CLAIMS

1. A transparent conductor including:

a substrate; and

a conductive network on the substrate, the conductive network comprising a plurality of metallic nanostructures; wherein the transparent conductor has a contrast ratio of greater than 1000.

2. The transparent conductor of claim 1 wherein the metallic nanostructures are metal nanowires, metal nanotubes, or a combination thereof.

3. The transparent conductor of claim 1 wherein the contrast ratio is greater than 3000.

4. The transparent conductor of claim 1 wherein the contrast ration is greater than 5000.

5. The transparent conductor of claim 1 having a light transmission of greater than 85%.

6. The transparent conductor of claim 1 having a light transmission of greater than 90%.

7. The transparent conductor of claim 1 having a light transmission of greater than 95%.

8. The transparent conductor of claim 1 having a surface resistivity of less than 1000 Ω/□.

9. The transparent conductor of claim 8 having a surface resistivity of less than 500 Ω/□.

10. The transparent conductor of claim 8 having a surface resistivity of less than 100 Ω/□.

11. The transparent conductor of claim 1 wherein the surface resistivity of the conductive layer is between 50 Ω/□ and 400 Ω/□.

12. The transparent conductor of claim 1 wherein the transparent conductor has a haze of less than 5%.

13. The transparent conductor of claim 1 wherein the transparent conductor has a haze of less than 1%.

14. The transparent conductor of claim 1 wherein the nanostructures are gold nanotubes.

15. The transparent conductor of claim 1 wherein the nanostructures are alloy or bimetallic nanotubes.

16. The transparent conductor of claim 15 wherein the nanostructures are gold/silver alloy or bimetallic nanotubes.

17. The transparent conductor of claim 1 wherein the nanostructures are oxidized nanotubes or oxidized nanowires.

18. The transparent conductor of claim 1 further comprising an overcoat over the conductive network.

19. The transparent conductor of claim 18 wherein baking the transparent conductor up to at least 100 °C for up to 1 hour changes the surface resistivity of the transparent conductor less than 1%.

20. The transparent conductor of claim 18 wherein baking the transparent conductor up to at least 200 °C for up to 1.5 hours changes the surface resistivity of the transparent conductor less than 1%.

21. The transparent conductor of claim 18 wherein exposing the transparent conductor to a 4% solution of KOH for up to 5 minutes changes the surface resistivity of the film by no more than 5%.

22. The transparent conductor of claim 18 wherein exposing the transparent conductor to a 5% solution of TMAH for up to 5 minutes changes the surface resistivity of the film by less than 1%.

23. The transparent conductor of claim 18 wherein exposing the transparent conductor to IPA for up to 30 minutes changes the surface resistivity of the film by less than 1%.

24. The transparent conductor of claim 18 wherein exposing the transparent conductor to NMP for up to 30 minutes changes the surface resistivity of the film by less than 1%.

25. A composition comprising:

a solvent;

a viscosity modifier;

a surfactant; and

a plurality of metal nanotubes wherein the percentage by weight of nanotubes is from 0.05% to 1.4%.

26. The composition of claim 25 wherein the solvent is water, an alcohol, a ketone, an ether, an hydrocarbon or an aromatic solvent.

27. The composition of claim 25 wherein the viscosity modifier is hydroxypropyl methyl cellulose (HPMC), methyl cellulose, xanthan gum, polyvinyl alcohol, carboxy methyl cellulose, or hydroxyl ethyl cellulose.

28. The composition of claim 25 wherein the surfactant is Zonyl® FSN, Zonyl® FSO, Zonyl® FFA, Zonyl® FSH, Triton, Dynol, n-Dodecyl-β-D-maltoside, or Novek®.

29. A composition comprising:

a solvent;

a viscosity modifier;

a surfactant; and

a plurality of metal nanotubes, wherein the ratio of the surfactant to the viscosity modifier is in the range of about 80 to about 0.01.

30. The composition of claim 29 wherein the ratio of the viscosity modifier to the metal nanotubes is in the range of about 5 to about 0.000625.

31. The composition of claim 29 wherein the ratio of the metal nanotubes to the surfactant is in the range of about 560 to about 5.

32. The composition of claim 29 having a viscosity of between 1 and 100 cP.

33. A process comprising:

forming template nanostructures of a first type of metallic material;

plating each of the template nanostructure with a plating metal of a second type of metallic material to form plated template nanostructures;

etching the template nanostructures to form hollow nanostructures of the plating metal; and

depositing the hollow nanostructures on a substrate to form a conductive network.

34. The process of claim 33 further comprising, after depositing, aligning substantially all of the hollow nanostructures along their respective longitudinal axes.

35. The process of claim 34 wherein the depositing comprises depositing and orienting a first population of the hollow nanostructures along a first direction, and depositing and orienting a second population of the hollow nanostructures along a second direction, the first direction and the second direction being orthogonal to one another.

36. The process of claim 33 wherein the plating is carried out by electroplating, electro-less plating or metal-metal displacement.

37. The process of claim 33 wherein the etching is carried out electrochemically or chemically.

38. The process of claim 33 wherein the plating is carried out by electro-less plating and the etching is carried out chemically in a solution phase.

39. The process of claim 33 wherein the conductive network has a contrast ratio of higher than 1000.

40. The process of claim 33 wherein the conductive network has a surface resistivity of no more than 500Ω/□.

41. The process of claim 33 wherein the conductive network is optically transparent.

42. The process of claim 33 wherein the template nanostructures are anisotropic nanostructures.

43. The process of claim 42 wherein the hollow nanostructure has a wall thickness that is less than a diameter of the template nanostructure.

44. The process of claim 42 wherein the template nanostructures are metallic nanowires.

45. The process of claim 44 wherein the template nanostructures are silver nanowires.

46. The process of claim 44 wherein the silver nanowires are about 30-80nm in diameters.

47. The process of claim 44 wherein the plating metal is gold, palladium, nickel, or platinum.

48. The process of claim 47 wherein the plating metal is gold and the hollow nanostructures are gold nanotubes

49. The process of claim 47 wherein the nanotubes are 10-20nm thick.

50. The process of claim 33 further comprising forming an overcoat on the conductive network.

51. A transparent conductor formed by the process of claim 33.

CLAIMS

1. A transparent conductor including:

a substrate; and

a conductive network on the substrate, the conductive network comprising a plurality of metallic nanostructures; wherein the transparent conductor has a contrast ratio of greater than 1000, wherein the metallic nanostructures are metal nanowires, metal nanotubes, or a combination thereof.

2. The transparent conductor of claim 1 wherein the contrast ratio is greater than 3000.

3. The transparent conductor of claim 1 wherein the contrast ration is greater than 5000.

4. The transparent conductor of claim 1 having a light transmission of greater than 85%.

5. The transparent conductor of claim 1 having a light transmission of greater than 90%.

6. The transparent conductor of claim 1 having a light transmission of greater than 95%.

7. The transparent conductor of claim 1 having a surface resistivity of less than 1000 Ω/□.

8. The transparent conductor of claim 7 having a surface resistivity of less than 500 Ω/□.

9. The transparent conductor of claim 7 having a surface resistivity of less than 100 Ω/□.

10. The transparent conductor of claim 1 having a surface resistivity between 50 Ω/□ and 400 Ω/□.

11. The transparent conductor of claim 1 wherein the transparent conductor has a haze of less than 5%.

12. The transparent conductor of claim 1 wherein the transparent conductor has a haze of less than 1%.

13. The transparent conductor of claim 1 wherein the nanostructures are gold nanotubes.

14. The transparent conductor of claim 1 wherein the nanostructures are alloy or bimetallic nanotubes.

15. The transparent conductor of claim 14 wherein the nanostructures are gold/silver alloy or bimetallic nanotubes.

16. The transparent conductor of claim 1 wherein the metallic nanostructures are oxidized nanotubes comprising metal oxide or oxidized nanowires comprising metal oxide.

17. The transparent conductor of claim 1 further comprising an overcoat over the conductive network, wherein the overcoat is

(a) a synthetic polymer selected from the group consisting of polyacrylics, epoxy, polyurethanes, polysilanes, silicones, poly(silico-acrylic) and siloxanes, or

(b) an anti-glare material selected from the group consisting of polystyrene/PMMA blend, lacquer comprising butyl acetate, nitrocellulose, wax and alkyd resin, polythiophenes,

polypyrroles, polyurethane, nitrocellulose, and acrylates, all of which may further comprise a light diffusing material such as colloidal or fumed silica,

(c) a protective film of polyester, polyethylene terephthalate (PET), polybutylene terephthalate, polymethyl methacrylate (PMMA), acrylic resin, polycarbonate (PC), polystyrene, triacetate (TAC), polyvinyl alcohol, polyvinyl chloride, polyvinylidene chloride, polyethylene, ethylene-vinyl acetate copolymers, polyvinyl butyral, metal ion-crosslinked ethylene-methacrylic acid copolymers, polyurethane, cellophane, or polyolefins.

18. The transparent conductor of claim 17 wherein baking the transparent conductor up to at least 100 °C for up to 1 hour changes the surface resistivity of the transparent conductor less than 1%.

19. The transparent conductor of claim 17 wherein baking the transparent conductor up to at least 200 °C for up to 1.5 hours changes the surface resistivity of the transparent conductor less than 1%.

20. The transparent conductor of claim 17 wherein exposing the transparent conductor to a 4% solution of KOH for up to 5 minutes changes the surface resistivity of the transparent conductor by no more than 5%.

21. The transparent conductor of claim 17 wherein exposing the transparent conductor to a 5% solution of TMAH for up to 5 minutes changes the surface resistivity of the transparent conductor by less than 1%.

22. The transparent conductor of claim 17 wherein exposing the transparent conductor to IPA for up to 30 minutes changes the surface resistivity of the transparent conductor by less than 1%.

23. The transparent conductor of claim 17 wherein exposing the transparent conductor to NMP for up to 30 minutes changes the surface resistivity of the transparent conductor by less than 1%.