CLAIMS

1. A method of manufacturing an LED device, the method comprising:

forming a nucleation layer on a substrate;

forming a defect reduction layer on the nucleation layer;

forming an n-type current spreading layer on the defect reduction layer;

forming at least one photoluminescent quantum well on the n-type current spreading layer;

forming an n-type layer on the at least one photoluminescent quantum well;

forming at least one electroluminescent quantum well on the n-type layer;

forming a p-type layer on the electroluminescent quantum well;

etching to form a first mesa and a second mesa separated by a trench, the trench having at least one side wall and extending to the n-type current spreading layer;

conformally depositing a dielectric layer on the first mesa and the second mesa;

forming a contact hole in the first mesa and the second mesa; and

forming a first contact on the first mesa and a second contact on the second mesa.

2. The method of claim 1, wherein the first contact comprises a first reflecting metal layer on a first transparent conductive oxide layer.

3. The method of claim 2, wherein the reflecting metal layer comprises one or more of silver (Ag), nickel (Ni), aluminium (Al), and titanium (Ti).

4. The method of claim 2 wherein the first transparent conductive oxide layer comprises one or more of indium tin oxide (ITO), gallium oxide (Ga_2O_3), zinc oxide (ZnO), tin oxide (SnO_2), and indium zinc oxide (InZnO).

5. The method of claim 1, wherein the at least one electroluminescent quantum well emits a first light having a first wavelength and the at least one photoluminescent quantum well absorbs at least a portion of the first light and emits a second light having a longer wavelength than the first light.

6. The method of claim 1, further comprising forming an n-type contact in the trench on the n-type current spreading layer.

7. The method of claim 5, wherein the electroluminescent quantum well comprises multiple quantum wells emitting a same wavelength of light.

8. The method of claim 5, wherein the photoluminescent quantum well comprises multiple quantum wells emitting a same wavelength of light.

9. The method of claim 1, wherein the substrate is a transparent substrate.

10. The method of claim 9, further comprising forming a dichroic reflector on the substrate opposite the n-type current spreading layer.

11. A method of manufacturing an LED device, the method comprising:

forming an n-type current spreading layer on a substrate;

forming at least one photoluminescent quantum well on the n-type current spreading layer;

forming an n-type layer on the at least one photoluminescent quantum well;

forming at least one electroluminescent quantum well on the n-type layer;

forming a p-type layer on the electroluminescent quantum well;

etching to form a first mesa and a second mesa separated by a trench, the trench having at least one side wall and extending to the n-type current spreading layer;

conformally depositing a dielectric layer on the first mesa and the second mesa;

forming a contact hole in the first mesa and the second mesa; and

forming a first contact on the first mesa and a second contact on the second mesa.

12. The LED method of claim 11, wherein the first contact comprises a first reflecting metal layer on a first transparent conductive oxide layer.

13. The method of claim 12, wherein the reflecting metal layer comprises one or more of silver (Ag), nickel (Ni), aluminium (Al), and titanium (Ti).

14. The method of claim 12, wherein the first transparent conductive oxide layer comprises one or more of indium tin oxide (ITO), gallium oxide (Ga_2O_3), zinc oxide (ZnO), tin oxide (SnO_2), and indium zinc oxide (InZnO).

15. The method of claim 11, wherein the at least one electroluminescent quantum well emits a first light having a first wavelength and the at least one photoluminescent quantum well absorbs at least a portion of the first light and emits a second light having a longer wavelength than the first light.

16. The method of claim 11, further comprising forming an n-type contact in the trench on the n-type current spreading layer.

17. The method of claim 15, wherein the electroluminescent quantum well comprises multiple quantum wells emitting a same wavelength of light and the photoluminescent quantum well comprises multiple quantum wells emitting a same wavelength of light.

18. The method of claim 11, wherein the substrate is a transparent substrate.

19. The method of claim 18, further forming comprising a dichroic reflector on the substrate opposite the n-type current spreading layer.

20. The method of claim 11, further comprising forming a nucleation layer on the substrate and a defect reduction layer on the nucleation layer.