

matrix formation. A photo-curable matrix material **618** comprising a mixture of prepolymers was coated over the network layer **600** within the area **614**. A mask **620** was placed upon the holders **610**. The mask **620** was a glass slide having a number of dark lines **624** of about 500  $\mu\text{m}$  wide. The matrix material was then irradiated under a Dymax 5000 lamp for 90 seconds. The matrix material cured in the regions exposed to light and remained liquid in the regions that were masked by the dark lines.

**[0268]** As shown in FIG. 25B, conductive film **630** was obtained after the photo-patterning described above. The lighter regions **634** were exposed to UV irradiation and the dark regions **638** were masked from the light exposure. Conductive film **640** was further subjected to an adhesive tape or a tacky roll to remove the matrix material and the nanowires in uncured regions **644**. As shown, the contrast between the uncured regions **644** and the cured regions **644** was pronounced. Following the adhesive tape treatment, the concentration of the nanowires dropped below the percolation threshold in the uncured regions **644**. Electrical measurements using fine probe tips showed that the uncured regions **644** were non-conductive.

**[0269]** FIGS. 26A-F show a photo-patterned conductive layer at higher magnifications. FIG. 26A shows the conductive film **640** immediately after photo-curing (5 $\times$ ). FIG. 26B shows the conductive film **640** after the adhesive tape treatment (5 $\times$ ), in which the cured region **648** appears much lighter than the uncured region **644**. At higher magnification (FIGS. 26C and 26D, 20 $\times$ ), it can be observed that the uncured region **644** has a lower concentration of nanowires than the cured region **648**. This contrast is more apparent in FIGS. 26E and 26F (100 $\times$ ).

**[0270]** As an alternative to removing the matrix material and nanowires in the uncured region using adhesive tapes or tacky rolls, a solvent may be used to wash the uncured regions. As shown in FIGS. 27A-D, a conductive film **700** was prepared as described above and exposed to UV irradiation through a brass aperture mask. FIG. 27A shows cured regions (conductive regions) **710** and uncured regions **720** after being washed with ethanol and wiped. FIGS. 27B-D illustrate, at increasing magnifications, the contrast of the nanowire concentration in the uncured regions **720** compared to that in the cured regions **710**. In the uncured regions **720**, most of the uncured matrix material and the silver nanowires had been removed by the ethanol washing. Photo-patterning therefore produces conductive regions and non-conductive region according to a predetermined pattern.

#### Example 7

##### Photo-Curable Formulations

**[0271]** The matrix material described in Example 6 can be formulated by combining an acrylate monomer (or prepolymer, as defined herein), a multi-functional acrylate monomer (or prepolymer) and at least one photoinitiator. Any acrylate monomers or prepolymers can be used, such as epoxy acrylates, more specifically, 2-ethylhexyl acrylate, 2-phenoxyethyl acrylate, lauryl acrylate, methacrylates, and the like. Any multi-functional acrylate monomer (or prepolymer) can be used to promote the formation of a crosslinking polymer network. Examples include trimethylolpropane triacrylate (TMPTA), tripropylene glycol diacrylate, bisphenol-A diacrylate, propoxylated (3) trimethylolpropane triacrylate, dipentaerythritol penta-acrylate. Any photoinitiator, for

example, ketone based initiators, can be used. Specific examples include: Ciba Irgacure 754, phenyl ketone such as Ciba Irgacure 184,  $\alpha$ -hydroxy ketones, glyoxylates, benzophenone,  $\alpha$ -amino ketones and the like. More specifically, a fast-curing formulation can be prepared by combining 60%-70% 2-ethylhexyl acrylate, 15%-30% trimethylolpropane triacrylate and about 5% Ciba Irgacure 754.

**[0272]** Other additives can be added to enhance the stability and/or promote the adhesion of the matrix and the nanowires. For example, an adhesion promoter (e.g., silanes) that promotes the coupling between organic matter and inorganic matter can be used. Examples of the silane-type adhesion promoters include GE Silquest A174, GE Silquest A1100 and the like. Antioxidants such as Ciba Irgonox 1010ff, Ciba Irgonox 245, Irgonox 1035 can be used. Moreover, additional or co-initiators can be used to promote the efficiency of the photoinitiator. Examples of coinitiator can include any types of tertiary amine acrylates, such as Sartomer CN373, CN371, CN384, CN386 and the like. An additional photoinitiator such as Ciba Irgacure OXE01 can be further added.

**[0273]** Below are four exemplary photo-curable formulations suitable as the matrix material used in this example:

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##### Formulation 1

75% 2-ethylhexyl acrylate;  
20% trimethylolpropane triacrylate (TMPTA);  
1% adhesion promoter (GE Silquest A1100);  
0.1% antioxidant (Ciba Irgonox 1010ff) and  
4% photoinitiator (Ciba Irgacure 754)

##### Formulation 2

73.9% 2-ethylhexyl acrylate;  
20% trimethylolpropane triacrylate (TMPTA);  
1% adhesion promoter (GE Silquest A1100);  
0.05% antioxidant (Ciba Irgonox 1010ff) and  
5% photoinitiator (Ciba Irgacure 754)

##### Formulation 3

73.1% tripropylene glycol diacrylate (TPGDA)  
22.0% trimethylolpropane triacrylate (TMPTA)  
4.9% photoinitiator (Ciba Irgacure 754)  
0.03% antioxidant (4-methoxyphenol)

##### Formulation 4

68% 2-ethylhexyl acrylate;  
20% trimethylolpropane triacrylate (TMPTA);  
1% adhesion promoter (GE Silquest A1100);  
0.1% antioxidant (Ciba Irgonox 1010ff) and  
5% photoinitiator I (Ciba Irgacure 754)  
5% coinitiator (Sartomer CN373)  
1% photoinitiator II (Ciba Irgacure OXE01)

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#### Example 8

##### Nanowire Dispersion

**[0274]** A nanowire dispersion, or ink, was formulated by combining about 0.08% wt. HPMC, about 0.36% wt. silver nanowires, about 0.005% wt. Zonyl® FSO-100 and about 99.555% wt. water. As an initial step, an HPMC stock solution was prepared. An amount of water equal to about  $\frac{3}{8}$  of the total desired volume of nanowire dispersion was placed in a beaker and heated to between 80° C. and 85° C. on a hotplate. Enough HPMC to make 0.5% wt. HPMC solution was added to the water and the hotplate was turned off. The HPMC and water mixture was stirred to disperse the HPMC. The remainder of the total amount of water was chilled on ice and then