CLAIMS

What is claimed is:

1. A method of determining the identity and concentration of a compound or mixture of compounds in an solution, the method comprising the steps of:

   contacting a first surface with the solution so that a boundary layer of solution is formed on the first surface;

   polling the first surface to determine the surface interaction between the first surface and the compound or mixture of compounds in the solution at the boundary layer; and

   determining the identity and concentration of the one or more compounds based on the surface interaction.

2. The method of claim 1, further comprising determining the identity and concentration of the one or more compounds based on the surface interaction and the bulk properties of the solution.
3. The method of claim 1, further comprising contacting a second surface with the solution.
4. The method of claim 1, wherein the step of contacting the first surface with the solution comprises contacting the first surface in an aqueous solution.
5. The method of claim 1, wherein the step of contacting the first surface with the solution comprises contacting the first surface with an intravenous drug solution.
6. The method of claim 1, wherein the first surface comprises a non-reactive surface of an electrode.
7. The method of claim 1, wherein the step of polling comprises applying an electrical signal to the first surface and measuring the complex admittance.
8. The method of claim 1, wherein the step of polling comprises applying a plurality of electrical signals and measuring the complex admittance at each signal.
9. The method of claim 1, wherein the step of polling comprises applying an electrical signal below the threshold for electrochemical reaction.
10. The method of claim 1, wherein the step of polling does not disturb the dynamic equilibrium of the boundary layer on the first surface.
11. The method of claim 1, wherein the step of determining comprises simultaneously determining the identity and concentration of the one or more compounds in the solution.
12. The method of claim 1, wherein the step of determining comprises comparing an indicator of surface interactions with a library of stored surface interactions to determine concentration and identity of the one or more compounds in the solution.
13. The method of claim 1, wherein the step of determining comprises comparing an indicator of surface interactions with a library of stored surface interactions to determine concentration and identity of all of the compounds in the solution.

14. A method of determining the identity, concentration, or identity and concentration of one or more compounds in an aqueous solution, the method comprising the steps of:

placing a pair of electrodes in contact with the aqueous solution so that a boundary layer of aqueous solution is formed on a first surface of one of the electrodes;

applying electrical excitation between the pair of electrodes to determine a complex admittance at the first surface, wherein the applied electrical excitation results in a voltage that is below the threshold level for electrochemical reactions at the first surface; and

determining the identity, concentration, or identity and concentration of one or more compounds in the aqueous solution based on the complex admittance measured between the electrodes.

15. The method of claim 14, wherein the wherein the applied electrical excitation results in a voltage that is below 500 mV.

16. The method of claim 14, wherein the step of determining the identity, concentration, or identity and concentration comprises simultaneously determining the identity and concentration.

17. The method of claim 14, further comprising recording the complex admittance at a plurality of current frequencies.

18. The method of claim 14, wherein the pair of electrodes comprises conductive surfaces made of different materials.

19. The method of claim 14, further comprising placing a third electrode in contact with the aqueous solution so that a boundary layer of aqueous solution is formed on a first surface of the third electrode, wherein the first surface of the third electrode is formed of a material that is different from the material forming conductive surfaces on electrodes of the pair of electrodes.

20. The method of claim 14, wherein the step of applying an electrical excitation comprises applying current at a plurality of frequencies.

21. The method of claim 14, wherein the step of applying an electrical excitation comprises applying electrical energy at a level that is below the thermal fluctuation energy in the fluid.

22. The method of claim 14, wherein the step of applying electrical excitation comprises applying excitation a level that does not disturb the equilibrium of the boundary layer on the first surface.

23. The method of claim 14, wherein the step of determining comprises comparing the complex admittance with a library of complex admittance to determine identity, concentration, or identity and concentration of the one or more compounds in the aqueous solution.

24. The method of claim 14, wherein the step of determining comprises comparing the complex admittance at different frequencies with a library of complex admittances to determine

identity, concentration, or identity and concentration of the one or more compounds in the aqueous solution.

25. The method of claim 14, wherein the step of determining comprises comparing the complex admittance at different frequencies with a library of complex admittances to identity and concentration of the all of the compounds in the aqueous solution.

26. A system for determining the identity of a drug solution by admittance spectroscopy, the system comprising:

a sensor comprising a plurality of electrodes having fluid-contacting surfaces;

a signal generator configured to provide electrical stimulation at a plurality of frequencies for application from the fluid-contacting surfaces of the sensor;

a processor configured to receive complex admittance data from the sensor at the plurality of frequencies and to determine the identity, concentration, or the identity and concentration of one or more compounds in the drug solution by comparing the complex admittance data to a library of predetermined complex admittance data.

27. The system of claim 26, wherein the fluid-contacting surfaces of the electrodes of the sensor are formed of a plurality of different materials.

28. The system of claim 26, wherein the fluid-contacting surfaces of the electrodes of the sensor are formed of a plurality of different geometries.

29. The system of claim 26, wherein the sensor comprises at least three different fluid-contacting surfaces formed of different materials, different size or different materials and geometries.

30. The systems of claim 26, wherein the sensor is configured to be single-use.

31. The system of claim 26, wherein the fluid-contacting surfaces of the sensor are calibrated to a predetermined standard that matches the predetermined complex admittance data.

32. The system of claim 26, wherein the sensor comprises at least six independent pairs of fluid-contacting surfaces.

33. The system of claim 26, further comprising a signal receiver configured to receive complex admittance data from the sensor and pass it on the processor.

34. The system of claim 26, further comprising a measurement cell configured to receive the drug solution so that the fluid-contacting surfaces of the sensor contact the drug solution.

35. The system of claim 26, wherein the signal generator is configured to apply a current frequency from about 1Hz to about 1 MHz.

36. The system of claim 26, further comprising a display configured to display the identity and concentration of the one or more compounds within the solution.

37. The system of claim 26, wherein the processor is further configured to determine the identity of the carrier diluent of the drug solution.

38. The system of claim 26, further comprising a controller configured to coordinate application of the signal from the signal generator and to acquisition of complex admittance data from the sensor.

39. The system of claim 26, wherein the processor comprises recognition logic configured to determine the likeliest match between the complex admittance data received from the sensor and the library of predetermined complex admittance data.

40. The system of claim 39, wherein the recognition logic comprises an adaptive neural network trained on the library of predetermined complex admittance data.

41. The system of claim 26, wherein the library of predetermined complex admittance data comprises complex admittance data measured for a plurality of individual compounds and mixtures of compounds in a carrier diluent at a plurality of frequencies.

42. The system of claim 26, wherein the sensor further comprises a second sensor element that is not a complex admittance electrode, and further wherein the processor is configured to use data from the second sensor element in addition to the complex admittance data to determine both the identity and the concentration one or more compounds in the drug solution.

43. The system of claim 42, wherein the second sensor element comprises an optical sensor.

44. The system of claim 26, wherein the processor is configured to receive complex admittance data from the sensor at the plurality of frequencies and to simultaneously determine the identity and concentration of one or more compounds in the drug solution by comparing the complex admittance data to a library of predetermined complex admittance data.

45. A system for determining the identity, concentration or identity and concentration of an intravenous drug solution by admittance spectroscopy, the system comprising:

a sensor comprising a plurality of electrodes having fluid-contacting surfaces;

a signal generator configured to provide current at a plurality of frequencies for application from one or more fluid-contacting surfaces of the sensor;

a signal receiver configured to receive complex admittance data from one or more fluid-contacting surfaces of the sensor;

a controller configured to coordinate the application of signals from the signal generator and the acquisition of complex admittance data from the sensor to create an admittance spectrographic fingerprint of the intravenous drug solution; and

a processor configured to receive the admittance spectrographic fingerprint and to determine the identity, concentration or identity and concentration of the intravenous drug solution by comparing the admittance spectrographic fingerprint to a library of admittance spectrographic data comprising complex admittance data measured from a plurality of known compounds and mixtures of compounds in a carrier solution at a plurality of frequencies and known concentrations.

46. The system of claim 45, wherein the fluid-contacting surfaces of the electrodes of the sensor are formed of a plurality of different materials.

47. The system of claim 45, wherein the fluid-contacting surfaces of the electrodes of the sensor are formed of a plurality of different geometries.

48. The system of claim 45, wherein the sensor comprises at least three different fluid-contacting surfaces formed of different materials, different geometries or different materials and geometries.

49. The systems of claim 45, wherein the sensor is configured to be single-use.

50. The system of claim 45, wherein the fluid-contacting surfaces of the sensor are calibrated to a predetermined standard that matches complex admittance data of the library of admittance spectrographic data.

51. The system of claim 45, further comprising a measurement cell configured to receive the intravenous drug solution so that the fluid-contacting surfaces of the sensor contact the intravenous drug solution.

52. The system of claim 45, wherein the signal generator is configured to apply an electrical excitation frequency from about 1 Hz to about 1 MHz.

53. The system of claim 45, further comprising a display configured to display the identity and concentration of the one or more compounds within the intravenous solution.

54. The system of claim 45, wherein the processor is further configured to determine the identity of the carrier solution of the intravenous drug solution.

55. The system of claim 45, wherein the processor comprises recognition logic configured to determine the likeliest match between the admittance spectrographic fingerprint and the library of admittance spectrographic data.

56. The system of claim 55, wherein the recognition logic comprises an adaptive neural network trained on the library of admittance spectrographic data.

57. The system of claim 45, wherein the library of predetermined complex admittance data comprises complex admittance data measured for a plurality of individual compounds and mixtures of compounds in a carrier solution at a plurality of frequencies.

58. The system of claim 45, wherein the sensor further comprises a second sensor element, and further wherein the processor is configured to use data from the second sensor element in addition to the complex admittance data to determine both the identity and the concentration one or more compounds in the intravenous drug solution.

59. The system of claim 58, wherein the second sensor element comprises an optical sensor.

60. A benchtop drug solution analyzer for determining the identity, concentration or identity and concentration of a drug solution by admittance spectroscopy, the analyzer comprising:

a measurement cell comprising a plurality of electrodes having fluid-contacting surfaces, the measurement cell configured to receive a sample of the drug solution;

a signal generator configured to provide electrical excitation at a plurality of frequencies for application from one or more pairs of electrodes of the measurement cell;

a signal receiver configured to receive complex admittance data from one or more pairs of electrodes of the measurement cell;

a controller configured to coordinate the application of signals from the signal generator, and the acquisition of complex admittance data from the signal receiver, to create an admittance spectrographic fingerprint of the drug solution; and

a processor configured to receive the admittance spectrographic fingerprint and to determine the identity, concentration or identity and concentration of one or more compounds in the drug solution by comparing the admittance spectrographic fingerprint to a library of admittance spectrographic data comprising complex admittance data measured from a plurality of known compounds and mixtures of compounds in a carrier solution at a plurality of frequencies and known concentrations.

61. The analyzer of claim 60, further comprising a housing at least partially enclosing the signal generator, single receiver and controller.
62. The analyzer of claim 60, further comprising a plurality of single-use measurement cells.
63. The analyzer of claim 60, wherein the measurement cell comprises at least three different fluid-contacting surfaces formed of different materials, different geometries or different materials and geometries.
64. The analyzer of claim 60, wherein the fluid-contacting surfaces of the measurement cell are calibrated to a predetermined standard that matches complex admittance data of the library of admittance spectrographic data.
65. The analyzer of claim 60, wherein the signal generator is configured to apply a current frequency from about 1 Hz to about 1 MHz.
66. The analyzer of claim 60, further comprising a display configured to display the identity and concentration of the one or more compounds within the drug solution.
67. The analyzer of claim 60, wherein the processor is further configured to determine the identity of the carrier solution of the drug solution.
68. The analyzer of claim 60, wherein the processor comprises recognition logic configured to determine the likeliest match between the admittance spectrographic fingerprint and the library of admittance spectrographic data.
69. The analyzer of claim 68, wherein the recognition logic comprises an adaptive neural network trained on the library of admittance spectrographic data.
70. The analyzer of claim 60, wherein the library of predetermined complex admittance data comprises complex admittance data measured for a plurality of individual compounds and mixtures of compounds in a carrier solution at a plurality of frequencies.
71. The analyzer of claim 60, wherein the measurement cell further comprises a second sensor element, and further wherein the processor is configured to use data from the second sensor element in addition to the admittance spectrographic fingerprint to determine both the identity and the concentration of one or more compounds in the drug solution.
72. The system of claim 71, wherein the second sensor element comprises an optical sensor.

73. The system of claim 60, wherein the processor is configured to receive the admittance spectrographic fingerprint and to simultaneously determine identity and concentration of one or more compounds in the drug solution.

74. A system for controlling the delivery of an intravenous fluid by determining the identity, concentration or identity and concentration of one or more components of the intravenous fluid using admittance spectroscopy, the system comprising:

a sensor having a plurality of complex admittance electrodes configured to contact an intravenous fluid;

a signal generator configured to provide electrical excitation at a plurality of frequencies for application across the plurality of complex admittance electrodes;

a processor configured to receive complex admittance data from the sensor at the plurality of frequencies and to determine the identity, concentration or the identity and the concentration of one or more compounds in the intravenous fluid by comparing the complex admittance data to a library of predetermined complex admittance data; and

a control output configured to regulate the operation of an intravenous drug delivery device based on the determined identity, concentration or concentration and identity of one or more compounds in the intravenous fluid.

75. The system of claim 74, wherein the intravenous drug delivery device comprises a pump.

76. The system of claim 74, wherein the sensor further comprises a flow sensor.

77. The system of claim 74, wherein the processor is configured to receive flow information from a flow sensor in communication with the intravenous fluid and to determine a delivered dose of the one or more compounds in the intravenous fluid.

78. The system of claim 74, wherein the control output is configured to modulate, adjust, turn off or suspend delivery of the intravenous drug delivery device.

79. The system of claim 74, wherein the processor is configured to simultaneously determine the identity and the concentration of one or more compounds in the intravenous fluid.

80. A method of determining the identity and concentrations of one or more compounds in a solution by admittance spectroscopy, the method comprising:

applying electrical excitation at a plurality of frequencies between at least one pair of fluid-contacting surfaces in contact with the solution;

determining the complex admittance between at least one pair of fluid-contacting surfaces at the plurality of frequencies;

creating an admittance spectrographic fingerprint of the solution comprising the complex admittance from the at least one pair of fluid-contacting surfaces at the plurality of frequencies; and

determining both the identity and the concentration one or more compounds in the solution by comparing the admittance spectrographic fingerprint to a library of

admittance spectrographic data comprising complex admittance data measured from a plurality of known compounds and mixtures of compounds in a carrier solution at a plurality of frequencies and known concentrations.

81. The method of claim 80, wherein the solution is an intravenous drug solution.

82. The method of claim 80, wherein the solution is a parenteral solution.

83. The method of claim 80, wherein the solution is a parenteral drug solution.

84. The method of claim 80, further comprising determining the identity and concentration of all of the components of the solution.

85. A method of determining the identity and concentrations of one or more compounds in a solution by admittance spectroscopy, the method comprising:

applying electrical excitation at a plurality of frequencies between two or more pairs of fluid-contacting surfaces in contact with the solution, wherein at least one of the fluid contacting surfaces is formed of a different material, different size, or different material and size than the other fluid contacting surfaces;

determining the complex admittance from the two or more pairs of fluid-contacting surfaces at the plurality of frequencies;

creating an admittance spectrographic fingerprint of the solution comprising the complex admittance from the two or more pairs of fluid-contacting surfaces at the plurality of frequencies; and

determining both the identity and the concentration one or more compounds in the solution by comparing the admittance spectrographic fingerprint to a library of admittance spectrographic data comprising complex admittance data measured from a plurality of known compounds and mixtures of compounds in a carrier solution at a plurality of frequencies and known concentrations.

86. The method of claim 85, wherein the solution is an intravenous drug solution.

87. The method of claim 85, wherein the solution is a parenteral solution.

88. The method of claim 85, further comprising determining the identity and concentration of all of the components of the solution.

89. A method of simultaneously verifying both the composition and concentration of an intravenous drug solution, the method comprising:

preparing the intravenous drug solution;

testing a sample of the intravenous drug solution and independently and simultaneously determining both the identity and concentration of one or more components of the intravenous drug solution.

90. The method of claim 89, wherein the step of testing comprises determining an admittance spectrographic fingerprint comprising a plurality of complex admittances taken at different frequencies.

91. The method of claim 89, wherein the step of testing comprises determining an admittance spectrographic fingerprint comprising a plurality of complex admittances taken at different frequencies and comparing the admittance spectrographic fingerprint to a library of admittance spectrographic data comprising complex admittance data measured from a plurality of known compounds and mixtures of compounds in a carrier solution at a plurality of frequencies and known concentrations.

CLAIMS

What is claimed is:

1. A method of determining the identity and concentration of a compound or mixture of compounds in an solution, the method comprising the steps of:

   contacting a first surface with the solution so that a boundary layer of solution is formed on the first surface;

   polling the first surface to determine the surface interaction between the first surface and the compound or mixture of compounds in the solution at the boundary layer; and

   determining the identity and concentration of the one or more compounds based on the surface interaction.

2. The method of claim 1, wherein the step of polling does not disturb the dynamic equilibrium of the boundary layer on the first surface.

3. The method of claim 1, wherein the step of determining comprises comparing an indicator of surface interactions with a library of stored surface interactions to determine concentration and identity of all of the compounds in the solution.

4. A method of determining the identity, concentration, or identity and concentration of one or more compounds in an aqueous solution, the method comprising the steps of:

   placing a pair of electrodes in contact with the aqueous solution so that a boundary layer of aqueous solution is formed on a first surface of one of the electrodes;

   applying electrical excitation between the pair of electrodes to determine a complex admittance at the first surface, wherein the applied electrical excitation results in a voltage that is below the threshold level for electrochemical reactions at the first surface; and

   determining the identity, concentration, or identity and concentration of one or more compounds in the aqueous solution based on the complex admittance measured between the electrodes.

5. The method of claim 4, wherein the pair of electrodes comprises conductive surfaces made of different materials.

6. The method of claim 4, wherein the step of determining comprises comparing the complex admittance at different frequencies with a library of complex admittances to identity and concentration of the all of the compounds in the aqueous solution.
7. A system for determining the identity of a drug solution by admittance spectroscopy, the system comprising:
    a sensor comprising a plurality of electrodes having fluid-contacting surfaces;
    a signal generator configured to provide electrical stimulation at a plurality of frequencies for application from the fluid-contacting surfaces of the sensor;
    a processor configured to receive complex admittance data from the sensor at the plurality of frequencies and to determine the identity, concentration, or the identity and concentration of one or more compounds in the drug solution by comparing the complex admittance data to a library of predetermined complex admittance data.
8. The system of claim 7, wherein the sensor comprises at least three different fluid-contacting surfaces formed of different materials, different size or different materials and geometries.
9. The system of claim 7, wherein the sensor further comprises a second sensor element that is not a complex admittance electrode, and further wherein the processor is configured to use data from the second sensor element in addition to the complex admittance data to determine both the identity and the concentration one or more compounds in the drug solution.
10. The system of claim 9, wherein the second sensor element comprises an optical sensor.
11. A system for determining the identity, concentration or identity and concentration of an intravenous drug solution by admittance spectroscopy, the system comprising:
    a sensor comprising a plurality of electrodes having fluid-contacting surfaces;
    a signal generator configured to provide current at a plurality of frequencies for application from one or more fluid-contacting surfaces of the sensor;
    a signal receiver configured to receive complex admittance data from one or more fluid-contacting surfaces of the sensor;

a controller configured to coordinate the application of signals from the signal generator and the acquisition of complex admittance data from the sensor to create an admittance spectrographic fingerprint of the intravenous drug solution; and

a processor configured to receive the admittance spectrographic fingerprint and to determine the identity, concentration or identity and concentration of the intravenous drug solution by comparing the admittance spectrographic fingerprint to a library of admittance spectrographic data comprising complex admittance data measured from a plurality of known compounds and mixtures of compounds in a carrier solution at a plurality of frequencies and known concentrations.

12. The system of claim 11, wherein the sensor comprises at least three different fluid-contacting surfaces formed of different materials, different geometries or different materials and geometries.

13. The system of claim 11, wherein the processor comprises recognition logic configured to determine the likeliest match between the admittance spectrographic fingerprint and the library of admittance spectrographic data.

14. A benchtop drug solution analyzer for determining the identity, concentration or identity and concentration of a drug solution by admittance spectroscopy, the analyzer comprising:

a measurement cell comprising a plurality of electrodes having fluid-contacting surfaces, the measurement cell configured to receive a sample of the drug solution;

a signal generator configured to provide electrical excitation at a plurality of frequencies for application from one or more pairs of electrodes of the measurement cell;

a signal receiver configured to receive complex admittance data from one or more pairs of electrodes of the measurement cell;

a controller configured to coordinate the application of signals from the signal generator, and the acquisition of complex admittance data from the signal

receiver, to create an admittance spectrographic fingerprint of the drug solution; and

a processor configured to receive the admittance spectrographic fingerprint and to determine the identity, concentration or identity and concentration of one or more compounds in the drug solution by comparing the admittance spectrographic fingerprint to a library of admittance spectrographic data comprising complex admittance data measured from a plurality of known compounds and mixtures of compounds in a carrier solution at a plurality of frequencies and known concentrations.

15. The analyzer of claim 14, wherein the processor comprises recognition logic configured to determine the likeliest match between the admittance spectrographic fingerprint and the library of admittance spectrographic data.

16. The analyzer of claim 14, wherein the library of predetermined complex admittance data comprises complex admittance data measured for a plurality of individual compounds and mixtures of compounds in a carrier solution at a plurality of frequencies.

17. A system for controlling the delivery of an intravenous fluid by determining the identity, concentration or identity and concentration of one or more components of the intravenous fluid using admittance spectroscopy, the system comprising:

a sensor having a plurality of complex admittance electrodes configured to contact an intravenous fluid;

a signal generator configured to provide electrical excitation at a plurality of frequencies for application across the plurality of complex admittance electrodes;

a processor configured to receive complex admittance data from the sensor at the plurality of frequencies and to determine the identity, concentration or the identity and the concentration of one or more compounds in the intravenous fluid by comparing the complex admittance data to a library of predetermined complex admittance data; and

a control output configured to regulate the operation of an intravenous drug delivery device based on the determined identity, concentration or concentration and identity of one or more compounds in the intravenous fluid.

18. The system of claim 17, wherein the intravenous drug delivery device comprises a pump.

19. A method of determining the identity and concentrations of one or more compounds in a solution by admittance spectroscopy, the method comprising:

applying electrical excitation at a plurality of frequencies between at least one pair of fluid-contacting surfaces in contact with the solution;

determining the complex admittance between at least one pair of fluid-contacting surfaces at the plurality of frequencies;

creating an admittance spectrographic fingerprint of the solution comprising the complex admittance from the at least one pair of fluid-contacting surfaces at the plurality of frequencies; and

determining both the identity and the concentration one or more compounds in the solution by comparing the admittance spectrographic fingerprint to a library of admittance spectrographic data comprising complex admittance data measured from a plurality of known compounds and mixtures of compounds in a carrier solution at a plurality of frequencies and known concentrations.

20. The method of claim 19, wherein the solution is an intravenous drug solution.

21. A method of determining the identity and concentrations of one or more compounds in a solution by admittance spectroscopy, the method comprising:

applying electrical excitation at a plurality of frequencies between two or more pairs of fluid-contacting surfaces in contact with the solution, wherein at least one of the fluid contacting surfaces is formed of a different material, different size, or different material and size than the other fluid contacting surfaces;

determining the complex admittance from the two or more pairs of fluid-contacting surfaces at the plurality of frequencies;

creating an admittance spectrographic fingerprint of the solution comprising the complex admittance from the two or more pairs of fluid-contacting surfaces at the plurality of frequencies; and

determining both the identity and the concentration one or more compounds in the solution by comparing the admittance spectrographic fingerprint to a library of admittance spectrographic data comprising complex admittance data measured from a plurality of known compounds and mixtures of compounds in a carrier solution at a plurality of frequencies and known concentrations.

22. The method of claim 21, wherein the solution is an intravenous drug solution.

23. A method of simultaneously verifying both the composition and concentration of an intravenous drug solution, the method comprising:

preparing the intravenous drug solution;

testing a sample of the intravenous drug solution and independently and simultaneously determining both the identity and concentration of one or more components of the intravenous drug solution.

24. The method of claim 23, wherein the step of testing comprises determining an admittance spectrographic fingerprint comprising a plurality of complex admittances taken at different frequencies and comparing the admittance spectrographic fingerprint to a library of admittance spectrographic data comprising complex admittance data measured from a plurality of known compounds and mixtures of compounds in a carrier solution at a plurality of frequencies and known concentrations.