CLAIMS

What is claimed is:

1. A magnetic levitation-based diagnosis system comprising:

a levitation device for separating a heterogeneous population of moieties wherein variances in the moieties are based on differences in magnetic susceptibility and/or intrinsic density, the device including at least one magnet producing a magnetic field, wherein the magnetic field is sized to interact with a microcapillary or microfluidic channel for reception of a sample containing the heterogeneous population of moieties;

wherein the microcapillary or microfluidic channel is defined by a plurality of layers having portions of the microcapillary or microfluidic channel formed therein, at least one of the plurality of layers providing an inlet channel into the microcapillary or microfluidic channel and at least two of the plurality of layers providing separate outlets from the microcapillary or microfluidic channel.

2. The system of claim 1, wherein the plurality of layers include at least two layers in which each of the at least two layers include a respective inlet and a respective outlet formed therein.

3. The system of claim 1, wherein each of the respective layers is formed from a laser-machined material.

4. The system of claim 1, wherein a thin film is disposed between at least two of the plurality of layers to establish a top and bottom outlet.

5. A method of sorting using the system of claim 1, the method comprising:

flowing a sample including the heterogeneous population of moieties and a paramagnetic medium into the at least one inlet and the microcapillary or microfluidic channel;

applying a magnetic field to the sample including the heterogeneous population of moieties to separate the heterogeneous population based on a difference in at least one of magnetic susceptibility and intrinsic density between individual members of the heterogeneous population of moieties and the paramagnetic medium;

thereafter flowing a first portion of the sample out of a top outlet and a second portion of the sample out of a bottom outlet, thereby separating a first group of the heterogeneous population of moieties from a second group of the heterogeneous population of moieties.

6. The method of claim 5, wherein the plurality of layers include at least three layers including a top, middle and bottom layer in which each of the three layers include a respective inlet and a respective outlet formed therein and wherein the step of flowing the sample into the at least one inlet and the microcapillary or microfluidic channel includes introducing the sample including the heterogeneous population of moieties and a paramagnetic medium into the bottom inlet and the paramagnetic medium into the top and middle inlets.

7. The method of claim 5, wherein the sample is a blood sample mixed with a paramagnetic medium and the blood sample includes circulating tumor cells (CTCs) or circulating tumor clusters/emboli (CTM) and wherein the CTCs/CTM are separated and flow into the top channel after exposure to the magnetic field in the microcapillary or microfluidic channel.

8. The method of claim 5, further comprising the step of stabilizing of separated population of moieties with the assistance of at least one of temperature and cross-linking.

9. A method of sorting using a system including a device for separating a population of biological or non-biological moieties, the device including at least one magnet producing a magnetic field, wherein the magnetic field is sized to interact with a microcapillary or microfluidic channel for reception of a sample containing the population of moieties, the method comprising:

flowing a sample including the population of moieties and a paramagnetic medium from an inlet into the microcapillary or microfluidic channel towards an outlet; and

while the sample is in the microcapillary or microfluidic channel, applying a magnetic field using the at least one magnet to the sample, wherein the application of the magnetic field blocks at least some, but not all, of members of the population of moieties from flowing towards the outlet, thereby separating the population of moieties.

10. The method of claim 9, wherein the blocking of at least some, but not all, of members of the population of moieties occurs at a magnetic edge of the magnetic field due to high magnetic induction.

11. The method of claim 9, wherein the population of moieties includes a blood sample in which the blood cells are blocked from moving past the magnetic field produced by the at least one magnet, but plasma is able to flow past the magnetic field produced by the at least one magnet through the microcapillary or microfluidic channel to the outlet.

12. The method of claim 9, further comprising the step of stabilizing of separated population of moieties with the assistance of at least one of temperature and cross-linking.

13. A method of assembling a multi-moiety assembly based on magnetic signatures using a magnetic levitation-based diagnosis system including a levitation device including at least one magnet producing a magnetic field, wherein the at least one magnet is proximate a microcapillary or microfluidic channel for reception of a sample containing a population of moieties, the method comprising:

introducing a sample including the population of moieties and a paramagnetic medium into the microcapillary or microfluidic channel; and

while the sample is in the microcapillary or microfluidic channel, applying a magnetic field using the at least one magnet to the sample, wherein the application of the magnetic field levitates at least a portion of the population of moieties to place the population of moieties in a spatial relationship to one another in which the population of moieties aggregate to form the multi-moiety assembly.

14. The method of claim 13, wherein the aggregation of the population of moieties to form the multi-moiety assembly occurs spontaneously over a duration of time while the population of moieties substantially remain in the spatial relationship established by the levitation induced by the magnetic field.

15. The method of claim 13, wherein the magnetic field is generated by permanent magnets.

16. The method of claim 13, wherein the magnetic field is generated by coils induced by electrical current.

17. The method of claim 13, wherein the system is capable of high-throughput multi-moiety assembly.

18. The method of claim 13, wherein the moieties are cells.

19. The method of claim 13, wherein the moieties are polymeric.

20. The method of claim 13, wherein the aggregation of the population of moieties to form the multi-moiety assembly occurs and is stabilized with the assistance of at least one of temperature and cross-linking.

21. A magnetic levitation-based diagnosis system for use with an imaging device, the system comprising:

a levitation device for separating a heterogeneous population of cells, wherein the variances in the cells are based on differences in magnetic susceptibility, the device including at least one magnet producing a magnetic field, wherein the at least one magnet is proximate a microcapillary or microfluidic channel for reception of a sample containing a heterogeneous population of cells;

a light source; and

a frame, the frame supporting the levitation device, and the light source, and is further configured to support an imaging device, the frame supporting the light source in a position to transmit light through the levitation device to the imaging device for real-time observation of at least a portion of heterogeneous population of cells.

22. The system of claim 21, further comprising a lens, wherein the frame supports the lens and the light source is positioned to further transmit light through the lens to the imaging device.

23. The system of claim 21, wherein the imaging device is one of a smartphone, a CMOS camera, and a CCD camera.

24. The system of claim 21, wherein data collected by the imaging device is transmitted over at least one of Bluetooth, wifi, and a cellular networks.

25. The system of claim 21, further comprising a neutral density filter supported by the frame, the neutral density filter positioned between the light source and the levitation device.

26. The system of claim 21, further comprising an imaging device supported by the frame in which the imaging device includes a camera, the frame receiving the imaging device in a position such that the camera is positioned to receive an image transmitted through the lens.

27. The system of claim 26, wherein the imaging device is configured to observe the separation of a heterogeneous population of cells in real-time.

28. The system of claim 21, wherein the frame is has a compacted position to reduce the size of the frame for portability and an expanded position in which the frame is expanded.

29. The system of claim 28, wherein, when the frame is in the expanded position, the frame is configured to receive the imaging device in recesses on a top surface thereof.

30. The system of claim 29, wherein the imaging device is compact and is inserted into a smartphone-like a protection case cover thereby linking the imaging device to the imaging path and establishing a position of the smartphone in the frame.

31. The system of claim 21, wherein, when the imaging device is received in the frame, the camera of the imaging device faces the lens and a display of the imaging device remains viewable for observation of the sample containing the heterogeneous population of cells.

32. The system of claim 31, wherein the system is further configured to count and quantify the number of levitated objects.

33. The system of claim 21, wherein the imaging device is capable of performing both white field and flourscent type imaging with the imaging device.

34. A method for observing a heterogeneous population of cells in a magnetic levitation-based diagnosis system, the method comprising the steps of:

placing the sample of the population of cells in a microcapillary or microfluidic channel of a levitation device;

placing an imaging device in a frame;

separating the population of cells in the levitation device; and

while separating the population of cells in the levitation device, using the imaging device to collect images of the separation of the population of cells.

35. The method of claim 34, wherein the collection of images of the separation of the population of cells occurs in real-time.

36. The method of claim 34, wherein the sample is blood.

37. The method of claim 34, wherein the sample is selected from a bodily fluid including saliva, urine, plasma, serum, and stool; swabs including skin, anal, nasal and vaginal swabs or environmental swabs from a door handle; and proximal fluids including tears, lavash fluid from lungs, interstitial tissue fluids from a breast.

38. The method of claim 34, further comprising at least one of counting and quantifying at least some of the population of cells from the collected images of the population of cells.

39. A magnetic levitation-based system comprising:

a levitation device for separating a heterogeneous population of moieties wherein variances in the moieties are based on differences in magnetic susceptibility and/or intrinsic density, the device including at least one magnet producing a magnetic field, wherein the magnetic field is sized to interact with a microcapillary or microfluidic channel for reception of a sample containing the heterogeneous population of moieties;

at least one needle at the inlet and/or outlet of the microcapillary or microfluidic channel introducing or withdrawing fluid from the microcapillary or microfluidic channel at a respective pre-defined position over the height and/or width of the microcapillary or microfluidic channel.

40. The magnetic levitation-based system of claim 39, comprising a plurality of needles at the inlet or the outlet, each of the plurality of needles being in communication with the microcapillary or microfluidic channel at a different spatial position.

41. The magnetic levitation-based system of claim 39, wherein a first injection needle at the inlet is at a different height than a second suction needle at the outlet.

42. A method of evaluating a quality of individual embryos and oocytes for use in reproductive medicine, the method comprising:

placing a sample including one or more embryos or oocytes in a microcapillary or microfluidic channel of a levitation device;

levitating the sample including embryos or oocytes in the levitation device; and

grading the quality of the embryos or oocytes on one or more of the density and levitation profile.

43. The method of claim 42, further comprising the step of selecting one or more of the embryos or oocytes based on the grading of the quality of the embryos or oocytes on one or more of the density and levitation profile and employing the one or more embryos or oocytes in an in vitro fertilization procedure.

44. A method for levitating a plurality of moieties encapsulated in droplets in a magnetic levitation system for droplet sequencing, the method comprising the steps of:

encapsulating the plurality of moieties in a plurality of droplets and suspending the plurality of droplets in a sample;

placing the sample containing the plurality of droplets in a microcapillary or microfluidic channel of the magnetic levitation system; and

levitating the plurality of droplets in the magnetic levitation system.

45. The method of claim 44, wherein the sample further includes a plurality of droplets not encapsulating any of the plurality of moieties.

46. A method for separating a heterogeneous population of cells, comprising:

obtaining a system comprising a microcapillary or microfluidic channel coupled to a single magnet;

providing the heterogeneous population of cells to the microcapillary or microfluidic channel; and

levitating the heterogeneous population of cells in the microcapillary or microfluidic channel based on their differences in magnetic susceptibility and density.

47. A method of separating and collecting a heterogeneous population of cells, the method comprising:

obtaining a microcapillary or microfluidic channel comprising two or more outlets;

placing in the microcapillary or microfluidic channel the heterogeneous population of cells in a paramagnetic medium;

separating the heterogeneous population of cells in the microcapillary or microfluidic channel based on their difference in magnetic susceptibility and density; and

withdrawing fluid comprising the separated cells from the two or more outlets using variable rates.

48. A method for separating fetal cells from a blood sample, comprising:

placing a blood sample and a paramagnetic medium in a microcapillary or microfluidic channel subjected to a magnetic field;

levitating cells within the microcapillary or microfluidic channel based on their magnetic susceptibility and density; and

isolating the fetal cells using a levitation height threshold of the microcapillary or microfluidic channel.