[0004] According to a first aspect of the present invention, a transparent photovoltaic device is provided. The transparent photovoltaic device includes a transparent substrate and a transparent bottom electrode coupled to the transparent substrate. The transparent photovoltaic device also includes an active layer coupled to the transparent bottom electrode and a transparent multilayer top electrode that includes a seed layer coupled to the active layer and a metal layer coupled to the seed layer. The transparent photovoltaic device is characterized by an average visible transmission (AVT) greater than 25%, and a top electrode sheet resistance that is less than 100 Ohm/sq, and a ratio of the AVT to fraction of transmitted solar radiation (AVT/T_{sol}) is greater than 1.3 and less than or equal to 2.5.

[0005] According to second aspect of the present invention, a transparent photovoltaic device is provided. The transparent photovoltaic device includes a transparent substrate and a transparent bottom electrode coupled to the transparent substrate. The transparent photovoltaic device also includes an active layer coupled to the transparent bottom electrode and a transparent multilayer top electrode. The transparent multilayer top electrode includes a seed layer deposited on the active layer, a first metal layer deposited on the seed layer, an interconnect layer deposited on the first metal layer, and a second metal layer deposited on the interconnect layer. The transparent photovoltaic device is characterized by an average visible transmission (AVT) greater than 25%, and a top electrode sheet resistance that is less than 100 Ohm/sq. In a specific embodiment, the ratio of the AVT to fraction of transmitted solar radiation (AVT/Tsol) is greater than 1.7 and less than or equal to 2.5.

[0006] According to a third aspect of the present invention, an insulated glass unit (IGU) including a transparent photovoltaic device is provided. The IGU includes a first glazing and a second glazing opposing the first glazing. The transparent photovoltaic device is disposed between the first glazing and the second glazing and includes a transparent substrate, a transparent bottom electrode coupled to the transparent substrate, an active layer coupled to the transparent bottom electrode, and a transparent multilayer top electrode. The transparent multilayer top electrode includes a charge selective seed layer coupled to the active layer and a metal layer coupled to the charge selective seed layer. The insulated glass unit is characterized by an average visible transmission (AVT) greater than 25% and a ratio of the AVT to fraction of transmitted solar radiation (AVT/T_{sol}) is greater than 1.3 and less than or equal to 2.5.

[0007] According to some embodiments, a photovoltaic device includes a transparent substrate, a transparent bottom electrode coupled to the transparent substrate, an active layer, which can include a tandem or multi-junction cell, coupled to the transparent bottom electrode, and a transparent top electrode. The transparent bottom electrode can include a first transparent conducting oxide layer, a second metal layer, and a second transparent conducting oxide layer. The active layer is transparent in the visible wavelength range in some embodiments and the active layer can include an organic small molecule semiconductor with selective absorption in the NIR.

[0008] The transparent top electrode includes a seed layer, which can be a charge selective seed layer, coupled to the active layer, and a metal layer coupled to the seed layer. The seed layer can include one of HAT-CN, TPBi:C60, indium tin oxide (ITO), ZnO, SnO_2, antimony doped tin oxide (ATO), aluminum-doped zinc-oxide (AZO), indium-doped cadmium-oxide, fluorine doped tin oxide (FTO), or a combination thereof and can have a seed layer thickness ranging from 0.1 nm to 100 nm. The metal layer can include at least one of Ag, Au, Al, Sn, or Cu. In some embodiments, the metal layer includes an alloy of Ag, Au, Sn, Al, Cu, or combinations thereof, for example, Al doped Ag or Sn doped Ag. The metal layer can have a thickness ranging from 3 nm to 30 nm. The transparent top electrode can also include an anti-reflection layer coupled to the metal layer.

[0009] The photovoltaic device is characterized by an AVT value that is greater than 25%, and a top electrode sheet resistance that is less than 100 Ohm/sq. The AVT can be greater 35%, greater than 45%, or greater than 60%.

[0010] According to some other embodiments, a transparent photovoltaic device includes a transparent substrate, a transparent bottom electrode coupled to the transparent substrate, an active layer coupled to the transparent bottom electrode, and a transparent top electrode. The transparent top electrode includes a seed layer coupled to the active layer, a first metal layer coupled to the seed layer, an interconnect layer (e.g., a transparent conducting oxide) coupled to the first metal layer, and a second metal layer coupled to the interconnect layer. The

CLAIMS

1. A transparent photovoltaic device comprising:

a transparent substrate;

a transparent bottom electrode coupled to the transparent substrate;

an active layer coupled to the transparent bottom electrode; and

a transparent multilayer top electrode comprising:

a seed layer coupled to the active layer; and

a metal layer coupled to the seed layer;

wherein the transparent photovoltaic device is characterized by an average visible transmission (AVT) greater than 25% and a top electrode sheet resistance that is less than 100 Ohm/sq, and a ratio of the AVT to fraction of transmitted solar radiation (AVT/T_{sol}) is greater than 1.3 and less than or equal to 2.5.

2. The transparent photovoltaic device of claim 1 wherein:

the seed layer is deposited on the active layer; and

the metal layer is deposited on the seed layer.

3. The transparent photovoltaic device of claim 1 wherein the transparent photovoltaic device is characterized by an emissivity less than 0.2.

4. The transparent photovoltaic device of claim 1 wherein the seed layer is charge selective.

5. The transparent photovoltaic device of claim 1 wherein the seed layer comprises TPBi:C60, ZnO, or some combination thereof.

6. The transparent photovoltaic device of claim 1 wherein the seed layer has a thickness ranging from 0.1 nm to 100 nm and the metal layer has a thickness ranging from 3 nm to 30 nm.

7. The transparent photovoltaic device of claim 1 wherein the transparent multilayer top electrode further comprises an anti-reflection layer deposited on the metal layer.

8. The transparent photovoltaic device of claim 1 wherein the active layer comprises a tandem cell connected through one or more charge recombination zones.

9. The transparent photovoltaic device of claim 1 wherein the active layer is transparent in a visible wavelength range and exhibits selective absorption at ultraviolet (UV) or near infrared (NIR) wavelengths.

10. The transparent photovoltaic device of claim 1 wherein the transparent bottom electrode comprises:

a first transparent seed layer;

a second metal layer deposited on the first transparent seed layer; and

a second transparent charge selective layer deposited on the second metal layer.

11. A transparent photovoltaic device comprising:

a transparent substrate;

a transparent bottom electrode coupled to the transparent substrate;

an active layer coupled to the transparent bottom electrode; and

a transparent multilayer top electrode comprising:

a seed layer deposited on the active layer;

a first metal layer deposited on the seed layer;

an interconnect layer deposited on the first metal layer; and

a second metal layer deposited on the interconnect layer.

wherein the transparent photovoltaic device is characterized by an average visible transmission (AVT) greater than 25%, and a top electrode sheet resistance that is less than 100 Ohm/sq.

12. The transparent photovoltaic device of claim 11 wherein the interconnect layer comprises a conductive transparent oxide.

13. The transparent photovoltaic device of claim 11 wherein a ratio of the AVT to fraction of transmitted solar radiation (AVT/Tsol) is greater than 1.7 and less than or equal to 2.5 and the transparent photovoltaic device is characterized by an emissivity less than 0.2.

14. The transparent photovoltaic device of claim 11 further comprising an anti-reflection layer deposited on the second metal layer.

15. The transparent photovoltaic device of claim 11 wherein the transparent bottom electrode comprises:

a first transparent seed layer;

a third metal layer deposited on the first transparent seed layer; and

a second transparent charge selective layer deposited on the third metal layer.

16. An insulated glass unit including a transparent photovoltaic device, the insulated glass unit comprising:

a first glazing; and

a second glazing opposing the first glazing;

wherein the transparent photovoltaic device is disposed between the first glazing and the second glazing and comprises:

a transparent substrate;

a transparent bottom electrode coupled to the transparent substrate;

an active layer coupled to the transparent bottom electrode; and

a transparent multilayer top electrode comprising:

a charge selective seed layer coupled to the active layer; and

a metal layer coupled to the charge selective seed layer;

wherein the insulated glass unit is characterized by an average visible transmission (AVT) greater than 25% and a ratio of the AVT to fraction of transmitted solar radiation (AVT/T_{sol}) is greater than 1.3 and less than or equal to 2.5.

17. The insulated glass unit of claim 16 wherein the insulated glass unit is characterized by a ratio of the AVT over a solar heat gain coefficient (SHGC) greater than 1.3 and less than or equal to 2.5.

18. The insulated glass unit of claim 16 wherein the transparent multilayer top electrode further comprises one or more interconnect layers and one or more additional metal layers, each of the one or more interconnect layers being coupled to an adjacent metal layer of the one or more additional metal layers.

19. The insulated glass unit of claim 18 wherein the insulated glass unit is characterized by a ratio of the AVT over a solar heat gain coefficient (SHGC) greater than 1.7 and less than or equal to 2.5.

20. The insulated glass unit of claim 16 wherein the transparent photovoltaic device further comprises an anti-reflection layer deposited on the metal layer.