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 25 wt% or less of the swellable and water-insoluble matrix or the water-soluble matrix.~~

~~7~~6. The microneedle array of any one of claims 1 to ~~6~~5, wherein the conductive polymer comprises poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate), polypyrrole, polyaniline, polythiophene, polyethyne, poly(p-phenylene), or poly(p-phenylene vinylene).

~~8~~7. The microneedle array of any one of claims 1 to ~~7~~6, wherein each of the microneedles has a length of 1000 μm or less.

~~9~~8. The microneedle array of any one of claims 1 to ~~8~~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.

~~10~~9. The microneedle array of any one of claims 1 to ~~9~~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.

~~11~~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.

~~12~~11. The device of claim ~~11~~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.

~~13~~12. The device of claim ~~12~~11, wherein the methacrylate-crosslinked hyaluronic acid is formed from hyaluronic acid having an average molecular weight ranging from 50 kDa to 300 kDa.

~~14~~13. The device of claim ~~11~~10, wherein the water-soluble polymer comprises hyaluronic acid, polyvinyl alcohol, poly(methylvinyl ether), poly(ethylene glycol), or poly(lactic-co-glycolic acid).

~~15~~14. The device of claim ~~14~~13, wherein the hyaluronic acid has an average molecular weight ranging from 3 kDa to 300 kDa.

~~16. The device of any one of claims 11 to 15, wherein the conductive polymer comprises 25 wt% or less of the swellable and water-insoluble matrix or the water-soluble matrix.~~

~~17~~15. The device of any one of claims ~~11~~10 to ~~16~~14, wherein the conductive polymer comprises poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate), polypyrrole, polyaniline, polythiophene, polyethyne, poly(p-phenylene), or poly(p-phenylene vinylene).

~~18~~16. The device of any one of claims ~~11~~10 to ~~17~~15, wherein each of the microneedles has a length of 1000 μm or less.

~~19~~17. The device of any one of claims ~~11~~10 to ~~18~~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.

~~20~~18. The device of any one of claims ~~11~~10 to ~~19~~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.

~~21~~19. The device of any one of claims ~~11~~10 to ~~20~~18, wherein the active agent comprises an anaesthetic agent and/or a drug.

~~22~~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.

~~23~~21. The method of claim ~~22~~20, wherein providing the aqueous solution comprises dissolving the functionalized polymer or the water-soluble polymer in water.

~~24~~22. The method of claim ~~22~~20 or ~~23~~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.

~~25~~23. The method of any one of claims ~~22~~20 to ~~24~~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).

~~26~~24. The method of any one of claims ~~22~~20 to ~~24~~22, wherein the water-soluble polymer comprises hyaluronic acid, polyvinyl alcohol, poly(methylvinyl ether), poly(ethylene glycol), or poly(lactic-co-glycolic acid).

~~27. The method of any one of claims 22 to 26, 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.~~

~~28. The method of claim 27, wherein the conductive polymer is mixed at a concentration of 25 wt% or less of the aqueous solution.~~

~~29~~25. The method of any one of claims ~~22~~20 to ~~28~~24, wherein the conductive polymer comprises poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate), polypyrrole, polyaniline, polythiophene, polyethyne, poly(p-phenylene), or poly(p-phenylene vinylene).

~~30~~26. The method of any one of claims ~~22~~20 to ~~29~~25, wherein the mold comprises a plurality of cavities shaped to form the microneedles.

~~31~~27. The method of any one of claims ~~22~~20 to ~~30~~26, wherein each of the plurality of cavities has a depth of 1000 μm or less.

~~32~~28. The method of any one of claims ~~22~~20 to ~~31~~27, further comprising centrifuging the mold with the aqueous solution provided therein.

~~33~~29. A method of delivering an active agent to a subject through the device of any one of claims ~~11~~10 to ~~21~~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.

~~34~~30. The method of claim ~~33~~29, wherein applying the microneedle array comprises inserting the microneedles into a first surface of the subject.

~~35~~31. The method of claim ~~34~~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.

~~36~~32. The method of any one of claims ~~33~~29 to ~~35~~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.

~~37~~33. The method of any one of claims ~~33~~29 to ~~36~~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.