GaN/n-Si heterojunction tandem solar cell are respectively illustrated in FIGS. **4**A and **4**B. The two depletion regions **130** and **132** can be seen in FIG. **4**A that correspond to depletion regions **110** and **112** shown in FIG. **2**. A InGaN bandgap of 1.8 eV was obtained by specifying the composition, which is close to the ideal for a top layer **102** matched to a bottom Si layer **104** having a band gap=1.1 eV in terms of maximum power conversion efficiency.

[0027] Under illumination, photons with energies greater than the 1.8 eV band gap of the $In_{0.45}Ga_{0.55}N$ layer **102** create electron-hole pairs in the InGaN layer **102**. The Si layer **104** absorbs light with energies between 1.1 and 1.8 eV and light with energy >1.8 eV that is not absorbed by the top InGaN layer **102**. Doping in both of the layers **102** and **104** can be adjusted to change the size of the depletion regions **130** and **132**. Efficient electron and hole recombination occurs at the InGaN/Si junction **105** such that under illumination, holes will go to the surface of the InGaN layer **102** and electrons will go into the Si layer **104**. A thin (~25 nm) heavily doped p++ layer can be used to provide an ohmic contact to the InGaN surface.

[0028] The depletion regions **130** and **132** are similar to "Schottky-like" depletion regions found in semiconductor materials, such that these two depletion regions **130** and **132** should achieve efficiency of in the solar cell **100** of approximately 42% for unconcentrated sunlight, similar to the efficiency achieved by 2J tandem cells.

[0029] In one or more embodiments, the dark current (i.e., the output current of the solar cell **100** when no light is acting as an input) can be reduced by heavy counter-doping (i.e., p^{++} in the n-type layer **104** or n^{++} in the p-type layer **102**) near the interface between at least one of the layers **102**, **104** and the respective one of the electrical contacts **106**, **108**. This will also increase the open circuit voltage and efficiency of the solar cell **100**. Referring to FIG. **5**A, a band diagram for a p-InGaN/n-Si heterojunction tandem solar cell is illustrated in which n^{++} counter-doping (e.g., a 10 nm layer of n^{++} 9×10^{17}) has been utilized in the p-type layer **102** adjacent to electrical contact **106**, where line **140** represents CBE (eV), line **142** represents VBE (eV) and line **144** represents E_F.

[0030] In one or more embodiments, the dark current can be reduced and the open circuit voltage increased through the use of a thin insulating interlayer (e.g., a thin layer of GaN) formed between the layers **102** and **104**. The interlayer will serve to increase the barrier for hole leakage from the p-InGaN layer **102** into the n-Si layer **104** while preventing electron leakage from the n-Si layer **104** into the p-InGaN layer **102**. Referring to FIG. **5**B, a band diagram for a p-InGaN/n-Si heterojunction tandem solar cell is illustrated in which a thin 5 nm GaN interlayer has been utilized between the p-InGaN layer **102** and the n-Si layer **104**.

[0031] Both of the approaches associated with reducing dark current using heavy counter-doping or a thin insulating layer illustrated in FIGS. **5**A and **5**B will increase the barrier against electron and hole leakage by about 0.1 to 0.2 eV compared designs without such features.

[0032] In order to form a tandem photovoltaic device using a single P-N junction, the conduction band minimum (CBM) in the upper layer **102** of the solar cell **100** is formed to be substantially aligned with or lower in energy with respect to the vacuum level than the valence band maximum (VBM) of the lower layer **104** of the solar cell **100**. The present disclosure allows a solar cell having the efficiency characteristics of a two-junction tandem solar cell to be made with a very simple single P-N junction design. By simply forming a p-InGaN layer **102**, which can be thin (<0.5 μm), over a bottom n-Si layer **104**, a tandem solar cell **100** can be produced with an efficiency above that of the best currently produced single junction Si solar cells. In one or more embodiments, the Si layer **104** can be formed using polycrystalline, multicrystalline or even amorphous Si. Such a tandem solar cell **100** can be produced with increased efficiency and lower costs compared to previously-known Si technology, which could revolutionize photovoltaics manufacturing.

1. A solar cell, comprising:
- a p-type layer;
- an n-type layer;
- a single p-n junction between the p-type layer and the n-type layer; and
- a plurality of depletion regions for charge separation associated with the single p-n junction.

2. The solar cell of claim **1**, wherein the solar cell includes two depletion regions.

3. The solar cell of claim **1**, wherein one of the p-type and n-type layers comprises an InGaN alloy.

4. The solar cell of claim **3**, wherein the other of the p-type and n-type layers comprises Si.

5. The solar cell of claim **1**, wherein one of the p-type and n-type layers comprises an InAlN alloy.

6. The solar cell of claim **4**, wherein the other of the p-type and n-type layers comprises Si.

7. The solar cell of claim **1**, wherein a conduction band of one of the p-type and n-type layers substantially aligns with a valence band in the other of the p-type and n-type layers to form the p-n junction as a low resistance tunnel junction between the p-type layer and the n-type layer.

8. The solar cell of claim **1**, wherein voltages produced in each of the depletion regions will add together to produce a combined output voltage for the solar cell.

9. The solar cell of claim **3**, wherein the InGaN alloy comprises $In_{1-x}Ga_xN$, where $0 \leqq x \leqq 1$.

10. The solar cell of claim **9**, wherein x is approximately 0.5.

11. The solar cell of claim **3**, wherein the InAlN alloy comprises $In_{1-x}Al_xN$, where $0 \leqq x \leqq 1$.

12. The solar cell of claim **11**, wherein x is approximately 0.3.

13. The solar cell of claim **1**, further comprising:
- a first electrical contact coupled to the p-type layer; and
- a second electrical contact coupled to the n-type layer.

14. The solar cell of claim **13**, further comprising a heavily counter-doped region in at least one of the p-type layer and the n-type layer respectively adjacent to at least one of the first and second electrical contacts.

15. The solar cell of claim **1**, further comprising an insulating interlayer between the p-type layer and the n-type layer.

16. A solar cell, comprising:
- a p-type layer,
- a first electrical contact coupled to the p-type layer;
- an n-type layer;
- a second electrical contact coupled to the n-type layer.
- a single p-n junction between the p-type layer and the n-type layer having a plurality of depletion regions for charge separation.

17. A single junction solar cell, comprising:
- a single p-n junction between a p-type subcell and an n-type subcell having a plurality of depletion regions for charge separation.