CLAIMS

1. A method for providing spatially positioned electrochemical reactions with an electrode array exposed on a surface of a semiconductor substrate, the electrode array exposed to a solution including one or more chemical or biological reagents and a plurality of cells attached to the semiconductor substrate, the method comprising:

selecting one or more electrodes in the electrode array;

controlling circuitry in the semiconductor substrate to apply, at the one or more electrodes, one or more stimulus signals including at least one of a patterning voltage or a patterning current for generation of gas in the solution to initiate an electrochemical reaction at the selected one or more electrodes; and

generating the gas at the selected one or more electrodes to cause at least one of permeabilization or detachment from the surface of the semiconductor substrate of at least one cell of the plurality of cells disposed on the selected one or more electrodes.

2. The method of claim 1, wherein the patterning voltage exceeds a redox potential for generation of gas in the solution.

3. The method of claim 1, wherein the permeabilization of at least one cell of the plurality of cells comprises forming in the at least one cell holes that are smaller than those formed when the at least one cell is detached from the surface of the semiconductor substrate.

4. The method of claim 1, wherein the gas comprises H_2, Cl_2, or O_2.

5. The method of claim 1, wherein the plurality of cells are a plurality of cells of a first type, and the method further comprises:

plating one or more cells of a second type on the surface of the semiconductor substrate at locations where the at least one cell of the first type has detached from.

6. The method of claim 1, further comprising:

mapping a time sequence of regrowth of the plurality of cells on the surface at positions where the at least one cell has detached from; and

based on the mapping, determining a growth rate of the plurality of cells.

7. The method of claim 6, further comprising:

measuring with the controlling circuitry an open-circuit potential at each of some or all electrodes in the electrode array to measure an extracellular redox potential; and

based on the mapping, determine a cellular metabolic state and respiration of the plurality of cells during growth.

8. The method of claim 6, further comprising:

measuring with the control circuitry a current at each of some or all remaining electrodes in the electrode array.

9. The method of claim 1, wherein the one or more stimulus signals are relative to a current or a potential of a reference electrode.

10. The method of claim 1, wherein the semiconductor substrate includes a plurality of voltage buffer circuits coupled with the electrode array, the method further comprising:

selecting a set of electrodes in the electrode array; and

controlling the voltage buffer circuits to measure an extracellular redox potential at each electrode of the set of electrodes.

11. A system comprising:

a semiconductor substrate comprising:

an electrode array including a plurality of individually addressable electrodes disposed on a surface of the semiconductor substrate;

a solution including one or more chemical or biological reagents and a plurality of cells attached to the semiconductor substrate; and

circuitry comprising a plurality of buffer circuits and that is controllable by one or more processors to:

apply, at a group of electrodes in the electrode array, one or more stimulus signals including at least one of a patterning voltage or a patterning current, relative to a potential of or

current at an electrode in the electrode array or a potential of or current at a reference electrode; and

measure, via the plurality of buffer circuits, an extracellular redox potential at each cell of a set of electrodes of the electrode array.

12. The system of claim 11, wherein the electrode array comprises a plurality of pads disposed on an insulative surface of the semiconductor substrate.

13. The system of claim 12, wherein the plurality of pads comprises Au or Pt.

14. The system of claim 11, wherein the reference electrode is a Ag/AgCl reference electrode.

15. The system of claim 11, wherein the electrode array comprises at least 1000, at least 4000, or at least 1,000,000 electrodes, and the circuitry comprises a plurality of recording circuits, each recording circuit configured to measure a current at an electrode of the electrode array.

16. The system of claim 15, wherein the plurality of recording circuits comprises at least 10 recording circuits, or at least 4000 recording circuits.

17. The system of claim 15, wherein each recording circuit comprises a transimpedance amplifier (TIA).

18. The system of claim 17, wherein the TIA comprises an impedance component having a resistance of at least 10 MOhm, wherein an output voltage of the TIA is proportional to a voltage across the impedance component.

19. The system of claim 18, wherein the impedance component comprises a switching capacitor.

20. A system for providing spatially positioned electrochemical reactions, the system comprising:

an electrode array exposed at a surface area of a semiconductor substrate;

a solution including one or more chemical or biological reagents and a plurality of cells attached to the surface area of the semiconductor substrate;

circuitry disposed in the semiconductor substrate and coupled to the electrode array;

at least one non-transitory computer-readable medium having stored thereon executable instructions; and

at least one processor programmed by the executable instructions to perform a method comprising acts of:

selecting a pattern of electrodes in the electrode array; and

controlling circuitry to apply, at the pattern of electrodes, one or more predetermined stimulus signals including at least one of a patterning voltage or a patterning current, relative to a potential of or current at an electrode in the electrode array or a potential of or current at a reference electrode, for generation of gas in the solution such that gas is generated at the pattern of electrodes to cause at least one of permeabilization or detachment from the surface of the semiconductor substrate of at least one cell of the plurality of cells that is disposed on the pattern of electrodes.

21. The system of claim 20, wherein the electrode array comprises a plurality of pads disposed on an insulative surface of the semiconductor substrate.

22. The system of claim 21, wherein the plurality of pads comprises Au or Pt.

23. The system of claim 20, wherein the reference electrode is a Ag/AgCl reference electrode.

24. The system of claim 20, wherein the electrode array comprises at least 1000, at least 4000, or at least 1,000,000 electrodes, and the circuitry comprises a plurality of recording circuits, each recording circuit configured to measure a current at an electrode of the electrode array.

25. The system of claim 24, wherein the plurality of recording circuits comprises at least 10 recording circuits, or at least 4000 recording circuits.

26. The system of claim 24, wherein each recording circuit comprises a transimpedance amplifier (TIA).

27. The system of claim 26, wherein the TIA comprises an impedance component having a resistance of at least 10 MOhm, wherein an output voltage of the TIA is proportional to a voltage across the impedance component.

28. The system of claim 27, wherein the impedance component comprises a switching capacitor.

29. The system of claim 20, wherein the circuitry comprises a plurality of buffer circuits coupled with the electrode array, wherein the circuitry is controllable by one or more processors to measure, via the plurality of buffer circuits, an extracellular redox potential at each cell of a set of electrodes of the electrode array.

30. A system comprising:

a semiconductor substrate comprising:

an electrode array including a plurality of at least 1000 individually addressable electrodes disposed on a surface of the semiconductor substrate;

a solution including one or more chemical or biological reagents and a plurality of cells attached to the semiconductor substrate; and

circuitry comprising at least 10 recording circuits and that is controllable by one or more processors to apply, at a group of electrodes in the electrode array, one or more stimulus signals including at least one of a patterning voltage or a patterning current, relative to a potential of or current at an electrode in the electrode array or a potential of or current at a reference electrode,

wherein each recording circuit is configured to measure a current at an electrode of the electrode array.

31. The system of claim 30, wherein the electrode array comprises a plurality of pads disposed on an insulative surface of the semiconductor substrate.

32. The system of claim 31, wherein the plurality of pads comprises Au or Pt.

33. The system of claim 30, wherein the reference electrode is a Ag/AgCl reference electrode.

34. The system of claim 30, wherein each recording circuit comprises a transimpedance amplifier (TIA).

35. The system of claim 34, wherein the TIA comprises an impedance component having a resistance of at least 10 MOhm, wherein an output voltage of the TIA is proportional to a voltage across the impedance component.

36. The system of claim 35, wherein the impedance component comprises a switching capacitor.

37. The system of claim 30, wherein the circuitry comprises a plurality of buffer circuits coupled with the electrode array, wherein the circuitry is controllable by one or more processors to measure, via the plurality of buffer circuits, an extracellular redox potential at each cell of a set of electrodes of the electrode array.