

CLAIMS

What is claimed is:

1. An image sensor structure, comprising:
 - an image layer comprising an array of light detectors disposed therein;
 - a device stack disposed over the image layer;
 - an array of light guides disposed in the device stack, each light guide associated with a light detector of the array of light detectors;
 - an array of nanowells disposed over the device stack, each nanowell of the array of nanowells associated with a first light guide of the array of light guides, each first light guide associated with a first light detector of the array of light detectors;
 - a first primer set disposed throughout a first well region of each nanowell; and
 - a different second primer set disposed throughout a second well region of each nanowell, the second well region adjacent the first well region at a region interface;
 - wherein the first and second primer sets are operable to attach a forward strand cluster of forward polynucleotide strands in the first well region and to attach an adjacent reverse strand cluster of reverse polynucleotide strands in the second well region.
2. The image sensor structure of claim 1, comprising:
 - each nanowell of the array of nanowells associated with a second light guide of the array of light guides, each second light guide associated with a second light detector of the array of light detectors;
 - the first well region disposed over the first light guide; and
 - the second well region disposed over the second light guide.
3. The image sensor structure of claim 2, wherein an area of the first well region is smaller than an area of the second well region.
4. The image sensor structure of claim 2, comprising:
 - the first and second well regions having substantially equal widths; and

the first well region having a length that is 90% or less of a length of the second region.

5. The image sensor structure of claim 2, comprising:

the first well region comprising:

a first section that is disposed over the entire first light guide, the first section having a first section width, and

a second section extending from the first section to the region interface, the second section having a second section width that is less than the first section width; and

the second well region comprising:

a third section that is disposed over the entire second light guide, the third section having a third section width, and

a fourth section extending from the third section to the region interface, the fourth section having a fourth section width that is less than the third section width,

wherein the second section width of the first well region and the fourth section width of the second well region are substantially equal.

6. The image sensor structure of claim 5, comprising:

the first section and third sections having substantially circular shapes;

wherein the first and third section widths are diameters of the first and third sections respectively.

7. The image sensor structure of claim 5, wherein the second and fourth section widths are 50% or less than the first and third section widths respectively.

8. The image sensor structure of claim 2, comprising:

an opaque layer disposed between the array of light guides and the first and second well regions of each nanowell;

the opaque layer extending under the entire region interface of the first and second well regions; and

the opaque layer covering less than an entire portion of top surfaces the first and second light guides associated with each nanowell.

9. The image sensor structure of claim 8, wherein the opaque layer does not cover any portion of the top surfaces of first and second light guides associated with each nanowell.

10. The image sensor structure of claim 8, wherein the opaque layer covers greater than 10% of the top surfaces of the first and second light guides associated with each nanowell.

11. The image sensor structure of claim 2, comprising:
the first light guide associated with a first light detector of the array of light detectors;
the second light guide associated with a second light detector of the array of light detectors;
each nanowell associated with the first and second light guides having a width that is less than the pitch between the first and second light detectors; and
the first and second light guides extending from their associated nanowell to their associated first and second light detectors at an acute angle relative to each other.

12. The image sensor structure of claim 1, comprising:
the first well region of each nanowell disposed over a first portion of the associated first light guide;
the second well region of each nanowell disposed over a second portion of the associated first light guide;
an array of first waveguides disposed over the device stack, each first waveguide associated with a nanowell of the array of nanowells, each first waveguide operable to illuminate excitation light on a forward strand cluster of forward polynucleotide strands attached in the first well-region of the first waveguide's associated nanowell; and
an array of second waveguides disposed over the device stack, each second waveguide associated with a nanowell of the array of nanowells, each second waveguide operable to

illuminate excitation light on a reverse strand cluster of reverse polynucleotide strands attached in the second well-region of the second waveguide's associated nanowell.

13. The image sensor structure of claim 12, comprising:
 - a waveguide layer disposed between the array of light guides and the first and second well regions of each nanowell;
 - each first waveguide of the array of waveguides disposed in the waveguide layer and extending under the first well region of the first waveguide's associated nanowell; and
 - each second waveguide of the array of waveguides disposed in the waveguide layer and extending under the second well region of the second waveguide's associated nanowell.
14. The image sensor structure of claim 12, comprising:
 - a passivation stack disposed over the device stack, where the array of nanowells is disposed in the passivation stack;
 - each first waveguide of the array of first waveguides disposed in the passivation stack adjacent a side of the first waveguide's associated nanowell; and
 - each second waveguide of the array of waveguides disposed in the passivation stack adjacent an opposing side of the second waveguide's associated nanowell.
15. The image sensor structure of claim 14, wherein:
 - each first waveguide of the array of first waveguides is operable to illuminate excitation light on a cluster of polynucleotide strands attached in the first or second well-region of a nanowell adjacent to the first waveguide's associated nanowell; and
 - each second waveguide of the array of second waveguides is operable to illuminate excitation light on a cluster of polynucleotide strands attached in the first or second well-region of a nanowell adjacent to the second waveguide's associated nanowell.
16. The image sensor structure of claim 1, wherein the first well region and second well region are bounded by a wall of the well, except at the region interface.

17. The image sensor structure of claim 1, further comprising a passivation stack disposed over the device stack, where the array of nanowells is disposed in the passivation stack.
18. The image sensor structure of any of claims 5 - 16, wherein an area of the first well region is smaller than an area of the second well region.
19. The image sensor structure of any of claims 5 - 16, comprising:
the first and second well regions having substantially equal widths; and
the first well region having a length that is 90% or less of a length of the second region.
20. The image sensor structure of any of claims 8-10, comprising:
the first well region comprising:
a first section that is disposed over the entire first light guide, the first section having a first section width, and
a second section extending from the first section to the region interface, the second section having a second section width that is less than the first section width; and
the second well region comprising:
a third section that is disposed over the entire second light guide, the third section having a third section width, and
a fourth section extending from the third section to the region interface, the fourth section having a fourth section width that is less than the third section width,
wherein the second section width of the first well region and the fourth section width of the second well region are substantially equal.
21. The image sensor structure of any of claims 15 and 16 , comprising:
an opaque layer disposed between the array of light guides and the first and second well regions of each nanowell;
the opaque layer extending under the entire region interface of the first and second well regions; and

the opaque layer covering less than an entire portion of top surfaces the first and second light guides associated with each nanowell.

22. The image sensor structure of claim 21, wherein the opaque layer does not cover any portion of the top surfaces of first and second light guides associated with each nanowell.

23. The image sensor structure of claim 21, wherein the opaque layer covers greater than 10% of the top surfaces of the first and second light guides associated with each nanowell.

24. The image sensor structure of any of claims 12 - 14, further comprising a passivation stack disposed over the device stack, where the array of nanowells is disposed in the passivation stack.

25. The image sensor structure of claims 12 - 14, wherein the first well region and second well region are bounded by a wall of the well, except at the region interface.

26. An image sensor structure, comprising:
an image layer comprising an array of light detectors disposed therein;
a device stack disposed over the image layer;
an array of light guides disposed in the device stack, each light guide associated with a light detector of the array of light detectors;
an array of nanowells disposed over the device stack, each nanowell of the array of nanowells associated with a first and a second light guide of the array of light guides;
a first primer set disposed throughout a first well region of each nanowell, the first well region disposed over the first light guide; and
a different second primer set disposed throughout a second well region of each nanowell, the second well region disposed over the second light guide and adjacent the first well region at a region interface;

wherein the first and second primer sets are operable to attach a forward strand cluster of forward polynucleotide strands in the first well region and to attach an adjacent reverse strand cluster of reverse polynucleotide strands in the second well region;

wherein an area of the first well region is smaller than an area of the second well region.

27. The image sensor structure of claim 26, comprising:

the first well region comprising:

a first section having a substantially circular shape that is disposed over the entire first light guide, the first section having a first section diameter, and

a second section extending from the first section to the region interface, the second section having a second section width that is less than the first section diameter; and

the second well region comprising:

a third section having a substantially circular shape that is disposed over the entire second light guide, the third section having a third section diameter, and

a fourth section extending from the third section to the region interface, the fourth section having a fourth section width that is less than the third section diameter,

wherein the second section width of the first well region and the fourth section width of the second well region are substantially equal.

28. The image sensor structure of any of claims 26 or 27, comprising:

an opaque layer disposed between the array of light guides and the first and second well regions of each nanowell;

the opaque layer extending under the entire region interface of the first and second well regions; and

the opaque layer covering less than an entire portion of top surfaces the first and second light guides associated with each nanowell.

29. The image sensor structure of claim 28, wherein the opaque layer does not cover any portion of the top surfaces of first and second light guides associated with each nanowell.

30. The image sensor structure of claim 26, comprising:
the first light guide associated with a first light detector of the array of light detectors;
the second light guide associated with a second light detector of the array of light detectors;
each nanowell associated with the first and second light guides having a width that is less than the pitch between the first and second light detectors; and
the first and second light guides extending from their associated nanowell to their associated first and second light detectors at an acute angle relative to each other.
31. An image sensor structure, comprising:
an image layer comprising an array of light detectors disposed therein;
a device stack disposed over the image layer;
an array of light guides disposed in the device stack, each light guide associated with a light detector of the array of light detectors;
an array of nanowells disposed over the device stack, each nanowell of the array of nanowells associated with a first light guide of the array of light guides;
a first primer set disposed throughout a first well region of each nanowell, the first well region disposed over a first portion of the first light guide; and
a different second primer set disposed throughout a second well region of each nanowell, the second well region disposed over a second portion of the first light guide, the second well region adjacent the first well region at a region interface;
wherein the first and second primer sets are operable to attach a forward strand cluster of forward polynucleotide strands in the first well region and to attach an adjacent reverse strand cluster of reverse polynucleotides in the second well region.
32. The image sensor structure of claim 31, comprising:
an array of first waveguides disposed over the device stack, each first waveguide associated with a nanowell of the array of nanowells, each first waveguide operable to illuminate excitation light on a forward strand cluster of forward polynucleotide strands attached in the first well-region of the first waveguide's associated nanowell, and

an array of second waveguides disposed over the device stack, each second waveguide associated with a nanowell of the array of nanowells, each second waveguide operable to illuminate excitation light on a reverse strand cluster of reverse polynucleotide strands attached in the second well-region of the second waveguide's associated nanowell.

33. A method comprising:

seeding a first primer set in a first well region of a nanowell of an image sensor structure with a polynucleotide strand;

deactivating a second primer set in a second well region of the nanowell to disable seeding of other polynucleotide strands in the second well region;

amplifying the first polynucleotide strand into a plurality of forward and reverse strands throughout the first well region;

cleaving the reverse strands from the first well region to form a forward strand cluster in the first well region;

activating the second primer set in the second well region to enable seeding and amplification in the second well region;

amplifying from the forward strand cluster of the first well region into the second well region to form a plurality of forward and reverse strands in the second well region;

cleaving the forward strands from the second well region to form a reverse strand cluster in the second well region; and

sequencing substantially simultaneously the forward strand cluster in the first well region and the reverse strand cluster in the second well region.

34. The method of claim 33, wherein:

deactivating the second primer set comprises masking the second well region; and

activating the second primer set comprises unmasking the second well region.

35. The method of claim 33, wherein sequencing substantially simultaneously comprises:

attaching first complementary nucleotides having first fluorescent tags to nucleotides of the forward strand cluster in the first well region,

attaching second complementary nucleotides having second fluorescent tags to nucleotides of the reverse strand cluster in the second well region,
radiating excitation light substantially simultaneously onto the forward strand cluster and the reverse strand cluster to fluoresce emissive light from the first and second tags,
receiving substantially simultaneously the emissive light from the first tags through a first light guide to a first light detector and the emissive light from the second tags through a second light guide to a second light detector to determine the sequence of nucleotides of the forward and reverse strands respectively.

36. The method of claim 35, wherein the first well region has an area that is smaller than an area of the second well-region.

37. The method of claim 35, wherein:
the first well region comprises:

a first section that is disposed over the entire first light guide, the first section having a first section width, and

a second section extending from the first section to a region interface between the first and second well regions, the second section having a second section width that is less than the first section width; and

the second well region comprises:

a third section that is disposed over the entire second light guide, the third section having a third section width, and

a fourth section extending from the third section to the region interface, the fourth section having a fourth section width that is less than the third section width.

38. The method of claim 35, wherein an opaque layer is disposed between the first and second light guides and the first and second well regions, the opaque layer extends under an entire region interface of the first and second well regions and the opaque layer covers less than an entire portion of the first and second light guides.

39. The method of claim 35, wherein:
the nanowell has a width that is less than a pitch between the first and second light detectors; and
the first and second light guides extend to their associated first and second light detectors at an acute angle relative to each other.
40. The method of claim 33, wherein:
the first well-region is disposed over a first portion of a first light guide; and
the second well-region is disposed over a second portion of the first light guide.
41. The method of claim 33, wherein sequencing substantially simultaneously comprises:
attaching first complementary nucleotides having first fluorescent tags to nucleotides of the forward strand cluster;
attaching second complementary nucleotides having second fluorescent tags to nucleotides of the reverse strand cluster;
radiating a substantially larger amount of excitation light onto the forward strand cluster than onto the reverse strand cluster to fluoresce a substantially larger amount of emissive light from the first tags than from the second tags;
receiving the emissive light from the first tags through a first light guide to a first light detector to determine the nucleotides of the forward strands;
radiating a substantially larger amount of excitation light onto the reverse strand cluster than onto the forward strand cluster to fluoresce a substantially larger amount of emissive light from the second tags than from the first tags; and
receiving the emissive light from the second tags through the first light guide to the first light detector to determine the nucleotides of the reverse strands.
42. The method of claim 41, wherein:
a first waveguide is disposed over the first light guide;
a second waveguide is disposed over the first light guide;

the excitation light is radiated through the first waveguide and onto the forward strand cluster; and

the excitation light is radiated through the second waveguide and onto the reverse strand cluster.

43. The method of claim 33, wherein sequencing substantially simultaneously comprises:
attaching first complementary nucleotides having first fluorescent tags to nucleotides of the forward strand cluster,

attaching second complementary nucleotides having second fluorescent tags to nucleotides of the reverse strand cluster,

radiating excitation light substantially simultaneously onto the forward strand cluster in the first well region and onto the reverse strand cluster in the second well region to fluoresce emissive light from the first and second tags,

receiving combined emissive light from the first and second tags through a first light guide to a first light detector; and

utilizing signal processing techniques to determine nucleotides in the forward and reverse strands associated with the combined emissive light detected in the first light detector.

44. The method of claim 33, wherein sequencing substantially simultaneously comprises:
receiving substantially simultaneously emissive light from first tags of the forward strands to a first light detector and emissive light from second tags of the reverse strands to a second light detector to determine the sequence of nucleotides of the forward and reverse strands respectively.

45. The method of claim 33, wherein sequencing substantially simultaneously comprises:
receiving emissive light from first tags of the forward strands to a first light detector and emissive light from second tags of the reverse strands to the first light detector to determine the sequence of nucleotides of the forward and reverse strands respectively.

46. The method of claim 45, wherein receiving emissive light from first tags of the forward strands to a first light detector is received substantially simultaneously as receiving emissive light from second tags of the reverse strands to the first light detector.

47. The method of claim 45, wherein receiving emissive light from first tags of the forward strands to a first light detector is received before receiving emissive light from second tags of the reverse strands to the first light detector.

48. The method of any of claims 35 – 47, wherein:
deactivating the second primer set comprises masking the second well region; and
activating the second primer set comprises unmasking the second well region.