

removing portions of the nanowire layer to create the desired patterned (subtractive patterning). Selective removal is often accomplished either by wet chemical etching or laser ablation. In both cases, one can be limited both by the width of the substrate that can be processed, which is typically less than 30" wide, and by the throughput, which is typically on the order of 1-10 ft/min or less. Also, both etching and laser ablation patterning can present certain process control challenges, related to management of chemical kinetic or photolytic phenomena. As such, a method of subtractive patterning a nanowire layer that does not require etching or laser ablation is needed.

FIRST EMBODIMENT:

The inventors have determined that a patterning process can be performed by the following sequence of steps: Coating a substrate with a conductive layer such as a nanowire layer. Optionally hardening or curing the nanowire layer. Applying a pattern on the nanowire layer with a resist matrix material to generate on the substrate one or more first regions of exposed nanowire layer and one or more second regions of the resist matrix material (typically a circuit pattern for a touch screen). Hardening or curing the resist matrix material. Over coating the pattern with a strippable polymer layer. Hardening or curing the strippable polymer layer. Peeling the strippable polymer layer from the substrate, removing the nanowire material in one or more first regions of the substrate and thereby forming a patterned nanowire layer. In another approach, the nanowire material can be replaced with a conductive polymer such as PEDOT and the same process used to pattern the conductive PEDOT layer.

The strippable polymer layer not only provides for efficient production of the necessary conductive patterns over a relatively wide and continuous, indefinite length of substrate thereby allowing the formation of multiple touch screens at a time, it can also be left in place after over coating to provide protection for the nanowire layer. The strippable polymer layer keeps the underlying conductive layer such as a nanowire layer clean, dust free, and protected from scratches (important attributes for a touch screen) during storage and transport. The strippable polymer layer can then be removed just before the next processing step(s) and wound into a roll and recycled.

In the first embodiment, the disclosure provide a method of forming a patterned conductive layer on a substrate including the steps of: coating a substrate with a conductive layer; applying a pattern on the conductive layer with a liquid resist matrix material to generate on the substrate one or more first regions of exposed conductive layer and one or more second regions of resist matrix material; hardening or curing the liquid resist matrix material; over coating the pattern with a strippable polymer layer; hardening or curing the strippable polymer layer; peeling the strippable polymer layer from the substrate, removing the exposed conductive layer from the substrate in the one or more first regions of the substrate, and thereby forming a patterned conductive layer on the substrate.

SECOND EMBODIMENT:

The inventors have determined that a patterning process can also be performed by the following sequence of steps: Coating a substrate with a conductive layer such as a nanowire layer. Optionally hardening or curing the nanowire layer. Applying a pattern on the nanowire layer with a strippable polymer material to generate on the substrate one or more first regions of exposed nanowire layer and one or more second regions of the strippable polymer material (typically the complement of a circuit pattern for a touch screen). Hardening or curing the strippable polymer material. Peeling the strippable polymer layer from the substrate, removing the nanowire layer in one or more second regions of the substrate and thereby forming a patterned nanowire layer. In another approach, the nanowire material can be replaced with a conductive polymer such as PEDOT and the same process used to pattern the conductive PEDOT layer.

Peeling the strippable polymer layer from the substrate can be achieved in one embodiment by first applying a liner to the pattern of strippable polymer material, for example with a liner having a pressure sensitive adhesive thereon, followed by peeling. In such case, the adhesive is contacted to the strippable polymer material, forming a bond with the strippable polymer material, allowing the peeling (separating) liner to separate the strippable polymer material and its underlying nanowire layer from the substrate.

The disclosure provide a method of forming a patterned conductive layer on a substrate including the steps of: coating a substrate with a conductive layer; applying a pattern on the conductive layer with a strippable polymer ~~layer-forming liquid-forming layer~~ to generate on the substrate one or more first regions of exposed conductive layer and one or more second regions covered with the strippable polymer ~~layer-forming liquid-forming layer~~; hardening or curing the strippable polymer ~~layer-forming liquid-forming layer~~ into a strippable polymer layer; and peeling the strippable polymer layer from the substrate and removing portions of the conductive layer in the one or more second regions of the substrate, and thereby forming a patterned conductive layer on the substrate.

In other embodiments, the patterned transparent conductive layer on a substrate can be used as a component of a touch screen device, the patterned transparent conductor comprising: a transparent substrate; a patterned conductive layer on a major surface of the substrate; a patterned resist matrix material layer attached to the patterned conductive layer having a wavy top surface; and an optically clear adhesive layer applied over the wavy top surface and the major surface of the transparent substrate. In further exemplary embodiments, a touch screen device, for example a cellular telephone, an electronic book, a tablet computer, a computer display, or a television display; incorporates the touch screen component.

Additional exemplary embodiments of the disclosure are described in the following Listing of Exemplary Embodiments:

LISTING OF EXEMPLARY EMBODIMENTS:

- A. A method of patterning a conductive layer on a substrate, comprising:
 - coating a substrate with a conductive layer;
 - applying a pattern on the conductive layer with a liquid resist matrix material to generate on the substrate one or more first regions of exposed conductive layer and one or more second regions of resist matrix material;
 - hardening or curing the liquid resist matrix material;
 - over coating the pattern with a strippable polymer layer;
 - hardening or curing the strippable polymer layer;
 - peeling the strippable polymer layer from the substrate, removing the exposed conductive layer from the substrate in the one or more first regions of the substrate, and thereby forming a patterned conductive layer on the substrate.
- B. The method according to embodiment A, wherein the conductive layer comprises nanowires.
- C. The method according to embodiment A or B, wherein over coating the pattern with the strippable polymer layer comprises over coating the one or more first regions and the one or more second regions with a strippable polymer layer-forming liquid.
- D. The method according to embodiment C, wherein the strippable polymer layer-forming liquid contacts between 50% to 99% of the exposed conductive layer in the one or more first regions.
- E. The method according to embodiment C or D, wherein the strippable polymer layer-forming liquid is selected from the group consisting of polymer solution, monomer, monomer solution, and polymer melt.
- F. The method according to embodiment E, wherein the strippable polymer layer-forming liquid comprises a polymer solution and over coating includes slot coating, roll coating, flood coating, notch bar coating, or spraying.
- G. The method according to any one of embodiments C, D, E or F, wherein the strippable polymer layer-forming liquid exhibits a viscosity between 10 and 2,500 cps (0.01-2.5 Pa-s).
- H. The method according to any one of embodiments C, D, E, F, or G, wherein the strippable polymer layer-forming liquid comprises PVA, an aliphatic polyester-polyurethane copolymer, an ethylene-acrylic acid copolymer, or a combination thereof.
- I. The method according to embodiment E, wherein the strippable polymer layer-forming liquid comprises a polymer melt and over coating includes thermal compression lamination.
- J. The method according to embodiment I, wherein the strippable polymer layer-forming liquid exhibits a viscosity of between 10,000 and 100,000,000 cps (10 and 100 Pa-s).
- K. The method according to any one of embodiments C-J, wherein the strippable polymer layer-forming liquid exhibits a yield stress.
- L. The method according to any one of embodiments C-K, wherein the strippable polymer layer-forming liquid exhibits a yield stress less than 100 Pa.

- M. The method according to any one of embodiments C-L, wherein the strippable polymer layer-forming liquid is deposited in a pattern over the first and second regions.
- N. The method according to embodiment M, wherein the patterned strippable polymer layer-forming liquid is deposited using flexographic, gravure, ink-jet, or screen printing
- O. The method according to embodiment N, wherein the patterned strippable polymer layer-forming liquid covers between 50 and 99% of the first and second regions.
- P. The method according to any one of embodiments C-O, wherein the resist matrix material contains an ultraviolet curable material.
- Q. The method according to any one of embodiments C-P, wherein the strippable polymer layer is from 2 μm to 100 μm thick.
- R. The method according to any one of embodiments C-Q, comprising applying an optically clear overlayer over the patterned resist matrix material after removing the strippable polymer layer.
- S. The method according to any one of embodiments C-R, wherein the resist matrix material comprises a thickness between 50 nanometers and 50 micrometers.
- T. The method according to any one of embodiments C-S, wherein the resist matrix material comprises an index of refraction of between 1.40 – 1.70.
- U. The method according to any preceding embodiment, further comprising coating a lead-forming conductive layer over at least one portion of the patterned conductive layer.
- V. The method according to embodiment U, wherein the step of coating the lead-forming conductive layer occurs after the peeling the strippable polymer layer from the substrate.
- W. The method according to any one of embodiments U or V, wherein the pattern of the resist matrix material includes interconnect pads, and wherein the lead forming conductive layer is coated above the interconnect pads with the lead-forming conductive layer contacting the patterned conductive layer along its exposed perimeter.
- X. The method according to any one of embodiments U, V or W, wherein the interconnect pads are patterned so as increase the length of the exposed perimeter.
- Y. The method according to any one of embodiments U, V, W or X, wherein at least one of a void space or a corrugated outer margin is used to increase the length of the exposed perimeter.
- Z. The method according to any one of embodiments U, V, W, X or Y, wherein the lead-forming conductive layer is an ink comprising silver particles.
- AA. A method of patterning a conductive layer on a substrate, comprising:
 - coating a substrate with a conductive layer;
 - applying a pattern on the conductive layer with a strippable polymer layer-forming liquid-forming layer to generate on the substrate one or more first regions of exposed conductive layer and one or more second regions covered with the strippable polymer layer-forming liquid-forming layer;
 - hardening or curing the strippable polymer layer-forming liquid-forming layer into a strippable polymer layer; and

Claims

1. A method of patterning a conductive layer on a substrate, comprising:
coating a substrate with a conductive layer;
5 applying a pattern on the conductive layer with a liquid resist matrix material to generate on the substrate one or more first regions of exposed conductive layer and one or more second regions of resist matrix material;
hardening or curing the liquid resist matrix material;
over coating the pattern with a strippable polymer layer;
10 hardening or curing the strippable polymer layer;
peeling the strippable polymer layer from the substrate, removing the exposed conductive layer from the substrate in the one or more first regions of the substrate, and thereby forming a patterned conductive layer on the substrate.
- 15 2. The method according to claim 1 wherein the conductive layer comprises nanowires.
3. The method according to claim 1 or 2 wherein over coating the pattern with the strippable polymer layer comprises over coating the one or more first regions and the one or more second regions with a strippable polymer layer-forming liquid.
- 20 4. The method according to claim 3 wherein the strippable polymer layer-forming liquid contacts between 50% to 99% of the exposed conductive layer in the one or more first regions.
- 25 5. The method according to claim 3 or 4, wherein the strippable polymer layer-forming liquid is selected from the group consisting of polymer solution, monomer, monomer solution, and polymer melt.
- 30 6. The method according to claim 5, wherein the strippable polymer layer-forming liquid comprises a polymer solution and over coating includes slot coating, roll coating, flood coating, notch bar coating, or spraying.
7. The method according to any one of claims 3, 4, 5 or 6 wherein the strippable polymer layer-forming liquid comprises a viscosity between 10 and 2,500 cps (0.01 and 2.5 Pa-s).
- 35 8. The method according to any one of claims 3, 4, 5, 6, or 7 wherein the strippable polymer layer-forming liquid comprises PVA.

9. The method according to claim 5 wherein the strippable polymer layer-forming liquid comprises a polymer melt and over coating includes thermal compression lamination.
- 5 10. The method according to claim 9 wherein the strippable polymer layer-forming liquid comprises a viscosity of between 10,000 and 100,000,000 cps (between 10 Pa-s and 100 kPa-s).
- 10 11. The method according to claim 3 wherein the strippable polymer layer-forming liquid comprises a yield stress.
12. The method according to claim 3 wherein the strippable polymer layer-forming liquid comprises a yield stress less than 100 Pa.
- 15 13. The method according to claim 3 wherein the strippable polymer layer-forming liquid is deposited in a pattern over the first and second regions.
14. The method according to claim 13 wherein the patterned strippable polymer layer-forming liquid is deposited using flexographic, gravure, ink-jet, or screen printing.
- 20 15. The method according to claim 14 wherein the patterned strippable polymer layer-forming liquid covers between 50% and 99% of the first and second regions.
- 25 16. The method according to claim 1 wherein the liquid resist matrix material contains an ultraviolet curable material.
17. The method according to claim 1 wherein the strippable polymer layer is from 2 μm to 100 μm thick.
- 30 18. The method according to claim 1 comprising applying an optically clear overlayer over the patterned resist matrix material after removing the strippable polymer layer.
19. The method according to claim 1 wherein the liquid resist matrix material comprises a thickness between 50 nanometers and 50 micrometers.
- 35 20. The method according to claim 1 wherein the liquid resist matrix material comprises an index of refraction of between 1.40 – 1.70.

21. The method of any preceding claim, further comprising coating a lead-forming conductive layer over at least one portion of the patterned conductive layer.
22. The method of claim 21, wherein the step of coating the lead-forming conductive layer occurs after the peeling the strippable polymer layer from the substrate.
23. The method according to claim 21 wherein the pattern of the liquid resist matrix material includes interconnect pads, and wherein the lead forming conductive layer is coated above the interconnect pads with the lead-forming conductive layer contacting the patterned conductive layer along its exposed perimeter.
24. The method according to claim 23 wherein the interconnect pads are patterned so as increase the length of the exposed perimeter.
25. The method according to claim 24 wherein at least one of a void space or a corrugated outer margin is used to increase the length of the exposed perimeter.
26. The method according to claim 21 wherein the lead-forming conductive layer is an ink comprising silver particles.
27. A method of patterning a conductive layer on a substrate, comprising:
coating a substrate with a conductive layer;
applying a pattern on the conductive layer with a strippable polymer layer-forming liquid-forming layer to generate on the substrate one or more first regions of exposed conductive layer and one or more second regions covered with the strippable polymer layer-forming liquid-forming layer;
hardening or curing the strippable polymer layer-forming liquid-forming layer into a strippable polymer layer; and
peeling the strippable polymer layer from the substrate and removing portions of the conductive layer in the one or more second regions of the substrate, and thereby forming a patterned conductive layer on the substrate.
28. The method of claim 27 wherein the conductive layer comprises nanowires.
29. The method of claim 27 wherein peeling the strippable polymer layer comprises contacting the strippable polymer layer with a pressure sensitive adhesive surface of a liner and then removing the liner from the substrate.

30. — A component of a touch screen having a patterned transparent conductor comprising:
a transparent substrate;
a patterned conductive layer on a major surface of the substrate;
a patterned resist matrix material layer attached to the patterned conductive layer, the
5 patterned resist matrix material having a wavy top surface; and
an optically clear adhesive layer applied over the wavy top surface and the major surface of
the transparent substrate.

31. — The component according to claim 30 wherein the resist matrix material is an ultraviolet
10 curable varnish.

32. — The component according to claim 30 or 31 wherein the patterned resist matrix material has a
thickness between 50 nanometers and 50 micrometers.

33. — The component according to any one of claims 30, 31 or 32 wherein the patterned resist
15 matrix material has an index of refraction of between 1.40 — 1.70.

34. — The component according to any one of claims 30-33, wherein the patterned conductive layer
is comprised of a plurality of electrically conductive circuit traces, wherein at least a first
20 portion of the electrically conductive circuit traces are electrically isolated from at least a
second portion of the electrically conductive circuit traces.

35. — The component according to claim 34, wherein the plurality of electrically conductive circuit
25 traces is comprised of a plurality of metal nanowires.

36. — The component according to any one of claims 34 or 35, wherein the plurality of electrically
conductive circuit traces is arranged in an array pattern or a grid pattern.

37. — The component according to any one of claims 34-36, wherein each of the plurality of
30 electrically conductive circuit traces is separated from an adjacent electrically conductive
circuit trace by a gap of at least 1 micrometer, and no more than 10,000 micrometers.

38. — The component according to claim 37, wherein the gap is at least 30 micrometers, and no
35 more than 300 micrometers.

39. — The component according to any one of claims 34-38, wherein each of the plurality of
electrically conductive circuit traces has a width from 1 micrometer to 1,000 micrometers.

40. — ~~The component according to claim 39, wherein each of the plurality of electrically conductive circuit traces has a width from 10 micrometers to 100 micrometers.~~

41. — ~~The component according to any one of claims 34-40, wherein the patterned resist matrix material on the patterned conductive layer is comprised of a plurality of hemispherical ridges, each individual hemispherical ridge substantially overlaying a single corresponding electrically conductive circuit trace selected from the plurality of electrically conductive circuit traces, thereby forming the wavy top surface of the patterned resist matrix material.~~

42. — ~~The component according to any one of claims 30-41, wherein the patterned resist matrix material layer is attached to the patterned conductive layer by adhesion between the patterned resist matrix material layer and the patterned conductive layer, optionally wherein an optically clear adhesive exhibiting a refractive index difference relative to a refractive index of the patterned resist matrix material layer of 0.05 or less is positioned between the patterned resist matrix material layer and the patterned conductive layer.~~

43. — ~~A touch screen device incorporating the component according to any one of claims 30-42.~~

44. — ~~The touch screen device of claim 43, selected from the group consisting of a cellular telephone, an electronic book, a tablet computer, a computer display, or a television display.~~