CLAIMS

1. A microneedle array comprising:

a base having microneedles disposed thereon, wherein each of the microneedles is formed of (i) a swellable and water-insoluble matrix comprising a crosslinked polymer or (ii) a water-soluble matrix comprising a water-soluble polymer; and

a conductive polymer homogenously incorporated in the swellable and water-insoluble matrix or the water-soluble matrix, wherein the conductive polymer comprises 5 wt% to 15 wt% of the swellable and water-insoluble matrix or the water-soluble matrix.

2. The microneedle array of claim 1, wherein the crosslinked polymer comprises an acrylate-crosslinked hydrophilic polymer, a furan-crosslinked hydrophilic polymer, or a catechol-crosslinked hydrophilic polymer, wherein the acrylate-crosslinked hydrophilic polymer comprises methacrylate-crosslinked hyaluronic acid, methacrylate-crosslinked polyvinyl alcohol, methacrylate-crosslinked poly(methylvinyl ether), or cross-linked poly(ethylene glycol) diacrylate.

3. The microneedle array of claim 2, wherein the methacrylate-crosslinked hyaluronic acid is formed from hyaluronic acid having an average molecular weight ranging from 3 kDa to 300 kDa.

4. The microneedle array of claim 1, wherein the water-soluble polymer comprises hyaluronic acid, polyvinyl alcohol, poly(methylvinyl ether), poly(ethylene glycol), or poly(lactic-co-glycolic acid).

5. The microneedle array of claim 4, wherein the hyaluronic acid has an average molecular weight ranging from 3 kDa to 300 kDa.

6. The microneedle array of any one of claims 1 to 5, wherein the conductive polymer comprises poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate), polypyrrole, polyaniline, polythiophene, polyethyne, poly(p-phenylene), or poly(p-phenylene vinylene).

7. The microneedle array of any one of claims 1 to 6, wherein each of the microneedles has a length of 1000 μm or less.

8. The microneedle array of any one of claims 1 to 7, wherein the base comprises the crosslinked polymer or the water-soluble polymer which the swellable and water-insoluble matrix or the water-soluble matrix is respectively formed of.

9. The microneedle array of any one of claims 1 to 8, wherein (i) the base has a surface for the active agent to be disposed thereon and/or (ii) the swellable and water-insoluble matrix or the water-soluble matrix further comprises the active agent disposed therein.

10. A device configured to deliver an active agent, the device comprising:

a microneedle array, wherein the microneedle array comprises:

a base having microneedles disposed thereon, wherein each of the microneedles is formed of (i) a swellable and water-insoluble matrix comprising a crosslinked polymer or (ii) a water-soluble matrix comprising a water-soluble polymer; and

a conductive polymer homogenously incorporated in the swellable and water-insoluble matrix or the water-soluble matrix, wherein the conductive polymer comprises 5 wt% to 15 wt% of the swellable and water-insoluble matrix or the water-soluble matrix; and

an iontophoresis unit comprising an anode and a cathode connectable to the microneedle array, wherein the iontophoresis unit is operable to deliver the active agent from the microneedle array.

11. The device of claim 10, wherein the crosslinked polymer comprises an acrylate-crosslinked hydrophilic polymer, a furan-crosslinked hydrophilic polymer, or a catechol-crosslinked hydrophilic polymer, wherein the acrylate-crosslinked hydrophilic polymer comprises methacrylate-crosslinked hyaluronic acid, methacrylate-crosslinked polyvinyl alcohol, methacrylate-crosslinked poly(methylvinyl ether), or crosslinked poly(ethylene glycol) diacrylate.

12. The device of claim 11, wherein the methacrylate-crosslinked hyaluronic acid is formed from hyaluronic acid having an average molecular weight ranging from 50 kDa to 300 kDa.

13. The device of claim 10, wherein the water-soluble polymer comprises hyaluronic acid, polyvinyl alcohol, poly(methylvinyl ether), poly(ethylene glycol), or poly(lactic-co-glycolic acid).

14. The device of claim 13, wherein the hyaluronic acid has an average molecular weight ranging from 3 kDa to 300 kDa.

15. The device of any one of claims 10 to 14, wherein the conductive polymer comprises poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate), polypyrrole, polyaniline, polythiophene, polyethyne, poly(p-phenylene), or poly(p-phenylene vinylene).

16. The device of any one of claims 10 to 15, wherein each of the microneedles has a length of 1000 μm or less.

17. The device of any one of claims 10 to 16, wherein the base comprises the crosslinked polymer or the water-soluble polymer which the swellable and water-insoluble matrix or the water-soluble matrix is respectively formed of.

18. The device of any one of claims 10 to 17, wherein (i) the base has a surface for the active agent to be disposed thereon and/or (ii) the swellable and water-insoluble matrix or the water-soluble matrix further comprises the active agent disposed therein.

19. The device of any one of claims 10 to 18, wherein the active agent comprises an anaesthetic agent and/or a drug.

20. A method of producing a microneedle array, wherein the microneedle array comprises:

a base having microneedles disposed thereon, wherein each of the microneedles is formed of (i) a swellable and water-insoluble matrix comprising a crosslinked polymer or (ii) a water-soluble matrix comprising a water-soluble polymer; and

a conductive polymer homogenously incorporated in the swellable and water-insoluble matrix or the water-soluble matrix, wherein the conductive polymer comprises 5 wt% to 15 wt% of the swellable and water-insoluble matrix or the water-soluble matrix;

wherein the method comprises:

providing an aqueous solution in a mold, wherein the aqueous solution comprises (i) a functionalized polymer, the conductive polymer and a photoinitiator, or (ii) the water-soluble polymer and the conductive polymer;

irradiating the aqueous solution to form the microneedle array when the aqueous solution comprises the functionalized polymer, the conductive polymer and the photoinitiator; and

removing the microneedle array from the mold,

wherein providing the aqueous solution comprises (i) mixing the functionalized polymer with the conductive polymer and a photoinitiator or (ii) mixing the water-soluble polymer with the conductive polymer, and wherein the conductive polymer is mixed at a concentration of 5 wt% to 15 wt% of the aqueous solution.

21. The method of claim 20, wherein providing the aqueous solution comprises dissolving the functionalized polymer or the water-soluble polymer in water.

22. The method of claim 20 or 21, wherein providing the aqueous solution comprises dissolving the functionalized polymer or the water-soluble polymer in water at a concentration ranging from 25 mg/mL to 100 mg/mL.

23. The method of any one of claims 20 to 22, wherein the functionalized polymer comprises an acrylate-functionalized hydrophilic polymer, a furan-functionalized hydrophilic polymer, or a catechol-functionalized hydrophilic polymer, wherein the acrylate-functionalized hydrophilic polymer comprises methacrylate-functionalized hyaluronic acid, methacrylate-functionalized polyvinyl alcohol, methacrylate-functionalized poly(methylvinyl ether), or diacrylate-functionalized poly(ethylene glycol).

24. The method of any one of claims 20 to 22, wherein the water-soluble polymer comprises hyaluronic acid, polyvinyl alcohol, poly(methylvinyl ether), poly(ethylene glycol), or poly(lactic-co-glycolic acid).

25. The method of any one of claims 20 to 24, wherein the conductive polymer comprises poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate), polypyrrole, polyaniline, polythiophene, polyethyne, poly(p-phenylene), or poly(p-phenylene vinylene).

26. The method of any one of claims 20 to 25, wherein the mold comprises a plurality of cavities shaped to form the microneedles.

27. The method of any one of claims 20 to 26, wherein each of the plurality of cavities has a depth of 1000 μm or less.

28. The method of any one of claims 20 to 27, further comprising centrifuging the mold with the aqueous solution provided therein.

29. A method of delivering an active agent to a subject through the device of any one of claims 10 to 19, the method comprising:

applying the microneedle array on the subject;

placing the anode and the cathode on the subject; and

operating the iontophoresis unit to deliver the active agent from the microneedle array.

30. The method of claim 29, wherein applying the microneedle array comprises inserting the microneedles into a first surface of the subject.

31. The method of claim 30, wherein placing the anode and the cathode on the subject comprises:

(i) arranging the anode on the first surface proximal to where the microneedle is applied and arranging the cathode on a second surface distal to where the anode is arranged when the active agent is anionic; or

(ii) arranging the cathode on the first surface proximal to where the microneedle is applied and arranging the cathode on a second surface distal to where the cathode is arranged when the active agent is cationic; or

(iii) arranging either the anode or the cathode on the first surface proximal to where the microneedle is applied and arranging the cathode or the anode, respectively, on a second surface to where the anode or cathode is arranged, respectively, when the active agent is neutral.

32. The method of any one of claims 29 to 31, wherein operating the iontophoresis unit comprises passing an electrical current between the anode and the cathode to establish a voltage for delivering the active agent from the microneedle array.

33. The method of any one of claims 29 to 32, wherein delivering the active agent from the microneedle array comprises delivering the active agent to and/or through

(i) a dermal layer of the subject; and/or

(ii) a mucosa of the subject; and/or

(iii) a deep dermis layer of the subject; and/or

(iv) a bone of the subject.