CLAIMS

1. A photovoltaic cell comprising collecting electrodes and a photoactive layer sandwiched between said collecting electrodes, wherein said photoactive layer comprises, as photoactive components, group IV-VI semiconductor nanocrystals, wherein said nanocrystals are either:

(i) core-shell semiconductor nanocrystals each comprising a core of a first group IV-VI semiconductor material having a selected band gap energy and a core-overcoating shell consisting of a second group IV-VI semiconductor material; or

(ii) core-alloyed shell semiconductor nanocrystals each comprising a core of a first group IV-VI semiconductor material having a selected band gap energy and a core-overcoating alloyed shell consisting of an alloy of said first group IV-VI semiconductor material and a second group IV-VI semiconductor material,

wherein the core has the structure of AB; the core-overcoating shell, if present, has the structure of AC; and the core-overcoating alloyed shell, if present, consists of an alloy of the AB_xC_{1-x} structure, wherein A is Pb; B is Se or Te; C is S; x is the mole fraction of B; and 1-x is the mole fraction of C, with x gradually changing within a range wherein $x<1$ and $x>0$.

2. The photovoltaic cell of claim 1, wherein said nanocrystals are core-shell semiconductor nanocrystals.

3. The photovoltaic cell of claim 1, wherein said nanocrystals are core-alloyed shell semiconductor nanocrystals.

4. The photovoltaic cell of claim 1, wherein said nanocrystals are in the form of spheroids or rods.

5. The photovoltaic cell of claim 1, wherein the band gap energy of said core semiconductor material is in the infrared range.

6. The photovoltaic cell of claim 5, wherein said core semiconductor material is PbSe or PbTe, preferably PbSe; said core-overcoating shell, if present, is made of PbS; and said core-overcoating alloyed shell, if present, has the $PbSe_xS_{1-x}$ structure wherein x is the mole fraction of Se and 1-x is the mole fraction of S, with x gradually changing within a range wherein $x<1$ and $x>0$.

7. The photovoltaic cell of claim 6, wherein (i) said nanocrystals are core-shell semiconductor nanocrystals, the core semiconductor material is PbSe, and the core-overcoating shell is made of PbS; or (ii) said nanocrystals are core-alloyed shell semiconductor nanocrystals, the core semiconductor material is PbSe, and the core-overcoating alloyed shell has the $PbSe_xS_{1-x}$ structure wherein x is the mole fraction of Se and 1-x is the mole fraction of S, with x gradually changing within a range wherein $x<1$ and $x>0$.

8. The photovoltaic cell of claim 1, wherein each one of said nanocrystals is a core-alloyed shell semiconductor nanocrystal, and said alloyed shell exhibits gradual change of the crystallographic lattice spacing and/or gradual change of the dielectric constant.

9. The photovoltaic cell of claim 1, wherein said group IV-VI semiconductor nanocrystals have a tunable single exciton absorption in the spectral range of 800-3500 nm.

10. The photovoltaic cell of claim 1, wherein said nanocrystals have a size in a range of about 2 nm to about 50 nm, preferably from about 2 nm to about 20 nm.

11. The photovoltaic cell of claim 1, wherein said group IV-VI semiconductor nanocrystals have an impact ionization process excited in the ultraviolet and visible spectral regime that leads to multiple carrier generation, thus enabling absorption processes that cover a wide spectral range.

12. The photovoltaic cell of claim 1, wherein said group IV-VI semiconductor nanocrystals have an efficient internal charge carrier separation.

13. The photovoltaic cell of claim 1, wherein said nanocrystals exhibit less than a 5% root-mean-square deviation (RMSD) in diameter.

14. The photovoltaic cell of claim 1, wherein said nanocrystals exhibit photoluminescence having quantum yields greater than 20%, preferably greater than 40%, more preferably greater than 60%, most preferably about 80%.

15. The photovoltaic cell of any one of claims 1 to 14, wherein said nanocrystals are packed as a single layer thin film, sandwiched between said collecting electrodes and acting as an insolating layer in a p-i-n configuration, wherein an efficient internal charge separation in each one of said nanocrystals allows the migration of a charge carrier to a relevant collecting electrode.

16. The photovoltaic cell of any one of claims 1 to 14, wherein said nanocrystals are packed as a bi-layer hetero-junction comprising a layer of nanocrystals in conjunction with either a second layer of nanocrystals or a conductive polymer film having a staggered energy band alignment that facilitate a charge transfer of a donor-acceptor pair, which is sandwiched between said collecting electrodes.

17. The photovoltaic cell of any one of claims 1 to 14, wherein said nanocrystals are packed as a single layer of a nanocrystal-conductive polymer blend having a staggered energy band alignment that facilitates a charge transfer of a donor-acceptor (D-A) pair, which is sandwiched between said collecting electrodes and permits an excess charge separation and a charge carrier diffusion to a relevant collecting electrode.

18. The photovoltaic cell of claim 16 or 17, wherein said conductive polymer is poly[2-methoxy-5-(2'-ethyl-hexyloxy)-1,4-phenylene vynylene] (MEH-PPV) or poly-3-hexylthiophene (P3HT).

19. The photovoltaic cell of any one of claims 1 to 14, wherein said nanocrystals are packed as a single layer of nanocrystals deposited onto a TiO_2 particle film and act as photo-sensitizers, injecting their electrons into the TiO_2 film.

CLAIMS

1. A photovoltaic cell comprising group IV-VI semiconductor nanocrystals as photoactive components, wherein said nanocrystals are either:

(i) core-shell semiconductor nanocrystals each comprising a core of a first group IV-VI semiconductor material having a selected band gap energy and a core-overcoating shell consisting of a second group IV-VI semiconductor material; or

(ii) core-alloyed shell semiconductor nanocrystals each comprising a core of a first group IV-VI semiconductor material having a selected band gap energy and a core-overcoating alloyed shell consisting of an alloy of said first group IV-VI semiconductor material and a second group IV-VI semiconductor material.

2. The photovoltaic cell of claim 1, wherein said nanocrystals are core-shell semiconductor nanocrystals.

3. The photovoltaic cell of claim 1, wherein said nanocrystals are core-alloyed shell semiconductor nanocrystals.

4. The photovoltaic cell of claim 1, wherein said nanocrystals are in the form of spheroids or rods.

5. The photovoltaic cell of claim 1, wherein the core and the core-overcoating shell, if present, each independently has the structure of AB or AC; and the core-overcoating alloyed shell, if present, consists of an alloy of the AB_xC_{1-x} structure, wherein A is Pb; B and C each independently is S, Se or Te; x is the mole fraction of B and 1-x is the mole fraction of C, with x gradually changing within a range wherein $x<1$ and $x>0$.

6. The photovoltaic cell of claim 1, wherein the band gap energy of said core semiconductor material is in the infrared range.

7. The photovoltaic cell of claim 6, wherein said core semiconductor material is PbS, PbSe or PbTe, preferably PbSe; said core-overcoating shell, if present, is made of PbS, PbSe or PbTe, preferably PbS; and said core-overcoating alloyed shell, if present, has the $PbSe_xS_{1-x}$ structure wherein x is the mole fraction of Se and 1-x is the mole fraction of S, with x gradually changing within a range wherein $x<1$ and $x>0$.

8. The photovoltaic cell of claim 7, wherein (i) said nanocrystals are core-shell semiconductor nanocrystals, the core semiconductor material is PbSe, and the core-overcoating shell is made of PbS; or (ii) said nanocrystals are core-alloyed shell semiconductor nanocrystals, the core semiconductor material is PbSe, and the core-overcoating alloyed shell has the $PbSe_xS_{1-x}$ structure wherein x is the mole fraction of Se and 1-x is the mole fraction of S, with x gradually changing within a range wherein $x<1$ and $x>0$.

9. The photovoltaic cell of claim 1, wherein each one of said nanocrystals is a core-alloyed shell semiconductor nanocrystal, and said alloyed shell exhibits gradual change of the crystallographic lattice spacing and/or gradual change of the dielectric constant.

10. The photovoltaic cell of claim 1, wherein said group IV-VI semiconductor nanocrystals have a tunable single exiton absorption in the spectral range of 800-3500 nm.

11. The photovoltaic cell of claim 1, wherein said nanocrystals have a size in a range of about 2 nm to about 50 nm, preferably from about 2 nm to about 20 nm.

12. The photovoltaic cell of claim 1, wherein said group IV-VI semiconductor nanocrystals have an impact ionization process excited in the ultraviolet and visible spectral regime that leads to multiple carrier generation, thus enabling absorption processes that cover a wide spectral range.

13. The photovoltaic cell of claim 1, wherein said group IV-VI semiconductor nanocrystals have an efficient internal charge carrier separation.

14. The photovoltaic cell of claim 1, wherein said nanocrystals exhibit less than a 5% root-mean-square deviation (RMSD) in diameter.

15. The photovoltaic cell of claim 1, wherein said nanocrystals exhibit photoluminescence having quantum yields greater than 20%, preferably greater than 40%, more preferably greater than 60%, most preferably about 80%.

16. The photovoltaic cell of any one of claims 1 to 15, wherein said nanocrystals are packed as a single layer thin film, sandwiched between collecting electrodes and acting as an insolating layer in a p-i-n configuration, wherein an efficient internal charge separation in each one of said nanocrystals allows the migration of a charge carrier to a relevant collecting electrode.

17. The photovoltaic cell of any one of claims 1 to 15, wherein said nanocrystals are packed as a bi-layer hetero-junction comprising a layer of nanocrystals in conjunction with either a second layer of nanocrystals or a conductive polymer film having a staggered energy band alignment that facilitate a charge transfer of a donor-acceptor pair, which is sandwiched between collecting electrodes.

18. The photovoltaic cell of any one of claims 1 to 15, wherein said nanocrystals are packed as a single layer of a nanocrystal-conductive polymer blend having a staggered energy band alignment that facilitates a charge transfer of a donor-acceptor (D-A) pair, which is sandwiched between collecting electrodes and permits an excess charge separation and a charge carrier diffusion to a relevant collecting electrode.

19. The photovoltaic cell of claim 17 or 18, wherein said conductive polymer is poly[2-methoxy-5-(2'-ethyl-hexyloxy)-1,4-phenylene vynylene] (MEH-PPV) or poly-3-hexylthiophene (P3HT).

20. The photovoltaic cell of any one of claims 1 to 15, wherein said nanocrystals are packed as a single layer of nanocrystals deposited onto a TiO_2 particle film and act as photo-sensitizers, injecting their electrons into the TiO_2 film.

21. A photovoltaic device comprising a photovoltaic cell and a photonic structure that acts as a fluorescence collector, harvesting a wide spectral range of solar radiation, comprising group IV-VI semiconductor nanocrystals as photoactive components, packed as a single layer between a pair of Bragg reflectors,

wherein said nanocrystals are either:

(i) core-shell semiconductor nanocrystals each comprising a core of a group IV-VI semiconductor material having a selected band gap energy and a core-overcoating shell consisting of a second group IV-VI semiconductor material; or

(ii) core-alloyed shell semiconductor nanocrystals each comprising a core of a group IV-VI semiconductor material having a selected band gap energy and a core-overcoating alloyed shell consisting of an alloy of said group IV-VI semiconductor material and a second group IV-VI semiconductor material,

said nanocrystals emit photons at their band-edge energy, and said photons are internally reflected within a photonic cavity and then emitted from said photonic cavity with an enhanced intensity tuned to the absorption edge of a photoactive material being a component of said photovoltaic cell.

22. The photovoltaic device of claim 21, wherein said nanocrystals are core-shell semiconductor nanocrystals.

23. The photovoltaic device of claim 21, wherein said nanocrystals are core-alloyed shell semiconductor nanocrystals.

24. The photovoltaic device of claim 21, wherein said nanocrystals are in the form of spheroids or rods.