CLAIMS

What is claimed is:

1. A tandem organic photovoltaic cell, comprising:

a first photoactive subcell;

a second photoactive subcell; and

an intermediate layer comprising graphene, disposed between the first photoactive subcell and the second photoactive subcell, that collects charges generated from the first photoactive subcell and the second photoactive subcell.

~~2. The tandem organic photovoltaic cell according to claim 1, wherein the intermediate layer has a sheet resistance that is less than 1k ohm per square.~~

~~3. The tandem organic photovoltaic cell according to claim 1, wherein the intermediate layer has an optical transparency that is greater than 80%.~~

~~4.~~2. The tandem organic photovoltaic cell according to claim 1, wherein the first photoactive subcell and the second photoactive subcell are electrically coupled in series or in parallel.

~~5. The tandem organic photovoltaic cell according to claim 1, wherein the first photoactive subcell and the second photoactive subcell are electrically coupled in parallel.~~

~~6.~~3. The tandem organic photovoltaic cell according to claim 1, wherein the first photoactive subcell comprises a substrate, a first electrode disposed on the substrate, a first hole transporting layer disposed on the first electrode, a first photoactive layer disposed on the first hole transporting layer, a first electron transporting layer disposed on the first photoactive layer and a second electrode disposed over the first electron transporting layer.

~~7.~~4. The tandem organic photovoltaic cell according to claim ~~6~~ 3, wherein

the second photoactive subcell comprises a third electrode, a second hole transporting layer disposed on the third electrode, a second photoactive layer disposed on the second hole transporting layer, a second electron transporting layer disposed on the second photoactive layer and a fourth electrode disposed over the second electron transporting layer.

~~8. The tandem organic photovoltaic cell according to claim 7, wherein the second electrode of the first photoactive subcell and the third electrode of the second photoactive subcell form a recombination contact zone that comprises the intermediate layer comprising graphene.~~

~~9. The tandem organic photovoltaic cell according to claim 8, wherein the recombination contact zone formed from the intermediate layer comprising graphene is configured to let both positive and negative charges recombine from the first photoactive subcell and the second photoactive subcell, and wherein the first electrode of the first photoactive subcell is configured as an electrical contact to collect holes while the fourth electrode of the second photoactive subcell is configured as an electrical contact to collect electrons.~~

~~10.~~5. The tandem organic photovoltaic cell according to claim 1, wherein the first photoactive subcell comprises a substrate, a first electrode disposed on the substrate, a first electron transporting layer disposed on the first electrode, a first photoactive layer disposed on the first electron transporting layer, a first hole transporting layer disposed on the first photoactive layer and a second electrode disposed over the first hole transporting layer.

~~11.~~6. The tandem organic photovoltaic cell according to claim ~~10~~ 5, wherein the second photoactive subcell comprises a third electrode, a second electron transporting layer disposed on the third electrode, a second photoactive layer disposed on the second electron transporting layer, a second hole transporting layer disposed on the second photoactive layer and a fourth electrode disposed over the second hole transporting layer.

~~12.~~7. The tandem organic photovoltaic cell according to claim ~~11~~ 6, wherein the second electrode of the first photoactive subcell and the third electrode of the second photoactive subcell form a recombination contact zone that comprises the intermediate layer comprising graphene.

~~13.~~8. The tandem organic photovoltaic cell according to claim ~~12~~ 7, wherein the recombination contact zone formed from the intermediate layer comprising graphene is configured to let both positive and negative charges recombine from the first photoactive subcell and the second photoactive subcell, and wherein the first electrode of the first photoactive subcell is configured as an electrical contact to collect holes or electrons while the fourth electrode of the second photoactive subcell is configured as an electrical contact to collect holes or electrons.

~~14. The tandem organic photovoltaic cell according to claim 9 or 13, wherein the first electrode of the first photoactive subcell and the fourth electrode of the second photoactive subcell have an electrical connection that is used to drive an external load.~~

~~15. The tandem organic photovoltaic cell according to claim 9 or 13, wherein the electrode collecting holes has a work function that is greater than 4.5 eV.~~

~~16. The tandem organic photovoltaic cell according to claim 9 or 13, wherein the electrode collecting electrons has a work function that is less than 4.5 eV.~~

~~17. The tandem organic photovoltaic cell according to claim 1, wherein the first photoactive subcell comprises a substrate, a first electrode disposed on the substrate, a first electron transporting layer disposed on the first electrode, a first photoactive layer disposed on the first electron transporting layer, a first hole transporting layer disposed on the first photoactive layer and a second electrode disposed over the first hole transporting layer.~~

~~18. The tandem organic photovoltaic cell according to claim 17, wherein~~

~~the second photoactive subcell comprises a third electrode, a second hole transporting layer disposed on the third electrode, a second photoactive layer disposed on the second hole transporting layer, a second electron transporting layer disposed on the second photoactive layer and a fourth electrode disposed over the second electron transporting layer.~~

~~19. The tandem organic photovoltaic cell according to claim 18, wherein the second electrode of the first photoactive subcell and the third electrode of the second photoactive subcell form a common electrode that comprises the intermediate layer comprising graphene.~~

~~20. The tandem organic photovoltaic cell according to claim 19, wherein the common electrode formed from the intermediate layer comprising graphene is configured to collect holes generated from the first photoactive subcell and the second photoactive subcell, and wherein the first electrode of the first photoactive subcell and the fourth electrode of the second photoactive subcell are used as electrical contacts to collect electrons generated from the first photoactive subcell and the second photoactive subcell.~~

~~21.~~9. The tandem organic photovoltaic cell according to claim 1, wherein the first photoactive subcell comprises a substrate, a first electrode disposed on the substrate, a first hole transporting layer disposed on the first electrode, a first photoactive layer disposed on the first hole transporting layer, a first electron transporting layer disposed on the first photoactive layer and a second electrode disposed over the first electron transporting layer.

~~22.~~10. The tandem organic photovoltaic cell according to claim ~~21~~ 9, wherein the second photoactive subcell comprises a third electrode, a second electron transporting layer disposed on the third electrode, a second photoactive layer disposed on the second electron transporting layer, a second hole transporting layer disposed on the second photoactive layer and a fourth electrode disposed over the second hole transporting layer.

~~23.~~11. The tandem organic photovoltaic cell according to claim ~~22~~ 10, wherein the second electrode of the first photoactive subcell and the third electrode of the second photoactive subcell form a common electrode that comprises the intermediate layer comprising graphene.

~~24.~~12. The tandem organic photovoltaic cell according to claim ~~23~~ 11, wherein the common electrode formed from the intermediate layer comprising graphene is configured to collect electrons generated from the first photoactive subcell and the second photoactive subcell, and wherein the first electrode of the first photoactive subcell and the fourth electrode of the second photoactive subcell are used as electrical contacts to collect holes generated from the first photoactive subcell and the second photoactive subcell.

~~25.~~13. The tandem organic photovoltaic cell according to claim ~~20 or 24~~ 12, wherein the first electrode of the first photoactive subcell and the fourth electrode of the second photoactive subcell have an electrical connection.

~~26. The tandem organic photovoltaic cell according to claim 20 or 24, wherein the common electrode and the first electrode of the first photoactive subcell have an electrical connection that is used to drive an external load.~~

~~27. The tandem organic photovoltaic cell according to claim 20 or 24, wherein the electrode collecting holes has a work function that is greater than 4.5 eV.~~

~~28. The tandem organic photovoltaic cell according to claim 20 or 24, wherein the electrode collecting electrons has a work function that is less than 4.5 eV.~~

~~29.~~14. A tandem photovoltaic cell, comprising:

two or more photoactive subcells;

a graphene film layer disposed between each pair of photoactive subcells in the two or more photoactive subcells, the graphene film layer providing an electrical connection between each pair of photoactive subcells, wherein the graphene film layer

provides a selective contact of a same polarity to each pair of photoactive subcells to collect charges generated therefrom.

~~30.~~15. The tandem photovoltaic cell according to claim ~~29~~ 14, wherein each pair of photoactive subcells in the two or more photoactive subcells are electrically coupled in series or in parallel.

~~31.~~16. The tandem photovoltaic cell according to claim ~~30~~ 15, wherein the graphene film layer forms a recombination contact zone that is configured to collect both positive and negative charges generated from each pair of photoactive subcells.

~~32. The tandem photovoltaic cell according to claim 29, wherein each pair of photoactive subcells in the two or more photoactive subcells are electrically coupled in parallel.~~

~~33.~~17. The tandem photovoltaic cell according to claim ~~32~~ 15, wherein the graphene film layer forms a common electrode that is configured to collect holes generated from each pair of photoactive subcells, while electrodes associated with each pair of photoactive subcells that are outwardly disposed from the graphene film layer are used as electrical contacts to collect electrons generated from each pair of photoactive subcells.

~~34. The tandem photovoltaic cell according to claim 29, wherein the graphene film layer comprises a single layer of graphene.~~

~~35. The tandem photovoltaic cell according to claim 29, wherein the graphene film layer comprises more than one layer of graphene.~~

~~36. The tandem photovoltaic cell according to claim 29, wherein the graphene film layer has a thickness that is greater than 0.5 nm.~~

~~37. The tandem photovoltaic cell according to claim 36, wherein the~~

graphene film layer has a thickness that ranges from about 0.5 nm to about 30 nm.

38. The tandem photovoltaic cell according to claim 29, wherein the graphene film layer has a sheet resistance that is less than 1k ohm per square.

39. The tandem photovoltaic cell according to claim 29, wherein the graphene film layer has an optical transparency that is greater than 80%.

40. A tandem optoelectronic device, comprising:

two or more optoelectronic active subcells; and

a graphene film layer disposed between each pair of optoelectronic active subcells in the two or more optoelectronic active subcells, the graphene film layer providing an electrical connection between each pair of optoelectronic active subcells, wherein the graphene film layer provides a selective contact of a same polarity to each pair of optoelectronic active subcells to collect charges generated therefrom.

41. A method of fabricating a tandem organic photovoltaic cell, comprising:

obtaining a graphene film layer;

disposing the graphene film layer as an intermediate layer between two or more organic photoactive subcells; and

electrically connecting the two or more organic photoactive subcells through the graphene film layer to collect charges generated from the two or more organic photoactive subcells.

42. The method according to claim 41, wherein obtaining the graphene film layer comprises synthesizing the graphene film layer.

43. The method according to claim 42, wherein synthesizing the graphene film layer comprises growing the graphene film layer.

44. The method according to claim 43, wherein growing the graphene film

~~layer comprises applying a chemical vapor deposition process.~~

~~45.~~18. ~~The~~ A method ~~according to claim 43, further~~ of preparing a graphene film layer for disposing between a first photoactive subcell and a second photoactive subcell, comprising:

doping the ~~grown~~ graphene film layer with a conductivity-enhancing dopant.

~~46.~~19. The method according to claim ~~43~~ 18, further comprising modifying the ~~grown~~ graphene film layer with a modifiying layer including a PEDOT polymer and a transition metal oxide.

~~47. The method according to claim 46, wherein the modifying layer comprises a PEDOT polymer.~~

~~48. The method according to claim 43, further comprising:~~

~~transferring the grown graphene film layer onto a targeted material;~~

~~transferring the graphene film layer from the targeted material onto one of the organic photoactive subcells; and~~

~~attaching another organic photoactive subcell onto a side of the graphene film layer that opposes the one of the organic photoactive subcells transferred thereto.~~

~~49.~~20. ~~The~~ A method ~~according to claim 48, wherein~~ of transferring ~~the~~ a grown graphene film layer onto ~~the~~ a targeted material ~~comprises using~~ comprising:

a dry transfer process based on a polydimethylsiloxane (PDMS) stamp and applying an etching process.

~~50. The method according to claim 48, wherein transferring the grown graphene film layer onto the targeted material comprising applying an etching process.~~

~~51. The method according to claim 41, wherein obtaining a graphene film layer comprises obtaining a molybedenum oxide (MoO_3) graphene film layer.~~

~~52. A series tandem organic photovoltaic cell device produced from the method of claim 41.~~

~~53. The series tandem organic photovoltaic cell device of claim 52, wherein the device has an open circuit V_{oc} that is about 1V for a sum of two organic photoactive subcells in the device.~~

~~54. A parallel tandem organic photovoltaic cell device produced from the method of claim 41.~~

~~55. The parallel tandem organic photovoltaic cell device of claim 54, wherein the device has a short circuit current density J_{sc} that is about 11.6 mA/cm^2 for a sum of two photoactive subcells in the device.~~

~~56. The parallel tandem organic photovoltaic cell device of claim 54, wherein the device has a power conversion efficiency that is up to 2.9% for a sum of two photoactive subcells in the device.~~

~~57. The device of claims 52 or 54, wherein the graphene film layer has a sheet resistance that is less than 1k ohm per square.~~

~~58. The device of claims 52 or 54, wherein the graphene film layer has an optical transparency that is greater than 80%.~~