CLAIMS

What is claimed is:

1. A system for electroporating a biological cell, the system comprising:

a micro fluidic channel adapted to receive a flow of a plurality of biological cells in a buffer solution, wherein the micro fluidic channel comprises a detection area;

a pair of electrodes adapted to apply an electrical field across the detection area;

a signal generator unit, wherein the signal generator unit is capable of generating a cell detection signal and a permeabilization signal through the electrodes;

a sensing unit, wherein the sensing unit is adapted to detect the impedance of the detection area; and

a controller unit, wherein the controller unit is adapted to control the signal generator unit according to the impedance detected by the sensing unit;

wherein the signal generator unit is capable of generating a delivery signal; and

wherein the controller unit controls the signal generator unit to stop generation of the permeabilization signal and generate the delivery signal according to the impedance detected by the sensing unit.

2. The system of claim 1, wherein the signal generator unit is capable of generating the cell detection signal and the permeabilization signal simultaneously.

3. The system of claim 1, wherein the sensing unit comprises a lock- in amplifier.

4. The system of claim 3, wherein the sensing unit further comprises an imaging device capable of measuring the fluorescence of a cell within the detection area.

5. The system of claim 1, wherein the microfluidic channel is capable of hydrodynamically centering the flow of a plurality of biological cells through the detection area.

6. The system of claim 1, wherein the system further comprises a second microfluidic channel adapted to receive a flow of buffer, and wherein the second microfluidic channel comprises a second detection area.

7. The system of claim 6, wherein the sensing unit is adapted to detect the impedance of the second detection area.

8. The system of claim 1, wherein the controller unit controls the signal generator unit to generate the permeabilization signal according to the impedance detected by the sensing unit.

9. A method for electroporating a biological cell in a buffer solution using the system of claim 1, the method comprising:
hydrodynamically focusing the biological cell to a detection area; generating a first electrical signal;
monitoring the impedance value of the detection area using the first electrical signal, wherein an increase in impedance value of the detection area over a baseline threshold indicates the presence of the biological cell;
generating, in response to an increase in impedance of the detection area, a second electrical signal;
determining whether the impedance value of the detection area is greater than a permeabilization threshold value; and
adjusting at least one parameter of the second electrical signal in response to determining the impedance value of the detection area.

10. The method according to claim 9, further comprising:
stopping the second electrical signal in response to determining that the measured impedance value is equal to the permeabilization threshold value; and generating a third electric signal, wherein the third electric signal causes delivery of a molecule into the cell focused within the detection area.

11. The method according to claim 10, further comprising:
determining whether the impedance value of the detection area is equal to the permeabilization threshold value; adjusting at least one parameter of the third electrical signal in response to determining the impedance value of the detection area is not equal to the permeabilization threshold value.

12. The method according to claim 11, further comprising:
stopping the third electrical signal in response to determining the impedance value of the detection area is one of: less than or equal to a viability threshold, or equal to the baseline threshold.

13. The method according to claim 12, wherein the third electrical signal is stopped in response to determining the impedance value of the detection area is less than or equal to the viability threshold.

14. The method according to claim 12, wherein the third electrical signal is stopped in response to determining the impedance value of the detection area is equal to the baseline threshold.

15. The method according to claim 9, wherein the baseline threshold is determined by continuously monitoring the impedance value of a second detection area through which only a buffer solution is flowing.

16. The method according to claim 9, wherein the at least one parameter of the second electrical signal is selected from the group of: electric field amplitude, pulse duration, pulse train frequency, duty cycle, and number of cycles.

17. The method according to claim 11, wherein the at least one parameter of the third electrical signal is selected from the group of: electric field amplitude, pulse duration, pulse train frequency, duty cycle, and number of cycles.

18. The method according to claim 9, wherein the permeabilization threshold value is determined experimentally.

19. The method according to claim 9, wherein the permeabilization threshold value is determined using a mathematical model.

20. The method according to claim 9, wherein the permeabilization threshold value corresponds to an optimal cell permeabilization that does not cause cell death.

21. A method for electroporating a plurality of biological cells, the method comprising:

hydrodynamically focusing a continuous flow of a plurality of biological cells into a single- file flow, wherein the single-file flow passes each of the plurality of biological cells through a detection area;
generating a first electrical signal;
monitoring the impedance value of the detection area using the first electrical signal, wherein an increase in impedance value of the detection area over a baseline threshold indicates the presence of each of the plurality of biological cells;
generating, in response to an increase in impedance of the detection area, a second electrical signal;
determining whether the impedance value of the detection area is greater than a permeabilization threshold value;
adjusting at least one parameter of the second electrical signal in response to determining the impedance value of the detection area.

22. The method according to claim 21, further comprising:
stopping the second electrical signal in response to determining that the measured impedance value is equal to the permeabilization threshold value; and generating a third electrical signal, wherein the third electrical signal causes delivery of a molecule into each of the plurality of biological cells focused within the detection area.

23. The method according to claim 22, further comprising:
determining whether the impedance value of the detection area is equal to the permeabilization threshold value;
adjusting at least one parameter of the third electrical signal in response to determining the impedance value of the detection area is not equal to the
permeabilization threshold value.

24. The method according to claim 23, further comprising:
stopping the third electrical signal in response to determining the impedance value of the detection area is one of: less than or equal to a viability threshold, or equal to the baseline threshold.

25. The method according to claim 24, wherein the third electrical signal is stopped in response to determining the impedance value of the detection area is less than or equal to the viability threshold.

26. The method according to claim 24, wherein the third electrical signal is stopped in response to determining the impedance value of the detection area is equal to the baseline threshold.

27. The method according to claim 21, wherein the baseline threshold is determined by continuously monitoring the impedance value of a second detection area through which only a buffer solution is flowing.

28. The method according to claim 21, wherein the at least one parameter of the second electrical signal is selected from the group of: electric field amplitude, pulse duration, pulse train frequency, duty cycle, and number of cycles.

29. The method according to claim 23, wherein the at least one parameter of the third electrical signal is selected from the group of: electric field amplitude, pulse duration, pulse train frequency, duty cycle, and number of cycles.

30. The method according to claim 21, wherein the permeabilization threshold value is determined experimentally.

31. The method according to claim 21, wherein the permeabilization threshold value is determined using a mathematical model.

32. The method according to claim 21, wherein the permeabilization threshold value corresponds to an optimal cell permeabilization that does not cause cell death.