Claims

1. A photodetector pixel comprising:

   a chiral plasmonic molecule array configured to generate heat upon incidence of an electromagnetic wave on the chiral plasmonic molecule array; and

   a thermoelectric layer configured to generate an electric current or voltage upon transfer of heat from the chiral plasmonic molecule array to the thermoelectric layer; wherein the chiral plasmonic molecule array comprises a metal layer;

   wherein the chiral plasmonic molecule array comprises one or more nanostructures;

   wherein the chiral plasmonic molecule array comprises a dielectric spacer such that the dielectric spacer is between the metal layer and the one or more nanostructures; and

   wherein the one or more nanostructures comprise one or more left hand (LH) chiral metamaterial nanostructures and one or more right hand (RH) chiral metamaterial nanostructures arranged along a plane.

2. The photodetector pixel according to claim 1,

   wherein the thermoelectric layer comprises any material that exhibits Seebeck effect.

3. The photodetector pixel according to claim 1 or claim 2,

   wherein the thermoelectric layer comprises a two-dimensional (2D) thermoelectric material.

4. The photodetector pixel according to any one of claims 1 to 3,

wherein the one or more left hand (LH) chiral metamaterial nanostructures are “Z” shaped nanostructures; and

wherein the one or more right hand (RH) chiral metamaterial nanostructures are “Z” shaped nanostructures.

5. The photodetector pixel according to any one of claims 1 to 4,

wherein the one or more nanostructures comprise a metal.

6. The photodetector pixel according to any one of claims 1 to 5, further comprising:

a substrate such that the chiral plasmonic molecule array and the thermoelectric layer are over the substrate.

7. A photodetector comprising:

a first photodetector pixel according to any one of claims 1 to 6;

a second photodetector pixel according to any one of claims 1 to 6, the second photodetector pixel oriented substantially 90º to the first photodetector pixel;

a third photodetector pixel oriented substantially 45º to the first photodetector pixel, wherein the third photodetector pixel comprises:

a chiral plasmonic molecule array configured to generate heat upon incidence of an electromagnetic wave on the chiral plasmonic molecule array; and

a thermoelectric layer configured to generate an electric current or voltage upon transfer of heat from the chiral plasmonic molecule array to the thermoelectric layer; wherein the chiral plasmonic molecule array comprises a metal layer;

wherein the chiral plasmonic molecule array comprises one or more nanostructures;

wherein the chiral plasmonic molecule array comprises a dielectric spacer such that the dielectric spacer is between the metal layer and the one or more nanostructures; and

wherein the one or more nanostructures comprise one or more left hand (LH) chiral metamaterial nanostructures; and

a fourth photodetector pixel oriented substantially 45º to the first photodetector pixel, wherein the fourth photodetector pixel comprises:

a chiral plasmonic molecule array configured to generate heat upon incidence of an electromagnetic wave on the chiral plasmonic molecule array; and

a thermoelectric layer configured to generate an electric current or voltage upon transfer of heat from the chiral plasmonic molecule array to the thermoelectric layer; wherein the chiral plasmonic molecule array comprises a metal layer;

wherein the chiral plasmonic molecule array comprises one or more nanostructures;

wherein the chiral plasmonic molecule array comprises a dielectric spacer such that the dielectric spacer is between the metal layer and the one or more nanostructures; and

wherein the one or more nanostructures comprise one or more right hand (RH) chiral metamaterial nanostructures;

wherein the third photodetector pixel or the fourth photodetector pixel is configured to determine an ellipticity angle of a state of polarization of the electromagnetic wave; and

wherein the first photodetector pixel and the second photodetector pixel are configured to determine an azimuthal angle of the state of polarization of the electromagnetic waves.

8. The photodetector according to claim 7,

wherein the one or more left hand (LH) chiral metamaterial nanostructures of the first photodetector pixel have an angle of substantially 20º relative to the one or more right hand (RH) chiral metamaterial nanostructures of the first photodetector pixel; and

wherein the one or more left hand (LH) chiral metamaterial nanostructures of the second photodetector pixel have an angle of substantially 20º relative to the one or more right hand (RH) chiral metamaterial nanostructures of the second photodetector pixel.

9. The photodetector according to claim 7 or claim 8,

wherein the ellipticity angle is also determined by the first photodetector pixel and the second photodetector pixel.

10. A method of forming a photodetector pixel, the method comprising:

forming a chiral plasmonic molecule array configured to generate heat upon incidence of an electromagnetic wave on the chiral plasmonic molecule array; and

forming a thermoelectric layer configured to generate an electric current or voltage upon transfer of heat from the chiral plasmonic molecule array to the thermoelectric layer;

wherein the chiral plasmonic molecule array comprises a metal layer;

wherein the chiral plasmonic molecule array comprises one or more nanostructures;

wherein the chiral plasmonic molecule array comprises a dielectric spacer such that the dielectric spacer is between the metal layer and the one or more nanostructures; and

wherein the one or more nanostructures comprise one or more left hand (LH) chiral metamaterial nanostructures and one or more right hand (RH) chiral metamaterial nanostructures arranged along a plane.

11. The method according to claim 10,

wherein the thermoelectric layer comprises any material that exhibits Seebeck effect.

12. The method according to claim 10 or claim 11,

wherein the thermoelectric layer comprises a two-dimensional (2D) thermoelectric material.

13. The method according to any one of claims 10 to 12,

wherein forming the chiral plasmonic molecule array comprises forming the metal layer over a substrate;

wherein forming the chiral plasmonic molecule array further comprises forming the dielectric spacer over the metal layer; and

wherein forming the chiral plasmonic molecule array also comprises forming the one or more nanostructures over the dielectric spacer.

14. The method according to claim 13,

wherein the metal layer is formed using electron beam evaporation or thermal evaporation;

where the dielectric spacer is formed using electron beam evaporation or thermal evaporation; and

wherein the one or more nanostructures is formed using a lithography process.

15. The method according to any one of claims 10 to 14,

wherein the thermoelectric layer is formed over the chiral plasmonic molecule array.

16. The method according to claim 15,

wherein the thermoelectric layer is formed over the chiral plasmonic molecule array via a dry-transfer method.

17. The method according to according to any one of claims 10 to 16,

wherein the one or more left hand (LH) chiral metamaterial nanostructures are “Z” shaped nanostructures; and

wherein the one or more right hand (RH) chiral metamaterial nanostructures are “Z” shaped nanostructures.

18. The method according to any one of claims 10 to 17,

wherein the one or more nanostructures comprise a metal.

19. A method of forming a photodetector, the method comprising:

forming a first photodetector pixel according to any one of claims 1 to 6;

forming a second photodetector pixel according to any one of claims 1 to 6, the second photodetector pixel oriented substantially 90º to the first photodetector pixel;

forming a third photodetector pixel oriented substantially 45º to the first photodetector pixel, wherein the third photodetector pixel comprises:

a chiral plasmonic molecule array configured to generate heat upon incidence of an electromagnetic wave on the chiral plasmonic molecule array; and

a thermoelectric layer configured to generate an electric current or voltage upon transfer of heat from the chiral plasmonic molecule array to the thermoelectric layer; wherein the chiral plasmonic molecule array comprises a metal layer;

wherein the chiral plasmonic molecule array comprises one or more nanostructures;

wherein the chiral plasmonic molecule array comprises a dielectric spacer such that the dielectric spacer is between the metal layer and the one or more nanostructures; and

wherein the one or more nanostructures comprise one or more left hand (LH) chiral metamaterial nanostructures; and

forming a fourth photodetector pixel oriented substantially 45^{0} to the first photodetector pixel, wherein the fourth photodetector pixel comprises:

a chiral plasmonic molecule array configured to generate heat upon incidence of an electromagnetic wave on the chiral plasmonic molecule array; and

a thermoelectric layer configured to generate an electric current or voltage upon transfer of heat from the chiral plasmonic molecule array to the thermoelectric layer; wherein the chiral plasmonic molecule array comprises a metal layer;

wherein the chiral plasmonic molecule array comprises one or more nanostructures;

wherein the chiral plasmonic molecule array comprises a dielectric spacer such that the dielectric spacer is between the metal layer and the one or more nanostructures; and

wherein the one or more nanostructures comprise one or more right hand (RH) chiral metamaterial nanostructures;

wherein the third photodetector pixel or the fourth photodetector pixel is configured to determine an ellipticity angle of a state of polarization of the electromagnetic wave; and

wherein the first photodetector pixel and the second photodetector pixel are configured to determine an azimuthal angle of the state of polarization of the electromagnetic waves.

20. The method according to claim 19,

wherein the one or more left hand (LH) chiral metamaterial nanostructures of the first photodetector pixel have an angle of substantially 20º relative to the one or more right hand (RH) chiral metamaterial nanostructures of the first photodetector pixel; and

wherein the one or more left hand (LH) chiral metamaterial nanostructures of the second photodetector pixel have an angle of substantially 20º relative to the one or more right hand (RH) chiral metamaterial nanostructures of the second photodetector pixel.

21. The method according to claim 19 or claim 20,

wherein the ellipticity angle is also determined by the first photodetector pixel and the second photodetector pixel.