano-silver thin film was applied on the surface thereof to form a transparent outer electrode, thereby forming sub linear cell A. The inner electrode of cell A is the Cu wire, PEDOT:PSS/MAPbI3/PCBM forms a pin-type photosensitive functional layer, and the nano-silver layer forms the transparent outer electrode. Then a Ti wire of 200 μm of the same length was taken, and after surface treatment, an n-type transport layer TiO2, an i-type perovskite semiconductor layer FAPbI3, and a p-type transport layer Spiro-OMeTAD were fabricated, and finally a nano-silver thin film was applied on the surface thereof to form a transparent outer electrode, thereby forming sub linear cell B. The inner electrode of cell B is the Ti wire, TiO2/FAPbI3/Spiro-OMeTAD forms a nip-type

photosensitive functional layer, and the nano-silver layer forms the transparent outer electrode. Sub linear cells A and B were placed side by side, a 9 μm silver wire was wound on their outer surface to form the connection electrode, and finally epoxy resin was fabricated on the outside thereof as the transparent protective layer. Since cell A is of a pin structure, its inner electrode is the positive electrode and its transparent outer electrode is the negative electrode; since cell B is of a nip structure, its inner electrode is the negative electrode and its transparent outer electrode is the positive electrode; after connection via the connection electrode, a photovoltaic cell assembly is formed, in which the inner electrode of cell A is the positive electrode and the inner electrode of cell B is the negative electrode. When the voltage and current between the inner electrode and the transparent outer electrode of cell A were directly measured, since the conductivity of the transparent outer electrode is poor, its open-circuit voltage was 0.08 V and its short-circuit current could not be measured; the open-circuit voltage of cell B was measured to be 0.27 V and its short-circuit current to be 31 μA. However, when the two sub linear cells were formed into a linear photovoltaic cell assembly by the method of the present patent, the open-circuit voltage measured between the two inner electrodes of cells A and B was 0.36 V and the short-circuit current was 33 μA. It can be seen that the open-circuit voltage and short-circuit current of the assembly are considerably improved compared with those of the respective sub-cells. In this example, the inner electrodes of the two sub linear cells A and B each have a diameter of 200 μm, the transparent outer electrode is a thin film made of 28 nm nano-silver, and the connection electrode is a 9 μm silver wire. When a sub linear cell is used alone, one end of the external circuit must be connected to the 200 μm inner electrode and the other end to the transparent outer electrode or the connection electrode; since the transparent outer electrode is a nanometer-thickness thin film and the diameter of the connection electrode is only 9 μm, connection is very difficult. After the method of the present invention is adopted, it is only necessary to connect the two ends of the external circuit to the inner electrodes of cells A and B; the size and strength of the inner electrode are far higher than those of the transparent outer electrode and the connection electrode, so the connection is more convenient and robust.

[0066] The above embodiment only gives the results of a typical linear photovoltaic cell assembly of the present invention; in fact, because the inner electrode has excellent conductivity, the two ends may be further connected to form a longer composite linear photovoltaic cell assembly. In addition, since the inner electrode usually has a certain size and strength, leading it out to the external circuit is simpler than the transparent outer electrode. This can facilitate the wider use of the linear cell; for example, this linear cell assembly may be woven to form a large-area cell module, satisfying various application requirements.

[0067] The above embodiments are merely several typical application solutions of the linear photovoltaic cell assembly structure claimed in the present invention, and do not represent all the rights claimed in the present invention, and should not be limited to the claims of these several embodiments. Although the present invention has been described in detail with reference to the foregoing embodiments, those skilled in the art should understand that they may still modify the technical solutions of the presently described embodiments or make equivalent substitutions of some of the technical features therein, and such modifications or substitutions do not cause the essence of the corresponding technical solutions to depart from the spirit and scope of the technical solutions of the present invention, and therefore cannot depart from the claims of the present invention.

CLAIMS

What is claimed is:

1. A linear photovoltaic cell assembly, characterized in that the photovoltaic cell assembly comprises: a first inner electrode, which is a linear electrical conductor; a first functional photosensitive layer, which coats the first inner electrode; a second inner electrode, which is a linear electrical conductor; a second functional photosensitive layer, which coats the second inner electrode; wherein the first functional photosensitive layer and the second functional photosensitive layer are arranged in parallel or twisted together and are electrically connected; and the first functional photosensitive layer and the second functional photosensitive layer have a photovoltaic effect, and the output voltages generated thereby are of opposite polarity.

2. The linear photovoltaic cell assembly according to claim 1, characterized in that the photovoltaic cell assembly further comprises a transparent outer electrode sleeved on the outer side of the first functional photosensitive layer and the second functional photosensitive layer.

3. The linear photovoltaic cell assembly according to claim 1, characterized in that the photovoltaic cell assembly further comprises a connection electrode sleeved on the outer side of the first functional photosensitive layer and the second functional photosensitive layer.

4. The linear photovoltaic cell assembly according to claim 1, characterized in that the photovoltaic cell assembly further comprises a transparent protective layer disposed on the outer side thereof.

5. The linear photovoltaic cell assembly according to claim 1, characterized in that the first functional photosensitive layer and the second functional photosensitive layer are each a heterojunction or homojunction formed of multiple layers of material, including a pn, np, pin, nip, nn+, pp+, nn-, or pp- structure, or a multilayer combination based on the said structures.

6. The linear photovoltaic cell assembly according to claim 3, characterized in that the structural form of the connection electrode includes: binding, winding or twisting with a conductive wire; a conductive snap ring; adhesion with a conductive tape; application of a conductive

adhesive; or covering with a conductive film.

7. The linear photovoltaic cell assembly according to claim 2, characterized in that the material of the transparent outer electrode includes a transparent oxide thin film, a transparent metal thin film, a transparent conductive nano thin film, a transparent conductive carbon film, or a conductive grid mesh.

8. The linear photovoltaic cell assembly according to claim 1, characterized in that the material of the first inner electrode and the second inner electrode includes a metal wire, a carbon fiber, or a conductive fiber, and may also employ an insulating wire whose outer surface is coated with a conductive layer.

9. The linear photovoltaic cell assembly according to claim 1, characterized in that the first inner electrode and the second inner electrode are solid-core or hollow-core conductive wires.

10. The linear photovoltaic cell assembly according to claim 1, characterized in that the photovoltaic cell assembly comprises one or more sets of the first inner electrode and the first functional photosensitive layer, and one or more sets of the second inner electrode and the second functional photosensitive layer.