[0007]

One simpler method suited for mass production is by premixing a dopant in a conductive paste as the electrode-forming material, as proposed in, for example, D. L. Meier, H. P. Davis, R. A. Garcia, J. A. Jessup, Proc. the 28th IEEE Photovoltaic Specialists Conference, p.69, 2000. With this method, P is added to Ag paste as dopant, for example, the paste is printed onto a silicon substrate, and the paste is fired at or above the eutectic point of Ag and Si. While the portion of silicon onto which the Ag paste has been applied is once melted and recrystallized upon cooling, P in the Ag paste is taken into the silicon, whereby a high concentration P-doped region is formed immediately below the electrode-forming portion. This method is commonly referred to as "self-doping" and the conductive paste for implementing the method is referred to as "self-doping paste." The above article reports that the method actually results in a good electrical contact between Ag and Si.

[0008]

On the other hand, the self-doping paste contains a dopant for forming a self-doped region, an additive for effectively forming a high-concentration doping layer, and the like in relatively high proportions. For this reason, while the self-doping paste provides a good electrical contact between electrode and silicon, the content of metal particles contributing to the conduction of charge extracted from the silicon substrate must be kept low. As a result, the sintered body of self-doping paste has a high interconnect resistance, giving rise to the problem that the output of the solar cell is reduced.

SUMMARY OF INVENTION

Technical Problem

[0009]

Embodiments~~An object~~ of the invention ~~which is made under the aforementioned circumstances is~~seek to provide a solar cell and solar cell module having the advantages of a good electrical

contact between a silicon substrate and an extraction electrode, a reduced loss by electrode interconnect resistance, and excellent cell characteristics.

Solution to Problem

[0010]

Making extensive investigations to attain the above object, the inventors have found that if a first electrode in the form of a sintered body of conductive paste containing a dopant for imparting conductivity to silicon is used as the extraction electrode, and a second electrode having a higher conductivity than the first electrode is used as the collector electrode, then the loss by contact resistance between silicon substrate and the extraction electrode and the loss by electrode resistance are reduced and solar cell characteristics are drastically improved. The invention is predicated on this finding.

[0011]

Accordingly, a first aspect of the invention provides ~~a solar cell and solar cell module as defined below.~~

~~[1]~~ A solar cell comprising a crystalline silicon substrate of one conductivity type having a light-receiving surface, an emitter layer formed on the light-receiving surface side of the substrate and having a dopant of opposite conductivity type added thereto, a passivation film formed on the surface of the substrate, an extraction electrode for extracting photogenerated charge from the silicon substrate, and a collector electrode in contact with at least a portion of the extraction electrode for collecting the charge drawn in the extraction electrode, characterized in that the extraction electrode includes a first electrode in the form of a sintered conductive paste containing a dopant for imparting the same conductivity type as the emitter layer to silicon, at least the first electrode is formed so as to penetrate through the passivation layer, and the collector electrode includes a second electrode having a higher conductivity than the first electrode, and a self-doped region is formed below the interface between the emitter layer of the silicon substrate and the first electrode, as a result of the dopant in the first electrode being diffused at a higher concentration than the emitter layer during the sintering step.

~~[2] The solar cell of [1] wherein~~There is disclosed below the interface between the emitter layer of the silicon substrate and the first electrode, a self-doped region is formed as a result of the dopant in the first electrode being diffused during the sintering step.

~~[3] The solar cell of [1] or [2] wherein t~~The self-doped region may have~~has~~ a lower resistivity than the emitter layer disposed adjacent thereto.

~~[4] The solar cell of any one of [1] to [3] wherein~~There is disclosed the first electrode may be~~is~~ formed of a conductive paste based on Ag and containing B, Al, Ga, P, As, In or Sb alone or a compound thereof or a combination thereof as the dopant.

~~[5] The solar cell of any one of [1] to [4] wherein t~~The first electrode may be~~is~~ partially contacted or entirely overlaid with the second electrode.

~~[6] The solar cell of any one of [1] to [5] wherein t~~The extraction electrode may have~~has~~ a laminate structure consisting of the first and second electrodes, and the collector electrode may have~~has~~ a monolayer structure consisting of the second electrode.

~~[7] The solar cell of any one of [1] to [5] wherein t~~The extraction electrode and the collector electrode each may have a laminate structure consisting of the first and second electrodes.

~~[8] The solar cell of any one of [1] to [5] wherein t~~The extraction electrode may consist~~s~~ of the first electrode, and the collector electrode may consist~~s~~ of the second electrode.

~~[9] The solar cell of any one of [1] to [8] wherein t~~The passivation film may comprise~~s~~ silicon oxide, silicon nitride, silicon carbide, aluminum oxide, amorphous silicon, microcrystalline silicon or titanium oxide or a combination thereof.

~~[10] A~~The solar cell may comprise~~inge~~ a crystalline silicon substrate having a non-light-receiving surface, a passivation film formed on the non-light-receiving surface of the substrate, an extraction electrode for extracting photogenerated charge from the silicon substrate, and a collector electrode may be disposed at least partially in contact

with the extraction electrode for collecting the charge collected in the extraction electrode, characterized in that the extract electrode may includes a first electrode in the form of a sintered conductive paste containing a dopant for imparting conductivity to silicon, at least the first electrode may beis formed so as to penetrate through the passivation layer, and the collector electrode may includes a second electrode having a higher conductivity than the first electrode.

~~[11] The solar cell of [10] wherein a~~At the interface between the silicon substrate and the first electrode, a self-doped region may beis formed as a result of the dopant in the first electrode being diffused during the sintering step.

~~[12] The solar cell of [10] or [11] wherein t~~The self-doped region may havehas a lower resistivity than a non-self-doped region disposed adjacent thereto.

~~[13] The solar cell of any one of [10] to [12] wherein t~~The first electrode may beis formed of a conductive paste based on Ag and containing B, Al, Ga, P, As, In or Sb alone or a compound thereof or a combination thereof.

~~[14] The solar cell of any one of [10] to [13] wherein t~~The first electrode may beis partially contacted or entirely overlaid with the second electrode.

~~[15] The solar cell of any one of [10] to [14] wherein t~~The extraction electrode may havehas a laminate structure consisting of the first and second electrodes, and the collector electrode may havehas a monolayer structure consisting of the second electrode.

~~[16] The solar cell of any one of [10] to [14] wherein t~~The extraction electrode and the collector electrode each may have a laminate structure consisting of the first and second electrodes.

~~[17] The solar cell of any one of [10] to [14] wherein t~~The extraction electrode may consists of the first electrode, and the collector electrode may consists of the second electrode.

~~[18] The solar cell of any one of [10] to [17] wherein t~~The passivation film may comprises silicon oxide, silicon nitride, silicon carbide, aluminum oxide, amorphous silicon,

microcrystalline silicon or titanium oxide or a combination thereof.

~~[19] A~~ A solar cell module comprising electrically connected solar cells according to the first aspect~~any one of [1] to [18]~~.

Advantageous Effects of Invention

[0012]

In a solar cell comprising extraction and collector electrodes, a self-doping electrode and a high conductivity electrode are used as the extraction electrode and collector electrode, respectively. Then the loss by silicon-electrode contact resistance and the loss by electrode resistance can be~~are~~ reduced and at the same time, optical and electric losses in the emitter layer can be~~are~~ reduced. Solar cell characteristics can be~~are~~ drastically improved. Also, the process can be implemented by conventional screen printing and similar techniques, which can be~~is~~ quite effective for cost savings.

BRIEF DESCRIPTION OF DRAWINGS

[0013]

FIG. 1 is a schematic perspective view of an exemplary structure of a conventional solar cell.

FIG. 2 is a schematic perspective view of an exemplary structure of a solar cell in one embodiment of the invention.

FIG. 3 is a schematic perspective view of an exemplary structure of a solar cell in another embodiment of the invention.

FIG. 4 is a schematic perspective view of an exemplary structure of a solar cell in a further embodiment of the invention.

FIG. 5 is a plan view of a printing plate for use in electrode formation according to the invention, (a) showing a pattern of extraction electrode alone, (b) showing a pattern of collector electrode alone, and (c) showing a combined pattern of extraction and collector electrodes.