CLAIMS

I/We claim:

1. A light emitting diode (LED) device, comprising:

a substrate with a thermal conductivity of greater than about 1.0W/(m·K);

an LED die carried by the substrate, the LED die being thermally coupled to the substrate;

an insulating material on the LED die, the insulating material being at least partially transparent;

a converter material spaced apart from the insulating material, the converter material including a phosphor; and

a conduction material in direct contact with both the converter material and the substrate, and the conduction material having a thermal conductivity greater than about 1.0W/(m·K).

2. The LED device of claim 1 wherein:

the substrate includes at least one of silicon (Si), gallium nitride (GaN), aluminum nitride (AlN), copper (Cu), aluminum (Al), tungsten (W), stainless steel (Fe), diamond (C), glass (SiO_2), silicon carbide (SiC), and aluminum oxide (Al_2O_3);

the LED die includes an N-type gallium nitride (GaN) material, an indium gallium nitride (InGaN) material, and a P-type GaN material on one another in series;

the insulating material includes at least one of a polyimide, a solvent-soluble thermoplastic polyimide, a ceramic material, and glass, the insulating material having a thermal conductivity less than about 0.15W/(m·K);

the converter material includes at least one of cerium(III)-doped yttrium aluminum garnet ("YAG"), neodymium-doped YAG, neodymium-chromium double-doped YAG, erbium-doped YAG, ytterbium-doped YAG, neodymium-cerium double-doped YAG, holmium-chromium-thulium triple-doped YAG, thulium-doped YAG, chromium(IV)-doped YAG, dysprosium-doped YAG, samarium-doped YAG, and terbium-doped YAG, CaS:Eu, $CaAlSiN_3$:Eu, $Sr_2Si_5N_8$:Eu, SrS:Eu, $Ba_2Si_5N_8$:Eu, Sr_2SiO_4:Eu, $SrSi_2N_2O_2$:Eu, $SrGa_2S_4$:Eu, $SrAl_2O_4$:Eu, Ba_2SiO_4:Eu,

$Sr_4Al_{14}O_{25}$:Eu, $SrSiAl_2O_3N$:Eu, $BaMgAl_{10}O_{17}$:Eu, $Sr_2P_2O_7$:Eu, $BaSO_4$:Eu, and SrB_4O_7:Eu;

the conduction material includes at least one of indium tin oxide (ITO), fluorine-doped tin oxide (FTO), and zinc oxide (ZnO); and

the conduction material includes a lateral portion generally corresponding to the LED die and at least one vertical portion extending from the lateral portion toward and in direct contact with the substrate.

3. The LED device of claim 1 wherein the conduction material is between the converter material and the insulating material.

4. The LED device of claim 1 wherein the converter material is between the conduction material and the insulating material.

5. The LED device of claim 1 wherein the conduction material includes a lateral portion generally corresponding to the LED die and two opposing vertical portions extending from the lateral portion toward and in direct contact with the substrate.

6. The LED device of claim 1 wherein:

the conduction material includes a lateral portion generally corresponding to the LED die and two opposing vertical portions extending from the lateral portion toward and in direct contact with the substrate; and

the converter material generally encapsulates the conduction material.

7. The LED device of claim 1 wherein:

the conduction material includes a lateral portion generally corresponding to the LED die and two opposing vertical portions extending from the lateral portion toward and in direct contact with the substrate;

the lateral portion of the conduction material includes a surface facing away from the LED die; and

the converter material is on the surface of the conduction material and with a width generally corresponding to an emission area of the LED die.

8. The LED device of claim 1 wherein:

the conduction material is a first conduction material between the converter material and the insulating material; and

the LED device further includes a second conduction material spaced apart from the first conduction material and in direct contact with the converter material.

9. The LED device of claim 1 wherein:

the conduction material is a first conduction material between the converter material and the insulating material;

the LED device further includes a second conduction material spaced apart from the first conduction material and in direct contact with the converter material;

the converter material includes a plurality of vias extending from the first conduction material to the second conduction material; and

the plurality of vias individually contain a third conduction material.

10. The LED device of claim 1 wherein:

the LED die is a first LED die;

the LED device further includes a second LED die carried by the substrate in a side-by-side arrangement with the first LED die; and

at least one of the insulating material, the converter material, and the conduction material encapsulates the first and second LED dies.

11. A light emitting diode (LED) device, comprising:

a heat sink;

an LED die thermally coupled to the heat sink;

a phosphor spaced apart from the LED die; and

a heat conduction path in direct contact with both the phosphor and the heat sink, the heat conduction path being configured to conduct heat from the phosphor to the heat sink.

12. The LED device of claim 11 wherein at least a portion of the heat conduction path is directly between the phosphor and the LED die.

13. The LED device of claim 11 wherein:

at least a portion of the heat conduction path is directly between the phosphor and the LED die; and

the LED die includes an electrical insulator proximate to the heat conduction path.

14. The LED device of claim 11 wherein:

the heat conduction path is a first heat conduction path; and

the LED device further includes a second heat conduction path in direct contact with the phosphor, the second heat conduction path being configured to conduct heat from the phosphor to the heat sink.

15. The LED device of claim 11 wherein:

the heat conduction path is a first heat conduction path;

the LED device further includes a second heat conduction path in direct contact with the phosphor, the second heat conduction path being configured to conduct heat from the phosphor to the heat sink; and

the first and second heat conduction paths are generally parallel to each other.

16. The LED device of claim 11 wherein:

the heat conduction path is a first heat conduction path; and

the LED device further includes a second heat conduction path and a third heat conduction path both in direct contact with the phosphor, the second heat conduction path being configured to conduct heat from the phosphor to the heat sink, and the third heat conduction path being configured to conduct heat from the phosphor to the first and/or second heat conduction paths.

17. The LED device of claim 11 wherein:

the heat conduction path is a first heat conduction path;

the LED device further includes a second heat conduction path and a third heat conduction path both in direct contact with the phosphor, the second heat conduction path being configured to conduct heat from the phosphor to the heat

sink, and the third heat conduction path being configured to conduct heat from the phosphor to the first and/or second heat conduction paths;

the first and second heat conduction paths are generally parallel to each other; and

the third heat conduction path is generally perpendicular to the first and/or second heat conduction paths.

18. The LED device of claim 11 wherein:

the LED device further includes an insulating material between the heat conduction path and the LED die; and

the insulating material is configured to resist a heat flow from the LED die to the phosphor.

19. The LED device of claim 11 wherein:

the LED device further includes an insulating material between the conduction material and the LED die;

the insulating material is configured to resist a heat flow from the LED die to the phosphor via the insulating material; and

the heat conduction path is also configured to conduct at least a portion of the heat flow to the heat sink.

20. A method of manufacturing a light emitting diode (LED) device, comprising:

attaching an LED die to a heat sink, the LED die being thermally coupled to the heat sink;

encapsulating the LED die with an insulating material that is at least partially transparent;

depositing a conduction material on the insulating material and the heat sink, the conduction material having a thermal conductivity greater than about 1.0W/(m·K); and

depositing a phosphor on the conduction material, the phosphor generally corresponding to the emission area of the LED die.

21. The method of claim 20 wherein depositing a conduction material includes depositing at least one of indium tin oxide (ITO), fluorine-doped tin oxide (FTO), and zinc oxide (ZnO) on the insulating material via physical vapor deposition (PVD).

22. The method of claim 20 wherein:

encapsulating the LED die includes encapsulating the LED die with at least one of a polyimide, a solvent-soluble thermoplastic polyimide, a ceramic material, and glass via spin coating or chemical vapor deposition (CVD); and

depositing a conduction material includes depositing at least one of indium tin oxide (ITO), fluorine-doped tin oxide (FTO), and zinc oxide (ZnO) on the insulating material via physical vapor deposition (PVD).

23. The method of claim 20 wherein depositing a conduction material includes:

depositing a first conduction material on the insulating material; and

after depositing the phosphor, depositing a second conduction material on the phosphor.

24. The method of claim 20 wherein depositing a conduction material includes:

depositing a first conduction material on the insulating material; and

after depositing the phosphor, depositing a second conduction material on the phosphor, the second conduction material being generally the same as the first conduction material.

25. The method of claim 20 wherein depositing a conduction material includes:

depositing a first conduction material on the insulating material;

after depositing the phosphor, depositing a second conduction material on the phosphor;

forming a plurality of vias in the phosphor, the vias individually extending directly between the first and second conduction materials; and

filling the plurality of vias with a third conduction material.

26. A light emitting diode (LED) device, comprising:

a heat sink;

an LED die thermally coupled to the heat sink, the LED die having an emission area;

a phosphor spaced apart from the LED die, the phosphor at least partially corresponding to the emission area of the LED die; and

means for conducting heat away from the phosphor to the heat sink.

27. The LED device of claim 26, further comprising means for resisting a heat flow from the LED die to the phosphor.

28. The LED device of claim 26 wherein:

the phosphor includes a first surface and a second surface opposite the first surface; and

the means for conducting heat away from the phosphor include means for conducting heat away from both the first and second surfaces of the phosphor.

29. The LED device of claim 26 wherein:

the phosphor includes a first surface and a second surface opposite the first surface; and

the means for conducting heat away from the phosphor include means for conducting heat away from the phosphor along a first direction generally parallel to the first and second surfaces and along a second direction generally perpendicular to the first direction.

CLAIMS

I/We claim:

1. A light emitting diode (LED) device, comprising:

a substrate with a thermal conductivity of greater than about 1.0W/(m·K);

an LED die carried by the substrate, the LED die being thermally coupled to the substrate;

an insulating material on the LED die, the insulating material being at least partially transparent;

a converter material spaced apart from the LED die, the converter material including a phosphor; and

a conduction material in direct contact with both the converter material and the substrate, the conduction material having a thermal conductivity greater than about 1.0W/(m·K), wherein the conduction material includes a lateral portion across from a forward-facing surface of the LED die and at least one vertical portion extending from the lateral portion toward the substrate such that the conduction material at least substantially covers the LED die.

2. The LED device of claim 1 wherein:

the substrate includes at least one of silicon (Si), gallium nitride (GaN), aluminum nitride (AlN), copper (Cu), aluminum (Al), tungsten (W), stainless steel (Fe), diamond (C), glass (SiO_2), silicon carbide (SiC), and aluminum oxide (Al_2O_3);

the LED die includes an N-type gallium nitride (GaN) material, an indium gallium nitride (InGaN) material, and a P-type GaN material on one another in series;

the insulating material includes at least one of a polyimide, a solvent-soluble thermoplastic polyimide, a ceramic material, and glass, the insulating material having a thermal conductivity less than about 0.15W/(m·K);

the converter material includes at least one of cerium(III)-doped yttrium aluminum garnet ("YAG"), neodymium-doped YAG, neodymium-chromium double-doped YAG, erbium-doped YAG, ytterbium-doped YAG, neodymium-cerium double-doped YAG, holmium-chromium-thulium triple-doped YAG, thulium-doped YAG, chromium(IV)-doped YAG, dysprosium-doped YAG, samarium-doped

YAG, and terbium-doped YAG, CaS:Eu, $CaAlSiN_3$:Eu, $Sr_2Si_5N_8$:Eu, SrS:Eu, $Ba_2Si_5N_8$:Eu, Sr_2SiO_4:Eu, $SrSi_2N_2O_2$:Eu, $SrGa_2S_4$:Eu, $SrAl_2O_4$:Eu, Ba_2SiO_4:Eu, $Sr_4Al1_4O_{25}$:Eu, $SrSiAl_2O_3N$:Eu, $BaMgAl_{10}O_{17}$:Eu, $Sr_2P_2O_7$:Eu, $BaSO_4$:Eu, and SrB_4O_7:Eu; and

the conduction material includes at least one of indium tin oxide (ITO), fluorine-doped tin oxide (FTO), and zinc oxide (ZnO).

3. The LED device of claim 1 wherein the conduction material is between the converter material and the insulating material.

4. The LED device of claim 1 wherein the converter material is between the conduction material and the insulating material.

5. The LED device of claim 1 wherein the vertical portion of the conduction material includes two opposing vertical portions extending from the lateral portion toward and in direct contact with the substrate.

6. The LED device of claim 1 wherein:

the vertical portion of the conduction material includes two opposing vertical portions extending from the lateral portion toward and in direct contact with the substrate; and

the converter material generally encapsulates the conduction material.

7. The LED device of claim 1 wherein:

the vertical portion of the conduction material includes two opposing vertical portions extending from the lateral portion toward and in direct contact with the substrate;

the lateral portion of the conduction material includes a surface facing away from the LED die; and

the converter material is on the surface of the conduction material and with a width generally corresponding to an emission area of the LED die.

8. The LED device of claim 1 wherein:

the conduction material is a first conduction material between the converter material and the insulating material; and

the LED device further includes a second conduction material spaced apart from the first conduction material and in direct contact with the converter material.

9. The LED device of claim 1 wherein:

the conduction material is a first conduction material between the converter material and the insulating material;

the LED device further includes a second conduction material spaced apart from the first conduction material and in direct contact with the converter material;

the converter material includes a plurality of vias extending from the first conduction material to the second conduction material; and

the plurality of vias individually contain a third conduction material.

10. The LED device of claim 1 wherein:

the LED die is a first LED die;

the LED device further includes a second LED die carried by the substrate in a side-by-side arrangement with the first LED die; and

at least one of the insulating material, the converter material, and the conduction material encapsulates the first and second LED dies.

11. The LED device of claim 1 wherein at least a portion of the conduction material comprises an at least generally transparent material.

12. The LED device of claim 1 wherein the insulating material, the conduction material, and the converter material are adjacent to each other in series.