patterned conductive patterned layers. However, precise registration between adjacent layers to form vias in a multi-layer construction can be difficult, time-consuming and expensive.

SUMMARY

[0007] To reliably manufacture electronic touch screen devices in a roll-to-roll process using printing processes such as, for example ink-jet, gravure, flexographic, or screen printing, reliable techniques for forming vias between non-adjacent conductive nanowire (NW) layers can reduce defects and lower product costs.

[0008] In general, the present disclosure relates to a self-forming via that can be easily created and reliably maintained during the application and registration of multiple printed conductive nanowire layers separated by insulating layers. In general, the present disclosure relates to a method for patterning an overcoat layer on a transparent conductive surface, wherein the conductive surface is on a conductive layer including nanowires. The conductive layer is disposed on a flexible substrate. In the method a patterned layer of a low surface energy material is formed in a first region of the conductive surface, with a second region remaining uncoated by the patterned layer. When a layer of a liquid overcoat composition is coated over the first and the second regions, the difference in the wettability of the first region relative to that of the second region destabilizes the layer of the liquid overcoat composition and causes the liquid overcoat composition to dewet from the low surface energy material and withdraw from the patterned layer. A first amount of the liquid overcoat composition recedes from the edges of the patterned layer and a collects in a first portion of the second region of the conductive surface. A second residual amount, which is smaller than the first amount, remains in a second portion of the second region of the conductive surface adjacent to the edges of the patterned. When the liquid overcoat composition is cured to form an overcoat layer, a via created in the second portion of the second region of the conductive surface can be utilized as an access point to form an electrical connection to the conductive surface. Using the via, an electrical connection can be formed with the conductive surface by various techniques such as, for example, applying a conductive paste in the via, or by directly bonding an electronic connection to the conductive surface in the via.

[0009] In some embodiments, the overcoat layer can act as a further substrate onto which another low surface energy pattern can be created and a further overcoat solution coated, or the overcoat layer can be removed as necessary. Third and subsequent patterned layers can be formed by repeating a similar surface wettability modification technique, but the via formed on the conductive surface by the initial low surface energy pattern remains in registration as the additional layers are added, and continues to provide a path for electrical connection to the conductive surface.

[0010] In one aspect, the present disclosure is directed to a composite article, including a conductive layer on at least a portion of a flexible substrate, wherein the substrate is a multi-layer optical film, wherein the conductive layer includes nanowires, and wherein the conductive layer has a conductive surface. A patterned layer of a low surface energy material is on a first region of the conductive surface. An overcoat layer free of conductive particulates is on a

first portion of a second region of the conductive surface unoccupied by the patterned layer. A via is in a second portion of the second region of the conductive surface between an edge of the patterned layer of the low surface energy material and the overcoat layer; and a conductive material in the via provides an electrical connection to the conductive surface.

[0011] In another aspect, the present disclosure is directed to a composite article including a conductive layer on at least a portion of a flexible substrate, wherein the conductive layer includes nanowires, and wherein the conductive layer has a conductive surface. A patterned conductive layer is on a first region of the conductive surface, wherein a second region of the conductive surface is uncovered by the patterned conductive layer; and a patterned low surface energy layer on a first portion of the patterned conductive layer, wherein a second portion of the patterned conductive layer is uncovered by the patterned low surface energy layer. An overcoat layer free of conductive particulates is on the second region of the conductive surface, and a via is between the overcoat layer and first portion of the patterned conductive layer, wherein the via overlies the second portion of the patterned conductive layer. A conductive material in the via provides an electrical connection to the patterned conductive layer and the conductive surface.

[0012] In yet another aspect, the present disclosure is directed to a method of forming a composite article, including: coating a patterned layer of a low surface energy material onto a first region of a conductive surface disposed on a flexible substrate, wherein the substrate is a multi-layer optical film, wherein the conductive surface includes nanowires, and wherein a second region of the conductive surface remains uncovered by the patterned layer; coating a layer of a liquid overcoat composition over the patterned layer of the low energy material and the second regions of the conductive surface, wherein the liquid overcoat composition has a surface energy different from the surface energy of the low surface energy material; de-wetting the liquid overcoat composition from the patterned layer of the low surface energy material such that the liquid overcoat composition withdraws from the patterned layer of the low surface energy material and a first amount of the liquid overcoat composition collects in a first portion of the second region of the conductive surface, wherein the liquid overcoat composition recedes from an edge of the patterned layer of the low surface energy material such that a second residual amount of the liquid overcoat composition less than the first amount remains in a second portion of the second region of the conductive surface adjacent to the edge of the patterned layer of the low surface energy material; curing the liquid overcoat composition to form a discontinuous overcoat layer in the first portion of the second region of the conductive surface and a via in the second portion of the second region of the conductive surface, wherein the via is adjacent to the edge of the patterned layer of the low surface energy material; and electrically contacting the conductive surface through the via.

[0013] In yet another aspect, the present disclosure is directed to a method of forming a composite article, including: coating a first patterned layer of a conductive material on a first region of a conductive surface on a conductive layer disposed on a flexible substrate, wherein the conductive surface includes nanowires, and wherein a second region of the conductive surface is uncoated by the first patterned layer of the conductive material; coating a second patterned layer of a low surface energy material on a first

CLAIMS:

1. A composite article, comprising:

a conductive layer on at least a portion of a flexible substrate, wherein the substrate is a multi-layer optical film, wherein the conductive layer comprises nanowires, and wherein the conductive layer comprises a conductive surface;

a patterned layer on a first region of the conductive surface, wherein the patterned layer comprises a low surface energy material;

an overcoat layer on a first portion of a second region of the conductive surface unoccupied by the patterned layer, wherein the overcoat layer is free of conductive particulates;

a via in a second portion of the second region of the conductive surface between an edge of the patterned layer of the low surface energy material and the overcoat layer; and

a conductive material in the via, wherein the conductive material provides an electrical connection to the conductive surface.

2. The composite article according to claim 1, wherein the via is uncovered by the overcoat layer.

3. The composite article according to claim 1, wherein the via is covered by the overcoat layer, and wherein the overcoat layer in the via has a thickness of no more than about 250 nm.

4. The composite article according to claim 1, wherein the via is covered by the overcoat layer, and wherein the overcoat layer in the via has a thickness of no more than about 100 nm.

5. The composite article according to any of claims 1 to 4, wherein the conductive material is selected from conductive adhesives, conductive pastes, and solder.

6. A composite article, comprising:

a conductive layer on at least a portion of a flexible substrate, wherein the conductive layer comprises nanowires, and wherein the conductive layer comprises a conductive surface;

a patterned conductive layer on a first region of the conductive surface, wherein a second region of the conductive surface is uncovered by the patterned conductive layer;

a patterned low surface energy layer on a first portion of the patterned conductive layer, wherein a second portion of the patterned conductive layer is uncovered by the patterned low surface energy layer;

an overcoat layer on the second region of the conductive surface, wherein the overcoat layer is free of conductive particulates;

a via between the overcoat layer and first portion of the patterned conductive layer, wherein the via overlies the second portion of the patterned conductive layer; and

a conductive material in the via, wherein the conductive material provides an electrical connection to the patterned conductive layer and the conductive surface.

7. The composite article according to claim 6, wherein the via is uncovered by the overcoat layer.

8. The composite article according to claim 6, wherein the via is covered by the overcoat layer, and wherein the overcoat layer in the via has a thickness of no more than about 250 nm.

9. The composite article according to claim 6, wherein the via is covered by the overcoat layer, and wherein the overcoat layer in the via has a thickness of no more than about 100 nm.

10. The composite article according to any of claims 6 to 9, wherein the substrate is an optical element.

11. The composite article according to any of claims 6 to 10, wherein the conductive material is selected from conductive adhesives, conductive pastes, and solder.

12. A touch screen display comprising:

a liquid crystal display;

a composite article according to any of claims 1 to 11; and

a flexible transparent surface overlying the electronic assembly.

13. A method of forming a composite article, comprising:

coating a patterned layer comprising a low surface energy material onto a first region of a conductive surface disposed on a flexible substrate, wherein the substrate is a multi-layer optical film, wherein the conductive surface comprises nanowires, and wherein a second region of the conductive surface remains uncovered by the patterned layer;

coating a layer of a liquid overcoat composition over the patterned layer of the low energy material and the second regions of the conductive surface, wherein the liquid overcoat composition has a surface energy different from the surface energy of the low surface energy material;

de-wetting the liquid overcoat composition from the patterned layer of the low surface energy material such that the liquid overcoat composition withdraws from the patterned layer of the low surface energy material and a first amount of the liquid overcoat composition collects in a first portion of the second region of the conductive surface, wherein the liquid overcoat composition recedes from an edge of the patterned layer of the low surface energy material such that a second residual amount of the liquid overcoat composition less than the first amount remains in a second portion of the second region of the conductive surface adjacent to the edge of the patterned layer of the low surface energy material;

curing the liquid overcoat composition to form a discontinuous overcoat layer in the first portion of the second region of the conductive surface and a via in the second portion of the second region of the conductive surface, wherein the via is adjacent to the edge of the patterned layer of the low surface energy material; and

electrically contacting the conductive surface through the via.

14. The method according to claim 13, wherein the via is uncovered by the overcoat layer.

15. The method according to claim 13, wherein the via is covered by the overcoat layer, and wherein the overcoat layer in the via has a thickness of no more than about 250 nm.

16. The method according to claim 13, wherein the via is covered by the overcoat layer, and wherein the overcoat layer in the via has a thickness of no more than about 100 nm.

17. The method according to claim 13, wherein the overcoat layer is free of electrically conductive particulates.

18. A method of forming a composite article, comprising:

coating a first patterned layer of a conductive material on a first region of a conductive surface on a conductive layer disposed on a flexible substrate, wherein the conductive surface comprises nanowires, and wherein a second region of the conductive surface is uncoated by the first patterned layer of the conductive material;

coating a second patterned layer of a low surface energy material on a first portion of the first patterned layer of the conductive material, wherein a second portion of the first patterned layer is uncoated by the second patterned layer;

coating a layer of a liquid overcoat composition onto the first and the second regions of the conductive surface, wherein the liquid overcoat composition has a surface energy greater than the surface energy of the low surface energy material in the second patterned layer;

de-wetting the liquid overcoat composition from the second patterned layer of the low surface energy material such that a first amount of the liquid overcoat composition withdraws from the second patterned layer and collects in the second region of the conductive surface, and wherein a second amount of the liquid overcoat composition less than the first amount remains in the second portion of the first patterned layer of the conductive material;

curing the liquid overcoat composition to form a discontinuous overcoat layer in the second region of the conductive surface, wherein the overcoat layer is separated from the second patterned layer by a via overlying the second portion of the first patterned layer; and

electrically contacting the second portion of the first patterned layer through the via.

19. The method according to claim 18, wherein the via is uncovered by the overcoat layer.

20. The method according to claim 18, wherein the via is covered by the overcoat layer, and wherein the overcoat layer in the via has a thickness of no more than about 250 nm.

21. The method according to claim 18, wherein the via is covered by the overcoat layer, and wherein the overcoat layer in the via has a thickness of no more than about 100 nm.

22. The method according to claim 18, wherein the overcoat layer is free of electrically conductive particulates.