CLAIMS

What is claimed is:

1. A scintillator material comprising a composition of Formula (I):

$$[(RE_{1-x}RE'_x)_{1-y-z}A_yB_z]_3Al_5O_{12} \quad (I),$$

wherein:

$0 \leq x \leq 1.0$;

$0 < y \leq 0.05$;

$0 < z \leq 0.1$;

RE is a first rare earth element;

RE' is a second rare earth element or a combination of a second rare earth element and at least one more or more additional rare earth elements, subject to the proviso that RE' does not comprise the first rare earth element RE;

A is a dopant ion selected from the group consisting of Pr, Nd, Sm, Eu, Gd, Tb, Yb, Bi, Sb, and any combination thereof, subject to the proviso that A does not comprise an ion of the same element as RE or RE'; and

B is at least one type of monovalent cation, optionally a cation of an element selected from the group consisting of Li, Na, K, Rb, Cs, and Fr.

2. The scintillator material of claim 1, wherein RE is Lu.

3. The scintillator material of claim 1 or claim 2, wherein RE' is Y.

4. The scintillator material of any one of claims 1-3, wherein $0.1 \leq x \leq 0.5$, optionally wherein x is 0.25.

5. The scintillator material of any one of claims 1-4, wherein A is Pr^{3+}.

6. The scintillator material of any one of claims 1-5, wherein $0.0001 \leq y \leq 0.015$, optionally wherein y is 0.004 or 0.012.

7. The scintillator material of any one of claims 1-6, wherein B is Li^+.

8. The scintillator material of any one of claims 1-7, wherein $0.0002 \leq z \leq 0.1$, optionally wherein $0.001 \leq z \leq 0.1$, further optionally wherein z is 0.002, 0.008, or 0.02.

9. A scintillator material comprising a composition of Formula (II):

$$[(Lu_{1-x}RE'_x)_{1-y-z}A_yB_z]_3Al_5O_{12} \quad (II),$$

wherein:

$0.05 \leq x \leq 1.0$;

$0 < y \leq 0.05$;

$0 < z \leq 0.1$;

RE' is selected from the group consisting of Ce, Dy, Er, Eu, Gd, Ho, La, Nd, Pr, Pm, Sm, Sc, Tb, Tm, Yb, Y and any combination thereof;

A is a dopant ion, optionally an ion of an element selected from the group consisting of Ce, Pr, Nd, Sm, Eu, Gd, Tb, Yb, Bi, Sb, and any combination thereof, subject to the proviso that A does not comprise an ion of the same element as RE'; and

B is at least one type of monovalent cation, optionally a cation of an element selected from the group consisting of Li, Na, K, Rb, Cs, and Fr.

10. The scintillator material of claim 9, wherein RE' is Y.

11. The scintillator material of claim 9 or claim 10, wherein $0.1 \leq x \leq 0.5$, optionally wherein x is 0.25.

12. The scintillator material of any one of claims 9-11, wherein A is Pr^{3+}.

13. The scintillator material of any one of claims 9-12, wherein $0.0001 \leq y \leq 0.015$, optionally wherein y is 0.004 or 0.012.

14. The scintillator material of any one of claims 9-13, wherein B is Li^+.

15. The scintillator material of any one of claims 9-14, wherein $0.0002 \leq z \leq 0.1$, optionally wherein $0.001 \leq z \leq 0.1$, further optionally wherein z is 0.002, 0.008, or 0.02.

16. A scintillator material comprising a composition of Formula (III):

$$[(Lu_{1-x}Y_x)_{1-y-z}A_yB_z]_3Al_5O_{12} \quad (III),$$

wherein:

$0.05 \leq x \leq 0.5$;

$0 < y \leq 0.05$;

$0 < z \leq 0.1$;

A is a dopant ion, optionally an ion of an element selected from the group consisting of Ce, Pr, Nd, Sm, Eu, Gd, Tb, Yb, Bi, Sb, and any combination thereof; and

B is at least one type of monovalent cation, optionally a cation of an element selected from the group consisting of Li, Na, K, Rb, Cs, and Fr.

17. The scintillator material of claim 16, wherein x is 0.25.

18. The scintillator material of claim 16 or claim 17, wherein A is Pr^{3+}.

19. The scintillator material of any one of claims 16-18, wherein $0.0001 \leq y \leq 0.015$, optionally wherein y is 0.004 or 0.012.

20. The scintillator material of any one of claims 16-19, wherein B is Li^+.

21. The scintillator material of any one of claims 16-20, wherein $0.0002 \leq z \leq 0.1$, optionally wherein $0.001 \leq z \leq 0.1$, further optionally wherein z is 0.002, 0.008, or 0.02.

22. The scintillator material of any one of claims 1-21, wherein the scintillator material comprises a material selected from the group consisting of $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:0.4%$Pr^{3+}$ codoped with 0.2%Li^+, $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:0.4%$Pr^{3+}$ codoped with 0.8% Li^+, $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:0.4%$Pr^{3+}$ codoped with 2.0% Li^+; $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:0.1.2%$Pr^{3+}$ codoped with 0.308 at% Na^+, $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:1.2%$Pr^{3+}$ codoped with 0.6 at% Li^+, $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:1.2%$Pr^{3+}$ codoped with 0.6 at% K^+,

$(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:1.2%$Pr^{3+}$ codoped with 2.4 at% Li^+, and $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:1.2%$Pr^{3+}$ codoped with 6 at% Li^+, optionally wherein the material is selected from the group consisting of $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:0.4%$Pr^{3+}$ codoped with 0.2%Li^+, $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:0.4%$Pr^{3+}$ codoped with 0.8% Li^+, and $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:0.4%$Pr^{3+}$ codoped with 2.0% Li^+.

23. The scintillator material of any one of claims 1-22, wherein the scintillator material exhibits one or more of increased light yield, improved energy resolution, and an accelerated fast decay component as compared to the scintillator material where B is absent.

24. The scintillator material of any one of claims 1-23, wherein the scintillator material is a single crystal material.

25. The scintillator material of any one of claims 1-23, wherein the scintillator material is a polycrystalline and/or a ceramic material.

26. A radiation detector comprising a photon detector and a scintillation material of any one of claims 1-25.

27. The radiation detector of claim 26, wherein the detector is a medical diagnostic device, a device for oil exploration, or a device for container or baggage scanning.

28. A method of detecting gamma rays, X-rays, cosmic rays and/or particles having an energy of 1 keV or greater, the method comprising using the radiation detector of claim 26.

29. A method of preparing a scintillator material of any one of claims 1-24, wherein the method comprises pulling a single crystal from molten raw materials.

30. A method of altering one or more scintillation and/or optical properties of a rare earth aluminum garnet scintillator comprising a matrix having the formula RE"$_3$Al$_5$O$_{12}$, wherein RE" is a mixture of at least two rare earth elements and wherein the scintillator further comprises at least one dopant selected from the group consisting of Ce, Pr, Nd, Sm, Eu, Gd, Tb, Yb, Bi, Sb, and any combination thereof, subject to the proviso that the dopant does not comprise an ion of the same element as any rare earth element of the rare earth aluminum garnet matrix, wherein the method comprises preparing the rare earth aluminum garnet scintillator in the presence of a monovalent codopant ion, thereby providing a codoped rare earth aluminum garnet scintillator material, optionally wherein the monovalent codopant ion is an alkali metal ion.

31. A method of altering one or more scintillation and/or optical properties of a rare earth aluminum garnet scintillator comprising a matrix having the formula RE"$_3$Al$_5$O$_{12}$, wherein RE" is a mixture of at least two rare earth elements and wherein the scintillator further comprises at least one dopant selected from the group consisting of Pr, Nd, Sm, Eu, Gd, Tb, Yb, Bi, Sb, and any combination thereof, subject to the proviso that the dopant does not comprise an ion of the same element as any rare earth element of the rare earth aluminum garnet matrix, optionally wherein the rare earth aluminum garnet scintillator is a praseodymium (Pr) doped lutetium yttrium aluminum garnet (LuYAG) scintillator, wherein the method comprises preparing the rare earth aluminum garnet scintillator in the presence of a monovalent codopant ion, thereby providing a codoped rare earth aluminum garnet scintillator material, optionally wherein the monovalent codopant ion is an alkali metal ion, further optionally wherein the monovalent codopant ion is Li^+.

32. The method of claim 30 or 31, wherein the codoped rare earth aluminum garnet scintillator material exhibits increased light yield, improved energy resolution, better proportionality, and/or faster decay time compared to the same rare earth aluminum garnet scintillator material without a codopant ion.

33. A scintillator material comprising a composition of Formula (I'):

$$[(RE_{1-x}RE'_x)_{1-y-z}A_yB'_z]_3Al_5O_{12} \quad (I'),$$

wherein:

$0 \leq x \leq 1.0$;

$0 < y \leq 0.05$;

$0 < z \leq 0.1$;

RE is a first rare earth element;

RE' is a second rare earth element or a combination of a second rare earth element and at least one more or more additional rare earth elements, subject to the proviso that RE' does not comprise the first rare earth element RE;

A is a dopant ion selected from the group consisting of Pr, Nd, Sm, Eu, Gd, Tb, Yb, Bi, Sb, and any combination thereof, subject to the proviso that A does not comprise an ion of the same element as RE or RE'; and

B' is a monovalent cation of a lithium isotope or a mixture thereof, optionally wherein B' is a monovalent cation of a lithium-6 isotope (i.e., $^6Li^+$).

34. The scintillator material of claim 33, wherein $0.0002 \leq z \leq 0.1$, optionally $0.001 \leq z \leq 0.1$.

35. The scintillator material of claim 33 or 34, wherein RE is Lu.

36. The scintillator material of any one of claims 33-35, wherein RE' is Y, optionally wherein x is about 0.25.

37. The scintillator material of any one of claims 33-36, wherein A is Pr^{3+}, optionally wherein $0.0001 \leq y \leq 0.015$, further optionally wherein y is 0.004 or 0.012.

38. A radiation detector comprising a photon detector and a scintillator material of any one of claims 33-37.

39. A method of detecting neutrons, wherein the method comprises using a radiation detector of claim 38.

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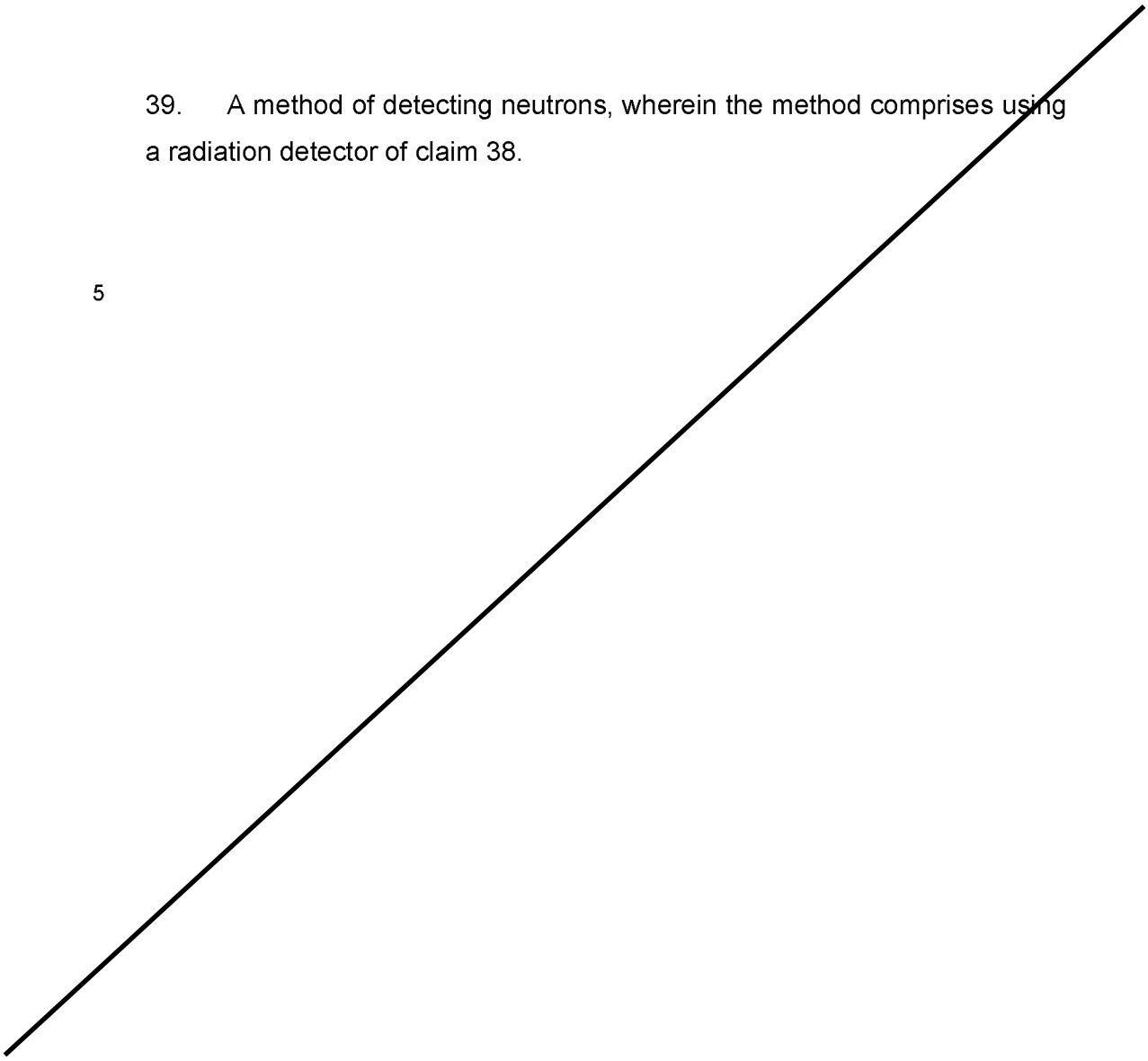

CLAIMS

1. A scintillator material comprising a composition of Formula (III):

$$[(Lu_{1-x}Y_x)_{1-y-z}A_yB_z]_3Al_5O_{12} \quad \text{(III)},$$

wherein:

$0.05 \leq x \leq 0.5$;

$0.0001 \leq y \leq 0.015$;

$0.0002 \leq z \leq 0.1$;

A is Pr^{3+}; and

B is at least one type of monovalent cation selected from the group consisting of Li, Na, and K.

2. The scintillator material of claim 1, wherein $0.1 \leq x \leq 0.5$, optionally wherein x is 0.25.

3. The scintillator material of claim 1 or claim 2, wherein y is 0.004 or 0.012.

4. The scintillator material of any one of claims 1-3, wherein B is a monovalent cation of a lithium isotope or a mixture thereof, optionally wherein B is a monovalent cation of a lithium-6 isotope (i.e., $^6Li^+$).

5. The scintillator material of any one of claims 1-4, wherein $0.001 \leq z \leq 0.1$, further optionally wherein z is 0.002, 0.008, or 0.02.

6. The scintillator material of any one of claims 1-5, wherein the scintillator material comprises a material selected from the group consisting of $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:0.4%$Pr^{3+}$ codoped with 0.2%Li^+, $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:0.4%$Pr^{3+}$ codoped with 0.8% Li^+, $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:0.4%$Pr^{3+}$ codoped with 2.0% Li^+; $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:1.2%$Pr^{3+}$ codoped with 0.308 at% Na^+, $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:1.2%$Pr^{3+}$ codoped with 0.6 at% Li^+, $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:1.2%$Pr^{3+}$ codoped with 0.6 at% K^+,

$(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:1.2%$Pr^{3+}$ codoped with 2.4 at% Li^+, and $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:1.2%$Pr^{3+}$ codoped with 6 at% Li^+, optionally wherein the material is selected from the group consisting of $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:0.4%$Pr^{3+}$ codoped with 0.2%Li^+, $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:0.4%$Pr^{3+}$ codoped with 0.8% Li^+, and $(Lu_{0.75},Y_{0.25})_3Al_5O_{12}$:0.4%$Pr^{3+}$ codoped with 2.0% Li^+.

7. The scintillator material of any one of claims 1-6, wherein the scintillator material is a single crystal material or a polycrystalline or a ceramic material.

8. A radiation detector comprising a photon detector and a scintillation material of any one of claims 1-7.

9. The radiation detector of claim 8, wherein the detector is a medical diagnostic device, a device for oil exploration, or a device for container or baggage scanning.

10. The use of the radiation detector of claim 8 for the detection of gamma rays, X-rays, cosmic rays and/or particles having an energy of 1 keV or greater, or for the detection of neutrons.

11. A method of preparing a scintillator material of any one of claims 1-7, wherein the method comprises pulling a single crystal from molten raw materials.

12. A method of altering one or more scintillation and/or optical properties of a rare earth aluminum garnet scintillator, wherein the rare earth aluminum garnet scintillator is a praseodymium (Pr) doped lutetium yttrium aluminum garnet (LuYAG) scintillator, wherein the method comprises preparing the rare earth aluminum garnet scintillator in the presence of a monovalent codopant ion, thereby providing a codoped rare earth aluminum garnet scintillator material, wherein the monovalent codopant ion is an alkali metal ion, optionally wherein the monovalent codopant ion is Li^+.