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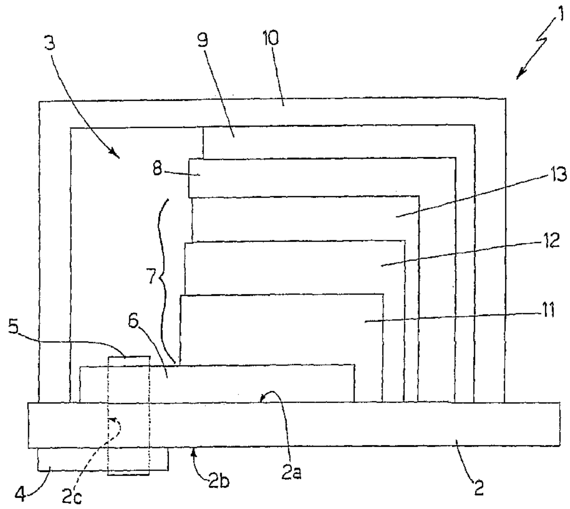

Fig. 1

(57) Abstract: Described herein is a tile (1) made up of: a ceramic base body (2) having an absorption of water equal to or less than 0.5 wt%; a photovoltaic cell (3) applied directly to a first surface (2a) of the ceramic base body (2); a device containing the electrical and/or electronic part (4), applied to a second surface (2b) of the ceramic base body (2); and an electrical connector (5), designed to connect the photovoltaic cell (3) electrically to the device containing the electrical and/or electronic part (4) through the ceramic base body (2).

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"CERAMIC TILE WITH SURFACE FUNCTIONALIZED WITH PHOTOVOLTAIC CELLS"

TECHNICAL FIELD

The present invention relates to a ceramic tile with its surface functionalized with photovoltaic cells.

BACKGROUND ART

With the accentuation of the problems linked to finding traditional energy sources, increasing attention is being directed to the study of the exploitation of alternative energy sources, such as for example solar energy. In this regard, for some time now devices have been produced that exploit the photovoltaic effect and thus convert the energy of solar radiation into electrical energy.

Devices of the above type, on account of their technical characteristics, also appear to afford interesting applications in the production of electrical energy in the private and public building sectors.

DISCLOSURE OF INVENTION

The aim of the present invention is to provide ceramic tiles that comprise photovoltaic cells on their exposed surfaces. In this way, it will be possible to use the tiles for coating external surfaces of buildings and at the same time have available devices capable of supplying the buildings themselves with electrical energy deriving from the conversion of solar energy or introducing said energy into the electrical-supply network.

Forming the subject of the present invention is a tile comprising at least one photovoltaic cell, said tile being characterized in that it comprises: a ceramic base body having an absorption of water equal to or less than 0.5 wt%; a photovoltaic cell applied directly to a first surface of said ceramic base body; a device containing the electrical and/or electronic part, applied to a second surface of said ceramic base body; and an electrical connector designed to connect said photovoltaic cell electrically to said device containing the electrical and/or electronic part through said ceramic base body.

According to a preferred embodiment, the photovoltaic cell comprises a layer of electro-conductive material set directly on said first surface of said ceramic base body, a plurality of active layers, and a layer of electro-conductive material with a preferably grid-like structure; said plurality of active layers comprises at least in succession a layer of an n type, a photo-active intermediate layer, and a layer of a p type.

According to a further preferred embodiment, said photovoltaic cell comprises a transparent conductive layer set between said active layers and said layer of electro-conductive material with a preferably grid-like structure.

BRIEF DESCRIPTION OF THE DRAWING

The examples that follow are provided by way of illustrative and non-limiting example to facilitate a better understanding of the invention with the aid of the figure of the annexed drawing, which is a lateral cross-sectional view of a detail of the tile according to the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Designated as a whole by 1 in the figure is the tile forming the subject of the present invention.

The tile 1 comprises a ceramic base body 2 having a porosity such as to define an absorption of water lower than or equal to 0.5 wt%, determined according to the ISO 10545-3 standard.

The tile 1 comprises: a photovoltaic cell 3 applied to a first surface 2a of the ceramic base body 2; a device 4 containing the electrical and/or electronic part and applied on a second surface 2b opposite to the surface 2a; and an electrical connector 5, which is housed within a hole 2c made in the ceramic base body 2 and through which it connects the photovoltaic cell 3 electrically to the device 4.

The photovoltaic cell 3 comprises in succession: a layer of conductive material 6, set in direct contact with the surface 2a; a complex of active layers 7; a layer of transparent conductive material 8; a preferably grid-shaped layer of conductive material 9; and a transparent protective layer 10.

In particular, the complex of active layers 7 comprises a layer of an n type 11, an intermediate photo-active layer 12, and a layer of a p type 13.

In what follows, two examples of the process of production of the tile forming the subject of the present invention are provided.

EXAMPLE 1

The production of the ceramic base body 2 is obtained by means of dry pressing of an atomized ceramic powder typically used for ceramic tiles, the humidity of which must be comprised between 3 and 6 wt%. Pressing is carried out at a pressure of between 35 MPa and 60 MPa. The operation of pressing can use a die that envisages, on the surface 2b, a recess for housing the device 4 that contains the electrical and/or electronic part.

The crude base body obtained by the operation of pressing is dried, and subsequently one or more holes 2c are made, only one of which is indicated in the figure.

The base body thus processed is subjected to a step of baking at a maximum temperature of between 1100°C and 1250°C. In this way, a ceramic base body 2 is obtained with a porosity equal to or less than 0.5 wt%, determined according to the ISO 10545-3 standard.

Next, applied, for example by means of serigraphic techniques, on the surface 2a of the ceramic base body 2 is an electro-conductive metal layer 6. The electro-conductive layer 6 can consist of a layer of metal, such as for example Ag or an Ag-Al mixture. In order to consolidate said metallic layer and cause it to acquire the necessary properties of electrical conductivity, the semifinished product is subjected to an appropriate thermal treatment that will depend upon the material used. For Ag-based and Ag-Al-based serigraphic pastes, said techniques envisage either a rapid heating/cooling combination undergoing the semifinished product at temperature of 700°C for 5 minutes, or else a thermal treatment from room temperature to 700°C at a heating rate of between 5 and 20°C/min. The final thickness of the conductive layer 6 deposited, after baking will range from 5 to 20 μm.

Deposited in succession on the conductive layer 6 by means of a CVD (Chemical Vapour Deposition) technique, preferably a Plasma-Enhanced CVD (PECVD) technique, are: a layer 11 of n-doped amorphous silicon of a thickness of approximately 30 nm, deposited at a maximum temperature of the substrate of approximately 210°C; a photo-active layer 12 of intrinsic amorphous silicon having a thickness of approximately 580 nm, deposited at a maximum temperature of the substrate of approximately 250°C; and a layer 13 of p-doped amorphous silicon having a thickness of approximately 15 nm, deposited at a maximum temperature of the substrate of approximately 250°C.

Deposited on top of the second layer 13 of amorphous silicon is a transparent electro-conductive layer 8 of indium-tin oxide (ITO) or fluorine-doped tin oxide (FTO), or other transparent metal oxide. Said deposition can be obtained by means of the technique of sputtering at a temperature of the substrate of approximately 250°C to obtain a layer 8 with a maximum thickness of approximately 75 nm.

Deposited on top of the transparent electro-conductive layer 8 is a layer of electro-conductive material 9, such as, for example, silver, preferably grid-shaped. The layer 9 can be deposited by means of the serigraphic technique, the doctor-blade technique, by ink-jet printing, sputtering, or by thermal evaporation. Furthermore, the layer 9 can be consolidated by means of an appropriate thermal treatment that will depend upon the material used.

At this point, a conductive connector 5, of a rigid or elastic type, is inserted within the through holes 2c previously made. The conductive connector 5 can be fixed to the ceramic material by means of special materials to ensure firm adhesion.

The connector of a rigid type comprises, at a first end, a head, which rests on the surface 2a, where it is soldered to the layer of conductive material 6, and can comprise, at a second end facing the surface 2b, a pin tin-soldered on the electrical and/or electronic device 4 or, alternatively, a threaded stem designed to be fixed to the electrical and/or electronic device 4 itself with nuts, thus enabling convenient maintenance. The particular conformations of the connector 5 are only described and not illustrated in the figure for reasons of simplicity.

Used as coating of the photovoltaic cell 3 is a protective transparent layer 10, designed to guarantee high transmittance of solar radiation, resistance to humidity and to atmospheric agents, stability to UV rays, and electrical insulation. The protective layer 10 may be constituted by a low-melting vitreous enamel or, alternatively, a polymeric layer of appropriate composition, such as for example polycarbonate or fluorinated polymers (e.g., polychlorotrifluoroethylene (PCTFE), or a combination of polymethyl methacrylate and polyvinyl fluoride).

Finally, on the surface 2b, the device 4 containing the electrical and/or electronic part is fixed to the connector 5 by being placed within the recess made in the ceramic base body 2. The device 4 containing the electrical and/or electronic part is known and not described in detail herein.

The device containing the electrical and/or electronic part 4 can assume the characteristic of electrically passive component, having the purpose of connecting the tiles in series or in parallel with respect to one another in order to raise the voltage and the current available to values that can be adequately handled by static converters of adequate power, which see to introducing the energy produced into the electrical-supply network. Otherwise, the device containing the electrical and/or electronic part 4 can provide, using MOSFET technology, the MPPT (Maximum Power Point Tracking) function, i.e., define the electrical conditions for supplying the maximum power available as a function of the conditions of insolation, and convey them on an intermediate bus with characteristics suitable to its subsequent introduction into the electrical-supply network, and/or direct use and/or use, for storage in batteries.

<u>EXAMPLE 2</u>

The ceramic tile produced in this second example differs from the tile produced according to Example 1 as regards the composition of the complex of active layers 7 and their production.

Specifically, the base body coming from the step of baking at a maximum temperature of between 1100°C and 1250°C and comprising the conductive layer 6 is subsequently heated to a temperature of 450°C. Deposited thereon is a layer 11 of a thickness of between 70 and 150 nm, preferably 100 nm, of compact TiO_2 by means of sputtering, with a hydro-alcoholic solution, of a precursor of titanium (for example, a solution of titanium(IV) isopropoxide or titanium(IV) isopropoxyacetylacetonate, as described in Kavan, L., Grätzel, M., "Highly efficient semiconducting TiO_2 photoelectrodes prepared by aerosol pyrolysis", Electrochim. Acta, 1995, 40, 5, 643-652). The semifinished product thus obtained is further heated to 500°C for approximately one hour.

The active layer 12, which consists of a mixture of powders of TiO_2 and $CuInS_2$, is deposited on top of the layer 11 of compact TiO_2. The active layer 12 can be made up of either a single layer of a mixture of powders (constituted, for example, for 50 wt% by TiO_2 powder and 50 wt% by $CuInS_2$ powder), or else be constituted by a number of layers; for example, three layers with weight ratios: 70-30/50-50/30-70 respectively of TiO_2 and $CuInS_2$. The active layer is deposited preferably by means of silk-screen printing, but also techniques can be used, such as, for example, the doctor-blade technique, ink-jet printing, printing with silicone rollers, or sputtering. The active layer 12 can be consolidated by means of an appropriate thermal treatment that will depend upon the characteristics of the material used.

The total thickness of the layer (or of the number of layers) is preferably between 1 and 5 μm.

Deposited, with the methods referred to previously, on top of the active layer 12 is a layer of pure $CuInS_2$ 13 with a thickness of between 0.08 and 0.12 μm, preferably 0.1 μm.

At this point, the preparation of the tile proceeds with the deposition of the transparent conductive layer 8, as described in Example 1.

As will emerge obvious to a person skilled in the art, the specific composition of the complex of active layers 7 can differ from the one described above. In particular, the layer of a p type 13 can be made with any compound having the general empirical formula $(IB)(IIIA)(VIA)_2$, where IB designates the elements Cu, Ag, Au; IIIA designates the elements Al, Ga, In, Ti; and VIA designates the elements S, Se, Te.

The present invention makes available a tile with a ceramic base capable of contributing considerably to energy saving, for example insulating a building from the thermal standpoint and simultaneously converting solar energy into electrical energy.

Furthermore, the production steps are conceived in such a way as to enable their integration with the technologies used in the ceramics sector in order to optimize the economics of the process as a whole.

CLAIMS

1. A tile (1) comprising at least one photovoltaic cell, said tile being characterized in that it comprises: a ceramic base body (2) having an absorption of water equal to or less than 0.5 wt%; a photovoltaic cell (3), applied directly on a first surface (2a) of said ceramic base body (2); a device containing the electrical and/or electronic part (4) applied to a second surface (2b) of said ceramic base body (2); and an electrical connector (5), designed to connect said photovoltaic cell (3) electrically to said device containing the electrical and/or electronic part (4) through said ceramic base body.

2. The tile according to Claim 1, characterized in that the photovoltaic cell comprises a layer of electro-conductive material (6), set directly on said first surface (2a) of said ceramic support (2), a plurality of active layers (7), and a layer of electro-conductive material with a preferably grid-like structure (9); said plurality of active layers (7) comprising in succession a layer of an n type (11), a photo-active layer (12) and a layer of a p type (13).

3. The tile according to Claim 2, characterized in that said photovoltaic cell (3) comprises a transparent conductive layer (8), set between said active layers (7) and said layer of electro-conductive material (9).

4. The tile according to Claim 3, characterized in that said photovoltaic cell (3) is coated, insulated and sealed by a protective layer (10) made of one of the materials comprised in the group constituted by vitreous enamel, polycarbonate, fluorinated polymers, polychlorotrifluoroethylene (PCTFE), and a combination of polymethyl methacrylate and polyvinyl fluoride.

5. The tile according to Claim 3 or Claim 4, characterized in that the layer of electro-conductive material (6) is constituted by Ag or Ag-Al, the layer of an n type (11) is constituted by n-doped amorphous silicon, the photo-active layer (12) is constituted by intrinsic silicon, the layer of a p type (13) is constituted by p-doped amorphous silicon, the transparent conductive layer (8) is constituted by ITO or FTO, and the layer of electro-conductive material (9) is constituted by Ag.

6. The tile according to Claim 3 or Claim 4, characterized in that the layer of electro-conductive material (6) is constituted by a material comprised in the group constituted by ITO, ZnO, Ag, Ag-Al, and Mo, the layer of an n type (11) is constituted by compact TiO_2, the photo-active layer (12) is constituted by a mixture of TiO_2 with a compound of general empirical formula $(IIIB)(IVA)(VIA)_2$, the layer of a p type (13) is constituted by a compound of general empirical formula $(IIIB)(IVA)(VIA)_2$, the transparent conductive layer (8) is constituted by ITO and the layer of electro-conductive material (9) is constituted by Ag;

- IB being one of the elements comprised in the group constituted by Cu, Ag, Au;
- IIIA being one of the elements comprised in the group constituted by Al, Ga, In, Ti; and
- VIA being one of the elements comprised in the group constituted by S, Se, Te.

7. The tile according to Claim 6, characterized in that the compound of general empirical formula $(IIIB)(IVA)(VIA)_2$ is $CuInS_2$.

8. A method for the production of a tile according to one of the preceding claims, characterized in that the ceramic base body (2) is obtained by means, in succession, of an operation of pressing, in which an atomized ceramic powder with a

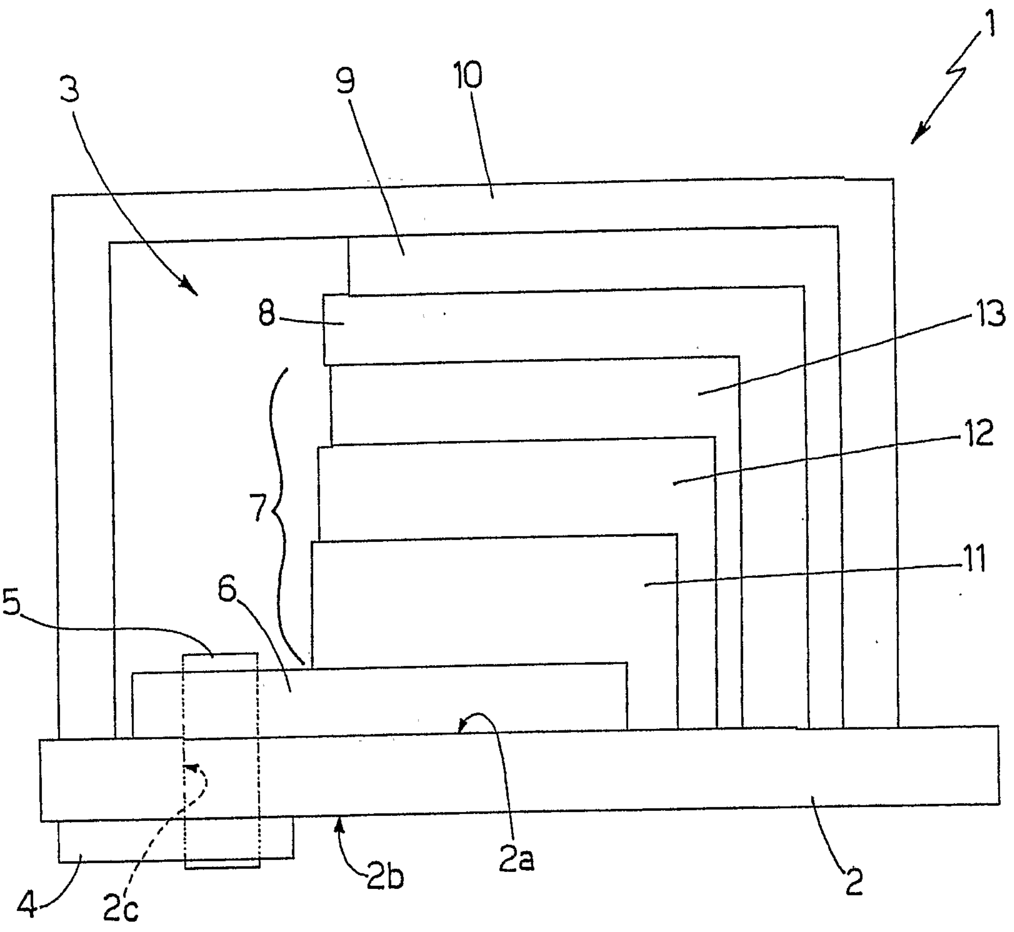
humidity of between 3 wt% and 6 wt% is subjected to an operation of pressing at a pressure of between 35 and 60 MPa, an operation of drying, and an operation of baking at a maximum temperature of between 1100 and 1250°C.

9. The method according to Claim 8, characterized in that it comprises a step of formation of a photovoltaic cell (3) on a surface (2a) of said ceramic base body (2); said step of formation of the photovoltaic cell (3) comprising a plurality of operations of deposition, in which a material previously formed is deposited for the production of respective functional layers (6, 8, 9, 11, 12, 13).

10. The method according to Claim 9, characterized in that each of said operations of deposition is obtained by means of a technique comprised between silk-screen printing, printing by means of silicone rollers, the doctor-blade technique, ink-jet printing, or sputtering.

11. The method according to any one of Claims 8 to 10, characterized in that said operations of deposition of the active layers (11, 12, 13) of amorphous silicon are obtained using the CVD (Chemical Vapour Deposition) technique.

12. The method according to Claim 11, characterized in that said operations of deposition of the active layers (11, 12, 13) of amorphous silicon are obtained by means of the Plasma-Enhanced CVD or Radio-Frequency CVD technique.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INTERNATIONAL SEARCH REPORT

International application No
PCT/IT2007/000241

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INV. H01L31/048 H01L31/0336

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	D. IENCINELLA, E. CENTURIONI, A. SALOMONI, B. MAZZANTI, M.G. BUSANA, A. FREGNI, S. FAZIO: "Solar Cells on Porcelain Stoneware Tiles" 21ST EUROPEAN PHOTOVOLTAIC SOLAR ENERGY CONFERENCE, 4 September 2006 (2006-09-04), - 8 September 2006 (2006-09-08) pages 1697-1699, XP002447141 Dresden, Germany paragraphs [0001], [02.1], [03.1] - [03.3]; figures 1,3,4 ----- -/--	1-7

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA/	Authorized officer
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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