CLAIMS

What is claimed is:

1. A saturable absorber device for use in a laser cavity, comprising:

an optical element; and

a saturable absorber material supported by the optical element and comprising a polarized ferroelectric material and a graphene substrate, wherein the graphene substrate is layered with the ferroelectric material to form a gate tunable graphene-ferroelectric hybrid saturable absorber.

2. The saturable absorber device of Claim 1, wherein the graphene substrate is single layer or multi-layer graphene.

3. The saturable absorber device of Claim 1, wherein the graphene substrate is a graphene sheet, activated reduced graphene oxide, a graphene flake, or a combination thereof.

4. The saturable absorber device of Claim 1, wherein the ferroelectric material is a polymer or copolymer comprising vinylidene fluoride, trifluoroethylene, 11-aminoundecanoic acid, thiourea, or a combination thereof.

5. The saturable absorber device of Claim 1, wherein the ferroelectric material is a ceramic material comprising bismuth ferrite, barium titanate, lead titanate, sodium nitrite, potassium phosphate, or a combination thereof.

6. The saturable absorber device of Claim 1, wherein the ferroelectric material is a hydrogen-bonded supramolecule polymer or copolymer comprising 5,5′-dimethyl-2,2′-bipyridine, 2,5-dichloro-3,6-dihydroxy-p-benzoquinone, 2,5-dibromo-3,6-dihydroxy-p-benzoquinone, 2,5-diiodo-3,6-dihydroxy-p-benzoquinone, or a combination thereof.

7. The saturable absorber device of Claim 1, wherein the ferroelectric material is an organic-inorganic compound comprising triglycine sulfate, H-1,4-

~~diazabicyclo[2.2.2] octane ammonium perrhenate (H-dabcoReO$_4$),~~ trisarcosine calcium chloride, or a combination thereof.

8. The saturable absorber device of Claim 1, wherein one or more graphene-ferroelectric hybrid saturable absorbers are stacked.

9. The saturable absorber device of Claim 1, wherein the doping level of the graphene-hybrid saturable absorber is dynamically modifiable via electrostatic gates to tune the resonant wavelength.

10. The saturable absorber device of Claim 9, wherein the resonant wavelength for each laser pulse can be changed individually.

11. The saturable absorber device of Claim 1, wherein the ferroelectric material is a ferroelectric thin film.

12. The saturable absorber device of Claim 1, wherein the graphene substrate is patterned in a micro-shape structure, comprising a circular array, a micro-ribbon array, or a combination thereof.

13. The saturable absorber device of Claim 1, wherein the optical element comprises an optical fiber.

14. A fiber laser, comprising:

a ring or linear laser cavity; and

a saturated absorber device arranged within the laser cavity, the saturable device, comprising: an optical element, and a saturable absorber material supported by the optical element, the saturable absorber material, comprising ferroelectric material and a graphene substrate, wherein the graphene substrate is layered with the ferroelectric material to form a gate tunable graphene-ferroelectric hybrid saturable absorber.

15. The fiber laser of Claim 14, wherein the saturable absorber device is ~~configured in the laser cavity so as to provide at least one of: wavelength~~

~~tuning, mode-locking, Q-switching, optical pulse shaping, optical switching,~~ and optical signal processing.

16. The fiber laser of Claim 14, wherein the ferroelectric material is a polymer or copolymer comprising vinylidene fluoride, trifluoroethylene, 11-aminoundecanoic acid, thiourea, or a combination thereof.

17. The fiber laser of Claim 14, wherein the ferroelectric material is a ceramic material comprising bismuth ferrite, barium titanate, lead titanate, sodium nitrite, potassium phosphate, or a combination thereof.

18. The fiber laser of Claim 14, wherein the ferroelectric material is a hydrogen-bonded supramolecule polymer or copolymer comprising 5,5′-dimethyl-2,2′-bipyridine, 2,5-dichloro-3,6-dihydroxy-p-benzoquinone, 2,5-dibromo-3,6-dihydroxy-p-benzoquinone, 2,5-diiodo-3,6-dihydroxy-p-benzoquinone, or a combination thereof.

19. The fiber laser of Claim 14, wherein the ferroelectric material is an organic-inorganic compound comprising triglycine sulfate, H-1,4-diazabicyclo[2.2.2] octane ammonium perrhenate (H-dabcoReO_4), trisarcosine calcium chloride, or a combination thereof.

20. The fiber laser of Claim 14, wherein the optical element comprises an optical fiber optionally containing a mode lock assembly.

21. The fiber laser of Claim 20, wherein the optical fiber and the saturable absorber material are mounted in the beam path on the core of the optical fiber with a mode locker assembly.

22. A method of forming a saturable absorber device, comprising:

a) providing an optical element; and

b) supporting with the optical element a saturable absorber material comprising a ferroelectric material and a graphene substrate.

~~23. A method of fabricating the saturable absorber material, comprising:~~

a) depositing a layer of graphene onto a substrate by template-directed chemical vapor deposition (CVD);

b) depositing a layer of ferroelectric material onto the graphene;

c) removing the substrate via wet chemical etching; and

d) doping the material from step (c) by applying an electric field to thereby obtain the graphene-ferroelectric hybrid saturable absorber material.

24. The method of Claim 23, wherein step (b) through step (c) are performed using roll-to-roll technique.

25. The method of Claim 23, wherein step (d) is performed using corona poling technique to obtain the desired remnant polarization state of the ferroelectric material layer.

CLAIMS

What is claimed is:

1. A saturable absorber device for use in a laser cavity, comprising:

an optical element; and

a saturable absorber material supported by the optical element and comprising a polarized ferroelectric material and a graphene substrate, wherein the graphene substrate is layered with the ferroelectric material to form a gate tunable graphene-ferroelectric hybrid saturable absorber.

2. The saturable absorber device of claim 1, wherein the graphene substrate is single layer graphene, multi-layer graphene, a graphene sheet, activated reduced graphene oxide, a graphene flake, or a combination thereof.

3. The saturable absorber device of claim 1, wherein the ferroelectric material is a polymer or copolymer comprising vinylidene fluoride, trifluoroethylene, 11-aminoundecanoic acid, thiourea, or a combination thereof.

4. The saturable absorber device of claim 1, wherein the ferroelectric material is a ceramic material comprising bismuth ferrite, barium titanate, lead titanate, sodium nitrite, potassium phosphate, or a combination thereof.

5. The saturable absorber device of claim 1, wherein the ferroelectric material is a hydrogen-bonded supramolecule polymer or copolymer comprising 5,5'-dimethyl-2,2'-bipyridine, 2,5-dichloro-3,6-dihydroxy-p-benzoquinone, 2,5-dibromo-3,6-dihydroxy-p-benzoquinone, 2,5-diiodo-3,6-dihydroxy-p-benzoquinone, or a combination thereof.

6. The saturable absorber device of claim 1, wherein the ferroelectric material is an organic-inorganic compound comprising triglycine sulfate, H-1,4-diazabicyclo[2.2.2] octane ammonium perrhenate (H-dabcoReO_4), trisarcosine calcium chloride, or a combination thereof.

7. The saturable absorber device of claim 1, wherein the doping level of the graphene-hybrid saturable absorber is dynamically modifiable via electrostatic gates to tune the resonant wavelength.

8. The saturable absorber device of claim 7, wherein the resonant wavelength for each laser pulse can be changed individually.

9. The saturable absorber device of claim 1, wherein the ferroelectric material is a ferroelectric thin film.

10. The saturable absorber device of claim 1, wherein the graphene substrate is patterned in a micro-shape structure, comprising a circular array, a micro-ribbon array, or a combination thereof.

11. The saturable absorber device of claim 1, wherein the optical element comprises an optical fiber.

12. A fiber laser, comprising:

a ring or linear laser cavity; and

a saturated absorber device arranged within the laser cavity, the saturable device, comprising: an optical element, and a saturable absorber material supported by the optical element, the saturable absorber material, comprising ferroelectric material and a graphene substrate, wherein the graphene substrate is layered with the ferroelectric material to form a gate tunable graphene-ferroelectric hybrid saturable absorber.

13. The fiber laser of claim 12, wherein the saturable absorber device is configured in the laser cavity so as to provide at least one of: wavelength tuning, mode-locking, Q-switching, optical pulse shaping, optical switching, and optical signal processing.

14. The fiber laser of claim 12, wherein the ferroelectric material is

1) a polymer or copolymer comprising vinylidene fluoride, trifluoroethylene, 11-aminoundecanoic acid, thiourea, or a combination thereof;

2) a ceramic material comprising bismuth ferrite, barium titanate, lead titanate, sodium nitrite, potassium phosphate, or a combination thereof;

3) a hydrogen-bonded supramolecule polymer or copolymer comprising 5,5'-dimethyl-2,2'-bipyridine, 2,5-dichloro-3,6-dihydroxy-p-benzoquinone, 2,5-dibromo-3,6-dihydroxy-p-benzoquinone, 2,5-diiodo-3,6-dihydroxy-p-benzoquinone, or a combination thereof; or

4) an organic-inorganic compound comprising triglycine sulfate, H-1,4-diazabicyclo[2.2.2]octane ammonium perrhenate (H-dabcoReO_4), trisarcosine calcium chloride, or a combination thereof.

15. The fiber laser of claim 12, wherein the optical element comprises an optical fiber optionally containing a mode lock assembly.

16. The fiber laser of claim 15, wherein the optical fiber and the saturable absorber material are mounted with a mode locker assembly.

17. A method of forming the saturable absorber device of claim 1, comprising:

a) providing an optical element; and

b) supporting with the optical element a saturable absorber material comprising a ferroelectric material and a graphene substrate.

18. A method of fabricating the saturable absorber material, comprising:

a) depositing a layer of graphene onto a substrate by template-directed chemical vapor deposition (CVD);

b) depositing a layer of ferroelectric material onto the graphene;

c) removing the substrate via wet chemical etching; and d) doping the material from step (c) by applying an electric field to thereby obtain the graphene-ferroelectric hybrid saturable absorber material.

19. The method of claim 18, wherein step (b) through step (c) are performed using roll-to-roll technique.

20. The method of claim 18, wherein step (d) is performed using corona poling technique to obtain the desired remnant polarization state of the ferroelectric material layer.