

CLAIMS

The invention claimed is:

- 1 1. Apparatus for controlling motion of liquid droplets, comprising:
2 a set of electrode pads arranged in an array or in paths defining one or more tracks over which
3 liquid droplets may be induced to move over a sequence of the electrode pads;
4 a surface over the electrode pads being dielectric, smooth to within 2 μ m, having a slide angle for a
5 5 μ l droplet of the liquid of no more than 5 degrees, and having a wetting affinity to the liquid that can be
6 altered by application of voltage to the electrode pads;
7 a control designed to alter the wetting characteristic of portions of the surface over respective
8 electrode pads to effect induced motion of the droplets over the tracks, the wetting characteristic to be
9 altered by controlling charging and discharging of the electrode pads in a desired sequence.

- 1 2. Apparatus for controlling motion of liquid droplets, comprising:
2 a smooth, hydrophobic surface, having portions with a wetting affinity to the liquid that can be
3 varied in a controlled manner to induce droplets of the liquid to move over the surface;
4 a control designed to vary the wetting characteristic of portions of the surface to effect induced
5 motion of the droplets over the tracks;
6 the apparatus being designed with the smooth hydrophobic surface open, with no overlying or
7 facing electrode or plate above the droplets.

3. The apparatus of any of claims 1 or 2:
 the smooth surface being hydrophobic;
 the smooth hydrophobic surface being formed as a textured surface of a solid, designed to hold a
thin layer of a second liquid that is immiscible with the liquid of the droplets, an upper surface of the second
liquid forming a liquid-liquid surface that is slippery with respect to the liquid droplets.

- 1 4. Apparatus for controlling motion of liquid droplets, comprising:
2 a solid surface that is textured to hold a thin layer of a second liquid that is immiscible with the liquid
3 of the droplets, an upper surface of the second liquid forming a liquid-liquid surface that is slippery with
4 respect to the liquid droplets, having a slide angle for a 5 μ l droplet of the droplet liquid of no more than 5
5 degrees, and having a wetting affinity to the droplet liquid that can be varied under control, the varying-
6 wetability portions being arranged in an array or in paths defining one or more tracks over which the liquid
7 droplets may be induced to move over a sequence of the varying-wetability portions; and

- 8 a control designed to vary the wetting characteristic of varying-wetability portions of the liquid-liquid
9 surface to effect induced motion of the droplets over the tracks.

5. The apparatus of claim 4, wherein:

the second liquid is an oil that has wetting affinity for the solid and is immiscible with the liquid of the droplets.

6. The apparatus of any of claims 2, 4, or 5, further comprising:

the varying-wetability portions being a surface arranged over a set of electrode pads arranged in an array or in paths defining one or more tracks over which liquid droplets may be induced to move over a sequence of the electrode pads, the varying-wetability portions being a dielectric surface over the electrode pads, the wetting characteristic to be altered by controlling charging and discharging of the electrode pads in a desired sequence.

7. The apparatus of claims 2, 4, 5, or 6:

the smooth, hydrophobic surface is smooth to within $1\mu\text{m}$, and has a slide angle for a $5\mu\text{l}$ droplet of the liquid of no more than 5 degrees.

8. The apparatus of any of claims 1, 4, 5, 6, or 7 :

the smooth surface being hydrophobic;

the apparatus being designed with the smooth hydrophobic surface being open, with no overlying or facing electrode or plate.

9. The apparatus of any of claims 1, 4, 5, 6, 7, or 8, further comprising:

a second plate overlying or facing the surface.

10. The apparatus of any of claims 1, 6, 7, or 8, wherein:

the electrodes are printed on a substrate using printed circuit board technology.

11. The apparatus of any of claims 1, 6, 7, or 8, wherein:

the electrodes are manufactured using thin-film transistor (TFT) technology.

12. The apparatus of any of claims 1, 6, or 7, or 8, wherein:

the electrodes are manufactured on a substrate using active matrix or passive matrix backplane technology.

13. The apparatus of any of claims 1, 4 to 8, and 9 to 12, wherein:
the slide angle is imparted to the surface by patterning or texturing to induce hydrophobicity.
14. The apparatus of any of the preceding claims, wherein:
the surface has a slide angle for a 5 μ l droplet of no more than 3°.
15. The apparatus of any of the preceding claims, wherein:
the surface has a slide angle for a 5 μ l droplet of no more than 1°.
16. The apparatus of any of the preceding claims, wherein:
the wetability of the varying-wetability portions of the surface is varied via application of light.
17. The apparatus of any of the preceding claims, wherein:
the varying-wetability portions of the surface operate by optoelectrowetting.
18. The apparatus of any of the preceding claims 1 to 17, wherein, wherein:
the varying-wetability portions of the surface operate by photoelectrowetting.
19. The apparatus of any of the preceding claims, wherein:
the surface is smoothed to within 1 μ m by polishing.
20. The apparatus of any of the preceding claims, wherein:
the surface is smoothed to within 1 μ m by applying a coating, the coating applied by at least one of
spin coating, spray coating, dip coating, or vapor deposition.
21. The apparatus of any of the preceding claims, wherein:
the surface coating is of a material that is both dielectric and hydrophobic.
22. The apparatus of any of the preceding claims, wherein:
the surface is smoothed to within 1 μ m by application of a sheet of a polymer stretched to remove
wrinkles.
23. The apparatus of any of the preceding claims, further comprising:
the apparatus includes stations for one or more of the group consisting of dispensing, mixing,
heating, cooling, application of magnetic field, application of electric field, addition of reagent, optical
inspection or assay, and isolation or purification of proteins, peptides, or biopolymers.

24. The apparatus of any of the preceding claims, further comprising:
the apparatus includes stations for two or more of the group consisting of dispensing, mixing, heating, cooling, application of magnetic field, application of electric field, addition of reagent, optical inspection or assay, and isolation or purification of proteins, peptides, or biopolymers.

25. The apparatus of any of the preceding claims, further comprising:
an acoustic transducer configured to introduce to introduce liquid droplets into the apparatus.

26. The apparatus of any of the preceding claims, further comprising:
a microdiaphragm pump configured to introduce to introduce liquid droplets into the apparatus.

27. The apparatus of any of the preceding claims, further comprising:
one or more inkjet nozzles configured to introduce liquid droplets into the apparatus.

28. The apparatus of any of the preceding claims, further comprising:
one or more syringe pumps configured to introduce liquid droplets into the apparatus.

29. The apparatus of any of the preceding claims, further comprising:
one or more capillary tubes configured to introduce liquid droplets into the apparatus.

30. The apparatus of any of the preceding claims, further comprising:
one or more pipette devices configured to introduce liquid droplets into the apparatus.

31. The apparatus of any of the preceding claims, further comprising:
the surface has one or more holes designed to introduce liquid droplets or reactants.

1 32. A method, comprising the steps of:
2 introducing a liquid droplet onto a surface over a set of electrode pads arranged in an array or in
3 paths defining one or more tracks over which the liquid droplet may be induced to move over a sequence of
4 the electrode pads;
5 the surface being dielectric, smooth to within 2 μ m, having a slide angle for a 5 μ l droplet of the
6 liquid of no more than 5 degrees, and having a wetting affinity to the liquid that can be altered by application
7 of voltage to the electrode pads;

8 controlling the wetting characteristic of portions of the surface over respective electrode pads to
9 effect induced motion of the droplet over the tracks, the wetting characteristic to be altered by controlling
10 charging and discharging of the electrode pads in a desired sequence.

1 33. A method, comprising the step of:
2 introducing a liquid droplet onto a smooth, hydrophobic surface, having portions with a wetting
3 affinity to the liquid that can be varied in a controlled manner, the varying-wettability portions being arranged
4 in an array or in paths defining one or more tracks over which liquid droplets may be induced to move over a
5 sequence of the varying-wettability portions;
6 varying the wetting characteristic of varying-wettability portions of the surface to effect induced
7 motion of the droplets over the tracks;
8 the apparatus being designed with the smooth hydrophobic surface open, with no overlying or
9 facing electrode or plate above the droplets.

34. The method of any of claims 32 and 33:
the surface being hydrophobic, and
the smooth, hydrophobic surface being formed as a textured surface of a solid, designed to hold a
thin layer of a second liquid that is immiscible with the liquid of the droplets, an upper surface of the second
liquid forming a liquid-liquid surface that is slippery with respect to the liquid droplets.

1 35. A method, comprising the step of:
2 introducing a liquid droplet onto a liquid-liquid interface, being a liquid surface of a second liquid
3 that is immiscible with the liquid of the droplets, formed on a solid surface that is textured to hold a thin layer
4 of the second liquid, an upper surface of the second liquid forming a liquid-liquid surface that is slippery with
5 respect to the liquid droplets, having a slide angle for a 5 μ l droplet of the droplet liquid of no more than 5
6 degrees, and having a wetting affinity to the droplet liquid that can be varied under control, the varying-
7 wettability portions being arranged in an array or in paths defining one or more tracks over which the liquid
8 droplets may be induced to move over a sequence of the varying-wettability portions; and
9 varying the wetting characteristic of varying-wettability portions of the liquid-liquid surface to effect
10 induced motion of the droplets over the tracks.

36. The method of any of claims 33, 34, or 35:
the varying-wettability portions being a surface arranged over a set of electrode pads arranged in an
array or in paths defining one or more tracks over which liquid droplets may be induced to move over a
sequence of the electrode pads, the varying-wettability portions being a dielectric surface over the electrode

pads, the wetting characteristic to be altered by controlling charging and discharging of the electrode pads in a desired sequence.

37. The method of any of claims 33, 34, 35, or 36:

the smooth, hydrophobic surface being smooth to within $1\mu\text{m}$, and having a slide angle for a $5\mu\text{l}$ droplet of the liquid of no more than 3 degrees.

38. The method of any of claims 32, and 35 to 37:

the apparatus being designed with the smooth hydrophobic surface open, with no overlying or facing electrode or plate above the droplets.

39. The method of claim 32, 36, or 37, wherein:

the electrodes are printed on a substrate using printed circuit board technology.

40. The method of any of the preceding claims 42 to 39, wherein:

the surface is smoothed to within $1\mu\text{m}$ by polishing.

1 41. Apparatus for controlling motion of liquid droplets, comprising:
2 a set of electrode pads arranged in an array or in paths defining one or more tracks over which
3 liquid droplets may be induced to move over a sequence of the electrode pads;
4 a surface over the electrode pads being dielectric, smooth to within $1\mu\text{m}$, the smooth surface being
5 formed as a thin layer of a second liquid that is immiscible with the liquid of the droplets, an upper surface of
6 the second liquid forming a liquid-liquid surface that is hydrophobic, having a slide angle for a $5\mu\text{l}$ droplet of
7 the liquid of no more than 5 degrees, and having portions whose wetting affinity to the liquid that can be
8 individually varied in a controlled manner by application of voltage to respective electrode pads, the varying-
9 wetability portions being arranged in an array or in paths defining one or more tracks over which liquid
10 droplets may be induced to move over a sequence of the varying-wetability portions, the second liquid laid
11 on a surface of an underlying solid substrate that is textured to hold the second liquid stable against gravity;
12 a control designed to alter the wetting characteristic of varying-wetability portions of the surface
13 over respective electrode pads to effect induced motion of the droplets over the tracks, the wetting
14 characteristic to be altered by controlling charging and discharging of the electrode pads in a desired
15 sequence;
16 the apparatus being designed with the smooth hydrophobic surface open, with no overlying or
17 facing electrode or plate above the droplets.