the layers **106** and **108**. Contact blocking layers **104** and **110** may be formed of any material that provides electrical isolation of the intermediate band of the GaNAs P-N junction by blocking the charge transport in the intermediate band of the GaNAs P-N junction between layers **106** and **108** without affecting the electron and hole collection efficiency of the GaNAs P-N junction.

In one or more embodiments, contact blocking layers **104** and **110** are lattice matched to a desired higher band gap of the GaNAs layers **106** and **108**. In one or more embodiments, the contact blocking layers comprise at least one of AlGaAs materials. When holes and electrons are formed in the GaNAs P-N junction layers **106** and **108** upon exposure to solar radiation, it is desirable that the holes and electrons travel across the P-N junction between layers **106** and **108** through the valence band and the higher conduction band, respectively of the layers **106** and **108** to generate the resultant current in IBSC **100**. The contact blocking layers **104** and **110** electrically isolate the IBand and block the passage of electrons into the adjacent layers of IBSC **100** through the IBand. In one or more embodiments, the composition of the GaNAs P-N junction layers **106** and **108** and the AlGaAs contact blocking layers **104** and **110** are tuned to align the conduction band of the contact blocking layers **104** and **110** with the higher conduction band of the GaNAs P-N junction layers **106** and **108**. By isolating the IBand of the GaNAs P-N junction layers **106** and **108** in this manner and effectively blocking the IBand from contact with neighboring layers of IBSC **100**, increased open circuit voltage ($V_{OC}$) dependent on the larger gap the absorber layer is achieved. The photocurrent can be further increased by utilizing the isolated IBand to absorb photons with energy below the band gap of the GaNAs P-N junction layers **106** and **108**.

In one or more embodiments, as illustrated in FIG. **1**, an AlGaAs blocking layer **104** is formed on a GaAs substrate layer **102**. An n-type GaNAs layer **106** is formed on the n-AlGaAs blocking layer **104**, where the n-AlGaAs blocking layer **104** is lattice-matched with its adjacent layers in order to maximize the overall quality of the material used, which in turn minimizes any material-based defects that occur from routine usage or testing that would otherwise harm efficiency of the IBSC **100**. A p-type GaNAs layer **108** is formed on the n-type GaNAs layer **106**. A $p^+$ $Ga_yAs$ layer **112** is formed on the p+-AlGaAs layer **110** in order to protect the AlGaAs layer from oxidation. For either of the blocking layers **104** and **110** described in any of the embodiments, an appropriate n-type or p-type layer of GaInP or any other layer of material known to those skilled in the art exhibiting similar blocking characteristics may be interchangeably utilized in place of AlGaAs.

In IBSC **100** of FIG. **1**, the bottom blocking layer **104** lets electrons through the higher conduction band but blocks holes while the top blocking layer **110** lets holes through but blocks electrons from either the IBand or the conduction band. When released in response to exposure to solar radiation, electrons wish to travel from the first P-N junction layer **106** through the first blocking layer **104** to the bottom substrate layer **102**, so the first blocking layer **104** facilitates this process. Likewise when released in response to solar radiation, holes wish to travel from the second P-N junction layer **108** to the protective layer **112**, such that the top blocking layer **110** facilitates this process. As will be further discussed in the graphical illustrations of the band diagrams in FIG. **2**, the blocking layers **104** and **110** enable the electrical isolation of the intermediate band of GaNAs absorber layers **106** and **108**, which in turn maximizes the voltage and the current flow throughout the entire IBSC **100** and hence optimizes the overall efficiency of the IBSC **100**.

Referring now to FIG. **2**, a graphical illustration of the calculated band diagram for one specific embodiment of the IBSC **100** of FIG. **1**. In this representative example, a 100 nm n-AlGaAs blocking layer **104** with 45% Al having an n doping ~$2\times10^{17}$ $cm^{-3}$ is formed on an $n^+$ GaAs substrate layer **102**. A 400 nm n-type GaNAs layer **106** that is Te doped $2\times10^{17}$ $cm^{-3}$ is formed on the n-AlGaAs blocking layer **104**, and a 100 nm p-type GaNAs layer **108** that is Zn doped $1\times10^{18}$ $cm^{-3}$ is formed on the n-type GaNAs layer **106**. Next, a 50 nm $p^+$ $Al_{0.75}Ga_{0.25}As$ blocking layer **110** is formed on the p-type GaNAs layer **108**. Finally, a 20 nm thick $p^+$ GaAs layer **112** is formed on the $p^{30}$ $Al_{0.75}Ga_{0.25}As$ blocking layer **110** to protect this layer from oxidation.

The calculated band diagram of FIG. **2** illustrates plots for the conduction band ($E_C$) **212**, the intermediate band (IBand) **214**, and the valence band ($E_V$) **216**. The x-axis of the calculated band diagram represents the distance from the surface of the structure in FIG. **1** in micron while the y-axis represents an energy measurement reading in units of eV (electron-volts) measured with respect to the Fermi energy level. The conduction band ($E_C$) **212** represents the energy band with empty states for electron conduction to occur, and the slope of the conduction band ($E_C$) **212** can reveal the rate of electron flow or charge transport throughout the IBSC **100**. Similarly, the valence band ($E_V$) **216** represents the energy band that is filled with electrons or with empty states for hole conduction, and the slope of the valence band ($E_V$) **216** can reveal the rate of hole flow or charge transport throughout the IBSC. As can be seen in FIG. **2**, the slope of both plots **212** and **216** show the electrons being repelled from the surface whereas holes are being drawn to the surface. The IBand plot **214** represents the intermediate band formed as a result of the anticrossing interaction between the N states and the GaAs conduction band ($E_C$) **212**. The IBand **214** in FIG. **2** is completely isolated in both sides and only acts as a “stepping stone” for the absorption of low energy photons.

Referring back to FIG. **1**, in one or more embodiments, IBSC **100** may be formed with the protective layer **112**, such as $p^+$ GaAs or the like, deposited on top of the contact blocking layer **110** for providing a protective covering over the other layers and to prevent the second blocking layer **110** from oxidizing, especially if the second blocking layer **110** is made from $Al_xGa_yAs$. Layer **112** may also function as a low resistance contact. The protective layer **112** may usually comprise n-type or p-type GaAs, depending on the desired configuration of the various layers of IBSC **100** for desired operation characteristics. In one or more embodiments, the protective layer **112** may optionally be deposited using known deposition techniques at a thinner thickness compared to the other layers of IBSC **100**.

Referring now to FIG. **3**, a graphical illustration of the carrier concentration profiles of the IBSC **100** of FIG. **1** is shown in accordance with one or more embodiments of the present disclosure. Carrier concentration profile graph of FIG. **3** has an x-axis describing the distance from the surface in μm, and carrier concentration on the y-axis in units of ($cm^{-3}$). The carrier concentration profile graph illustrates a carrier concentration plot of electrons **312** and a carrier concentration plot of holes **314**. As can be seen from these plots of FIG. **3**, the concentration of holes is highest near the surface, shown by activity in the holes plot **314**, where top blocking layer **110** resides, wherein top blocking layer **110** lets holes through but blocks electrons. Then, farther away from the surface both hole and electron concentration become very small in the p/n junction depletion region extending from 0.1 to 0.18 m. Deeper on the n-type side of the IBSC structure **100**, the concentration of holes is negligibly small and the plot