GROUP III-NITRIDE SOLAR CELL WITH GRADED COMPOSITIONS

CROSS REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims priority to U.S. Provisional Patent Application Ser. No. 61/019,536, entitled "Group III-Nitride Solar Cell with Graded Compositions," filed on Jan. 7, 2008, the contents of which are incorporated herein by reference.

STATEMENT OF GOVERNMENTAL INTEREST

[0002] The invention described and claimed herein was made in part utilizing funds supplied by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231. The government has certain rights in this invention.

BACKGROUND OF THE INVENTION

[0003] 1. Field of the Invention

[0004] The disclosure relates to solar cells and, more particularly, to a compositional grading of Group III-nitride alloys in solar cells for improved solar cell performance.

[0005] 2. Background Discussion

[0006] Solar or photovoltaic cells are semiconductor devices having P-N junctions which directly convert radiant energy of sunlight into electrical energy. Conversion of sunlight into electrical energy involves three major processes: absorption of sunlight into the semiconductor material; generation and separation of positive and negative charges creating a voltage in the solar cell; and collection and transfer of the electrical charges through terminals connected to the semiconductor material. A single depletion region for charge separation typically exists in the P-N junction of each solar cell.

[0007] Current traditional solar cells based on single semiconductor material have an intrinsic efficiency limit of approximately 31%. A primary reason for this limit is that no one material has been found that can perfectly match the broad ranges of solar radiation, which has a usable energy in the photon range of approximately 0.4 to 4 eV. Light with energy below the bandgap of the semiconductor will not be absorbed and converted to electrical power. Light with energy above the bandgap will be absorbed, but electron-hole pairs that are created quickly lose their excess energy above the bandgap in the form of heat. Thus, this energy is not available for conversion to electrical power.

[0008] Higher efficiencies have been attempted to be achieved by using stacks of solar cells with different band gaps, thereby forming a series of solar cells, referred to as "multijunction," "cascade," or "tandem" solar cells. Tandem solar cells are the most efficient solar cells currently available. Tandem cells are made by connecting a plurality (e.g., two, three, four, etc.) P-N junction solar cells in series. Tandem cells are typically formed using higher gap materials in the top cell to convert higher energy photons, while allowing lower energy photons to pass down to lower gap materials in the stack of solar cells. The bandgaps of the solar cells in the stack are chosen to maximize the efficiency of solar energy conversion, where tunnel junctions are used to series-connect the cells such that the voltages of the cells sum together. Such multijunction solar cells require numerous layers of materials to be formed in a stacked arrangement.

SUMMARY

[0009] In accordance with one or more embodiments, a compositionally graded Group III-nitride alloy is provided for use in a solar cell. In one or more embodiment, an alloy of either InGaN or InAlN is formed in which the Indium (In) composition is graded between two areas of the alloy. In one or more embodiments, the compositionally graded Group III-nitride alloy possesses direct band gaps having a very large tuning range, for example extending from about 0.7 to 3.4 eV for InGaN and from about 0.7 to 6.2 eV for InAlN.

[0010] In accordance with one or more embodiments, a single P-N junction solar cell is provided having multiple regions for charge separation while allowing the electrons and holes to recombine such that the voltages associated with both depletion regions of the solar cell will add together. In one or more embodiments, the conduction band edge (CBE) of a top layer in the solar cell is formed to line up with the valence band edge (VBE) of a lower layer in the solar cell. In accordance with one or more embodiments, a single P-N junction solar cell is provided having a compositionally graded Group III-nitride alloy of either InGaN or InAlN formed on one side of the P-N junction with Si formed on the other side in order to produce characteristics of a tandem solar cell with its two energy gaps through the formation of only a single P-N junction.

[0011] In accordance with one or more embodiments, a multijunction tandem solar cell is provided in which one of the solar cells includes a compositionally graded Group III-nitride alloy. In accordance with one or more embodiments, a tandem solar cell is provided having a low-resistance tunnel junction formed between two solar cells in which one of the solar cells includes a compositionally graded Group III-nitride alloy.

[0012] In accordance with one or more of the embodiments described herein, the Group III-nitride alloy utilized in the single P-N junction solar cell is either an $In_xGa_{1-x}N$ alloy or an $In_xAl_{1-x}N$ alloy in which the Indium (In) composition can be graded over a wide range (e.g., anywhere between x=0.0 to x=1.0) between two surfaces of a layer of the alloy in order to provide a wide range of direct gap grading. Solar cells formed in accordance with one or more embodiments using a compositionally graded Group III-nitride alloy will allow higher power conversion efficiencies to be achieved.

[0013] In accordance with one or more embodiments, a solar cell is provided having a compositionally graded alloy of either InGaN or InAlN formed on one side of the P-N junction with Si formed on the other side, wherein an additional n+ layer is formed between the Si layer and a contact to produce a back surface field (BSF).

DRAWINGS

[0014] The above-mentioned features and objects of the present disclosure will become more apparent with reference to the following description taken in conjunction with the accompanying drawings wherein like reference numerals denote like elements and in which:

[0015] FIG. **1** is a block diagram representation of a single P-N junction tandem solar cell in accordance with one or more embodiments of the present disclosure.

[0016] FIG. **2** is a more detailed perspective view of FIG. **1** showing the various regions in a single P-N junction tandem solar cell in accordance with one or more embodiments of the present disclosure.