CLAIMS

What is claimed is:

1. A method for separating viral particles from other components in a sample, the method comprising:

directing the sample through at least one channel of a microfluidic device having at least one electrode arranged therein, the sample containing the viral particles;

separating the viral particles from the other components of the sample by generating at least one dielectrophoretic force that acts on the sample using the at least one electrode; and

detecting a presence of the viral particles in the sample based on a response of the viral particles to the at least one dielectrophoretic force generated by the at least one electrode.

2. The method of claim 1, wherein the viral particles comprise full capsids and the other components of the sample comprise empty and/or partially filled capsids.

3. The method of claim 1 or any other preceding claim, further comprising labeling the sample.

4. The method of clam 3, wherein labeling the sample comprises labeling the sample with a chemical agent.

5. The method of claim 4, wherein the chemical agent is configured to selectively label the viral particles or the other components in the sample.

6. The method of claim 5, wherein selectively labeling the sample comprises labeling the other components with the chemical agent and not labeling the viral particles with the chemical agent.

7. The method of claim 6, wherein the selectively labeling modifies a response of the other components to the at least one dielectrophoretic force acting on the sample.

8. The method of claim 5, wherein the selectively labeling modifies a response of the viral particles to the at least one dielectrophoretic force acting on the sample.

9. The method of claim 7, wherein the chemical agent comprises gadolinium triacetate.

10. The method of claim 1 or any other preceding claim, further comprising condensing the viral particles into a region subsequent to separating the viral particles from the other components of the sample.

11. The method of claim 1 or any other preceding claim, further comprising flushing the other components from a region of the microfluidic device containing the at least one electrode.

12. The method of claim 1 or any other preceding claim, further comprising determining a quantity of the viral particles.

13. The method of claim 11, further comprising determining a quantity of the other components of the sample.

14. The method of claim 1 or any other preceding claim, further comprising determining a ratio of the viral particles to the other components of the sample.

15. The method of claim 1 or any other preceding claim, wherein the at least one electrode comprises at least one circular-shaped and/or partially-center-symmetric electrode.

16. The method of claim 1 or any other preceding claim, wherein an infectivity of the viral particles is unaffected by the directing, separating, and detecting.

17. The method of claim 1 or any other preceding claim, wherein each of the viral particles have a diameter of 400 nm or less.

18. A system configured to separate viral particles from other components in a sample, the system comprising:

a microfluidic device comprising at least one channel having at least one electrode arranged therein, wherein the at least one channel is configured to receive the sample, the sample containing the viral particles; and

a controller configured to:

generate at least one dielectrophoretic force that acts on the sample using the at least one electrode to separate the viral particles from the other components; and

detect a presence of the viral particles based on a response of the viral particles to the dielectrophoretic forces generated by the at least one electrode.

19. The system of claim 18, wherein the viral particles comprise full capsids and the other components comprise empty and/or partially filled capsids.

20. The system of claim 18 or any other preceding claim, wherein the controller is further configured to label the sample.

21. The system of claim 20, wherein labeling the sample comprises labeling the sample with a chemical agent.

22. The system of claim 21, wherein the chemical agent is configured to selectively label the viral particles or the other components in the sample.

23. The system of claim 22, wherein selectively labeling the sample comprises labeling the other components with the chemical agent and not labeling the viral particles with the chemical agent.

24. The system of claim 23, wherein selectively labeling the sample modifies a response of the other components to the at least one dielectrophoretic force acting on the sample.

25. The system of claim 22, wherein the selectively labeling modifies a response of the viral particles to the at least one dielectrophoretic force acting on the sample.

26. The system of claim 24, wherein the chemical agent comprises gadolinium triacetate.

27. The system of claim 18 or any other preceding claim, wherein the controller is further configured to condense the viral particles into a region subsequent to separating the viral particles from the other components of the sample.

28. The system of claim 18 or any other preceding claim, wherein the controller is further configured to flush the other components from a region of the microfluidic device containing the at least one electrode.

29. The system of claim 18 or any other preceding claim, wherein the controller is further configured to determine a quantity of the viral particles.

30. The system of claim 18 or any other preceding claim, wherein the controller is further configured to determine a quantity of the other components.

31. The system of claim 18 or any other preceding claim, wherein the controller is further configured to determine a ratio of the viral particles to the other components of the sample.

32. The system of claim 18 or any other preceding claim, wherein the at least one electrode comprises at least one circular-shaped and/or partially-center-symmetric electrode.

33. The system of claim 18 or any other preceding claim, wherein an infectivity of the viral particles is unaffected by the generating and detecting performed by the controller.

34. The system of claim 18 or any other preceding claim, wherein each of the viral particles have a diameter of 400 nm or less.

35. A method for separating components of a sample, the components comprising full capsid viral particles and empty and/or partially filled capsids, the method comprising:

labeling the sample with a chemical agent, wherein the labeling modifies a response of the empty and/or partially filled capsids to at least one dielectrophoretic force acting on the sample relative to a response of the full capsid viral particles to the at least one dielectrophoretic force acting on the sample;

directing the sample through at least one channel of a microfluidic device having at least one electrode arranged therein;

generating, using the at least one electrode, the at least one dielectrophoretic force that acts on the sample, wherein the empty and/or partially filled capsids respond differently to the at least one dielectrophoretic force than the full capsid viral particles at least in part due to the labeling; and

differentiating between the empty and/or partially filled capsids and the full capsid viral particles based on responses of the components of the sample to the at least one dielectrophoretic force.

36. The method of claim 35, wherein the labeling increases a difference between a dielectric function and/or a complex permativitty of each empty and/or partially filled capsid and a dielectric function and/or a complex permativitty of each full capsid viral particle.

37. The method of claim 35 or any other preceding claim, wherein the chemical agent comprises gadolinium triacetate.

38. The method of claim 35 or any other preceding claim, wherein the labeling increases a difference between a mass of each empty and/or partially filed capsid and a mass of each full capsid viral particle.

39. The method of claim 35 or any other preceding claim, further comprising determining a ratio of full capsid viral particles to empty and/or partially filled capsids.

40. The method of claim 35 or any other preceding claim, further comprising separating the full capsid viral particles from the empty and/or partially filled capsids by condensing the full capsid viral particles into a region.

41. The method of claim 35 or any other preceding claim, further comprising flushing the empty and/or partially filled capsids from a region of the microfluidic device containing the at least one electrode.

42. The method of claim 35 or any other preceding claim, wherein the at least one electrode comprises at least one circular-shaped and/or partially-center-symmetric electrode.

43. The method of claim 35 or any other preceding claim, wherein an infectivity of the full capsid viral particles is unaffected by the labeling, directing, generating, and differentiating.

44. The method of claim 35 or any other preceding claim, wherein each of the full capsid viral particles and the empty and/or partially filled capsids have a diameter of 400 nm or less.

45. A system configured to separate components of a sample, the components comprising full capsid viral particles and empty and/or partially filled capsids, the system comprising:

a microfluidic device comprising at least one channel having at least one electrode arranged therein, wherein the at least one channel is configured to receive the sample; and

a controller configured to:

direct the sample through the at least one channel of the microfluidic device, the sample being labeled with a chemical agent that modifies a response of the empty and/or partially filled capsids to at least one dielectrophoretic force acting on the sample relative to a response of the full capsid viral particles to the at least one dielectrophoretic force acting on the sample;

generate, using the at least one electrode, the at least one dielectrophoretic force that acts on the sample, wherein the empty and/or partially filed capsids respond differently to the at least one dielectrophoretic force than the full capsid viral particles at least in part due to the labeling; and

differentiating between the empty and/or partially filled capsids and the full capsid viral particles based on responses of the components of the sample to the at least one dielectrophoretic force.

46. The system of claim 45, wherein the labeling increases a difference between a dielectric function and/or a complex permativitty of each empty and/or partially filled capsid and a dielectric function and/or a complex permativitty of each full capsid viral particle.

47. The system of claim 45 or any other preceding claim, wherein the chemical agent comprises gadolinium triacetate.

48. The system of claim 45 or any other preceding claim, wherein the labeling increases a difference between a mass of each empty and/or partially filed capsid and a mass of each full capsid viral particle.

49. The system of claim 45 or any other preceding claim, wherein the controller is further configured to determine a ratio of full capsid viral particles to empty and/or partially filled capsids.

50. The system of claim 45 or any other preceding claim, wherein the controller is further configured to separate the full capsid viral particles from the empty and/or partially filled capsids by condensing the full capsid viral particles into a region.

51. The system of claim 45 or any other preceding claim, wherein the controller is further configured to flush the empty and/or partially filled capsids from a region of the microfluidic device containing the at least one electrode.

52. The system of claim 45 or any other preceding claim, wherein the at least one electrode comprises at least one circular-shaped and/or partially-center-symmetric electrode.

53. The system of claim 45 or any other preceding claim, wherein an infectivity of the full capsid viral particles is unaffected by the directing, generating, and differentiating.

54. The system of claim 45 or any other preceding claim, wherein each of the full capsid viral particles and the empty and/or partially filled capsids have a diameter of 400 nm or less.

55. A method for determining a ratio of full capsid viral particles to empty and/or partially filled capsids in a sample, the method comprising:

labeling the sample with a chemical agent, the chemical agent selectively labeling only the empty and/or partially filled capsids of the sample;

directing the sample through at least one channel of a microfluidic device having at least one electrode arranged therein;

generating, using the at least one electrode, at least one dielectrophoretic force that acts on the sample, wherein the at least one dielectrophoretic force causes the empty and/or partially

filled capsids and the full capsid viral particles to separate from each other at least in part due to the labeling; and

subsequent to the generating the at least one dielectrophoretic force, determining a ratio of full capsid viral particles to empty and/or partially filled capsids.

56. The method of claim 55, wherein the labeling increases a difference between a dielectric function and/or a complex permativitty of each empty and/or partially filled capsid and a dielectric function and/or a complex permativitty of each full capsid viral particle.

57. The method of claim 55 or any other preceding claim, wherein the chemical agent comprises gadolinium triacetate.

58. The method of claim 55 or any other preceding claim, wherein the labeling increases a difference between a mass of each empty and/or partially filed capsid and a mass of each full capsid viral particle.

59. The method of claim 55 or any other preceding claim, wherein each of the full capsid viral particles and the empty and/or partially filled capsids have a diameter of 400 nm or less.

60. The method of claim 55 or any other preceding claim, further comprising flushing the empty and/or partially filled capsids from a region of the microfluidic device containing the at least one electrode.

CLAIMS

1. A method for separating components of a sample, the components comprising full capsid viral particles and empty and/or partially filled capsids, the method comprising:

labeling the sample with a chemical agent, wherein the labeling modifies a response of the empty and/or partially filled capsids to at least one dielectrophoretic force acting on the sample relative to a response of the full capsid viral particles to the at least one dielectrophoretic force acting on the sample;

directing the sample through at least one channel of a microfluidic device having at least one electrode arranged therein;

separating the full capsid viral particles from the empty and/or partially filled capsids at least in part by generating, using the at least one electrode, the at least one dielectrophoretic force that acts on the sample, wherein the empty and/or partially filled capsids respond differently to the at least one dielectrophoretic force than the full capsid viral particles at least in part due to the labeling; and

differentiating between the empty and/or partially filled capsids and the full capsid viral particles based on responses of the components of the sample to the at least one dielectrophoretic force.

2. The method of claim 1, wherein the labeling increases a difference between a dielectric function and/or a complex permittivity of each empty and/or partially filled capsid and a dielectric function and/or a complex permittivity of each full capsid viral particle.

3. The method of claim 1, wherein the chemical agent comprises gadolinium triacetate.

4. The method of claim 1, wherein the labeling increases a difference between a mass of each empty and/or partially filed capsid and a mass of each full capsid viral particle.

5. The method of claim 1, further comprising determining a ratio of full capsid viral particles to empty and/or partially filled capsids.

6. The method of claim 1, further comprising separating the full capsid viral particles from the empty and/or partially filled capsids by condensing the full capsid viral particles into a region.

7. The method of claim 1, further comprising flushing the empty and/or partially filled capsids from a region of the microfluidic device containing the at least one electrode.

8. The method of claim 1, wherein the at least one electrode comprises at least one circular-shaped and/or partially-center-symmetric electrode.

9. The method of claim 1, wherein an infectivity of the full capsid viral particles is unaffected by

the labeling, directing, generating, and differentiating.

10. The method of claim 1, wherein each of the full capsid viral particles and the empty and/or partially filled capsids have a diameter of 400 nm or less.

11. A system configured to separate components of a sample, the components comprising full capsid viral particles and empty and/or partially filled capsids, the system comprising:

a microfluidic device comprising at least one channel having at least one electrode arranged therein, wherein the at least one channel is configured to receive the sample; and

a controller configured to:

direct the sample through the at least one channel of the microfluidic device, the sample being labeled with a chemical agent that modifies a response of the empty and/or partially filled capsids to at least one dielectrophoretic force acting on the sample relative to a response of the full capsid viral particles to the at least one dielectrophoretic force acting on the sample;

separate the full capsid viral particles from the empty and/or partially filled capsids at least in part by generating, using the at least one electrode, the at least one dielectrophoretic force that acts on the sample, wherein the empty and/or partially filed capsids respond differently to the at least one dielectrophoretic force than the full capsid viral particles at least in part due to the labeling; and

differentiate between the empty and/or partially filled capsids and the full capsid viral particles based on responses of the components of the sample to the at least one dielectrophoretic force.

12. The system of claim 11, wherein the labeling increases a difference between a dielectric function and/or a complex permittivity of each empty and/or partially filled capsid and a dielectric function and/or a complex permittivity of each full capsid viral particle.

13. The system of claim 11, wherein the chemical agent comprises gadolinium triacetate.

14. The system of claim 11, wherein the labeling increases a difference between a mass of each empty and/or partially filed capsid and a mass of each full capsid viral particle.

15. The system of claim 11, wherein the controller is further configured to determine a ratio of full capsid viral particles to empty and/or partially filled capsids.

16. The system of claim 11, wherein the controller is further configured to separate the full capsid viral particles from the empty and/or partially filled capsids by condensing the full capsid viral particles into a region.

17. The system of claim 11, wherein the controller is further configured to flush the empty and/or

partially filled capsids from a region of the microfluidic device containing the at least one electrode.

18. The system of claim 11, wherein the at least one electrode comprises at least one circular-shaped and/or partially-center-symmetric electrode.

19. The system of claim 11, wherein an infectivity of the full capsid viral particles is unaffected by the directing, generating, and differentiating.

20. The system of claim 11, wherein each of the full capsid viral particles and the empty and/or partially filled capsids have a diameter of 400 nm or less.