

WHAT IS CLAIMED IS:

1. An apparatus, comprising:
 - (a) a flow cell body defining one or more flow channels and a plurality of wells, each flow channel of the one or more flow channels to receive a flow of fluid, each well of the plurality of wells being fluidically coupled with the corresponding flow channel of the one or more flow channels, each well of the plurality of wells defining a corresponding depth;
 - (b) a plurality of electrodes, each electrode of the plurality of electrodes being positioned in a corresponding well of the plurality of wells, the plurality of electrodes to effect writing of polynucleotides in the corresponding wells of the plurality of wells;
 - (c) an imaging assembly to capture images indicative of one or more nucleotides in a polynucleotide; and
 - (d) one or more barrier features positioned in or between the plurality of wells, the barrier features to contain reactions in each well of the plurality of wells or reduce diffusion between the plurality of wells.
2. The apparatus of claim 1, each electrode of the plurality of electrodes defining an aperture.
3. The apparatus of claim 2, the imaging assembly including at least one image sensor to receive light through the aperture of each electrode of the plurality of electrodes.
4. The apparatus of any one or more of claims 2 through 3, each electrode of the plurality of electrodes being annularly shaped.
5. The apparatus of any one or more of claims 2 through 3, each electrode of the plurality of electrodes comprising a plurality of electrode segments arranged in

quadrants, the aperture being defined at a central region of the arrangement of quadrants.

6. The apparatus of any one or more of claims 1 through 5, further comprising an integrated circuit positioned under the flow cell body, the integrated circuit to drive the electrodes to thereby effect writing of polynucleotides in the corresponding wells of the plurality of wells.

7. The apparatus of claim 6, the integrated circuit being further in communication with the imaging assembly.

8. The apparatus of any one or more of claims 6 through 7, the integrated circuit comprising a complementary metal-oxide-semiconductor (CMOS) chip.

9. The apparatus of any one or more of claims 1 through 8, the plurality of wells being formed as a plurality of discrete recesses arranged in a pattern along a base surface of the corresponding flow channel of the one or more flow channels.

10. The apparatus of any one or more of claims 1 through 9, each well of the plurality of wells being defined by at least one sidewall and a floor.

11. The apparatus of claim 10, each electrode of the plurality of electrodes being positioned on the floor of the corresponding well of the plurality of wells.

12. The apparatus of claim 10, each electrode of the plurality of electrodes being positioned on a sidewall of the at least one sidewall of the corresponding well of the plurality of wells.

13. The apparatus of any one or more of claims 10 through 12, the floor of each well of the plurality of wells further defining an opening, the opening to provide a path for fluid communication between the corresponding well of the plurality of wells and a fluid source.

14. The apparatus of claim 13, the barrier features comprising a plurality of valves, each valve of the plurality of valves being positioned in the opening of each corresponding well of the plurality of wells.

15. The apparatus of claim 14, each valve of the plurality of valves comprising a hydrogel material.

16. The apparatus of claim 15, the hydrogel material to transition between an expanded state and a contracted state, the hydrogel material to effectively close the aperture of the well of the plurality of wells in the expanded state, the hydrogel material to effectively open the aperture of the well of the plurality of wells in the contracted state.

17. The apparatus of any one or more of claims 15 through 16, each valve of the plurality of valves comprising a hydrogel ring defining an opening aligned with the aperture of the corresponding well of the plurality of wells.

18. The apparatus of claim 14, each valve of the plurality of valves comprising an electroactive polymer material.

19. The apparatus of any one or more of claims 14 through 18, each valve of the plurality of valves to transition between an open state and a closed state in response to changes in pH, the apparatus further comprising a pH driving feature to selectively vary a pH value associated with each valve of the plurality of valves to thereby selectively transition the valve of the plurality of valves between the open state and the closed state.

20. The apparatus of any one or more of claims 14 through 19, each valve of the plurality of valves to transition between an open state and a closed state in response to changes in temperature, the apparatus further comprising a temperature driving feature to selectively vary a temperature value associated with each valve of the plurality of valves to thereby selectively transition the valve of the plurality of valves between the open state and the closed state.

21. The apparatus of claim 20, each valve of the plurality of valves comprising a heat swellable polymer.

22. The apparatus of any one or more of claims 14 through 21, each valve of the plurality of valves being biased toward a closed state, each valve of the plurality of valves to open in response to fluid pressure against the valve of the plurality of valves exceeding a threshold.

23. The apparatus of any one or more of claims 14 through 22, further comprising a control module to control opening and closing of each valve of the plurality of valves.

24. The apparatus of claim 23, the control module to selectively activate the plurality of valves to allow deblocking agent to pass through the apertures of the plurality of wells.

25. The apparatus of any one or more of claims 1 through 24, the one or more barrier features including a flow gradient generator, the flow gradient generator to provide a fluid flow profile that varies across the depth of each well of the plurality of wells.

26. The apparatus of claim 25, the flow gradient generator to provide a reduced flow of fluid or fluid pressure at a bottom region of each well of the plurality of wells, with an increased flow of fluid or fluid pressure at a top region of each well of the plurality of wells.

27. The apparatus of any one or more of claims 25 through 26, the flow gradient generator comprising a pump.

28. The apparatus of any one or more of claims 26 through 27, the flow gradient generator comprising a bubble generator.

29. The apparatus of any one or more of claims 1 through 28, the one or more barrier features including a temperature gradient generator, the temperature gradient generator to provide a temperature profile that varies across the depth of each well of the plurality of wells.

30. The apparatus of claim 29, the temperature gradient generator to provide a relatively higher temperature in a bottom region of each well of the plurality of wells and a relatively lower temperature in a top region of each well of the plurality of wells.

31. The apparatus of any one or more of claims 1 through 28, the one or more barrier features including a temperature gradient generator, the temperature gradient generator to provide a temperature profile that varies between the plurality of wells.

32. The apparatus of claim 31, the temperature gradient generator to provide a relatively higher temperature within each well of the plurality of wells and a relatively lower temperature in spaces between the plurality of wells.

33. The apparatus of any one or more of claims 1 through 32, the one or more barrier features comprising a plurality of hydrophobic partitions positioned along a base surface of the flow cell body between adjacent wells of the plurality of wells.

34. The apparatus of claim 33, the plurality of hydrophobic partitions extending from the base surface of the flow cell body toward an upper surface of the flow cell body.

35. The apparatus of any one or more of claims 33 through 34, the plurality of hydrophobic partitions to transition from positions along the base surface of the flow cell body between adjacent wells of the plurality of wells to positions over each corresponding well of the plurality of wells, such that the plurality of

hydrophobic partitions are to transition from being barriers between the plurality of wells to being caps over the plurality of wells.

36. The apparatus of claim 35, the plurality of hydrophobic partitions to move in response to an applied voltage.

37. The apparatus of any one or more of claims 35 through 36, each hydrophobic partition of the plurality of hydrophobic partitions to cover a two more wells of the plurality of wells simultaneously.

38. The apparatus of any one or more of claims 35 through 36, each hydrophobic partition of the plurality of hydrophobic partitions to cover only a single well of the plurality of wells, such that each well of the plurality of wells has a respective hydrophobic partition of the plurality of hydrophobic partitions.

39. The apparatus of any one or more of claims 34 through 38, each hydrophobic partition of the plurality of hydrophobic partitions comprising a volume of a fluid.

40. The apparatus of claim 39, each hydrophobic partition of the plurality of hydrophobic partitions comprising a volume of an oil.

41. The apparatus of any one or more of claims 1 through 40, the one or more barrier features comprising a pH driving feature to selectively adjust pH values associated with each well of the plurality of wells to thereby provide variation in pH values among adjacent wells of the plurality of wells.

42. The apparatus of claim 41, the pH driving feature comprising a bubble generator.

43. The apparatus of any one or more of claims 41 through 42, the pH driving feature comprising electrodes.

44. The apparatus of any one or more of claims 1 through 43, the plurality of electrodes to effect writing of polynucleotides in the form of DNA strands in the corresponding wells of the plurality of wells.

45. The apparatus of any one or more of claims 1 through 44, the plurality of electrodes including electrodes positioned in a bottom region of each well of the plurality of wells, the electrodes positioned in the bottom region of each well of the plurality of wells to drive a redox reaction within the corresponding well of the plurality of wells.

46. The apparatus of claim 45, each electrode of the electrodes positioned in the bottom region of each well of the plurality of wells comprising a copper element.

47. The apparatus of any one or more of claims 45 through 46, the plurality of electrodes further including electrodes positioned on surfaces of interstitial spaces between wells of the plurality of wells, the electrodes positioned on surfaces of interstitial spaces between wells of the plurality of wells providing the one or more barrier features.

48. The apparatus of claim 47, the electrodes positioned on surfaces of interstitial spaces between wells of the plurality of wells to provide a reverse current that sharpens boundaries defined by the electrodes positioned in the bottom region of each well of the plurality of wells.

49. An apparatus, comprising:
- (a) a body defining an upper flow channel a plurality of wells, the upper flow channel to receive a flow of fluid containing nucleotides, each well of the plurality of wells being fluidically coupled with the corresponding flow channel, each well of the plurality of wells having a floor with an aperture;

- (b) a lower channel positioned under the floor of each well of the plurality of wells, the lower channel to receive fluid containing a deblocking agent;
- (c) a plurality of valves, each valve of the plurality of valves to transition between an open and closed state, each valve of the plurality of valves to permit fluid communication between the lower channel and the corresponding well of the plurality of wells in the open state, each valve of the plurality of valves to reduce fluid communication between the lower channel and the corresponding well of the plurality of wells in the closed state; and
- (d) a plurality of electrodes, each electrode of the plurality of electrodes being positioned in a corresponding well of the plurality of wells, the plurality of electrodes to effect writing of polynucleotides in the corresponding wells of the plurality of wells.

50. The apparatus of claim 49, further comprising an imaging assembly to capture images indicative of one or more nucleotides in a polynucleotide.

51. The apparatus of any one or more of claims 49 through 50, each valve of the plurality of valves comprising a hydrogel material.

52. The apparatus of any one or more of claims 49 through 50, each valve of the plurality of valves comprising an electroactive polymer.

53. The apparatus of any one or more of claims 49 through 50, each valve of the plurality of valves comprising a heat swellable polymer.

54. The apparatus of any one or more of claims 49 through 53, each valve of the plurality of valves being biased toward a closed state, each valve of the plurality of valves to open in response to fluid pressure against the valve exceeding a threshold.

55. An apparatus, comprising:
- (a) a flow cell body defining one or more flow channels and a plurality of wells, each flow channel of the one or more flow channels to receive a flow of fluid, each well of the plurality of wells being fluidically coupled with the corresponding flow channel of the one or more flow channels, each well of the plurality of wells defining a corresponding depth;
 - (b) a plurality of electrodes, each electrode of the plurality of electrodes being positioned in a corresponding well of the plurality of wells, the plurality of electrodes to effect writing of polynucleotides in the corresponding wells of the plurality of wells; and
 - (c) a flow gradient generator, the flow gradient generator to provide a fluid flow profile that varies across the depth of each well of the plurality of wells.

56. The apparatus of claim 55, further comprising an imaging assembly to capture images indicative of one or more nucleotides in a polynucleotide.

57. The apparatus of any one or more of claims 55 through 56, the flow gradient generator to provide a reduced flow of fluid or fluid pressure at a bottom region of each well of the plurality of wells, with an increased flow of fluid or fluid pressure at a top region of each well of the plurality of wells.

58. An apparatus, comprising:
- (a) a flow cell body defining one or more flow channels and a plurality of wells, each flow channel of the one or more flow channels to receive a flow of fluid, each well of the plurality of wells being fluidically coupled with the corresponding flow channel of the one or more flow channels, each well of the plurality of wells defining a corresponding depth;

- (b) a plurality of electrodes, each electrode of the plurality of electrodes being positioned in a corresponding well of the plurality of wells, the plurality of electrodes to effect writing of polynucleotides in the corresponding wells of the plurality of wells; and
- (c) a temperature gradient generator, the temperature gradient generator to provide a temperature profile that varies across the depth of each well of the plurality of wells.

59. The apparatus of claim 58, further comprising an imaging assembly to capture images indicative of one or more nucleotides in a polynucleotide.

60. The apparatus of any one or more of claims 58 through 59, the temperature gradient generator to provide a relatively higher temperature in a bottom region of each well of the plurality of wells and a relatively lower temperature in a top region of each well of the plurality of wells.

61. An apparatus, comprising:

- (a) a flow cell body defining one or more flow channels and a plurality of wells, each flow channel of the one or more flow channels to receive a flow of fluid, each well of the plurality of wells being fluidically coupled with the corresponding flow channel of the one or more flow channels, each well of the plurality of wells defining a corresponding depth;
- (b) a plurality of electrodes, each electrode of the plurality of electrodes being positioned in a corresponding well of the plurality of wells, the plurality of electrodes to effect writing of polynucleotides in the corresponding wells of the plurality of wells; and
- (c) a temperature gradient generator, the temperature gradient generator to provide a temperature profile that varies between the plurality of wells.

62. The apparatus of claim 61, further comprising an imaging assembly to capture images indicative of one or more nucleotides in a polynucleotide.

63. The apparatus of any one or more of claims 61 through 62, the temperature gradient generator to provide a relatively higher temperature within each well of the plurality of wells and a relatively lower temperature in spaces between the plurality of wells.

64. An apparatus, comprising:

- (a) a flow cell body defining one or more flow channels, an upper surface, a base surface, and a plurality of wells formed in the base surface, each flow channel of the one or more flow channels to receive a flow of fluid, each well of the plurality of wells being fluidically coupled with the corresponding flow channel of the one or more flow channels;
- (b) a plurality of electrodes, each electrode of the plurality of electrodes being positioned in a corresponding well of the plurality of wells, the plurality of electrodes to effect writing of polynucleotides in the corresponding wells of the plurality of wells; and
- (c) a plurality of hydrophobic partitions positioned along the base surface of the flow cell body between adjacent wells of the plurality of wells, the plurality of hydrophobic partitions extending from the base surface of the flow cell body toward an upper surface of the flow cell body.

65. The apparatus of claim 64, further comprising an imaging assembly to capture images indicative of one or more nucleotides in a polynucleotide.

66. The apparatus of any one or more of claims 64 through 65, the plurality of hydrophobic partitions to move from positions along the floor of the flow cell body between adjacent wells of the plurality of wells to positions over each corresponding well of the plurality of wells, such that the plurality of hydrophobic

partitions are to transition from being barriers between the plurality of wells to being caps over the plurality of wells.

67. The apparatus of claim 66, the plurality of hydrophobic partitions to move in response to an applied voltage.

68. The apparatus of any one or more of claims 64 through 67, each hydrophobic partition of the plurality of hydrophobic partitions comprising a volume of a fluid.

69. An apparatus, comprising:

- (a) a flow cell body defining one or more flow channels, an upper surface, a base surface, and a plurality of wells formed in the base surface, each flow channel of the one or more flow channels to receive a flow of fluid, each well of the plurality of wells being fluidically coupled with the one or more flow channels;
- (b) a plurality of electrodes, each electrode of the plurality of electrodes being positioned in a corresponding well of the plurality of wells, the plurality of electrodes to effect writing of polynucleotides in the corresponding wells of the plurality of wells; and
- (c) a pH driving feature to selectively adjust pH values associated with each well of the plurality of wells to thereby provide variation in pH values among adjacent wells of the plurality of wells.

70. The apparatus of claim 69, further comprising an imaging assembly to capture images of polynucleotides written in the wells of the plurality of wells.

71. The apparatus of any one or more of claims 69 through 70, the pH driving feature comprising a device selected from the group consisting of a bubble generator and a set of electrodes.

72. An apparatus, comprising:
- (a) a flow cell body defining one or more flow channels, each flow channel of the one or more flow channels to receive a flow of fluid, at least one of the one or more flow channels having:
 - (i) a floor, and
 - (ii) a plurality of wells defined as recesses in the floor, each well of the plurality of wells being fluidically coupled with the corresponding flow channel, the flow cell body further defining interstitial spaces between adjacent wells of the plurality of wells;
 - (b) a plurality of electrode assemblies, each electrode assembly of the plurality of electrode assemblies being positioned in a corresponding well of the plurality of wells, the plurality of electrode assemblies to generate machine-written polynucleotides in the corresponding wells of the plurality of wells; and
 - (c) one or more barrier features positioned above the plurality of wells or in the plurality of wells, the one or more barrier features to reduce optical cross-talk between the plurality of wells.

73. The apparatus of claim 72, further comprising an imaging assembly to capture images indicative of one or more nucleotides in machine-written polynucleotides written in the wells of the plurality of wells.

74. The apparatus of any one or more of claims 72 through 73, the one or more barrier features comprising an electrically activated polarizer.

75. The apparatus of claim 74, each of the polarizers being positioned in an upper region of a corresponding well of the plurality of wells.

76. The apparatus of any one or more of claims 74 through 75, each of the polarizers defining an opening to permit fluid to flow from the at least one of the one or more flow channels into the corresponding well of the plurality of wells.

77. The apparatus of any one or more of claims 72 through 76, further comprising a light source, the light source to project light to two or more wells of the plurality of wells that are positioned to simultaneously receive the light projected from the light source.

78. The apparatus of claim 77, the polarizers to selectively permit or restrict passage of light from the light source to the two or more wells that are positioned to simultaneously receive the light projected from the light source.

79. The apparatus of any one or more of claims 72 through 78, the one or more barrier features comprising photoguides.

80. The apparatus of any one or more of claims 72 through 79, the plurality of electrode assemblies to generate machine-written polynucleotides in the form of DNA strands.

81. A method comprising:
- flowing fluid through a flow cell, the fluid containing nucleotides, the flow cell comprising a flow cell body defining one or more flow channels, each flow channel of the one or more flow channels to receive a flow of fluid, at least one of the one or more flow channels having:
 - (i) a floor,
 - (ii) a plurality of wells defined as recesses in the floor, each well of the plurality of wells being fluidically coupled with the corresponding flow channel of the one or more flow channels, the floor of the flow channel of the one or more flow channels defining interstitial spaces between adjacent wells of the plurality of wells, and

- (iii) a plurality of barrier features above the wells of the plurality of wells or in the wells of the plurality of wells;

activating electrode assemblies at bottom regions of each well of the plurality of wells to generate machine-written polynucleotides within each well of the plurality of wells, the machine-written polynucleotides representing stored data; and
activating the plurality of barrier features to reduce optical cross-talk between adjacent wells of the plurality of wells.

82. The method of claim 81, activating the electrode assemblies at the bottom region of each well of the plurality of wells comprising generating a positive current, activating the plurality of barrier features comprising generating a negative current.

83. The method of any one or more of claims 81 through 82, activating the plurality of barrier features comprising adding a charge tag to at least some of the nucleotides.

84. The method of claim 83, each charge tag being positively charged.

85. The method of claim 84, each charge tag imparting a net positive charge to the corresponding nucleotide of the nucleotides.

86. The method of claim 83, each charge tag being negatively charged.

87. The method of any one or more of claims 83 through 86, each charge tag being attached to one or more regions of the corresponding nucleotide of the nucleotides selected from a ribose, a phosphate group, or a base.

88. The method of any one or more of claims 83 through 87, each charge tag being cleaved before a ligation event.

89. The method of any one or more of claims 83 through 87, each charge tag being cleaved after a ligation event

90. A method comprising:
- flowing fluid through a flow cell, the fluid containing nucleotides, the flow cell comprising a flow cell body defining one or more flow channels, each flow channel of the one or more flow channels to receive a flow of fluid, each flow channel of the one or more flow channels having:
- (i) a floor,
 - (ii) a plurality of wells defined as recesses in the floor, each well of the plurality of wells being fluidically coupled with the corresponding flow channel of the one or more flow channels, the floor of the flow channel of the one or more flow channels defining interstitial surfaces between adjacent wells of the plurality of wells, and
 - (iii) a plurality of barrier features positioned above the plurality of wells or in the plurality of wells, the plurality of barrier features to reduce optical cross-talk between the plurality of wells;
- determining a first subset of the plurality of wells that are unused, and that are not adjacent to a used well of the plurality of wells;
- activating electrode assemblies at bottom regions of each well of the first subset to generate machine-written polynucleotides within each well of the first subset, the machine-written polynucleotides within each well of the first subset representing stored data, while leaving the plurality of barrier features deactivated;
- determining a second subset of the plurality of wells that are unused, but that are adjacent to a used well of the plurality of wells; and
- activating electrode assemblies at bottom regions of each well of the second subset to generate machine-written polynucleotides within each well of the second subset, the machine-written

polynucleotides the machine-written polynucleotides within each well of the second subset representing stored data, after activating the barrier features to reduce optical cross-talk between adjacent wells of the plurality of wells.

91. The method of claim 90, further comprising:
receiving a request for stored data;
determining a set of target wells from the plurality of wells in which the stored data is represented by machine-written polynucleotides;
determining whether each well of the set of target wells is adjacent to any used wells of the plurality of wells; and
where a target well of the set of target wells is adjacent to any used well, activating an integrated circuit to detect fluorescence emitted from a fluorophore of a machine-written polynucleotide and read the stored data from the target well of the set of target wells that is adjacent to a used well, after activating the barrier features to reduce optical cross-talk with the adjacent wells of the plurality of wells.
92. The method of claim 91, further comprising:
where the target well is adjacent to any used well, performing a cross-talk quality control check on the read stored data; and
where the cross-talk quality control check verifies that that read stored data is not corrupted, providing the read stored data to a requesting device.
93. The method of any one or more of claims 90 through 92, further comprising:
receiving a request for stored data;
determining a set of target wells from the plurality of wells in which the stored data is represented by machine-written polynucleotides;

determining whether each well of the set of target wells is adjacent to any used wells of the plurality of wells; and
where a target well of the set of target wells is not adjacent to any used well, activating an integrated circuit to detect fluorescence of emitted from a fluorophore of a machine-written polynucleotide and read the stored data from the target well of the set of target wells that is not adjacent to a used well, while leaving the barrier features deactivated.

94. The method of any one or more of claims 91 through 93, further comprising, where the target well is not adjacent to any used well of the plurality of wells, providing the read stored data to a requesting device without performing a cross talk quality control check on the read stored data.