of one of sapphire, SiC, GaN and ZnO. At least one of biscyclopentadienyl magnesium (Cp_2Mg), diethyl zinc (DEZn) and silane is used as dopants. A light emitting diode emits light in a range of about 400 nm to 750 nm. InN molar fraction of well layer x is important for the emission range extension to the longer wavelength. With higher x in $In_xGa_{1-x}N$ quantum well layer, emission wavelength extends to longer wavelength. When x is equal to or more than 0.3, range of the emission spectrum from the MQW structure extends to 600 nm or longer. Incorporation of Zn or Zn and Si into the $In_xGa_{1-x}N$ quantum well layer is important for the increase of the emission power from the MQW structure, especially for longer wavelength range.

[0012] According to still another aspect of the present invention, a quantum well structure that emits white light. The quantum well structure comprises: an $In_xGa_{1-x}N$ quantum well layer; indium-rich InGaN quantum dots embedded in the $In_xGa_{1-x}N$ quantum well layer, where $x>0.3$ or $x=0.3$; and an $In_yGa_{1-y}N$ quantum barrier layer over the quantum dots and the quantum well layer.

[0013] According to still another aspect of the present invention, a quantum well structure that emits white light. The quantum well structure comprises an $In_xGa_{1-x}N$ quantum well layer, indium-rich InGaN quantum dots embedded in the $In_xGa_{1-x}N$ quantum well layer, and an $In_yGa_{1-y}N$ quantum barrier layer over the quantum dots and the quantum well layer. The indium-rich InGaN quantum dots are doped with p-type dopant

[0014] In the above aspects, the InGaN quantum well layer is doped with p-type dopant. The InGaN quantum well layer is doped with p-type

CLAIMS

1. A white-light emitting diode, comprising:

an n-type semiconductor layer;

one or more quantum well structures each comprising an $In_xGa_{1-x}N$ quantum well layer and an $In_yGa_{1-y}N$ barrier layer, where $x>0.3$ or $x=0.3$, and the quantum well structure encompassing $In_zGa_{1-z}N$ quantum dots where $x<y<z\leq 1$, the quantum well structures being formed over the n-type semiconductor layer;

a p-type semiconductor layer formed over the quantum well structures;

a first electrode formed over the p-type semiconductor; and

a second electrode formed over at least a portion of a surface of the second section of the n-type semiconductor layer.

2. A white-light emitting diode, comprising:

an n-type semiconductor layer;

one or more quantum well structures each comprising an $In_xGa_{1-x}N$ quantum well layer and an $In_yGa_{1-y}N$ barrier layer, where $x>y$, the quantum well structure encompassing $In_zGa_{1-z}N$ quantum dots where $x<z\leq 1$, the well layer $In_xGa_{1-x}N$ containing p-type dopant, and the quantum well structures being formed over the n-type semiconductor layer;

a p-type semiconductor layer formed over the quantum well structures;

a first electrode formed over the p-type semiconductor; and

a second electrode formed over at least a portion of a surface of the n-type semiconductor layer.

3. The diode of claim 2, wherein the $In_xGa_{1-x}N$ quantum well layer contains both p-type dopant and n-type dopant.

4. The diode of claim 1, wherein the $In_xGa_{1-x}N$ quantum well layer contains p-type dopant, and $x>0.3$ or $x=0.3$.

5. The diode of claim 1, wherein the $In_xGa_{1-x}N$ well layer contains both p-type dopant and n-type dopant, and $x>0.3$ or $x=0.3$.

6. The diode of claim 1, wherein the quantum well structures have a continuous emission spectrum ranging from 420nm to 750nm.

7. The diode of any one of claim 1, claim 2, and claim 6, wherein the quantum dots are formed by first flowing at least one of TMIn, TEIn or EDMIn at a first flow rate and a first time to form nuclei, and then flowing at least one of TMIn, TEIn or EDMIn with TMG and ammonia at a second flow rate to make the nuclei grow and be capped in the quantum well layer.

8. The diode of claim 7, wherein the number of the quantum well structures is between about 1 to 30.

9. The diode of claim 7, wherein a thickness of the $In_xGa_{1-x}N$ quantum well layer is about 1 to 10 nm and a thickness of the $In_yGa_{1-y}N$ quantum barrier layer is about 5 to 30 nm.

10. The diode of claim 7, wherein $1>x>y>0$ or $y=0$.

11. The diode of claim 7, wherein the n-type semiconductor layer is formed on a substrate and the substrate is made of one of sapphire, SiC, GaN and ZnO.

12. The diode of claim 7, wherein at least one of biscyclopentadienyl magnesium, diethyl zinc and silane is used as dopants during the growth of the quantum well layer.

13. A quantum well structure that emits white light, which comprises:

an $In_xGa_{1-x}N$ quantum well layer;

indium-rich InGaN quantum dots embedded in the $In_xGa_{1-x}N$ quantum well layer, where $x>0.3$; and

an $In_yGa_{1-y}N$ quantum barrier layer over the quantum dots and the quantum well layer.

14. A quantum well structure that emits white light, which comprises:

an $In_xGa_{1-x}N$ quantum well layer doped with p-type dopant;

indium-rich InGaN quantum dots embedded in the $In_xGa_{1-x}N$ quantum well layer; and

an $In_yGa_{1-y}N$ quantum barrier layer over the quantum dots and the quantum well layer.

15. The quantum well structure of claim 14, wherein the InGaN quantum well layer contains n-type dopant.

16. The quantum well structure of claim 13, wherein the InGaN quantum well layer contains p-type dopant.

17. The quantum well structure of claim 13, wherein the InGaN quantum well layer contains both p-type dopant and n-type dopant.

18. The quantum well structure of any one of claim 13 and claim 14, wherein the quantum well structure is provided to emit light ranging from 420 nm to 750 nm and the light has a continuous emission spectrum ranging from 420nm to 750nm.

19. The quantum well structure of any one of claim 13 and claim 14, wherein the quantum dots are formed by first flowing at least one of

TMIn, TEIn or EDMIn at a first flow rate and a first time to form nuclei, and then flowing at least one of TMIn, TEIn or EDMIn with TMG and ammonia at a second flow rate to make the nuclei grow and be capped in the quantum wells.

20. The quantum well structure of any one of claim 13 and claim 14, wherein a thickness of the $In_xGa_{1-x}N$ quantum well layer is about 1 to 10 nm and a thickness of the $In_yGa_{1-y}N$ quantum barrier layer is about 5 to 30 nm.

21. The quantum well structure of any one of claim 13 and claim 14, wherein $1>x>y>0$ or $y=0$.

22. The quantum well structure of any one of claim 13 and claim 14, wherein at least one of biscyclopentadienyl magnesium, diethyl zinc and silane is used as dopants during the growth of the quantum well layer.

of one of sapphire, SiC, GaN and ZnO. At least one of biscyclopentadienyl magnesium (Cp_2Mg), diethyl zinc (DEZn) and silane is used as dopants. A light emitting diode emits light in a range of about 400 nm to 750 nm. InN molar fraction of well layer x is important for the emission range extension to the longer wavelength. With higher x in $In_xGa_{1-x}N$ quantum well layer, emission wavelength extends to longer wavelength. When x is equal to or more than 0.3, range of the emission spectrum from the MQW structure extends to 600 nm or longer. Incorporation of Zn or Zn and Si into the $In_xGa_{1-x}N$ quantum well layer is important for the increase of the emission power from the MQW structure, especially for longer wavelength range.

[0012] According to still another aspect of the present invention, a quantum well structure that emits white light. The quantum well structure comprises: an $In_xGa_{1-x}N$ quantum well layer; indium-rich InGaN quantum dots embedded in the $In_xGa_{1-x}N$ quantum well layer, where $x>0.3$ or $x=0.3$; and an $In_yGa_{1-y}N$ quantum barrier layer over the quantum dots and the quantum well layer.

[0013] According to still another aspect of the present invention, a quantum well structure that emits white light. The quantum well structure comprises an $In_xGa_{1-x}N$ quantum well layer, indium-rich InGaN quantum dots embedded in the $In_xGa_{1-x}N$ quantum well layer, and an $In_yGa_{1-y}N$ quantum barrier layer over the quantum dots and the quantum well layer. The indium-rich InGaN quantum dots are doped with p-type dopant

[0014] In the above aspects, the $In_xGa_{1-x}N$ quantum well layer is doped with p-type dopant. The $In_xGa_{1-x}N$ quantum well layer is doped with p-type

CLAIMS

1. A quantum well structure that emits white light, which comprises:

an $In_xGa_{1-x}N$ quantum well layer doped with p-type dopant;

indium-rich InGaN quantum dots embedded in the $In_xGa_{1-x}N$ quantum well layer; and

an $In_yGa_{1-y}N$ quantum barrier layer over the quantum dots and the quantum well layer, wherein the $In_xGa_{1-x}N$ quantum well layer contains n-type dopant.

2. The quantum well structure of claim 1, wherein the $In_xGa_{1-x}N$ quantum well layer contains p-type dopant.

3. The quantum well structure of claim 1, wherein the $In_xGa_{1-x}N$ quantum well layer contains both p-type dopant and n-type dopant.

4. The quantum well structure of claim 1, wherein the quantum well structure is provided to emit light ranging from 420nm to 750nm and the light has a continuous emission spectrum ranging from 420nm to 750nm.

5. The quantum well structure of claim 1, wherein the quantum dots are formed by first flowing at least one of TMIn, TEIn or EDMIn at a first flow rate and a first time to form nuclei, and then flowing at least one of TMIn, TEIn or EDMIn with TMG and ammonia at a second flow rate to make the nuclei grow and be capped in the quantum wells.

6. The quantum well structure of claim 1, wherein a thickness of the $In_xGa_{1-x}N$ quantum well layer is 1 to 10nm and a thickness of the $In_yGa_{1-y}N$ quantum barrier layer is 5 to 30nm.

7. The quantum well structure of claim 1, wherein $1>x>y>0$ or $y=0$.

8. The quantum well structure of anyone of claim 1, wherein at least one of biscyclopentadienyl magnesium, diethyl zinc and silane is used as a dopant during the growth of the quantum well layer.