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~~2. 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~~3. The microneedle array of claim ~~4~~2, wherein the hyaluronic acid has an average molecular weight ranging from 3 kDa to 300 kDa.

~~64~~. The microneedle array of any one of claims 1 to ~~53~~, wherein the conductive polymer comprises poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate), polypyrrole, polyaniline, polythiophene, polyethyne, poly(p-phenylene), or poly(p-phenylene vinylene).

~~75~~. The microneedle array of any one of claims 1 to ~~64~~, wherein each of the microneedles has a length of 1000 μm or less.

~~86~~. The microneedle array of any one of claims 1 to ~~75~~, 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.

~~97~~. The microneedle array of any one of claims 1 to ~~86~~, 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.

~~108~~. 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~~9. The device of claim ~~10~~8, wherein the water-soluble polymer comprises hyaluronic acid, polyvinyl alcohol, poly(methylvinyl ether), poly(ethylene glycol), or poly(lactic-co-glycolic acid).

~~14~~10. The device of claim ~~13~~9, wherein the hyaluronic acid has an average molecular weight ranging from 3 kDa to 300 kDa.

~~15~~11. The device of any one of claims ~~10~~8 to ~~14~~10, wherein the conductive polymer comprises poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate), polypyrrole, polyaniline, polythiophene, polyethyne, poly(p-phenylene), or poly(p-phenylene vinylene).

~~16~~12. The device of any one of claims ~~10~~8 to ~~15~~11, wherein each of the microneedles has a length of 1000 μm or less.

~~17~~13. The device of any one of claims ~~10~~8 to ~~16~~12, 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~~14. The device of any one of claims ~~10~~8 to ~~17~~13, 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~~15. The device of any one of claims ~~10~~8 to ~~18~~14, wherein the active agent comprises an anaesthetic agent and/or a drug.

~~20~~16. 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~~17. The method of claim ~~20~~16, wherein providing the aqueous solution comprises dissolving ~~the functionalized polymer or~~ the water-soluble polymer in water.

~~22~~18. The method of claim ~~20~~16 or ~~21~~17, 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~~19. The method of any one of claims ~~20~~16 to ~~22~~18, wherein the water-soluble polymer comprises hyaluronic acid, polyvinyl alcohol, poly(methylvinyl ether), poly(ethylene glycol), or poly(lactic-co-glycolic acid).

~~25~~20. The method of any one of claims ~~20~~16 to ~~24~~19, wherein the conductive polymer comprises poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate), polypyrrole, polyaniline, polythiophene, polyethyne, poly(p-phenylene), or poly(p-phenylene vinylene).

~~26~~21. The method of any one of claims ~~20~~16 to ~~25~~20, wherein the mold comprises a plurality of cavities shaped to form the microneedles.

~~27~~22. The method of any one of claims ~~20~~16 to ~~26~~21, wherein each of the plurality of cavities has a depth of 1000 μm or less.

~~28~~23. The method of any one of claims ~~20~~16 to ~~27~~22, further comprising centrifuging the mold with the aqueous solution provided therein.

~~29~~24. A method of delivering an active agent to a subject through the device of any one of claims ~~10~~8 to ~~19~~15, 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~~25. The method of claim ~~29~~24, wherein applying the microneedle array comprises inserting the microneedles into a first surface of the subject.

~~31~~26. The method of claim ~~30~~25, 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~~27. The method of any one of claims ~~29~~24 to ~~31~~26, 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~~28. The method of any one of claims ~~29~~24 to ~~32~~27, 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.