[0024] FIG. 5 is a graph illustrating the expected overall resistivity as a function of the diameters of nanowires.

[0025] FIG. 6 shows an SEM image of a single silver nanowires connecting between two metal contacts.

[0026] FIG. 7 illustrates a network of filamentous proteins that function as biological templates for a transparent conductor.

[0027] FIG. 8 illustrates a protein scaffold coupled to conductive particles via various binding sites.

[0028] FIG. 9 illustrates the formation of a conductive network of biological templates based on the coupling of associate peptides.

[0029] FIG. 10A illustrates schematically an embodiment of a metal nanowires-based transparent conductor.

[0030] FIG. 10B illustrates schematically another embodiment of a metal nanowires-based transparent conductor.

[0031] FIG. 10C shows schematically a further embodiment of a metal nanowire based transparent conductor in which portions of the nanowires are exposed on a surface of the transparent conductor.

[0032] FIG. 10D shows an SEM image of silver nanowires protruding out of a surface of the transparent conductor.

[0033] FIG. 10E illustrates schematically another embodiment of a metal nanowires-based transparent conductor.

[0034] FIG. 11 illustrates schematically a further embodiment of a metal nanowires-based transparent conductor having a multi-layer structure.

[0035] FIG. 12 shows a transparent conductor structure having a reservoir for delivering a vapor phase inhibitor (VPI).

[0036] FIGS. 13A-13D show an example of a fabrication process of a transparent conductor.

[0037] FIG. 14A shows an example of a fabrication process of a transparent conductor by web coating.

[0038] FIG. 14B shows another example of a fabrication process of a transparent conductor by web coating.

[0039] FIG. 15A shows a web coating system and a flow process for fabricating a transparent conductor.

[0040] FIG. 15B shows an SEM image of a conductive layer following a post-treatment of pressure application.

[0041] FIGS. 16A-16C show an example of a lamination process.

[0042] FIGS. 17A-17C show another example of a lamination process.

[0043] FIG. 18 shows an example of photo-patterning a conductive layer.

[0044] FIGS. 19A-19B show an example of a continuous photo-patterning method suitable for a web coating process.

[0045] FIG. 20 shows a partial system and a process of fabricating a patterned transparent conductor.

[0046] FIG. 21 shows a display device comprising transparent electrodes based on metal nanowires.

[0047] FIG. 22 shows a touch screen device comprising two transparent conductors based on metal nanowires.

[0048] FIG. 23 shows a typical release profile of H_2S gas from freshly cooked egg yolks.

[0049] FIG. 24A shows the light transmissions of six samples of conductive films before and after an accelerated H_2S corrosion test.

[0050] FIG. 24B shows the resistances of six samples of conductive films before and after an accelerated H_2S corrosion test.

[0051] FIG. 24C shows the hazes of six samples of conductive films before and after an accelerated H_2S corrosion test.

[0052] FIG. 25A shows an example of directly patterning a nanowire-based transparent conductive film.

[0053] FIG. 25B shows photographs of the patterned conductive films before and after an adhesive tape treatment.

[0054] FIGS. 26A-26F show photographs of the patterned conductive films before and after an adhesive tape treatment at various levels of magnification.

[0055] FIGS. 27A-27D show photographs of another exemplary conductive film before and after a solvent treatment.

DETAILED DESCRIPTION

[0056] Certain embodiments are directed to a transparent conductor based on a conductive layer of nanowires. In particular, the conductive layer includes a sparse network of metal nanowires. In addition, the conductive layer is transparent, flexible and can include at least one surface that is conductive. It can be coated or laminated on a variety of substrates, including flexible and rigid substrates. The conductive layer can also form part of a composite structure including a matrix material and the nanowires. The matrix material can typically impart certain chemical, mechanical and optical properties to the composite structure. Other embodiments describe methods of fabricating and patterning the conductive layer.

Conductive Nanowires

[0057] FIG. 1 illustrates a nanowire 2 having an aspect ratio equal to the length L_1 divided by the diameter d_1. Suitable nanowires typically have aspect ratios in the range of 10 to 100,000. Larger aspect ratios can be favored for obtaining a transparent conductor layer since they may enable more efficient conductive networks to be formed while permitting lower overall density of wires for a high transparency. In other words, when conductive nanowires with high aspect ratios are used, the density of the nanowires that achieves a conductive network can be low enough that the conductive network is substantially transparent.

[0058] One method to define the transparency of a layer to light is by its absorption coefficient. The illumination of light passing through a layer can be defined as:

$$I=I_o e^{-ax}$$

in which I_o is the incoming light on a first side of the layer, I is the illumination level that is present on a second side of the layer, and e^{-ax} is the transparency factor. In the transparency factor, a is the absorption coefficient and x is the thickness of the layer. A layer having a transparency factor near 1, but less than 1 can be considered to be substantially transparent.

[0059] FIGS. 2-5 illustrate some of the optical and electrical characteristics of the conductive nanowires.

[0060] FIG. 2 shows a theoretical model of the light absorption of silver nanoellipsoids at various wavelengths of light. Depending on widths and lengths, silver nanoellipsoids exhibit a high extinction coefficient to a narrow band of light in the wavelengths between 400 and 440 nanometers and to wavelengths of light above 700 nm. However, they are substantially transparent between about 440 to about 700 nm, which falls in the visible range.

[0061] FIG. 3 shows the absorption spectrum of a layer of silver nanowires deposited on a polyethylene terephthalate (PET) substrate. As shown by the absorption profile, the silver nanowire layer on PET substrate is substantially transparent between about 440 nm to 700 nm, agreeing with the results of the theoretical model shown in FIG. 2.

[0062] FIGS. 4 and 5 show the results of theoretical modeling of the resistivity of metal nanowires based on their diameters. For a larger diameter of nanowire, the resistivity decreases substantially although it will absorb more light. As