CLAIMS

What is claimed:

1. A process of exporting micro-objects from a micro-fluidic device comprising: an enclosure comprising a substrate and a micro-fluidic structure disposed on said substrate, wherein the enclosure defines a flow region configured to contain a liquid medium, said enclosure comprising an inlet and an outlet, each associated with said flow region, for respectively inputting and removing said liquid medium from said flow region, said outlet providing a passage through said enclosure;

said flow region comprising a channel disposed inside said enclosure, said channel having a plurality of holding pens which open off of said channel, each holding pen of said plurality comprising a connection region and an isolation region, wherein said isolation region is configured to:

hold a group of micro-objects;

isolate the group of micro-objects from micro-objects in others of said plurality of holding pens; and;

limit exchange of nutrients and waste between said holding pen and said channel to occur by diffusion;

a first electrode, a second electrode, and an electrode activation substrate comprising DEP electrodes at an inner surface of said flow region, wherein said process comprises:

flowing a liquid medium through a channel within an enclosure of said microfluidic device;

stopping the flow of said liquid medium in said channel;

selecting a group of micro-objects located in a holding pen that is one of a plurality of holding pens, wherein each of said plurality of holding pens opens to said channel inside said enclosure of said micro-fluidic device;

moving said selected group of micro-objects to said channel; and

exporting said selected group of micro-objects by resuming flow of said medium in said channel, wherein said flow of said liquid medium carries said selected group of micro-objects to said outlet, through a passage in said enclosure and into an export device.

2. The process of claim 1, wherein each micro-object of said selected group is a biological cell.

3. The process of claim 2, wherein said selected group is a single biological cell.

4. The process of claim 2, wherein said selected group is a clonal population of biological cells.

5. The process of any one of claims 1 to 4, wherein:

said selecting comprises determining that said group of micro-objects has a particular activity or physical characteristic.

6. The process of any one of claims 1 to 5, wherein:

said selecting said group of micro-objects and moving said selected group comprises activating DEP electrodes in a pattern that trap said selected group of micro-objects.

7. The process of any one of claims 1 to 6 wherein said moving said selected group of micro-objects further comprises moving said selected group to a staging area located in said channel.

8. The process of claim 1, wherein said exporting further comprises inserting an opening of a proximal end of said export device into an export interface disposed over said passage in said enclosure, to thereby place said opening at said proximal end of said export device to engage said passage.

9. The process of claim 8, wherein:

said export interface comprises a self-closing cover disposed over and covering said passage; and

said inserting comprises opening said cover by pressing said proximal end of said export device against a separation in said cover and moving said proximal end of said export device to engage said passage.

10. The process of claim 8, wherein:

said export interface comprises a self-healing cover disposed over and covering said passage; and

said inserting comprises piercing said cover with said proximal end of said export device and positioning said proximal end of said export device to engage said passage.

11. The process of any one of claims 1 to 10, wherein said selected group of micro-objects is exported in a medium or other solution having a volume of 1 μL or less.

12. The process of any one of claims 1 to 11 further comprising, after said exporting, inspecting said staging area and/or said export device for any un-exported micro-objects of said selected group.

13. The process of any one of claims 8 to 12 further comprising, after said exporting, inspecting said export interface for any un-exported micro-objects of said selected group.

14. The process of any one of claims 12 to 13 further comprising removing any un-exported ones of said micro-objects from said staging area, said export device, and/or said export interface.

15. The process of claim 7, wherein:

said passage in said enclosure is a second passage in said enclosure and is disposed adjacent a second end of said staging area,

said moving comprises moving said selected group to a middle portion of said staging area between said second end and an opposite first end of said staging area, and

said exporting comprises:

flowing a liquid from a first export device through a first passage in said enclosure toward said first end of said staging area and thereby generating a flow from said first end of said staging area to said second end of said staging area, and

drawing said micro-objects of said selected group from said second end of said staging area through said second passage in said enclosure into an opening at a proximal end of a second export device disposed adjacent said second passage.

16. A micro-fluidic apparatus comprising:

an enclosure comprising a substrate and a micro-fluidic structure disposed on said substrate, wherein the enclosure defines a flow region configured to contain a liquid medium, said enclosure comprising an inlet and an outlet, each associated with said flow region, for respectively inputting and removing said liquid medium from said flow region, said outlet providing a passage through said enclosure;

wherein said flow region comprises a channel disposed inside said enclosure, said channel having a plurality of holding pens which open off of said channel, each holding pen of said plurality comprising a connection region and an isolation region, wherein said isolation region is configured to:

hold a group of micro-objects;

isolate the group of micro-objects from micro-objects in others of said plurality of holding pens; and;

limit exchange of nutrients and waste between said holding pen and said channel to occur by diffusion;

a first electrode, a second electrode, and an electrode activation substrate comprising DEP electrodes at an inner surface of said flow region; and

an export interface disposed on said enclosure comprising an opening to said passage, said export interface configured to interface an export device such that an opening in a first end of said export device is positioned to engage said passage through said enclosure, wherein said export interface comprises a cover that covers entirely said passage through said enclosure.

17. The apparatus of claim 16, wherein said enclosure comprises at least one staging area comprising an area on an interior surface of said enclosure or a structure in said flow region.

18. The apparatus of claim 17, wherein said at least one staging area is located adjacent to said passage through said enclosure.

19. The apparatus of claim 17, wherein said at least one staging area is located in said channel.

20. The apparatus of claim 17, wherein said enclosure comprises a plurality of staging areas.

21. The apparatus of claim 16, wherein:

said cover comprises a separation dividing said cover into contiguous flaps,

said flaps are biased to contact one another to thereby cover entirely said passage through said enclosure, and

said flaps are sufficiently flexible to move apart to form an opening to receive said first end of said export device in response to a force of said first end of said export device being pressed against said separation.

22. The apparatus of claim 16, wherein said cover comprises a self-healing material that can be pierced by and thus form a hole for receiving said export device but self-heals and thereby closes said hole when said export device is removed from said material.

23. The process of claim 6, wherein said DEP electrodes are activated by directing patterned light onto said inner surface of said flow region.

24. The process of claim 2, wherein said biological cell is an immunological cell, a cancer cell, a transformed cell, or a stem cell.

25. The process of claim 2, wherein said biological cell is an embryo, an oocyte, or a sperm.

26. The process of claim 2, wherein said selected group of micro-objects is exported in a volume of said liquid medium of about 1 microliter to about 5 microliters.

27. The process of claim 1, further comprising neutralizing any un-exported ones of said micro-objects located in said enclosure, said export interface, and/or said export device.

28. The process of claim 1, wherein said exporting comprises discarding a leading volume of said liquid medium.

29. The apparatus of claim 20, wherein each holding pen comprises one staging area of said plurality of staging areas.

30. The apparatus of claim 16, wherein said export interface comprises a cover that is removable or breachable by said export device.

31. The apparatus of claim 16, wherein said export device comprises a tubular housing that defines an internal passage having a diameter of about 50 microns to about 300 microns.

32. The apparatus of claim 16, wherein said micro-fluidic structure comprises a cover.

33. The apparatus of claim 32, wherein said first electrode is part of said cover, said second electrode and said electrode activation substrate are part of said substrate, and said flow region is between said cover and said substrate.

34. The apparatus of claim 16, wherein said electrode activation substrate comprises a layer of photoconductive material.

35. The apparatus of claim 16, wherein said electrode activation substrate comprises a semiconductor material comprising a plurality of doped layers, electrically insulating layers, and electrically conductive layers that form semiconductor integrated circuits.

36. The apparatus of claim 16, wherein said electrode activation substrate comprises an array of phototransistors.

37. The apparatus of claim 16, wherein said flow region comprises a plurality of interconnected channels and chambers.

38. The apparatus of claim 16, wherein each said holding pen of said plurality is defined by a physical barrier.