silicon/electrode contacts (see, for example, S. W. Glunz, R. Preu, S. Schaefer, E. Schneiderlochner, W. Pfleging, R. Ludemann, G. Willeke, Proc. the 28th IEEE Photovoltaic Shepcialists Conference, p.168, 2000).

SUMMARY OF INVENTION

Technical Problem

[0005]

However, formation of narrow contact or point contact structure electrodes requires increased costs because of many steps involved and also because a resist material, etching paste or the like is newly necessary for patterning, failing to take full advantage of the passivation effect. Also, the method using laser requires an expensive apparatus and cumbersome evaporation and other steps for metal film formation, suggesting that the merits are economically offset.

[0006]

Embodiments~~An object~~ of the invention seek~~which is made under the aforementioned circumstances is~~ to provide a solar cell and solar cell module having the advantages of reduced charge losses at the electrode/silicon interface, improved short-circuit current and open-circuit voltage, improved solar cell characteristics, and manufacture at low costs.

Solution to Problem

[0007]

According to a first aspect~~To attain the above object~~, the invention provides a ~~solar cell and solar cell module as defined below. [1] A~~ solar cell comprising a crystalline silicon substrate having at least a p-n junction, a passivation film formed thereon, and electrodes formed thereon by printing and heat treating a conductive paste, characterized in that the electrodes include a first electrode~~ which is~~ formed as~~such that~~ an extraction electrode which may contact the silicon substrate for extracting photogenerated carriers from the silicon substrate, and a second electrode~~ which is~~ formed on the first electrode as extraction and~~such that a~~ collector electrodes having a higher conductivity than the first electrode, wherein the first electrode is entirely overlaid with the second electrode, the collector electrode portion of the second electrode may contact the first

electrode for collecting the carriers drawn in the first electrode, and the second electrode and the silicon substrate contact only partially or nowhere ~~at least~~ outside the point of contact between the first and second electrodes.

T~~[2] The solar cell of [1] wherein t~~he area of the non-contact portion between the second electrode and the silicon substrate, excluding the area of a contact portion between the first and second electrodes, may accounts for at least 20% of the area equal to the area given by the width and the overall length of the second electrode minus the area of a contact portion between the first and second electrodes.

T~~[3] The solar cell of [1] or [2] wherein t~~he first electrode may be~~is~~ partially contacted or entirely overlaid with the second electrode.

T~~[4] The solar cell of any one of [1] to [3] wherein t~~he first electrode may be~~is~~ formed from a conductive paste containing B, Al, Ga, P, As, In or Sb alone or a compound thereof, and a region having a high concentration of the element diffused therein may be~~is~~ included in the silicon substrate beneath the first electrode.

T~~[5] The solar cell of any one of [1] to [4] wherein t~~he passivation film may comprise~~s~~ silicon oxide, silicon nitride, silicon carbide, aluminum oxide, amorphous silicon, microcrystalline silicon or titanium oxide or a combination thereof.

T~~[6] The solar cell of any one of [1] to [5] wherein t~~he collector electrode comprising the first and second electrodes combined may be~~is~~ formed on a light-receiving surface or a non-light-receiving surface of the solar cell or both.

~~[7]~~ A solar cell module comprising electrically connected solar cells according to the first aspect~~any one of [1] to [6]~~.

According to a second aspect, there is provided a method for manufacturing a solar cell, comprising the steps of: forming a diffusion layer on a surface of a crystalline silicon substrate to form a p-n junction, forming a passivation film on the diffusion layer, printing a first conductive paste containing conductive powder and glass frit on the passivation film using a printing plate having a pattern of an extraction electrode alone, firing the printed first conductive paste to form an extraction electrode as a first electrode which penetrates through the passivation film to establish electrical conduction to the silicon substrate, printing a second conductive paste having a less content of glass frit than the glass frit content in the first conductive paste or zero content of glass frit on the first electrode and the passivation film using a printing plate having a pattern of extraction and collector electrodes combined so as to overlie the first electrode, and firing the printed second conductive paste to form extraction and collector electrodes as a second electrode having a higher conductivity than the first electrode, wherein the first electrode is overlaid with the second electrode, the collector electrode portion of the second electrode may contact the first electrode for collecting the carriers drawn in the first electrode, and the second electrode and the silicon substrate contact only partially or nowhere outside the point of contact between the first and second electrodes.

Advantageous Effects of Invention

[0008]

Since the passivation film is completely or partially left between the collector electrode and the silicon, the invention can reduces charge losses at the electrode/silicon

interface, can improve~~s~~ the short-circuit current and open-circuit voltage, and can ameliorate~~s~~ solar cell characteristics. Furthermore, the process can be implemented using the existing screen-printing technology or the like, which can be~~is~~ extremely effective in reducing costs.

BRIEF DESCRIPTION OF DRAWINGS

[0009]

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 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.

FIG. 5 is a diagram showing one impact on solar cell characteristics according to the invention.

FIG. 6 is a diagram showing the impact of the amount of glass frit added according to the invention.

FIG. 7 is a view illustrating the area of passivation film beneath electrodes according to the invention.

DESCRIPTION OF EMBODIMENTS

[0010]

FIG. 2 illustrates a solar cell in one embodiment of the invention. The solar cell includes a silicon substrate 201 in which an impurity is diffused at a high concentration to form a diffusion layer 202 and a p-n junction, that is, silicon substrate 201 having at least a p-n junction, a passivation film 203 formed thereon, and electrodes formed thereon by printing and heat treating a conductive paste.
The electrodes include a first electrode 204 which is formed