

CLAIMS

What is claimed is:

1. A semiconductor device for use with a biochemical sensor comprising a multiple-well array, the semiconductor device comprising:
 - a wafer;
 - at least two reticle areas disposed within the wafer, each reticle area having a plurality of circuitry of a same design, wherein each reticle area comprises:
 - at least one well circuit configured to be in electrical communication with a well of the multiple-well array, and
 - a routing circuit configured to route a signal of a first type from a first side of the reticle area towards a second side of the reticle area along a first direction, and to route a signal of a second type from a third side of the reticle area towards a fourth side of the reticle area along a second direction different from the first direction.
2. The semiconductor device of claim 1, wherein the at least two reticle areas are in electrical communication with each other.
3. The semiconductor device of claim 2, further comprising a plurality of cross-reticle connections configured to place the at least two reticle areas in electrical communication.
4. The semiconductor device of claim 3, wherein the at least two reticle areas are disposed on a first surface of the wafer, the semiconductor device further comprising an redistribution layer (RDL) on the first surface, wherein at least a portion of the plurality of cross-reticle connections comprise conductors disposed in the RDL layer.
5. The semiconductor device of claim 4, further comprising an interposer facing a second surface of the wafer opposite the first surface.
6. The semiconductor device of claim 5, wherein the interposer is a printed circuit board (PCB).

7. The semiconductor device of claim 6, wherein the interposer comprises a cavity, and wherein the wafer is mounted in the cavity.
8. The semiconductor device of any one of claims 1-7, wherein the signal of a first type is a digital signal and the signal of a second type is an analog signal.
9. The semiconductor device any one of claims 1-8, wherein a routing circuit in a first reticle area is configured to receive a signal of the first type from a second reticle area that is adjacent the first reticle area along the first direction.
10. The semiconductor device of claim 9, wherein the routing circuit in the first reticle area is further configured to receive a signal of the second type from a third reticle area that is adjacent the first reticle area along the second direction.
11. The semiconductor device of any one of claims 1-10, wherein the routing circuit comprises one or more shift registers configured to route the signal of the first type.
12. The semiconductor device of any one of claims 1-11, wherein the routing circuit comprises at least one digital bus, and at least one analog bus.
13. The semiconductor device of any one of claims 1-12, wherein the at least one well circuit is configured to be in electrical communication with a plurality of electrodes arranged in an electrode array in the well.
14. The semiconductor device of claim 13, wherein the plurality of electrodes comprise at least 1000 electrodes.
15. The semiconductor device of claim 14, wherein the plurality of electrodes comprise at least 4000 electrodes.
16. The semiconductor device of any one of claims 13-15, wherein each well circuit comprises a plurality of peripheral circuits, each peripheral circuit comprising a stimulation circuit and a recording circuit.

17. The semiconductor device of claim 16, wherein the stimulation circuit comprises a current injector.
18. The semiconductor device of any one of claims 16 or 17, further comprising one or more switches configured to selectively couple a subset of peripheral circuits within a well circuit to a subset of electrodes within the electrode array.
19. The semiconductor device of any one of claims 1-18, wherein the semiconductor device is configured to be coupled underneath the multiple-well array, such that each well circuit is in electrical communication with and disposed adjacent a corresponding well in the multiple-well array.
20. The semiconductor device of any one of claims 1-19, wherein each reticle area comprises more than one well circuit.
21. The semiconductor device of claim 18, wherein the one or more switches are further configured to selectively couple a subset of peripheral circuits with one or more optoelectronic components.
22. The semiconductor device of claim 21, wherein the one or more optoelectronic components comprise a light-emitting diode, a photodetector, or a combination thereof.
23. The semiconductor device of any one of claims 18 or 21, wherein an electrode of the subset of electrodes is a reference electrode.
24. The semiconductor device of any one of claims 3-7, wherein each reticle area has a rectangular shape having sides aligned with the first and second directions.
25. The semiconductor device of any one of claims 13-18, wherein the at least two reticle areas are an array of reticle areas arranged in rows along the first direction and in columns along the second direction, wherein adjacent reticle areas in each row are connected by an array of cross-reticle connections arranged along the second direction, and wherein adjacent reticle areas in each column are connected by an array of cross-reticle connections arranged along the first direction.

26. The semiconductor device of claim 25, wherein the semiconductor device is configured to be coupled underneath the multiple-well array, whereby each reticle area is underneath a corresponding well of the multiple-well array.
27. The semiconductor device of any one of claims 25 or 26, wherein each reticle area has a width of at least 9 mm.
28. The semiconductor device any one of claims 25-27, wherein each reticle area has a width of at least 18 mm.
29. The semiconductor device of any one of claims 1-28, wherein the multiple-well array has at least 96 wells.
30. The semiconductor device of any one of claims 1-29, wherein the wafer has a lateral dimension that equals or is bigger than a maximum lateral extent of the multiple-well array.
31. The semiconductor device of any one of claims 1-30, wherein the wafer comprises silicon.
32. The semiconductor device of claim 31, wherein each of the reticle areas is an integrated circuit that comprises complementary metal oxide-semiconductor (CMOS) components.
33. A method of operating a semiconductor device to assess a biochemical sensor comprising a multiple-well array, the semiconductor device comprising a wafer, and at least two reticle areas disposed within the wafer, each reticle area having a plurality of circuitry of a same design, wherein each reticle area comprises at least one well circuit and a routing circuit, the method comprising:
- electrically communicating, using the at least one well circuit, with a well of the multiple-well array; and
 - routing, with the routing circuit, a signal of a first type from a first side of the reticle area towards a second side of the reticle area along a first direction, and a signal of a second type from a third side of the reticle area towards a fourth side of the reticle area along a second direction different from the first direction.

34. The method of claim 33, wherein the signal of a first type is a digital signal and the signal of a second type is an analog signal.

35. The method of any one of claims 33 or 34, wherein routing the signal of the first type and the signal of the second type comprises:

transmitting a signal of the first type from a second reticle area to a first reticle area that is adjacent the second reticle area along the first direction; and

transmitting a signal of the second type from a third reticle area to the first reticle area, wherein the third reticle area is adjacent the first reticle area along the second direction.

36. The method of any one of claims 33-35, wherein electrically communicating with the well comprises:

providing one or more stimulus to a cell disposed in the multiple-well array, measuring one or more characteristics of the cell, or a combination thereof.

37. The method of claim 36, wherein the one or more characteristics of the cell comprises: an impedance, an adhesion, a redox potential, an action potential, a conduction velocity, a synapse mapping, or a combination thereof.

38. The method of any one of claims 36 or 37, wherein the one or more stimulus comprises a current or a voltage.

39. The method of any one of claims 36-38, wherein each well circuit comprises a plurality of peripheral circuits, each peripheral circuit comprising a stimulation circuit and a recording circuit, and wherein electrically communicating with the well further comprises:

selectively coupling, with one or more switches in the semiconductor device, a subset of peripheral circuits within the well circuit to a subset of electrodes within an electrode array in the well;

providing, with the stimulation circuits in the subset of peripheral circuits, one or more stimulus to the cell via the subset of electrodes; and

measuring, with the recording circuits in the subset of peripheral circuits, one or more characteristics of the cell via the subset of electrodes.

40. The method of claim 39, further comprising:
selectively coupling an optoelectronic component with a peripheral circuit;
with the optoelectronic component, emitting a light signal to or receiving a light signal from the cell disposed in the multiple-well array.
41. An apparatus for electrical assessment of a biological specimen, comprising:
a plate having a multiple-well array for holding the biological specimen, each well of the multiple-well array having a plurality of electrodes disposed therein;
a wafer having a first surface facing a first side of the plate, comprising:
an array of reticle areas, each reticle area having a plurality of circuitry of a same design, wherein each reticle area comprises:
at least one well circuit configured to be in electrical communication with electrodes in a well of the multiple-well array, and
a routing circuit configured to route a signal of a first type from a first side of the reticle area towards a second side of the reticle area along a first direction, and to route a signal of a second type from a third side of the reticle area towards a fourth side of the reticle area along a second direction different from the first direction;
and
a first substrate having a wafer attach surface facing a second surface of the wafer opposite the first surface, the first substrate comprising a plurality of conductors that electrically connect at least a portion of the array of reticle areas to a plurality of pads disposed on a mounting surface of the first substrate opposite the wafer attach surface.
42. The apparatus of claim 41, wherein the first substrate is an interposer that comprises a cavity, wherein the wafer attach surface is disposed within the cavity, and wherein the second surface of the wafer is attached to the wafer attach surface of the first substrate.
43. The apparatus of any one of claims 41 or 42, further comprising a lid coupled to a second side of the plate opposite the first side.
44. The apparatus of claim 43, wherein the lid comprises a plurality of reference electrodes, each reference electrode extending into a corresponding well of the multiple-well array.

45. The apparatus of any one of claims 43 or 44, wherein the lid comprises a plurality of photodetectors, each photodetector facing a corresponding well of the multiple-well array.
46. The apparatus of any one of claims 41-45, further comprising a second substrate having a plurality of conductive structures disposed at a first surface facing the mounting surface of the first substrate, each conductive structure electrically connected to a corresponding pad of the plurality of pads on the mounting surface of the first substrate.
47. The apparatus of claim 46, wherein the second substrate and the first substrate is coupled via a magnetic force.
48. The apparatus of any one of claims 41-47, further comprising an enclosure that surrounds the wafer and the plate on at least five sides.
49. The apparatus of any one of claims 41-48, wherein the biological specimen comprises a plurality of single cells.
50. The apparatus of claim 49, wherein the plurality of electrodes within a well are configured to be in electrical communication with an interior of a single cell disposed in the well.
51. The apparatus of any one of claims 41-50, wherein the signal of a first type is a digital signal and the signal of a second type is an analog signal.
52. The apparatus of claim 51, wherein a routing circuit in a first reticle area is configured to receive a signal of the first type from a second reticle area that is adjacent the first reticle area along the first direction, and the routing circuit in the first reticle area is further configured to receive a signal of the second type from a third reticle area that is adjacent the first reticle area along the second direction.
53. The apparatus of any one of claims 41-52, wherein each well circuit comprises a plurality of peripheral circuits, each peripheral circuit comprising a stimulation circuit and a recording circuit, and the apparatus further comprises one or more switches configured to

selectively couple a subset of peripheral circuits within a well circuit to a subset of electrodes within the plurality of electrodes.

54. The apparatus of any one of claims 41-53, wherein each well has an opening that is open towards the wafer, and wherein the plurality of electrodes comprise an array of conductors disposed on an insulative surface of the wafer.