Claims

1. ~~A method of moving a micro-object in a fluidic medium within a microfluidic device, the~~A microfluidic device comprising: an enclosure having a microfluidic structure and a base, wherein the base comprises a common electrical conductor ~~and the microfluidic structure comprises a cover with a biasing electrode~~, wherein the microfluidic structure and an outer surface of the base together define a flow path ~~disposed between the biasing electrode of the cover and the common electrical conductor of the base~~ within the enclosure, and wherein the base comprises an array of transistor structures, each said transistor structure in the array comprising a lateral bipolar transistor connecting a corresponding region of the outer surface of the base to the common ~~conductor and a vertical bipolar transistor connecting the corresponding region of the outer surface of the base to the common conductor, and wherein the corresponding regions of the outer surface of the base are disposed to contact directly fluidic medium in the flow path,~~electrical conductor.

~~the method comprising:~~
~~providing biasing power to the biasing electrode and the common electrical conductor of the base; and~~
~~activating a first of the transistor structures at a first of the corresponding regions of the outer surface of the base,~~
~~wherein said activating induces a first current flow in at least a lateral bipolar transistor of the first transistor structure and creates an eletrokinetic force in the vicinity of the activated first transistor structure sufficient to move a nearby micro-object in the flow path.~~

2. The ~~method of claim 1, wherein the first current flow induces a non-uniform electric field in the flow path between the activated first transistor structure and the biasing electrode, the non-uniform electric field producing the electrokinetic force, and wherein the electrokinetic force repels the nearby micro-object away from the non-uniform electric field.~~

~~3. The method of claim 1, wherein the activating also induces a second current flow in a vertical transistor of the activated first transistor structure.~~

~~4. The method of claim 3, wherein the second current flow enhances the electrokinetic force.~~

~~5. The method of claim 3, wherein the second current flow increases a magnitude of the electrokinetic force by at least 25%.~~

~~6. The method of claim 3, wherein a current density of the first current flow in the lateral transistor is at least 1.5 times greater than a current density of the second current flow in the vertical transistor of the activated first transistor structure.~~

~~7. The method of claim 1, wherein activating the first transistor structure comprises directing a beam of light onto the base region of the first transistor structure.~~

~~8. The method of claim 7, wherein the beam of light has an intensity of about 0.1 W/cm^2 to about 1000 W/cm^2.~~

~~9. The method of claim 1, wherein the micro-object comprises one of a polystyrene bead about 1 μm to about 50 μm in diameter and a glass bead about 1 μm to about 50 μm in diameter.~~

~~10. The method of claim 1, wherein the micro-object is a biological cell.~~

~~11. The method of claim 1, wherein the fluidic medium in the flow path of the~~ microfluidic device ~~has an electrical conductivity of about 10 mS/m to about 2 S/m.~~

~~12. The method of claim 1, further comprising maintaining a temperature of the fluidic medium in the flow path at about 5° C to about 55° C.~~

~~13. The method of claim 1, wherein providing the biasing power comprises providing biasing power with a peak-to-peak voltage of about 1 Vppk to about 50 Vppk.~~

~~14. The method of claim 1, wherein providing the biasing power comprises providing biasing power at a frequency of about 100 kHz to about 10 MHz.~~

~~15. The method of claim 1, wherein providing the biasing power comprises providing biasing power that has a square waveform, a sine waveform, or a triangular waveform.~~

~~16. The method of claim 1, wherein the common conductor comprises an N+ semiconductor substrate upon which the array of transistor structures rests.~~

~~17. The method of claim 16, wherein the N+ semiconductor substrate has a resistivity of about 0.025 ohm-cm to about 0.050 ohm-cm.~~

~~18. The method of claim 1, wherein a pitch of the transistor structures of the array is about 1000 nm to about 20,000 nm.~~

~~19. The method of claim 1, wherein the microfluidic structure and the base together further define a holding pen connected to the flow path.~~

~~20. The method of claim 19, wherein the flow path comprises a fluidic channel, and wherein the holding pen opens to the fluidic channel.~~

~~21. The method~~ of claim 1, wherein each said transistor structure in the array ~~comprises~~ <u>further comprises a vertical bipolar transistor connecting the corresponding region of the outer surface of the base.</u>

3. The microfluidic device of claim 1 or 2, wherein each said transistor structure in the array comprising a collector region, a base region, and an emitter region, ~~a~~wherein the base region ~~surrounding~~surrounds the emitter region, ~~and a collector region surrounding the base region,~~ wherein the ~~base region and the~~ collector region ~~each comprise a respective lateral portion and a respective vertical portion, wherein the lateral portion of the~~ surrounds the base region, wherein the base region has a lateral width that is between about 10 nm and about 400 nm, and wherein each said transistor structure in the array is physically separated from ~~adjacent~~other transistor structures ~~by an~~in the array ~~of trenches having electrically insulative material disposed therein~~.

~~22~~4. The ~~method~~microfluidic device of claim ~~21~~1, wherein each said transistor structure in the ~~lateral portion of~~array is physically separated from the ~~base region has~~other transistor structures in the array by a ~~width that is between about 200 nm and about 300 nm.~~

~~23. The method of claim 21~~trench, wherein ~~the vertical portion of the base region has a thickness equal to or greater than the width of the lateral portion of the base region.~~

~~24. The method of claim 23, wherein the vertical portion of the base region has a thickness two to four times greater than the width of the lateral portion of the base region.~~

~~25. The method of claim 24, wherein the vertical portion of the base region has a thickness about 3.5 times greater than the width of the lateral portion of the collector region.~~

~~26. The method of claim 21, wherein the lateral portion of the collector region has a width that is between about 100 nm and about 1000 nm.~~

~~27. The method of claim 26, wherein the lateral portion of the collector region has a width that is between about 600 nm and about 750 nm.~~

~~28. The method of claim 21, wherein the vertical portion of the collector region has a thickness equal to or greater than the width of the lateral portion of the collector region.~~

~~29. The method of claim 28, wherein the vertical portion of the collector region has a thickness two to ten times greater than the width of the lateral portion of the collector region.~~

~~30. The method of claim 29, wherein the vertical portion of the collector region has a thickness four to eight times greater than the width of the lateral portion of the collector region.~~

~~31. The method of claim 30, wherein the vertical portion of the collector region has a thickness about six times greater than the width of the lateral portion of the collector region.~~

~~32. The method of claim 21, wherein the emitter region has a vertical thickness of about 10 nm to about 500 nm, wherein the vertical portion of the base region has a thickness 6 to 12 times greater than the vertical thickness of the emitter region, and wherein the vertical portion~~

~~of the collector region has a thickness 3 to 6 times greater than the thickness of the vertical portion of the base region.~~

~~33. The method of claim 32, wherein the vertical thickness of the emitter region is about 50 nm to about 150 nm.~~

~~34. The method of claim 21, wherein the base region comprises a p-type dopant and the collector and emitter regions each comprise an n-type dopant.~~

~~35. The method of claim 21, wherein the collector region has a resistivity of about 5 ohm-cm to about 10 ohm-cm.~~

~~36. The method of claim 21, wherein the trench has~~ a vertical depth ~~that~~of the trench is at least 10% greater than a combined vertical depth of the collector, base, and emitter regions.

~~37~~5. The ~~method~~ microfluidic device of claim ~~21~~3, wherein the base region has a vertical ~~depth~~ thickness that is about two to four times greater than the lateral width of the ~~trench is about 2,000 nm to about 11,000 nm~~base region.

6. The microfluidic device of claim 3, wherein the base region comprises a p-type dopant selected from the group consisting of Boron, Aluminum, Beryllium, Zinc, and ~~wherein the trench~~Cadmium, wherein the common electrical conductor comprises an N+ semiconductor substrate upon which the array of transistor structures rests, wherein the N+ semiconductor substrate comprises a dopant selected from the group consisting of Antimony, Arsenic, and Phosphorus, wherein the collector region comprises an n-type dopant selected from the group consisting of Antimony, Arsenic, and Phosphorus, and wherein the emitter region comprises an n-type dopant selected from the group consisting of Antimony, Arsenic, and Phosphorus.

7. The microfluidic device of claim 3, wherein the collector region has a lateral width that is between about 600 nm and about ~~100~~750 nm.

8. The microfluidic device of claim 3, wherein the collector region has a vertical thickness and a lateral width, wherein the vertical thickness of the collector region is about four to eight times greater than the lateral width of the collector region.

9. The microfluidic device of claim 3, wherein a vertical thickness of the emitter region is about 50 nm to about ~~1000~~150 nm.

~~38~~10. The ~~method~~ microfluidic device of claim ~~21~~1, wherein a pitch of the transistor structures of the array is about 5000 nm to about 10,000 nm.

11. The microfluidic device of claim 3, further ~~comprises~~comprising a dielectric border disposed on the outer surface of the base between adjacent pairs of the transistor structures of the array, wherein the border overlays a perimeter portion of the emitter region of each said transistor structure of the array but comprises windows exposing an interior portion of ~~each emitter region~~the emitter region, wherein the windows of the dielectric border expose the interior portions of the emitter regions of the transistor structures of the array to direct contact with fluidic medium in the flow path.

~~39~~12. The ~~method~~microfluidic device of claim ~~38~~11, wherein ~~the dielectric border has~~ a vertical thickness ~~that~~ of the border is about 750 nm to about 2,000 nm~~.~~

~~40. The method of claim 38,~~, and wherein the dielectric border overlays the perimeter portion of the emitter region by about 10 nm to about 200 nm.

13. The microfluidic device of claim 1, further comprising a biasing electrode, wherein the flow path is disposed between the biasing electrode and the common electrical conductor of the base; wherein: the transistor structures of the array connect different regions of the outer surface of the base to the common electrical conductor, and the regions of the outer surface of the base are disposed to contact directly fluidic medium in the flow path.

14. The microfluidic device of claim 1, wherein: the base comprises a first section and a second section electrically insulated from the first section; the array of transistor structures is a first array of said transistor structures in the first section, the base comprising a second array of said transistor structures in the second section; the common electrical conductor is a first common conductor that is common to the transistor structures of the first section but not the transistor structures of the second section; and the base further comprises a second common conductor that is common to the transistor structures of the second section but not the transistor structures of the first section.

15. A microfluidic apparatus, comprising: a first microfluidic device; and a second microfluidic device, wherein each of the first and second microfluidic devices is configured

according to the microfluidic device of claim 1, wherein the enclosure of the first microfluidic device is separate and distinct from the enclosure of the second microfluidic device, and wherein the common electrical conductor of the first microfluidic device and the common electrical conductor of the second microfluidic device are electrically connected and compose an electrical conductor common to the first microfluidic device and the second microfluidic device.

16. A system comprising a microfluidic device according to claim 1, further comprising control equipment for controlling operation of the microfluidic device.

17. The system of claim 16, wherein the control equipment comprises a light source, a spatial light modulator, and a light path for directing selected patterns of light into the enclosure.

18. A method of moving a micro-object in a fluidic medium in the microfluidic device of claim 13, the method comprising: providing biasing power to the biasing electrode and the common electrical conductor of the base; and activating a first of the transistor structures at a first of the regions of the outer surface of the base, wherein said activating creates an electrokinetic force in the vicinity of the activated first transistor structure sufficient to move a nearby micro-object in the flow path.

19. -The method of claim 18, wherein the activating induces a first current flow in the lateral bipolar transistor of the first transistor structure, and wherein the electrokinetic force moves the nearby micro-object away from the first region of the outer surface of the base that corresponds to the activated first transistor structure.

20. The method of claim 18, wherein the micro-object is a biological cell selected from the group consisting of SP2, HeLa, embryo, sperm, oocytes, and jurkat.