CLAIMS

1. A tandem photovoltaic device, comprising, in this superimposition order:

A/ a silicon-based sub-cell A comprising at least:

- a substrate made of crystalline~~, for example monocrystalline or polycrystalline, silicon in particular N-type or P-type doped~~ silicon; and

- at least one layer, distinct from said substrate, made of N- or P-doped amorphous or polycrystalline silicon;

and B/ a perovskite-based sub-cell B, comprising at least:

- an N-type conductive or semiconductor layer;

- a P-type conductive or semiconductor layer; and

- a perovskite-type layer that is active from a photovoltaic point of view, interposed between said N-type and P-type conductive or semiconductor layers,

wherein said N-type conductive or semiconductor layer is based on individualised nanoparticles of N-type metal oxide(s), and has an atomic carbon content lower than or equal to 20%,

the active layer being in contact with the N-type metal oxide individualised nanoparticles.

2. The tandem photovoltaic device according to the preceding claim, wherein said sub-cell A is a silicon heterojunction sub-cell or a TOPCon-type architecture sub-cell.

3. The tandem photovoltaic device according to claim 1~~ or 2~~, wherein said sub-cell A is a silicon heterojunction sub-cell, ~~in particular comprises~~comprising, in this stacking order:

- a first electrode denoted $E1^A$;

- a layer made of N-doped or P-doped amorphous silicon;

~~- advantageously, a layer based on intrinsic amorphous silicon, serving as a passivation layer;~~

- said substrate made of crystalline~~, in particular monocrystalline, silicon in particular N-type doped;~~

~~- advantageously, a layer based on intrinsic amorphous silicon, serving as a passivation layer~~ silicon;

- a layer made of P-doped or N-doped amorphous silicon; and

- optionally, a second electrode $E2^A$.

4. The tandem photovoltaic device according to claim 1~~ or 2~~, wherein said sub-cell A is a TOPCon-type architecture sub-cell, comprising~~ in particular~~:

- said substrate made of N- or P-doped crystalline silicon;

- at the face of the substrate intended to form the rear face of the tandem photovoltaic device, a layer made of highly N+ or P+ doped polycrystalline silicon, said layer made of highly doped polycrystalline silicon being separated from said substrate by a passivation layer made of oxide so-called "tunnel oxide~~", in particular silicon oxide SiO_x, in particular SiO_2, or aluminium oxide AlO_x;~~";

- on the side of the opposite face of the substrate, at least one layer made of highly P+ or N+ doped crystalline or polycrystalline silicon of the electrical type opposite to that of the substrate.

5. The tandem photovoltaic device according to ~~any one of the preceding claims~~claim 1, wherein said N-type metal oxide nanoparticles are selected from among particles of zinc oxide, titanium oxides TiO_x with x comprised between 1 and 2, tin oxide, doped zinc oxides, ~~for example aluminium-doped zinc oxide, indium-doped zinc oxide, gallium-doped zinc oxide, doped titanium oxides, for example titanium oxide doped with nitrogen, phosphorus, iron, tungsten or manganese; and mixtures thereof; in particular from among tin oxide nanoparticles, doped zinc oxide nanoparticles, in particular aluminium-doped zinc oxide~~doped titanium oxides; and mixtures thereof.

6. The tandem photovoltaic device according to ~~any one of the preceding claims~~claim 1, wherein said metal oxide nanoparticles have an average particle size comprised between 2 and 100 nm~~, in particular comprised between 5 and 50 nm, in particular comprised between 5 and 20 nm and more particularly between 8 and 15 nm.~~.

7. The tandem photovoltaic device according to ~~any one of the preceding claims~~claim 1, wherein said N-type conductive or semiconductor layer of the sub-cell B has an atomic carbon content lower than or equal to 17~~%, preferably lower than or equal to 15%, in particular comprised between 0 and 15~~%.

8. The tandem photovoltaic device according to ~~any one of the preceding claims~~claim 1, wherein said perovskite-type active layer of the sub-cell B is formed by a perovskite material of formula ABX_3, with:

A representing a cation or a combination of metallic or organic cations;

.~~-~~B representing one or more metallic element(s), ~~such as~~chosen among lead, tin, bismuth and antimony; and

. X representing one or more ~~anion(s), in particular one or more~~ halide(s~~), and more particularly selected from among chloride, bromide, iodide and mixtures thereof;~~) anion(s);

said perovskite material ~~being in particular~~ of formula $Cs_xFA_{1-x}Pb(I_{1-y}Br_y)_3$ with $x<0.17$; $0<y<1$ and FA symbolising the formamidinium cation.

~~8.~~9. The tandem photovoltaic device according to ~~any one of the preceding claims~~claim 1, wherein said perovskite-based sub-cell B comprises, in this stacking order:

- optionally a first electrode $E1^B$;

- said lower conductive or semiconductor layer of the N type in the case of a NIP structure or of the P type in the case of a PIN structure;

- said perovskite-type active layer;

- said upper conductive or semiconductor layer of the P type in the case of a NIP structure or of the N type in the case of a PIN structure,

said N-type layer being based on individualised nanoparticles of N-type metal oxide(s), and has an atomic carbon content lower than or equal to 20%,

- a transparent second electrode, called the upper electrode, $E2^B$, and more particularly formed of a layer made of metallised transparent conductive oxide.

~~9.~~10. The tandem photovoltaic device according to ~~any one of claims 3 and 5 to 9~~claim 3, said device being of the HET/perovskite type with a 2T structure, comprising, in this superimposition order, at least:

- a sub-cell A as described according to claim 3, comprising in this superimposition order:

. said first electrode denoted $E1^A$~~, in particular formed of a metallised conductive transparent layer~~;

. said layer made of N-doped or P-doped amorphous silicon~~, preferably made of N-doped or P-doped hydrogenated amorphous silicon;~~;

~~. advantageously, said layer based on intrinsic amorphous silicon, preferably hydrogenated, serving as a passivation layer;~~

. said substrate made of crystalline~~, in particular monocrystalline and in particular N-type doped,~~ silicon;

~~. advantageously, said layer based on intrinsic amorphous silicon, preferably hydrogenated "a-SiH(i)" serving as a passivation layer;~~

. said layer made of P-doped or N-doped amorphous silicon~~, preferably P-doped or N-doped hydrogenated amorphous silicon~~;

- an electronically conductive or semiconductor intermediate layer, called "recombination layer";

- a sub-cell B as defined in claim 9, comprising in this superimposition order:

. said lower conductive or semiconductor layer of the N type in the case of a NIP structure or of the P type in the case of a PIN structure;

. said perovskite-type active layer;

. said upper conductive or semiconductor layer of the P type in the case of a NIP structure or of the N type in the case of a PIN structure, and

. said second electrode, called the upper electrode, $E2^B$~~, in particular formed of a metallised transparent conductive oxide layer~~.

~~10.~~11. The device according to ~~any one of the preceding claims, characterised in that~~claim 1, wherein the N-type metal oxide individualised nanoparticles are made of SnO_2.

~~11.~~12. A method of manufacturing a tandem photovoltaic device according to ~~any one of claims 1 to 11~~claim 1, comprising at least the following steps:

(a) making said silicon-based sub-cell A; and

(b) making said sub-cell B *via* at least one step of forming said N-type conductive or semiconductor layer from a dispersion of N-type metal oxide nanoparticles in a solvent medium, at a temperature lower than or equal to 150°C, and in operating conditions adjusted so as to obtain the desired atomic carbon content in said N layer, lower than or equal to 20%

and a step during which the active layer is formed over the surface of the N-type metal oxide nanoparticles.

~~12.~~13. The method according to ~~the preceding~~ claim 12, wherein said N-type conductive or semiconductor layer is formed at a temperature lower than or equal to 120°C~~, in particular lower than or equal to 100°C, in particular lower than or equal to 80°C, preferably lower than or equal to 50°C, and more particularly at room temperature~~.

~~13.~~14. The method according to claim 12~~ or 13~~, wherein the carbon content in said N-type conductive or semiconductor layer is controlled by adjusting the level of carbon precursor compounds of the implemented dispersion of metal oxide nanoparticles~~, in particular by implementing a dispersion of metal oxide nanoparticles stabilised *via* the surface potential of the nanoparticles.~~.

~~14.~~15. The method according to ~~any one of claims~~claim 12~~ to 14~~, wherein the carbon content in said N-type conductive or semiconductor layer is controlled, by subjecting, after deposition of said dispersion of metal oxide nanoparticles and prior to the deposition of the overlying layer, the N-type layer to a treatment for eliminating carbon~~, in particular by UV irradiation, by UV-ozone, with ozone and/or by plasma, in particular oxidising; preferably by a treatment by UV irradiation, by UV-ozone and/or with ozone~~.

16. The method according to claim 15, wherein the treatment for eliminating carbon is a treatment by UV irradiation, by UV-ozone, with ozone or by plasma.