

What is claimed is:

1. A method of fabricating optoelectronic modules each of which includes at least one optoelectronic device and at least one optical element, the method comprising:
 - providing, on a support surface, a plurality of singulated transparent substrates separated laterally from one another;
 - using a vacuum injection technique to cover sidewalls of each of the singulated transparent substrates with a non-transparent material; and
 - forming spacer elements that project away from the support surface.
2. The method of claim 1 including forming or applying an optical element on the surface of each singulated transparent substrate by an embossing-type replication technique after placing the singulated transparent substrates on the support surface.
3. The method of claim 1 further including forming or applying an optical element on a transparent wafer and subsequently separating the transparent wafer into the plurality of singulated transparent substrates.
4. The method of claim 3 including attaching the transparent wafer to UV dicing tape before separating the transparent wafer into the plurality of singulated transparent substrates.
5. The method of claim 1 including forming the spacer elements as part of the same vacuum injection technique used to cover the sidewalls of the singulated transparent substrates with a non-transparent material.
6. The method of claim 2 wherein a single combined replication and vacuum injection tool is used for the embossing-type replication technique and for the vacuum injection technique.

7. The method of any one of claims 1 – 6 wherein the transparent substrates are in a plane, wherein the optical elements are on a first side of the plane, and the spacer elements are on a second side of the plane.
8. The method of claim 1 wherein the optical elements are formed by an embossing-type replication technique after formation of the spacer elements, wherein the spacer elements are formed as part of the same vacuum injection process used to cover the sidewalls of the singulated transparent substrates with a non-transparent material.
9. The method of claim 1 further including, prior to forming a respective optical element on a surface of each of the singulated transparent substrates, inserting the singulated transparent substrates within openings of a non-transparent wafer that is on the support surface.
10. The method of claim 1 wherein the transparent substrates are in a plane, the method further including:
- using a first vacuum injection tool to form the spacer elements on a first side of the plane and to cover the sidewalls of the transparent substrates with a non-transparent material during a first vacuum injection process; and
 - using a second combined replication and vacuum injection tool to form the optical elements on a second side of the plane during an embossing-type replication process and to form projections on the second side of the plane during a second vacuum injection process.
11. The method of claim 10 wherein the projections serve as non-transparent baffles for the optoelectronic modules.
12. The method of claim 10 wherein the projections serve as alignment features for the optoelectronic modules.

13. The method of any one of claims 10 – 12 wherein forming the projections on the second side of the plane includes filling openings in the second combined replication and vacuum injection tool with a non-transparent material.

14. The method of claim 1 wherein the transparent substrates are disposed within openings of a non-transparent wafer that is on the support surface, wherein the transparent substrates and the non-transparent wafer are in a plane, and wherein the support surface has openings adjacent one side of the plane, the method further including:

providing a combined replication and vacuum injection tool on a second side of the plane;

performing an embossing-type replication process to form the optical elements on the transparent substrates; and

performing a vacuum injection process to form the spacer elements and to fill the openings in the support surface with a non-transparent material.

15. The method of claim 14 wherein there are channels through the plane defined by the transparent substrates and the non-transparent wafer, wherein at least some of the channels are next to sidewalls of the transparent substrates, and wherein the channels extend between the openings in the support surface and spaces in the combined replication and vacuum injection tool that correspond to the spacer elements, the method including:

performing a single vacuum injection process to fill the channels, the openings in the support surface and the spaces in the combined replication and vacuum injection tool with a non-transparent material.

16. The method of claim 14 wherein the support surface is a surface of a vacuum chuck.

17. The method of any one of claims 1 – 16 wherein the non-transparent material covering the sidewalls of the singulated transparent substrates is a polymer containing a non-transparent filler.

18. The method of claim 17 wherein the polymer comprises epoxy.
19. The method of claim 17 wherein the non-transparent filler comprises carbon black.
20. The method of any one of claims 1 – 19 wherein each spacer element has a respective free end, the method further including attaching a substrate wafer to the free ends of the spacer elements so as to form a vertical stack, wherein a plurality of optoelectronic devices are mounted on the substrate wafer.
21. The method of any claims 1 – 19 wherein each spacer element has a respective free end, the method further including attaching a structural element to the free ends of the spacer elements so as to form a vertical stack, wherein the structural element is on a surface of a substrate wafer on which are mounted a plurality of optoelectronic devices each of which is surrounded laterally by the structural element.
22. The method of claim 21 wherein the structural element includes a metal frame.
23. The method of claim 21 or claim 22 further including separating the vertical stack into a plurality of individual modules each of which includes at least one of the optoelectronic devices and at least one of the optical elements.
24. A method of fabricating optoelectronic modules each of which includes at least one optoelectronic device and at least one optical element, the method comprising:
- providing a plurality of singulated transparent substrates within openings of a non-transparent wafer disposed on a support surface, wherein the transparent substrates and the non-transparent wafer are in a plane and wherein the support surface has openings adjacent a first side of the plane, and wherein each of the singulated transparent substrates has a respective optical element on its surface;
 - filling the openings in the support surface with a first non-transparent material using a first vacuum injection process; and

forming non-transparent spacer elements on the second side of the plane using a second vacuum injection process.

25. The method of claim 24 including forming a respective optical element on each of the transparent substrates on a second side of the plane using an embossing-type replication technique.

26. The method of claim 24 further including applying or forming an optical element to a transparent wafer and subsequently separating the transparent wafer into the plurality of singulated transparent substrates.

27. The method of claim 26 including attaching the transparent wafer to UV dicing tape before separating the transparent wafer into the plurality of singulated transparent substrates.

28. The method of any one of claims 24 - 27 wherein there are channels through the plane defined by the transparent substrates and the non-transparent wafer, wherein the channels are next to the openings in the support surface, and wherein at least some of the channels are next to sidewalls of the transparent substrates, the method including:

performing a single vacuum injection process to fill the channels and the openings in the support surface with the first non-transparent material.

29. The method of claim 28 wherein the spacer elements are composed of a second non-transparent material different from the first non-transparent material.

30. The method of claim 24 wherein the support surface is a surface of a vacuum chuck.

31. The method of claim 24 wherein the filled openings in the support surface correspond to baffles for the optoelectronic modules.

32. The method of claim 24 wherein the filled openings in the support surface correspond to alignment features for the optoelectronic modules.

33. The method of claim 25 including using a single combined replication and vacuum injection tool to perform the embossing-type replication technique and the first vacuum injection process.

34. A method of fabricating optoelectronic modules each of which includes at least one optoelectronic device and at least one optical element, the method comprising:

providing a wafer that has a plurality of transparent portions laterally spaced from one another, wherein each of the transparent portions is surrounded laterally by non-transparent material, wherein the wafer is in a plane and is disposed on a support surface that has openings adjacent a first side of the plane;

providing a combined replication and vacuum injection tool on a second side of the plane;

forming a respective optical element on each of the transparent portions on the second side of the plane by an embossing-type replication technique using the combined replication and vacuum injection tool; and

filling the openings in the support surface with a first non-transparent material and forming spacer elements composed of the non-transparent material on the second side of the plane by a vacuum injection process using the combined replication and vacuum injection tool.

35. The method of claim 34 further including attaching a substrate wafer to free ends of the spacer elements so as to form a vertical stack, wherein a plurality of optoelectronic devices are mounted on the substrate wafer.

36. The method of claim 35 further including separating the vertical stack into a plurality of individual modules each of which includes at least one of the optoelectronic devices and at least one of the optical elements.

37. The method of any one of claims 34- 36 wherein there are channels through the plane defined by the wafer, and wherein the channels extend between the openings in the support surface and spaces in the combined replication and vacuum injection tool that correspond to the spacer elements, the method including:

performing a single vacuum injection process to fill the channels, the openings in the support surface and the spaces in the combined replication and vacuum injection tool with the non-transparent material.

38. The method of any one of claims 34 - 37 wherein the support surface is a surface of a vacuum chuck.

39. An optoelectronic module comprising:

an optoelectronic device mounted on a substrate;

a transparent cover separated from the substrate by a spacer; and

an optical element on the transparent cover;

wherein sidewalls of the transparent cover are covered by a first material that is non-transparent to light emitted by or detectable by the optoelectronic device, and wherein the first non-transparent material is surrounded laterally by a second different non-transparent material.

40. The optoelectronic module of claim 39 wherein the first non-transparent material is a polymer containing a non-transparent filler.

41. The optoelectronic module of any one of claims 39 – 40 wherein the second non-transparent material is a glass-reinforced epoxy laminate material.

42. The optoelectronic module of any one of claims 39 – 41 wherein the transparent cover is tilted at an angle with respect to a plane of the substrate.

43. The optoelectronic module of any one of claims 39 – 42 wherein the spacer also is tilted with respect to the plane of the substrate.

44. A method of fabricating optoelectronic modules, the method comprising:
- supporting a plurality of singulated transmissive substrates by a combined replication and vacuum injection tool;
 - replicating optical elements onto at least one side of each singulated transmissive substrate using an embossing-type replication technique while the singulated transmissive substrates are supported by the combined replication and vacuum injection tool;
 - using a vacuum injection technique to form a respective spacer feature on a first side of each singulated transmissive substrate and to form wall features separating adjacent ones of the singulated transmissive substrates from one another, while the singulated transmissive substrates are supported by the combined replication and vacuum injection tool;
 - removing from the combined replication and vacuum injection tool a structure comprising the transmissive substrates, the passive optical elements, the spacer features and the wall features; and
 - attaching the structure to a support substrate on which are mounted a plurality of optoelectronic devices so as to obtain a stack in which each transmissive spans across a plurality of the optoelectronic devices separated from one another by one of the spacer features.
45. The method of claim 44 further including:
- forming an opening through each transmissive substrate, each opening disposed over a respective one of the spacer features; and
 - substantially filling the openings in the transmissive substrates with a material that is non-transparent to light emitted by or detectable by the optoelectronic devices.
46. The method of claim 45 wherein forming an opening includes forming a trench in the transmissive substrate.
47. The method of any one of claims 45 - 46 wherein the openings are formed by dicing, micromachining or laser cutting.

48. The method of any one of claims 45 - 47 wherein each of the openings extends partially into a respective one of the spacers features.

49. The method of any one of claims 44 - 48 further including:

subsequently separating a resulting structure into multiple optoelectronic modules each of which includes a first transmissive cover over a first one of the optoelectronic devices and a second transmissive cover over a second one of the optoelectronic devices.

50. A method of fabricating optoelectronic modules, the method comprising:

supporting a plurality of singulated transmissive substrates on a sacrificial substrate in a first vacuum injection tool;

using a vacuum injection technique to form a respective spacer feature on a first side of each transmissive substrate and to form wall features separating adjacent ones of the transmissive substrates from one another while the transmissive substrates are supported in the first vacuum injection tool;

replicating optical elements onto at least one side of each transmissive substrate using an embossing-type replication technique;

removing a first structure from the first vacuum injection tool and separating the first structure from the sacrificial substrate, wherein the first structure comprises the transmissive substrates, the passive optical elements, the spacer features and the wall features; and

attaching a support substrate to the spacer features such that the spacer features separate the support substrate from the transmissive substrates, wherein there are a plurality of optoelectronic devices mounted on the support substrate, and wherein each transmissive substrate spans across a plurality of the optoelectronic devices separated from one another by one of the spacer features.

51. The method of claim 50 further including replicating passive optical elements onto a second side of each transmissive substrate using an embossing-type replication technique.

52. The method of any one of claims 50 - 51 further including:

forming an opening through each transmissive substrate, each opening disposed over a respective one of the spacer features; and

substantially filling the openings in the transmissive substrates with a material that is non-transparent to light emitted by or detectable by the optoelectronic devices.

53. The method of claim 52 wherein forming an opening includes forming a trench in the transmissive substrate.

54. The method of any one of claims 52 - 53 wherein the openings are formed by dicing, micromachining or laser cutting.

55. The method of any one of claims 52 - 54 wherein each of the openings extends partially into a respective one of the spacers features.

56. The method of any one of claims 50 - 55 further including:

subsequently separating a resulting structure into multiple optoelectronic modules each of which includes a first transmissive cover over a first one of the optoelectronic devices and a second transmissive cover over a second one of the optoelectronic devices.

57. An optoelectronic module comprising:

an optoelectronic device mounted on a substrate; and

a transparent cover held at a distance from the substrate by a spacer, wherein the spacer is composed of a material that is non-transparent to light emitted by or detectable by the optoelectronic device;

wherein sidewalls of the transparent cover are covered by a material that is non-transparent to light emitted by or detectable by the optoelectronic device.

58. The module of claim 57 further including at least one of an optical element, an optical filter or a focal length correction layer on a surface of the transparent cover.

59. The module of claim 57 including a dielectric band-pass filter on a surface of the transparent cover.
60. The module of any one of claims 57 - 59 further including an optics assembly over an object-side of the transparent cover, wherein the optics assembly includes one or more lenses stacked over the transparent cover.
61. The module of claim 60 wherein each optics assembly includes a stack of injection molded lenses.
62. An optoelectronic module comprising:
a metal substrate having sidewalls encapsulated laterally by a molded cavity;
an optoelectronic device mounted on the metal substrate, the molded cavity laterally encircling the optoelectronic device;
a transparent cover having sidewalls encapsulated laterally by a material that is non-transparent to light emitted by or detectable by the optoelectronic device; and
a spacer having one end attached to the molded cavity and separating the molded cavity from the transparent cover.
63. The module of claim 62 wherein the material laterally encapsulating the sidewalls of the transparent cover is a polymer containing a non-transparent filler.
64. The module of claim 65 wherein the polymer material includes epoxy, acrylate, polyurethane or silicone, and wherein the non-transparent filler includes carbon black, a pigment or a dye.
65. The module of any one of claims 62 – 64 wherein the spacer is composed of the same material as the material laterally encapsulating the sidewalls of the transparent cover.
66. The module of any of claims 62 – 65 wherein the optoelectronic device is a light emitting element.

67. A method of fabricating optoelectronic modules each of which includes at least one optoelectronic device and at least one optical element, the method comprising:

providing a substrate wafer that comprises a metal frame and a molded cavity, wherein portions of the metal frame are encapsulated laterally by the molded cavity, the metal frame having a plurality of optoelectronic devices mounted thereon and separated laterally from one another;

providing a spacer/optics structure comprising a plurality of singulated transparent substrates separated laterally from one another, the spacer/optics structure including a spacer element that projects away from the transparent substrates, wherein sidewalls of each of the transparent substrates is encapsulated laterally by a non-transparent material; and

attaching an end of the spacer element to the molded cavity to form a stack.

68. The method of claim 67 wherein portions of the molded cavity laterally surround respective ones of the optoelectronic devices.

69. The method of any one of claims 67 - 68 wherein the material laterally encapsulating the sidewalls of the transparent substrates is a polymer containing a non-transparent filler.

70. The method of claim 69 wherein the polymer material includes epoxy, acrylate, polyurethane or silicone, and wherein the non-transparent filler includes carbon black, a pigment or a dye.

71. The method of any one of claims 67 - 70 wherein the spacer elements are composed of the same material as the material laterally encapsulating the sidewalls of the transparent substrates.

72. The method of any one of claims 67 - 71 further including separating the stack into the plurality of modules.

What is claimed is:

1. A method of fabricating optoelectronic modules each of which includes at least one optoelectronic device and at least one optical element, the method comprising:

providing, on a same support surface, a plurality of singulated transparent substrates separated laterally from one another, each of the singulated transparent substrates having lateral sidewalls that face lateral sidewalls of other ones of the singulated transparent substrates;

using a vacuum injection technique to cover the lateral sidewalls of each of the singulated transparent substrates with a non-transparent material in contact with the lateral sidewalls by providing the non-transparent material in spaces laterally separating the singulated transparent substrates from one another; and

forming spacer elements that project away from the support surface.

2. The method of claim 1 including forming or applying an optical element on the surface of each singulated transparent substrate by an embossing-type replication technique after placing the singulated transparent substrates on the support surface.

3. The method of claim 2 wherein a single combined replication and vacuum injection tool is used for the embossing-type replication technique and for the vacuum injection technique.

4. The method of claim 1 further including forming or applying an optical element on a transparent wafer and subsequently separating the transparent wafer into the plurality of singulated transparent substrates.

5. The method of claim 4 including attaching the transparent wafer to UV dicing tape before separating the transparent wafer into the plurality of singulated transparent substrates.

6. The method of claim 1 including forming the spacer elements as part of the same vacuum injection technique used to cover the sidewalls of the singulated transparent substrates with a non-transparent material.
7. The method of claim 1 wherein the transparent substrates are in a plane, wherein the optical elements are on a first side of the plane, and the spacer elements are on a second side of the plane.
8. The method of claim 1 wherein the optical elements are formed by an embossing-type replication technique after formation of the spacer elements, wherein the spacer elements are formed as part of the same vacuum injection process used to cover the sidewalls of the singulated transparent substrates with a non-transparent material.
9. The method of claim 1 further including, prior to forming a respective optical element on a surface of each of the singulated transparent substrates, inserting the singulated transparent substrates within openings of a non-transparent wafer that is on the support surface.
10. The method of claim 1 wherein the transparent substrates are in a plane, the method further including:
 - using a first vacuum injection tool to form the spacer elements on a first side of the plane and to cover the sidewalls of the transparent substrates with a non-transparent material during a first vacuum injection process; and
 - using a second combined replication and vacuum injection tool to form the optical elements on a second side of the plane during an embossing-type replication process and to form projections on the second side of the plane during a second vacuum injection process.
11. The method of claim 10 wherein the projections serve as non-transparent baffles for the optoelectronic modules.

12. The method of claim 10 wherein the projections serve as alignment features for the optoelectronic modules.

13. The method of claim 10 wherein forming the projections on the second side of the plane includes filling openings in the second combined replication and vacuum injection tool with a non-transparent material.

14. The method of claim 1 wherein the transparent substrates are disposed within openings of a non-transparent wafer that is on the support surface, wherein the transparent substrates and the non-transparent wafer are in a plane, and wherein the support surface has openings adjacent one side of the plane, the method further including:

providing a combined replication and vacuum injection tool on a second side of the plane;

performing an embossing-type replication process to form the optical elements on the transparent substrates; and

performing a vacuum injection process to form the spacer elements and to fill the openings in the support surface with a non-transparent material.

15. The method of claim 14 wherein there are channels through the plane defined by the transparent substrates and the non-transparent wafer, wherein at least some of the channels are next to sidewalls of the transparent substrates, and wherein the channels extend between the openings in the support surface and spaces in the combined replication and vacuum injection tool that correspond to the spacer elements, the method including:

performing a single vacuum injection process to fill the channels, the openings in the support surface and the spaces in the combined replication and vacuum injection tool with a non-transparent material.

16. The method of claim 14 wherein the support surface is a surface of a vacuum chuck.

17. The method of claim 1 wherein the non-transparent material covering the sidewalls of the singulated transparent substrates is a polymer containing a non-transparent filler.
18. The method of claim 17 wherein the polymer comprises epoxy.
19. The method of claim 17 wherein the non-transparent filler comprises carbon black.
20. The method of claim 1 wherein each spacer element has a respective free end, the method further including attaching a substrate wafer to the free ends of the spacer elements so as to form a vertical stack, wherein a plurality of optoelectronic devices are mounted on the substrate wafer.
21. The method of claim 1 wherein each spacer element has a respective free end, the method further including attaching a structural element to the free ends of the spacer elements so as to form a vertical stack, wherein the structural element is on a surface of a substrate wafer on which are mounted a plurality of optoelectronic devices each of which is surrounded laterally by the structural element.
22. The method of claim 21 wherein the structural element includes a metal frame.
23. The method of claim 21 further including separating the vertical stack into a plurality of individual modules each of which includes at least one of the optoelectronic devices and at least one of the optical elements.
24. A method of fabricating optoelectronic modules, the method comprising:
 - supporting a plurality of singulated transmissive substrates in an apparatus comprising a combined replication and vacuum injection tool;
 - replicating optical elements onto at least one side of each of the singulated transmissive substrates using an embossing-type replication technique while the singulated transmissive substrates are supported in the apparatus including the combined replication and vacuum injection tool;

using a vacuum injection technique to form a respective spacer feature on a first side of each of the singulated transmissive substrates and to form wall features separating adjacent ones of the singulated transmissive substrates from one another, while the singulated transmissive substrates are supported in the apparatus including the combined replication and vacuum injection tool;

removing from the combined replication and vacuum injection tool a structure comprising the transmissive substrates, the optical elements, the spacer features and the wall features; and

attaching the structure to a support substrate on which a plurality of optoelectronic devices are mounted.

25. The method of claim 24 further including:

forming an opening through each transmissive substrate, each opening disposed over a respective one of the spacer features; and

substantially filling the openings in the transmissive substrates with a material that is non-transparent to light emitted by or detectable by the optoelectronic devices.

26. The method of claim 25 wherein forming an opening includes forming a trench in the transmissive substrate.

27. The method of claim 25 wherein the openings are formed by dicing, micromachining or laser cutting.

28. The method of claim 25 wherein each of the openings extends partially into a respective one of the spacers features.

29. The method of claim 24 further including:

subsequently separating the structure attached to the support substrate into multiple optoelectronic modules each of which includes at least one of the optoelectronic devices.