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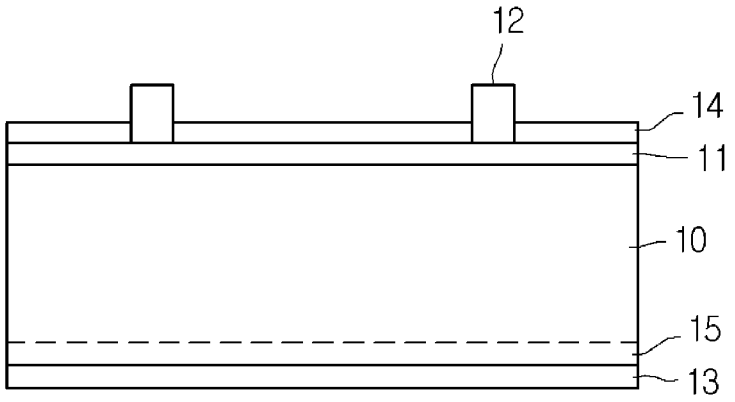
(54) **Title**: GLASS FRIT, PASTE COMPOSITION, AND SOLAR CELL

[Fig. 1]



(57) **Abstract**: Disclosed are glass frit, paste composition, and a solar cell. The glass frit contained in the paste composition for a front electrode of the solar cell includes about 71.8 weight% to about 90 weight% of PbO, about 4.9 weight% to about 12 weight % of SiO_2, about 4.9 weight% to about 11 weight% of B_2O_3, about 0.5 weight% to about 5 weight% of ZnO, about 0.3 weight% to about 0.5 weight% of Fe_2O_3, about 0.2 weight% to about 0.5 weight% of Cr_2O_3, about 0.1 weight% to about 0.4 weight% of Co_2O_3 or CoO, and about 0.3 weight% to about 0.5 weight% of MnO_2.

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Description

Title of Invention: GLASS FRIT, PASTE COMPOSITION, AND SOLAR CELL

Technical Field

[1] The disclosure relates to glass frit, paste composition including the same, and a solar cell including an electrode formed by using the paste composition.

Background Art

[2] Recently, the development of next generation clean energy has become more important due to the lack of fossil fuel. Among the next generation clean energy, a solar cell is spotlighted as an energy source for solving the future energy problem because it rarely causes environmental pollution and has the semi-permanent life span and there exists infinite resources for the solar cell.

[3] The solar cell may include front and back electrodes formed on a silicon substrate having N and P type semiconductors. After the paste composition for the front electrode has been formed on an anti-reflective layer, if heat is applied to the paste composition, the paste composition flows through the anti-reflective layer by the glass frit due to the punch through phenomenon so that the front electrode is electrically connected to the silicon substrate. Therefore, the glass frit has the important function for the paste composition. However, if the glass frit is not optimized, high efficiency cannot be achieved.

Disclosure of Invention

Technical Problem

[4] The disclosure provides glass frit capable of realizing high-efficiency solar cell and paste composition including the same, and the solar cell including a front electrode formed by using the paste composition.

Solution to Problem

[5] According to the embodiment, glass frit constituting paste composition for a front electrode of a solar cell includes about 71.8 weight% to about 90 weight% of PbO, about 4.9 weight% to about 12 weight% of SiO_2, about 4.9 weight% to about 11 weight% of B_2O_3, about 0.5 weight% to about 5 weight% of ZnO, about 0.3 weight% to about 0.5 weight% of Fe_2O_3, about 0.2 weight% to about 0.5 weight% of Cr_2O_3, about 0.1 weight% to about 0.4 weight% of Co_2O_3 or CoO, and about 0.3 weight% to about 0.5 weight% of MnO_2.

[6] The glass frit further comprises about 0.1 weight% to about 5 weight% of Al_2O_3.

[7] The glass frit further comprises about 0.1 weight% to about 0.2 weight% of MgO.

[8] The glass frit further comprises about 0.1 weight% to about 5 weight% of TiO_2.

[9] The glass frit comprises at least one selected from the group consisting of SrO, BaO, and ZrO.

[10] The glass frit comprises less than about 5 weight% of at least one selected from the group consisting of SrO, BaO, and ZrO.

[11] The glass frit further comprises at least one selected from the group consisting of AgO, Ag_2O, and CaO.

[12] The further comprises about 0.1 weight% to about 5 weight% of at least one selected from the group consisting of AgO, Ag_2O, and CaO.

[13] A paste composition for a front electrode of a solar cell includes glass frit comprising about 71.8 weight% to about 90 weight% of PbO, about 4.9 weight% to about 12 weight% of SiO_2, about 4.9 weight% to about 11 weight% of B_2O_3, about 0.5 weight% to about 5 weight% of ZnO, about 0.3 weight% to about 0.5 weight% of Fe_2O_3, about 0.2 weight% to about 0.5 weight% of Cr_2O_3, about 0.1 weight% to about 0.4 weight% of Co_2O_3 or CoO, and about 0.3 weight% to about 0.5 weight% of MnO_2, conductive powder, and an organic vehicle.

[14] The paste composition includes about 1 weight% to about 10 weight% of the glass frit, about 60 weight% to about 90 weight% of the conductive powder, about 10 weight% to about 20 weight% of the organic vehicle, and about 1 weight% to about 10 weight% of a dispersing agent.

[15] The organic vehicle includes a solvent and an organic binder. The organic binder includes at least one selected from the group consisting of acrylate resin, ethyl-cellulous, nitrocellulous, a polymer of ethylcellulous and phenol resin, wood rosin, and polymethacrylate of alcohol. The solvent includes at least one selected from the group consisting of butylcarbitolacetate, butylcarbitol, butylcellosolve, butylcello-solveacetate, propyleneglycolmonomethylether, dipropyleneglycolmonomethylether, propyleneglycolmonomethylpropionate, ethyletherpropionate, terpineol, propyleneglycolmonomethyletheracetate, dimethylamino formaldehyde, methylethylketone, gamma-butyrolactone, ethyllactate, and texanol.

[16] The glass frit further includes about 0.1 weight% to about 5 weight% of Al_2O_3.

[17] The glass frit further includes about 0.1 weight% to about 0.2 weight% of MgO.

[18] The glass frit further includes about 0.1 weight% to about 5 weight% of TiO_2.

[19] The glass frit includes at least one selected from the group consisting of SrO, BaO, and ZrO.

[20] The glass frit includes less than about 5 weight% of at least one selected from the group consisting of SrO, BaO, and ZrO.

[21] The glass frit further includes at least one selected from the group consisting of AgO, Ag_2O, and CaO.

[22] The glass frit includes about 0.1 weight% to about 5 weight% of at least one selected

from the group consisting of AgO, Ag_2O, and CaO.

[23] A solar cell comprising a front electrode formed by using the paste composition.

[24]

Advantageous Effects of Invention

[25] According to the embodiment, the efficiency of the solar cell can be increased.

Brief Description of Drawings

[26] FIG. 1 is a sectional view showing a solar cell;

[27] FIG. 2 is a photograph showing a front electrode manufactured using a paste composition according to the first embodiment; and

[28] FIG. 3 is a photograph showing the front electrode manufactured using the paste composition according to the first embodiment.

Best Mode for Carrying out the Invention

[29] Hereinafter, glass frit, paste composition including the glass frit and used for a front electrode for a solar cell (hereinafter, referred to as paste composition), and the solar cell including the front electrode manufactured using the paste composition according to the embodiment will be described in detail.

[30] The paste composition according to the embodiment may include conductive powder, an organic vehicle, glass frit, and additions, and the details thereof will be described in more detail.

[31]

[32] (a) Conductive Powder

[33] The conductive powder includes silver (Ag), silver oxide, the alloy of Ag, the compound of Ag, or material capable of extracting Ag powder through a sintering process. The conductive powder may include the single material or the mixture of at least two kinds of the above materials. However, preferably, the conductive powder may include silver powder.

[34] The conductive powder may have various shapes such as a spherical shape or a flake shape. The conductive powder may include the single material or the mixture of at least two materials.

[35] As the grain size of the Ag powder is increased, the sintering speed is lowered. Accordingly, the grain size of the Ag powder may be set by taking into consideration a desired sintering speed and an influence exerted on a process of forming an electrode. For example, the grain size of the Ag powder may be in the range of about 0.5um to about 4um. If the mean grain size of the Ag powder is less than 0.5, spaces among the conductive powders for receiving organic materials may be diminished, so distribution does not smoothly occur. If the mean grain size of the Ag powder exceeds 4, air gaps of conductive powders may be enlarged, so that the degree of compaction is degraded,

and resistance is increased.

[36] The purity of Ag powder may have various values to satisfy a condition generally required as an electrode. For example, the Ag powder may have the purity of about 90% or more, and preferably has the purity of about 95% or more.

[37] In this case, about 60 weight% to about 90 weight% of conductive powders may be contained in the whole paste composition. If less than 60 weight% of the conductive powder is used, the resistance of the front electrode may be increased due to a small amount of conductive powder. If more than 90 weight% of the conductive powder is used, the viscosity is increased, so that the printing property of the paste is degraded, and the price of the paste may be increased.

[38]

[39] (b) Glass Frit

[40] The glass frit is mixed with the conductive powders to allow the conductive powders to be strongly bonded to a substrate in a sintering process.

[41] The glass frit may be selected from the group consisting of PbO, SiO_2, B_2O_3, ZnO, Fe_2O_3, Cr_2O_3, Co_2O_3 (or CoO) and MnO_2 based-compositions. The glass frit may additionally include Al_2O_3, MgO, TiO_2, SrO, BaO, ZrO, AgO (or Ag_2O), and CaO. If at least two compositions are contained in the glass frit, the compositions and the composition ratio may exert an influence on the contact property between the front electrode and the silicon substrate. In this regard, according to the embodiment, the glass frit includes various oxides. In contrast, the conventional glass frit includes restricted types of oxides. The conventional glass frit mainly includes PbO and SiO_2.

[42] In this case, the glass frit includes about 71.8 weight% to about 90 weight% of PbO, about 4.9 weight% to about 12 weight% of SiO_2, about 4.9 weight% to about 11 weight% of B_2O_3, about 0.5 weight% to about 5 weight% of ZnO, about 0.3 weight% to about 0.5 weight% of Fe_2O_3, about 0.2 weight% to about 0.5 weight% of Cr_2O_3, about 0.1 weight% to about 0.4 weight% of Co_2O_3 (or CoO), and about 0.3 weight% to about 0.5 weight% of MnO_2.

[43] In this case, about 71.8 weight% to about 90 weight% of PbO, about 4.9 weight% to about 12 weight% of SiO_2, and about 4.9 weight% to about 11 weight% of B_2O_3 allow the paste composition to etch an anti-reflective layer (for example, SiN layer) to pass through the anti-reflective layer while adjusting an amount of Ag infiltrating into the silicon substrate. Accordingly, the contact characteristic between the front electrode formed by using the paste composition and the silicon substrate can be improved.

[44] ZnO is added in order to improve the light absorption coefficient. As described above, about 0.5 weight% to about 5 weight% of ZnO may be contained. This range of the ZnO can minimize the variation in a glass transition temperature and a glass characteristic while improving efficiency.

[45] Fe_2O_3, Cr_2O_3, Co_2O_3 (or CoO), and MnO_2 is added in order to improve excitation voltage effect by reducing excitation voltage. The excitation voltage means the minimum voltage to supply the minimum energy required to excite atoms or molecules in a ground state due to the collision of the atoms or the molecules. As described above, according to the embodiment, Fe_2O_3, Cr_2O_3, Co_2O_3 (or CoO), and MnO_2 is contained so that the excitation voltage can be reduced, thereby improving the efficiency of a solar cell.

[46] In this case, about 0.3 weight% to about 0.5 weight% of Fe_2O_3, about 0.2 weight% to about 0.5 weight% of Cr_2O_3, about 0.1 weight% to about 0.4 weight% of Co_2O_3 or CoO, and about 0.3 weight% to about 0.5 weight% of MnO_2 can be contained, and theses composition ratio ranges minimize the variation in glass transition temperature and characteristics while improving efficiency.

[47] In addition, the glass frit according to the embodiment may further contain Al_2O_3. The Al_2O_3 is contained to improve the contact effect between the glass frit and the conductive powder. In this case, Al_2O_3 occupies about 0.1 weight% to about 5 weight% based on the whole content of the glass frit. If less than 0.1 weight% of Al_2O_3 is contained in the glass frit, the contact effect is not sufficiently represented. If more than 5 weight% of Al_2O_3 is contained in the glass frit, the glass transition temperature may be raised, so that glass melting may be difficult.

[48] The glass frit according to the embodiment may include SrO, BaO, or ZrO, so that light absorption efficiency can be improved, shunt resistance (Rsh) can be increased, and the series resistance can be lowered. In general, the electrical characteristics of the solar cell depend on the series resistance (Rs) and the shunt resistance (Rsh). The composition of the interface of the front electrode and the fine structure of the front electrode determine the series resistance (Rs). SrO, BaO or ZrO can improve the light absorption coefficient and is contained in the glass frit. In addition, the series resistance (Rs) can be reduced, and the shunt resistance (Rsh) can be increased, so that the efficiency of the solar cell can be improved.

[49] The glass frit may contain less than 5 weight% of SrO, BaO, or Zr. For example, the glass frit may contain 0.1 weight% to 5 weight% of SrO, BaO, or ZrO.

[50] In addition, the glass frit according to the embodiment contains AgO or Ag_2O so that the crystallization effects of silver can be improved. Accordingly, after metallization has been performed, silver is extracted, so that efficiency can be improved. In this case, the glass frit may contain about 0.1 weight% to about 5 weight% of AgO or Ag_2O. For example, the glass frit may contain about 1 weight% of AgO or Ag_2O. In these composition ratio ranges, the crystallization of silver can be effectively achieved.

[51] In addition, the glass frit further contains CaO, so that the glass transition temperature can be adjusted. The glass frit may contain about 0.1 weight% to about 5

weight% of CaO. For example, the glass frit may contain about 2 weight% of CaO. In this range, the glass transition temperature can be effectively adjusted.

[52] The glass frit does not contain an alkali-based compound such as Li_2O, Na_2O or K_2O. When the alkali-based compound is contained in the paste composition, the alkali-based compound may cause Ag migration or color change. In other words, the glass frit contains alkali-based compound so that the reliability can be improved.

[53] Such the glass frit may occupy about 1 weight% to about 10 weight% based on the whole content of the paste composition. If less than 1 weight% of the glass frit is contained in the paste composition, a desired effect may not be obtained. If more than 10 weight% of the glass frit is contained in the paste composition, an anti-reflective layer may be excessively etched.

[54]

[55] (c) Organic Vehicle

[56] When the front electrode is formed, the front electrode may include an organic vehicle together with the conductive powder and the glass frit such that the front electrode has the form of a paste to obtain the optimum characteristic.

[57] The front electrode may include various organic vehicles. The organic vehicle may include the mixture solution of a solvent and an organic binder.

[58] The organic binder may include one selected from the group consisting of acrylate resin, ethylcellulous, nitrocellulous, a polymer of ethylcellulous and phenol resin, wood rosin, and polymethacrylate of alcohol. Preferably, the organic binder may include ethylcellulous.

[59] The solvent may include one or at least two selected from the group consisting of butylcarbitolacetate, butylcarbitol, butylcellosolve, butylcellosolveacetate, propyleneglycolmonomethylether, dipropyleneglycolmonomethylether, propyleneglycolmonomethylpropionate, ethyletherpropionate, terpineol, propyleneglycolmonomethyletheracetate, dimethylamino formaldehyde, methylethylketone, gamma-butyrolactone, ethyllactate, and texanol. Preferably, the solvent may include butylcarbitolacetate.

[60] The organic vehicle may be selected from the group consisting of a phosphoric dispersing agent, a thixotropic agent, a leveling agent, and an anti-foaming agent. The thixotropic agent may include urea, amide, or urethane-based polymer/organic material, or may include inorganic silica.

[61] The paste composition may include 10 weight% to 20 weight% of the organic vehicle may be contained. The composition ratio range provides viscosity facilitating printing (e.g., screen printing) and prevents a paste from flowing down after the printing has been finished. Accordingly, the composition of the coated paste may represent a proper aspect ratio.

[62] Preferably, the paste composition for the front electrode according to the embodiment contains about 1 weight% to 10 weight% of other dispersing agents and thixotropic agents. According to the embodiment, various types of dispersing agents and thixotropic agents may be used. In other words, generally-known dispersing agents and thixotropic agents may be used. The thixotropic agents may include urea, amide, or urethanebased polymer/organic material or may include inorganic-based silica.

[63] In addition, the paste composition additionally includes additions if necessary. For example, the additions may include a sintering additive, a thickening agent, a stabilizer, or a surfactant.

[64] Hereinafter, a method of preparing the glass frit and the paste composition including the same and a method of manufacturing a solar cell by using the paste composition according to the embodiment will be described.

[65]

[66] Preparation of Glass Frit

[67] Regarding the composition of the glass frit according to the embodiment, materials constituting the glass frit are mixed with each other such that the materials have the above composition range. In this case, the mixture is achieved by using a ball mill or a planetary mill.

[68] After drying the composition at a temperature of about 110℃, the composition is sintered at the temperature of about 900℃ to 1300℃, and quenched at a temperature of 25℃ which is a normal temperature.

[69] The result is coarsely pulverized by a disk mill, and then finely pulverized by the planetary mill, thereby preparing the composition of the glass frit.

[70] The grains of the glass frit may have various sizes. Preferably, the grains of the glass frit may have a mean size of about 0.1 nm to about 10 nm. If the mean size of the grains of the glass frit is in the above range, the paste may have proper viscosity. In addition, interfacial reaction can be prevented from being reduced.

[71]

[72] Preparation of Paste composition

[73] About 1 weight% to about 10 weight% of the glass frit is preferably mixed with about 60 weight% to about 90 weight% of silver powder which is conductive powder. The glass frit and the silver powder may be mixed and stirred by various mixing and stirring units capable of uniformly mixing and stirring the glass frit and the silver powder.

[74] The organic vehicle serving as a binder is added to the mixture and stirred. This is necessary to prepare the mixture of the glass frit and the silver powder in the form of a paste. In this case, the content of the organic vehicle is preferably in the range of about 10 weight% to about 20 weight%.

[75] The composition ratio range allows the paste composition to easily be screen-printed and have the proper viscosity. In addition, the composition ratio range prevents the paste composition from flowing down after the printing has been finished, so that a proper aspect ratio can be obtained.

[76] About 1 weight% to about 10 weight% of dispersing agents and various additions are added to the result and mixed with the result by using the generally-known mixing and stirring units so that the uniform paste composition can be prepared. A solvent is added to the paste composition having the mixture, and mixed with the paste composition.

[77] Through the above process steps, the paste composition including the conductive powder, the glass frit, and the organic vehicle and used to form a front electrode may be prepared.

[78]

[79] Manufacturing of Solar Cell

[80] Referring to FIG. 1, the solar cell includes a P type silicon substrate 10 provided at a front surface thereof with an N type semiconductor part 11, a front electrode 12 electrically connected to the N type semiconductor part 11, and a back electrode 13 electrically connected to the P type silicon substrate 10. An anti-reflective layer 14 may be formed on a top surface of the N type semiconductor part 11 except for the front electrode 12. The front electrode 12 may be connected to the N type semiconductor part 11 through the anti-reflective layer 14. In addition, the silicon substrate 10 having the back electrode 13 is provided thereon with a BSF (Back Surface Field) 15.

[81] In order to manufacture the solar cell, a tabbing electrode is primarily printed. Thereafter, the tabbing electrode is dried at a temperature of about 190℃ to about 210℃. Thereafter, the back electrode 13 is printed by using generally-known back surface paste composition including aluminum particles and dried at a temperature of about 190℃.

[82] After the back electrode 13 has been dried and completed, the paste composition according to the embodiment is printed on the front electrode 12 and dried under a condition the same as a condition in which the back electrode 12 is dried. Accordingly, the solar cell has been completely manufactured.

[83] The front and rear electrodes 12 and 13 include metallic electrodes including silver and aluminum. However, the electrode according to the embodiment may include various kinds of materials. The silver electrode has superior conductivity and aluminum electrode has superior electrical conductivity and superior affinity with respect to the silicon substrate 10 so as to be smoothly bonded with the silicon substrate 10.

[84] The front and rear electrodes 12 and 13 may be formed on the silicon substrate through generally-well known schemes. Preferably, the front and rear electrodes 12

and 13 may be formed on the silicon substrate through the screen-printing scheme. In other words, the front electrode 12 is formed by screen-printing the paste for the front electrode according to the embodiment on a position, at which the front electrode 12 is formed, as described above and then performing an annealing process. When the back electrode 13 is subject to the annealing process, aluminum constituting the electrode is spread through the back surface of the substrate 10, so that the BSF 15 may be formed at the boundary surface between the rear electrode 13 and the silicon substrate 10. After the BSF 15 has been formed, the BSF 15 prevents carriers from moving to the back surface of the silicon substrate 10 and recombined. If the recombination of the carriers is prevented, the open voltage and the reliability are improved, so that the conversion efficiency of the solar cell can be improved.

[85] The front and rear electrodes 12 and 13 may be formed by using a conventional photolithography process and a conventional metal deposition process in addition the screen-printing process. Therefore, the front and rear electrodes 12 and 13 according to the embodiment may be formed through various processes.

[86] Hereinafter, embodiments of the disclosure will be described. The embodiments may have various modifications within the scope of the disclosure.

[87]

[88] **Embodiment 1 (SJ7)**

[89] Preparation of Glass Frit

[90] About 77.9 weight% of PbO, about 11.6 weight% of SiO_2, about 7.6 weight% of B_2O_3, about 0.4 weight% of Al_2O_3, about 1.2 weight% of ZnO, about 0.4 weight% of Fe_2O_3, about 0.4 weight% of Cr_2O_3, about 0.1 weight% of CoO, and about 0.4 weight% of MnO_2 are mixed with each other by using a ball mill and dried at a temperature of about 80°C. Then, the mixture is melted at a temperature of about 1000°C, and quenched at a normal temperature. The result is coarsely pulverized by using a disk mill, and finely pulverized by using a planetary mill. Accordingly, the glass frit having a mean grain size of about 3 um can be prepared.

[91]

[92] Preparation of Paste Composition

[93] About 5 weight% of the glass frit, about 75 weight% of silver powder, and about 20 weight% of an organic vehicle are uniformly mixed with each other and stirred through a ball mill scheme, so that the paste composition has been prepared.

[94] After forming a front electrode on a single silicon wafer cell using the paste composition, five-time tests are performed. The results of the average measurement efficiency obtained through the five-time tests are represented table 1.

[95]

[96] **Embodiment 2 (SJ22)**

[97] Preparation of Glass Frit

[98] About 77.9 weight% of PbO, about 7.52 weight% of SiO_2, about 4.525 weight% of B_2O_3, about 0.4 weight% of Al_2O_3, about 1.2 weight% of ZnO, 1 weight% of Ag_2O, about 2 weight% of $CaCO_3$, about 3 weight% of $BaCO_3$, about 0.4 weight% of Fe_2O_3, about 0.4 weight% of Cr_2O_3, about 0.10 weight% of Co_2O_3, and about 0.4 weight% of MnO_2 are mixed with each other by using a ball mill and dried at a temperature of about 80℃. Then, the mixture is melted at a temperature of about 1000℃, and quenched. The result is coarsely pulverized by using the disk mill, and finely pulverized by using the planetary mill. Accordingly, the glass frit having a mean grain size of about 3 um can be prepared.

[99]

[100] Preparation of Paste Composition

[101] About 5 weight% of the glass frit, about 75 weight% of silver powder, and about 20 weight% of an organic vehicle are uniformly mixed with each other and stirred through a ball mill scheme, so that the paste composition has been prepared.

[102] After forming a front electrode on a single silicon wafer cell using the paste composition, five-time tests are performed. The results of the average measurement efficiency obtained through the five-time tests are represented table 1. The photograph of the front electrode manufactured by using the paste composition according to the first embodiment is shown in FIG. 2, and the photograph of the section of the front electrode manufactured by using the paste composition according to the first embodiment is shown in FIG. 3.

[103]

[104] Table 1

[Table 1]

[Table]

	실시예 1	실시예 2
Isc (A)	8.61	8.51
Poc (V)	0.624	0.627
Pmax (W)	4.09	4.19
Ipm (A)	8.03	7.96
Vpm (A)	0.51	0.53
Jsc (mA/cm^2)	36.02	35.63
F.F(%)	0.762	0.785
Eff(%)	17.12	17.550
Rsh (Ohm)	19.93	13.79
Rs (Ohm)	0.0066	0.0125
C Area	238.95	238.95

[105] Referring to FIG. 1, the solar cell according to the first and second embodiments has a superior characteristic. Referring to FIG. 2, the front electrode according to the first embodiment has a superior contact characteristic. Referring to FIG. 3, the front electrode according to the first embodiment is formed through the anti-reflective layer, so that metallization can be smoothly achieved.

[106] Any reference in this specification to one embodiment, an embodiment, example embodiment, etc., means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. The appearances of such phrases in various places in the specification are not necessarily all referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with any embodiment, it is submitted that it is within the purview of one skilled in the art to effect such feature, structure, or characteristic in connection with other ones of the embodiments.

[107] Although embodiments have been described with reference to a number of illustrative embodiments thereof, it should be understood that numerous other modifications and embodiments can be devised by those skilled in the art that will fall within the spirit and scope of the principles of this disclosure. More particularly, various variations and modifications are possible in the component parts and/or arrangements of the subject combination arrangement within the scope of the disclosure, the drawings and the appended claims. In addition to variations and modifications in

the component parts and/or arrangements, alternative uses will also be apparent to those skilled in the art.

[108]

Claims

[Claim 1] Glass frit constituting paste composition for a front electrode of a solar cell, the glass frit comprising:
about 71.8 weight% to about 90 weight% of PbO;
about 4.9 weight% to about 12 weight% of SiO_2;
about 4.9 weight% to about 11 weight% of B_2O_3;
about 0.5 weight% to about 5 weight% of ZnO;
about 0.3 weight% to about 0.5 weight% of Fe_2O_3;
about 0.2 weight% to about 0.5 weight% of Cr_2O_3;
about 0.1 weight% to about 0.4 weight% of Co_2O_3 or CoO; and
about 0.3 weight% to about 0.5 weight% of MnO_2.

[Claim 2] The glass frit of claim 1, wherein the glass frit further comprises about 0.1 weight% to about 5 weight% of Al_2O_3.

[Claim 3] The glass frit of claim 1, wherein the glass frit further comprises about 0.1 weight% to about 0.2 weight% of MgO.

[Claim 4] The glass frit of claim 1, further comprising about 0.1 weight% to about 5 weight% of TiO_2.

[Claim 5] The glass frit of claim 1, wherein the glass frit comprises at least one selected from the group consisting of SrO, BaO, and ZrO.

[Claim 6] The glass frit of claim 1, wherein the glass frit comprises less than about 5 weight% of at least one selected from the group consisting of SrO, BaO, and ZrO.

[Claim 7] The glass frit of claim 1, further comprising at least one selected from the group consisting of AgO, Ag_2O, and CaO.

[Claim 8] The glass frit of claim 1, further comprising about 0.1 weight% to about 5 weight% of at least one selected from the group consisting of AgO, Ag_2O, and CaO.

[Claim 9] A paste composition for a front electrode of a solar cell comprising:
glass frit comprising about 71.8 weight% to about 90 weight% of PbO, about 4.9 weight% to about 12 weight% of SiO_2, about 4.9 weight% to about 11 weight% of B_2O_3, about 0.5 weight% to about 5 weight% of ZnO, about 0.3 weight% to about 0.5 weight% of Fe_2O_3, about 0.2 weight% to about 0.5 weight% of Cr_2O_3, about 0.1 weight% to about 0.4 weight% of Co_2O_3 or CoO, and about 0.3 weight% to about 0.5 weight% of MnO_2;
conductive powder; and
an organic vehicle.

[Claim 10] The paste composition of claim 9, wherein the paste composition includes about 1 weight% to about 10 weight% of the glass frit, about 60 weight% to about 90 weight% of the conductive powder, about 10 weight% to about 20 weight% of the organic vehicle, and about 1 weight% to about 10 weight% of a dispersing agent.

[Claim 11] The paste composition of claim 9, wherein the organic vehicle includes a solvent and an organic binder,
wherein the organic binder includes at least one selected from the group consisting of acrylate resin, ethylcellulous, nitrocellulous, a polymer of ethylcellulous and phenol resin, wood rosin, and polymethacrylate of alcohol, and
wherein the solvent includes at least one selected from the group consisting of butylcarbitolacetate, butylcarbitol, butylcellosolve, butylcellosolveacetate, propyleneglycolmonomethylether, dipropyleneglycolmonomethylether, propyleneglycolmonomethylpropionate, ethyletherpropionate, terpineol, propyleneglycolmonomethyletheracetate, dimethylamino formaldehyde, methylethylketone, gamma-butyrolactone, ethyllactate, and texanol.

[Claim 12] The paste composition of claim 9, wherein the glass frit further comprises about 0.1 weight% to about 5 weight% of Al_2O_3.

[Claim 13] The paste composition of claim 9, wherein the glass frit further comprises about 0.1 weight% to about 0.2 weight% of MgO.

[Claim 14] The paste composition of claim 9, wherein the glass frit further comprises about 0.1 weight% to about 5 weight% of TiO_2.

[Claim 15] The paste composition of claim 9, wherein the glass frit includes at least one selected from the group consisting of SrO, BaO, and ZrO.

[Claim 16] The paste composition of claim 9, wherein the glass frit includes less than about 5 weight% of at least one selected from the group consisting of SrO, BaO, and ZrO.

[Claim 17] The paste composition of claim 9, wherein the glass frit further comprises at least one selected from the group consisting of AgO, Ag_2O, and CaO.

[Claim 18] The paste composition of claim 9, wherein the glass frit includes about 0.1 weight% to about 5 weight% of at least one selected from the group consisting of AgO, Ag_2O, and CaO.

[Claim 19] A solar cell comprising a front electrode formed by using the paste composition claimed according to claim 9.

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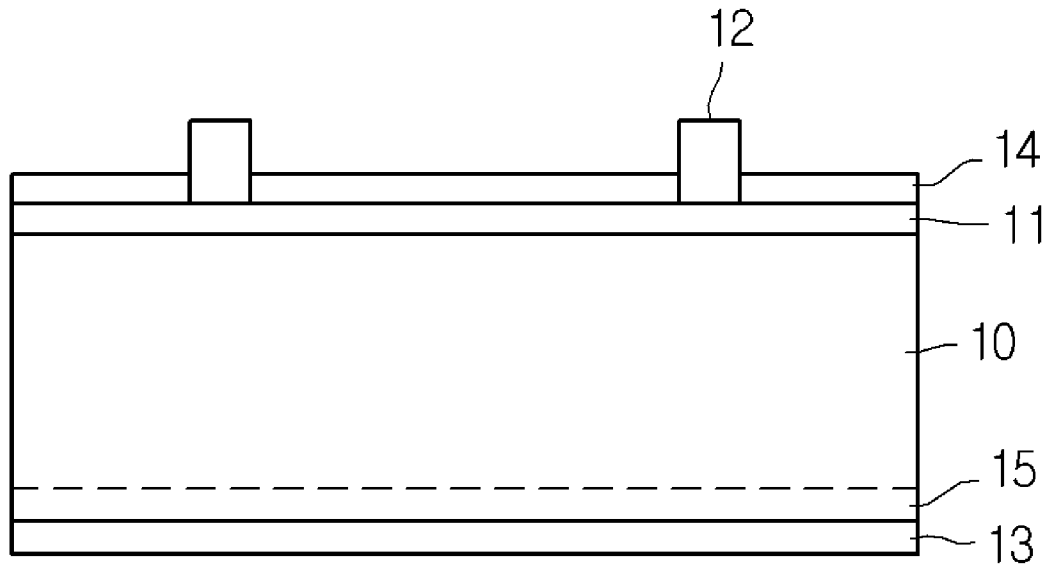
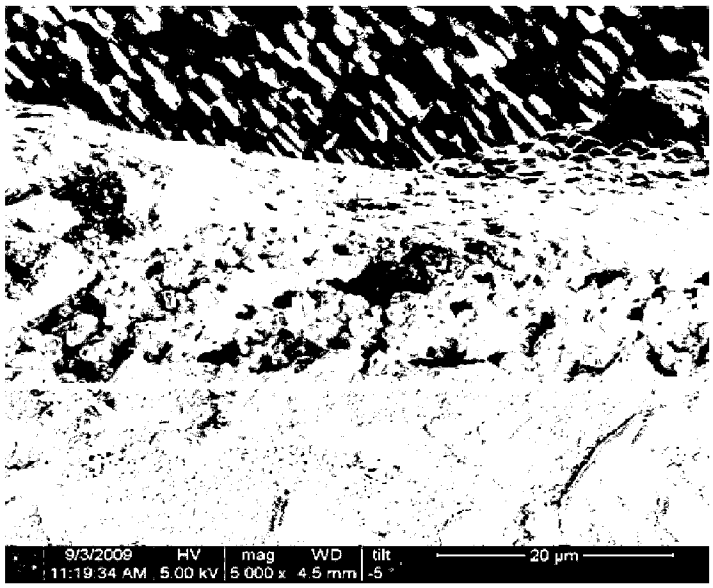
[Fig. 1]



[Fig. 2]



[Fig. 3]