

POSITIVE WORKING PHOTODEFINABLE RESIN COATED METAL FOR
MASS PRODUCTION OF MICROVIAS IN MULTILAYER PRINTED WIRING
5 BOARDS

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of copending provisional application 60/044,327
10 filed April 16, 1997.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

15 The present invention pertains to the production of printed circuit boards. More particularly, the invention concerns the production of high density, built-up multilayer circuit boards by constructing microvias with positive working photoimageable dielectric materials.

20 DESCRIPTION OF THE PRIOR ART

Due to the growth of faster, smaller, less expensive integrated circuit products, the ability to wire-bond has reached the limit of the available technology and chips must be mounted using a flip-chip approach. This leads to a direct chip attachment package. The requirement to fan-out the high number of I/O's from the underside of the chip
25 places increasing demands on the utilization of the printed circuit board area. Plated-through-holes use too much space and block routing channels. This drives the need for a high density package with a significant number of interconnections on the outer surface of the board, as well as for increasing use of blind microvias.

Resin coated copper (RCC) has been used to fabricate high density built-up multilayer circuit boards. Currently microvias in such circuit boards fabricated with RCC are produced by two methods, including plasma etching and laser drilling. As such, only printed circuit fabricators with access to plasma etching or laser drilling equipment can provide these advanced, blind-via boards. The high cost of the plasma and laser equipment hinders widespread adoption of RCC technology. In addition, the technical disadvantages associated with the plasma etching and laser drilling techniques, such as undercutting due to isotropic etching of plasma, and low throughput due to sequential drilling by laser, also limit large scale commercialization of RCC based high density multilayer circuit boards.

Photovia processes, which use photoimageable dielectric materials to fabricate built-up multilayer printed circuit boards have been developed. In these processes, photodielectrics are coated onto a patterned core and photoimaged to define via holes. The via holes along with the surface of the dielectric layer are then plated with copper. U.S. patent 5,354,593 sequentially laminates and photoimages two photodielectrics onto a conductive core to define via holes and then copper plates the via holes. U.S. Patent 5,451,721 produces a multilayer printed circuit board by applying a photosensitive resin layer onto a core having metal lines on its surface. After imaging to form via holes, the resin layer is deposited with a copper layer by electroless plating techniques. U.S. Patent 5,334,487 produces a patterned layer on a substrate by applying and exposing different photosensitive compositions onto opposite sides of a copper foil. One side is developed and the copper etched, followed by developing the other side and metallization of through holes. The photovia technologies allow for fabrication of high density interconnection printed circuit boards with conventional equipment but they suffer from similar drawbacks such as difficult copper plating processes and poor resin-to-copper adhesion. These problems usually lead to poor reliability of the circuit boards. These problems are solved by the present invention whereby a positive photosensitive dielectric composition on a conductive foil is laminated onto conductive lines on a substrate. After imaging the foil, and imaging

and curing the photosensitive dielectric composition, vias are formed to the conductive lines. Thereafter the conductive lines are connected through the vias to the conductive foil, and then the conductive foil is patterned.

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SUMMARY OF THE INVENTION

The invention provides a process for producing a printed circuit board which comprises:

- (a) attaching a photosensitive element onto a pattern of conductive lines on the surface of a substrate; which photosensitive element comprises a positive working
10 photosensitive dielectric composition on a surface of a conductive foil, such that the photosensitive dielectric composition is positioned on the conductive lines;
- (b) applying a layer of a photoresist onto an opposite surface of said foil;
- (c) imagewise exposing the photoresist to actinic radiation and developing the photoresist to thereby form imagewise removed and imagewise nonremoved portions
15 of the photoresist such that the imagewise removed portions are above at least some conductive lines;
- (d) removing the portions of the conductive foil underlying the imagewise removed portions of the photoresist without removing the underlying photosensitive dielectric composition;
- 20 (e) overall exposing the photosensitive dielectric composition to actinic radiation through the removed portions of the conductive foil; optionally heating the photosensitive dielectric composition to reduce developer solubility of the nonexposed portions thereof; developing the photosensitive dielectric material to thereby remove only the portions of the photosensitive dielectric composition underlying the removed
25 portions of the conductive foil, thereby forming vias to the conductive lines;
- (f) curing the nonremoved portions of the photosensitive dielectric composition;
- (g) electrically connecting the conductive lines through the vias to a part of the conductive foil; and
- (h) patterning the conductive foil to thereby produce a pattern of conductive foil lines.

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The invention also provides a process for producing a printed circuit board in which step (a) above comprises the steps of applying a layer of a positive working photosensitive dielectric composition onto a surface of a conductive foil thereby forming a photosensitive element and then attaching the photosensitive element via the photosensitive dielectric composition onto a pattern of conductive lines on the surface of a substrate such that the photosensitive dielectric composition is positioned on the conductive lines.

The invention further provides a process for producing a printed circuit board which comprises:

- (a) attaching a photosensitive element onto a pattern of conductive lines on the surface of a substrate; which photosensitive element comprises a positive working photosensitive dielectric composition on a surface of a conductive foil, such that the photosensitive dielectric composition is positioned on the conductive lines;
- (b) removing the conductive foil;
- (c) imagewise exposing a portion of the photosensitive dielectric composition to actinic radiation; optionally heating the photosensitive dielectric composition to reduce developer solubility of the nonexposed portions thereof; and developing the dielectric composition to thereby form imagewise removed and imagewise nonremoved portions of the dielectric composition such that the imagewise removed portions are above at least some conductive lines;
- (d) curing the nonremoved portions of the photosensitive dielectric composition;
- (e) simultaneously forming an electrically conductive layer on the nonremoved portions of the dielectric composition and electrically connecting the conductive lines through the vias to the electrically conductive layer; and
- (f) patterning the electrically conductive layer to thereby produce a pattern of conductive lines.

The invention still further provides a process for producing a printed circuit board in which step (a) in the preceding paragraph comprises the steps of applying a layer of a

positive working photosensitive dielectric composition onto a surface of a conductive foil thereby forming a photosensitive element and then attaching the photosensitive element via the photosensitive dielectric composition onto a pattern of conductive lines on the surface of a substrate such that the photosensitive dielectric composition is
5 positioned on the conductive lines.

By the process of the invention microvias are produced by using positive acting photosensitive resin coated metals such as copper. This product and process allows a substantial reduction in the cost of printed circuit board fabrication process as
10 compared to plasma or laser drilling techniques. The photomicrovia technology also avoids the technical barriers associated with the plasma and laser drilling methods such as undercutting due to isotropic etching of plasma and low throughput due to sequential drilling by laser. This invention permits easy copper plating and better copper-to-resin adhesion compared to existing photovia technologies.

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BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a schematic view of a photosensitive element according to the invention laminated to a substrate having metallic lines.

20 Figure 2 shows a post lamination view of a photosensitive element positioned on the substrate and after a photoresist is applied to the opposite side of the photographic element.

Figure 3 shows the structure of Figure 3 after photoresist removal and foil imaging.

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Figure 4 shows the structure of Figure 3 after an imaging of the dielectric composition.

Figure 5 shows the structure of Figure 4 after removal of the exposed areas of the dielectric composition to form vias.

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Figure 6 shows the structure of Figure 5 after plating the vias and providing an electrical connection between the conductive lines and the conductive foil.

Figure 7 shows another embodiment of the invention where the photosensitive element according to the invention laminated to a printed substrate having metallic lines and the entire conductive foil removed.

Figure 8 shows the structure of Figure 7 after an imaging of the dielectric composition.

Figure 9 shows the structure of Figure 8 after removal of the exposed areas of the dielectric composition to form vias.

Figure 10 shows the structure of Figure 9 after plating the vias and the top of the dielectric composition to provide a conductive top surface.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

One performs the process of the invention by employing a photosensitive element which comprises a positive working photosensitive dielectric composition applied onto a surface of a conductive foil. The positive working photosensitive dielectric composition is one which is suitable for use as a permanent dielectric in electronic circuits.

Suitable conductive foils include copper, copper alloys, aluminum, aluminum alloy, and the like, however, copper foils are most preferred.

Suitable positive working photosensitive dielectric compositions nonexclusively include a positive acting, photoimageable composition which is produced by admixing a photoacid generator capable of generating an acid upon exposure to actinic radiation, an organic acid anhydride monomer or polymer, at least one epoxy, a nitrogen-containing curing catalyst, and an optional phenol-containing monomer or polymer.

The photoacid generator used herein is one which generates an acid upon exposure to actinic radiation such as ultraviolet radiation. Photoacid generators are known in the photoimaging art and include, but are not limited to, onium compounds such as aryl
5 derivatives of sulfonium, iodonium and diazonium salts, and organic compounds with photolabile halogen atoms.

Preferred photoacid generators include triarylsulfonium and diaryliodonium salts with hexafluorophosphate, hexafluoroantimonate, hexafluoroarsenate, and tetrafluoroborate
10 anions. Non-limiting examples of suitable iodonium salts are salts of diphenyliodonium, dinaphthylidonium, di(4-chlorophenyl)iodonium, tolyl(dodecylphenyl)iodonium, naphthylphenyliodonium, 4-(tri-fluoromethylphenyl)phenyliodonium, 4-ethylphenyl-phenyliodonium, di(4-acetylphenyl)iodonium, tolylphenyliodonium, 4-butoxyphenylphenyliodonium, di(4-phenylphenyl)iodonium, and the like. Di-phenyliodonium salts are preferred. Non-limiting examples of suitable sulfonium salts are salts of triphenylsulfonium, dimethylphenylsulfonium, tritolylsulfonium, di(methoxynaphthyl)methylsulfonium, dimethylnaphthylsulfonium, 4-butoxyphenyldiphenylsulfonium, and 4-acetoxy-phenyldiphenylsulfonium. Tri-phenylsulfonium salts are preferred. Organic
15 compounds with photolabile halogen atoms include alpha-halo-p-nitrotoluenes, alpha-halomethyl-s-triazines, carbon tetrabromide, and the like. These acid generators may be used singly or in combination of two or more thereof.

The photoacid generator component is preferably present in an amount of from about 0.05
25 % to about 20% of the total weight of the nonsolvent parts of the composition, more preferably from about 0.2 % to about 10%, and most preferably from about 0.5 % to about 5% by weight of the nonsolvent parts of the composition.

The composition then contains an organic acid anhydride monomer or polymer
30 component. Suitable acid anhydrides are anhydride functional polymers, having a

number average molecular weight of from about 500 to about 50,000, preferably from about 1,000 to about 10,000. Nonlimiting examples of suitable anhydrides include styrene-maleic anhydride, styrene-alkyl methacrylate-itaconic anhydride, methyl methacrylate-butyl acrylate-itaconic anhydride, butyl acrylate-styrene-maleic
5 anhydride, and the like. Preferred are styrene-maleic anhydride polymers with styrene to maleic anhydride molar ratio of from about 1:1 to about 3:1. Also suitable are dodecenyl succinic anhydride, trimellitic anhydride, chloroendic anhydride, phthalic anhydride, methylhexahydrophthalic anhydride, 1-methyl tetrahydrophthalic anhydride, hexahydrophthalic anhydride, methylnadic anhydride, methylbutenyltetrahydrophthalic
10 anhydride, benzophenone tetracarboxylic dianhydride, methylcyclohexenedicarboxylic anhydride. These acid anhydrides may be used singly or in combination of two or more thereof.

This anhydride component is preferably present in the composition in an amount of from
15 about 10 % to about 90 %, more preferably from about 20 % to about 80 % and most preferably from about 35 % to about 65 % by weight of the nonsolvent parts of the composition.

The composition then contains an epoxy component. The epoxy may vary in the
20 structure of their backbones and substituent groups as well as in molecular weights, equivalent epoxy weights (EEW) and in the number of epoxy groups per molecule. Suitable epoxies have number average molecular weights ranging from about 100 to about 20,000, preferably from about 200 to about 5,000 and have an EEW of from about 50 to about 10,000, preferably from about 100 to about 2,500, and have an
25 average number of epoxy groups per molecule of from about 1 to about 40, preferably from about 2 to about 10.

Particularly suitable epoxy resins include, for example, the diglycidyl ethers of resorcinol, catechol, hydroquinone, biphenol, bisphenol A, bisphenol F, bisphenol K,
30 tetrabromobisphenol A, phenol-formaldehyde novolac resins, alkyl substituted phenol-

formaldehyde resins, phenol-hydroxybenzaldehyde resins, cresol-hydroxybenzaldehyde resins, dicyclopentadiene-phenol resins, dicyclopentadiene-substituted phenol resins tetramethylbiphenol, tetramethyl-tetrabromobiphenol, any combination thereof and the like. Also suitable are the alkylene oxide adducts of compounds of more than one
5 aromatic hydroxyl group per molecule such as the ethylene oxide, propylene oxide, or butylene oxide adducts of dihydroxy phenols, biphenols, bisphenols, halogenated bisphenols, alkylated bisphenols, trisphenols, phenol-aldehyde novolac resins, halogenated phenol-aldehyde novolac resins, alkylated phenolaldehyde novolac resins, phenol-hydroxybenzaldehyde resins, cresol-hydroxybenzaldehyde resins, any
10 combination thereof and the like. Also suitable are the glycidyl ethers of compounds having an average of more than one aliphatic hydroxyl group per molecule such as aliphatic polyols and polyether polyols. Non-limiting examples include polyglycidyl ethers of polyethylene glycols, polypropylene glycols, glycerol, polyglycerols, trimethylolpropane, butanediol, sorbitol, pentaerythritol, and combinations thereof.

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The epoxy component is preferably present in an amount of from about 10 % to about 90 %, more preferably from about 20 % to about 80 % and most preferably from about 35 % to about 65 % by weight of the nonsolvent parts of the composition. The molar ratio of epoxy to anhydride is preferably from 0.1 to 10, more preferably 0.2 to 5, most
20 preferably 0.5 to 2.0.

The composition then contains a nitrogen containing catalyst which catalyzes the curing between the epoxy and anhydride and optional phenolic. Preferred catalysts are secondary and tertiary amines as well as phosphines and arsines and blends thereof. Preferred
25 amine catalysts are imidazoles, for example, imidazole, benzimidazole, 2-methyl imidazole, 2-ethyl-4-methylimidazole; 1,2-dimethylimidazole; 2-hexylimidazole, 2-cyclohexylimidazole, 2-phenylimidazole, 2-phenyl-4-methylimidazole, 1-benzylimidazole, 1-ethyl-2-methylbenzimidazole, 2-methyl-5,6-benzimidazole, 1-vinylimidazole, 1-allyl-2-methylimidazole, 2-cyanoimidazole, 2-chloroimidazole, 2-
30 bromoimidazole, 1-(2-hydroxypropyl)-2-methylimidazole, 2-phenyl-4,5-

dimethylolimidazole, 2-phenyl-4-methyl-5-hydroxymethylimidazole. 2-chloromethylbenzimidazole, 2-hydroxybenzimidazole. 2-ethyl-4-methyl imidazole; 2-cyclohexyl-4-methyl imidazoles; 2-butoxy-4-allyl imidazole; 2-carboethoxybutyl, 4-methyl-imidazole, 2-methyl-4-mercaptoethyl imidazole, and 2-phenyl imidazole. More preferred are 1-methyl imidazole, 2-ethyl imidazole, 2-ethyl-4-methylimidazole, 2-phenylimidazole, 2-methyl-4-nitroimidazole, 4-methylimidazole. A more detailed description of the chemistry of the imidazoles and benzimidazoles including their properties and structural formulas is found in the book by Klaus Hofmann entitled *"Imidazole and Its Derivates"* published by Interscience Publishers, Inc., New York (1953).

Other preferred heterocyclic secondary and tertiary amines or nitrogen-containing compounds which can be employed herein include, for example, imidazolidines, imidazolines, oxazoles, pyrroles, thiazoles, pyridines, pyrazines, morpholines, pyridazines, pyrimidines, pyrrolidines, pyrazoles, quinoxalines, quinazolines, phthalazines, quinolines, purines, indazoles, indoles, indolazines, phenazines, phenarsazines, phenothiazines, pyrrolines, indolines, piperidines, piperazines and combinations thereof. Also suitable are other aliphatic cyclic amines such as 1,5-diazabicyclo[4.3.0]non-5-ene, 1,4-diazabicyclo[2.2.2]octane, 1,8-diazabicyclo[5.4.0]undec-7-ene. Also preferred are secondary and tertiary non-cyclic amines such as, for example, octyldimethylamine, tris-dimethylaminomethyl phenol, benzyldimethylamine, N,N-dimethylamine, triethylamine, trimethylamine, N,N,N',N'-tetramethylbutane-diamine, N,N,N',N'-tetramethylhexane-diamine, triisooctylamine, N,N-dimethyl aniline, triphenyl amine, and the like.

Suitable phosphines include, for example, triphenyl phosphine, trimethyl phosphine, tripropyl phosphine, tributyl phosphine, tripentyl phosphine, triheptyl phosphine, trioctyl phosphine, trinonyl phosphine, tridecyl phosphine, tridodecyl phosphine, bis(diphenylphosphino)-methane, 1,2-bis(diphenylphosphino)-ethane, 1,3-bis(diphenylphosphino)-propane, 1,2-bis(dimethylphosphino)-ethane, 1,3-

bis(dimethylphosphino)-propane, and combinations thereof. Suitable arsines include, for example, triphenyl arsine, tributyl arsine, and combinations thereof.

The catalyst amount is preferably present in an amount of from about 0.01 to about 5 10%, more preferably from about 0.02 to about 5%, and most preferably from about 0.05 to about 2% by weight of the nonsolvent parts of the composition.

The composition then contains an optional aromatic hydroxyl containing compounds such as a phenolic monomer or polymer or mixture thereof. Suitable aromatic hydroxyl 10 containing compounds which can be employed herein include, for example, compounds having an average of more than one phenolic hydroxyl group per molecule. Suitable such compounds include, for example, dihydroxy phenols, bi-phenols, bisphenols, halogenated bisphenols, alkylated bisphenols, trisphenols, phenol-aldehyde resins, halogenated phenol-aldehyde novolac resins, alkylated phenol-aldehyde novolac resins, 15 phenol-hydroxybenzaldehyde resins, alkylated phenol-hydroxybenzaldehyde resins, the ethylene oxide, propylene oxide, or butylene oxide adducts of dihydroxy phenols, biphenols, bisphenols, halogenated bisphenols, alkylated bisphenols, trisphenols, phenol-aldehyde novolac resins, halogenated phenol-aldehyde novolac resins, alkylated phenol-aldehyde novolac resins, cresol-aldehyde novolac resins, phenol- 20 hydroxybenzaldehyde resins, cresol-hydroxybenzaldehyde resins, vinyl phenol polymers, any combination thereof and the like.

When phenol containing compounds or polymers are used, it is preferably present in an amount of from about 1% to about 50%, more preferably from about 5% to about 25 40%, and most preferably from about 10% to about 30% based on the weight of the nonsolvent parts of the composition.

When phenol containing compounds or polymers are used, the catalyst amount is preferably from about 0.01 to about 10%, more preferably from about 0.02 to about

5%, and most preferably from about 0.05 to about 2% based on the weight of the nonsolvent parts of the composition.

When phenol containing compounds or polymers are used the photoacid amount is preferably from about 0.05 to about 20%, more preferably from about 0.2 to about 10%, and most preferably from about 0.5 to about 5% based on the weight of the nonsolvent parts of the overall composition.

When phenol containing compounds or polymers are used the epoxy is preferably from about 10% to about 90%, more preferably from about 20% to about 70%, and most preferably from about 30% to about 60 % based on the weight of the nonsolvent parts of the overall composition.

When phenol containing compounds or polymers are used the anhydride is preferably from about 10% to about 90%, more preferably from about 20% to about 70%, and most preferably from about 30% to about 60 % based on the weight of the nonsolvent parts of the overall composition.

When phenol containing compounds or polymers are used, the molar ratio of epoxy to combined anhydride and phenolic is from about 0.1 to about 10, more preferably from about 0.2 to about 5, and most preferably from about 0.5 to about 2.0. The molar ratio of anhydride to phenolic is from about 20 to about 0.5, preferably from about 10 to about 1.0.

Other additives that may be optionally included in the compositions of the invention are fillers, colorants such as dyes and pigments, surfactants, fire retardants, plasticizers, antioxidants and the like. Nonexclusive examples of colorants usable in the present invention are as follows: Permanent Yellow G (C.I. 21095), Permanent Yellow GR (C.I. 21100), Permanent Yellow DHG (C.I. 21090), Permanent Rubine L6B (C.I. 15850:1), Permanent Pink F3B (C.I. 12433), Hostaperm Pink E (73915), Hostaperm

Red Violet ER (C.I. 46500), Permanent Carmine FBB (12485), Hostaperm Blue B2G (C.I. 74160), Hostaperm Blue A2R (C.I. 74160), and Printex 25. Surfactants that may be used include, for example, nonylphenoxy poly(ethyleneoxy) ethanol; octylphenoxy ethanol at up to 10% by weight of the composition. Plasticizers which may be used
5 include, for example, phosphoric acid tri-(beta-chloroethyl)-ester; stearic acid; dicamphor; polypropylene; acetal resins; phenoxy resins; and alkyl resins at up to 10 % by weight of the composition. The plasticizer additives improve the coating properties of the material and enable the application of a film that is smooth and of uniform thickness to the substrate.

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The components of the photodielectric composition may be mixed in any suitable medium solvent and coated onto the conductive foil by any convenient means.
15 Solvents which can be used in preparing the photopolymerizable composition of this invention include alcohols such as methanol, ethanol, propanol and butanol; ketones such as acetone, methyl ethyl ketone, methyl isobutyl ketone, cyclohexanone, diisobutyl ketone, etc., esters such as ethyl acetate, butyl acetate, amyl acetate, methyl formate, ethyl propionate, dimethyl phthalate, ethyl benzoate and methyl Cellosolve
20 acetate; aromatic hydrocarbons such as toluene, xylene, benzene, ethylbenzene; halogenated hydrocarbons such as carbon tetrachloride, trichloroethylene, chloroform, 1,1,1-trichloroethane, 1,2-dichloroethane, monochlorobenzene, chloronaphthalene; ethers such as tetrahydrofuran, diethyl ethers ethylene glycol monoethyl ether acetate, ethylene glycol monomethyl ether, etc., dimethylformamide, dimethyl sulfoxide, etc.,
25 and mixtures thereof. The most preferred solvents are ethyleneglycol monomethylether, ethyleneglycol monoethylether and dimethyl formamide which dissolve the other components of the photographic coating. A suitable amount of the solvent which can be employed in the photopolymerizable composition of this invention ranges from about 20% to about 1,000%, preferably 50% to 500%, by
30 weight of the total non-solvent parts of the composition. The prepared

photodielectric composition is then coated on the foil substrate by well known techniques such as but not limited to spin coating, slot die coating, extruding, Meyer rod drawing, blade drawing, screen coating, curtain coating, dip coating, or spray coating. Once the photodielectric composition coating is applied to the substrate, the solvents are evaporated to yield a dry coating weight of from about 20 to about 200 g/m², more preferably from about 40 to about 150 g/m², and most preferably from about 50 to about 100 g/m². A protective film may optionally be attached to the photodielectric composition until it is ready for use. Suitable positive photodielectric resins may also be obtained commercially, for example, under the trade name of AZ-P4620 Clariant Corporation of Somerville, New Jersey.

As seen in Figure 1, the photosensitive element comprising the conductive foil 2 and photosensitive dielectric composition 4 is then attached onto a pattern of conductive lines 6 which is on the surface of a substrate 8. Suitable substrates include those which are well known in the art for producing printed circuit boards such as polyesters, polyimides, epoxies, cyanate ester, teflon and silicon. Each of the foregoing can be reinforced by glass fibers or organic polymeric fibers. The pattern of conductive lines may be a metal such as copper, copper alloys, aluminum, alloy, and the like, however, copper is most preferred. Within the context of the invention, the term metal lines includes electrical bonding pads. These may be produced by well known photolithographic and etching processes. Preferably the photosensitive element is attached to the metal lines and the substrate by means of lamination. That is, the photosensitive element and the substrate are passed through the nip of a set of heated rollers or a heated press in an laminating device with the temperature at about from about 90°C to about 150°C.

As seen in Figure 2, one then applies a layer of a photoresist 10 onto an opposite surface of foil 2. Notice that the dielectric composition layer 4 is now positioned both above and between the conductive lines 6. The photoresist may be positive working or negative working. Useful positive working photoresists include those compositions

described above as being useful for the photosensitive dielectric composition. Suitable positive working photoresists are well known in the art and may comprise a positive working o-quinone diazide radiation sensitizer. The o-quinone diazide sensitizers include the o-quinone-4-or-5-sulfonyl-diazides disclosed in U. S. Patents Nos.

5 2,797,213; 3,106,465; 3,148,983; 3,130,047; 3,201,329; 3,785,825; and 3,802,885.

When o-quinone diazides are used, preferred binding resins include a water insoluble, aqueous alkaline soluble or swellable binding resin, which is preferably a novolak. The production of novolak resins is well known in the art. A procedure for their manufacture is described in Chemistry and Application of Phenolic Resins, Knop A.

10 and Scheib, W.; Springer Verlag, New York, 1979 in Chapter 4 which is incorporated herein by reference. Suitable novolak resins are water insoluble, aqueous alkali soluble resins having a preferred molecular weight in the range of from about 6,000 to about 14,000, or more preferably from about 8,000 to about 12,000. The amount of the sensitizers and binder can be experimentally varied by one skilled in the art depending
15 on the desired product characteristics. The components are blended with a suitable solvent, such as those listed above, coated onto the conductive foil and dried. Suitable photoresist compositions are described in U.S. patent 4,588,670. Negative photoresists are also widely commercially available. Alternatively, the photoresist may be a dry film photoresist such as MacDermid Aqua Mer dry film photoresist.

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The photoresist is then imagewise exposed to actinic radiation. As used herein "actinic radiation" is defined as light in the visible, ultraviolet or infrared regions of the spectrum, as well as electron beam, ion or neutron beam or X-ray radiation. Actinic radiation may be in the form of incoherent light or coherent light, for example, light
25 from a laser. Sources of actinic light, and exposure procedures, times, wavelengths and intensities may vary widely depending on the desired degree of photo-reaction and other factors known to those of ordinary skill in the art. Such conventional photo-reaction processes and their operational parameters are well known in the art. Sources of actinic radiation and the wavelength of the radiation may vary widely, and any
30 conventional wavelengths and sources can be used. Exposure may be to ultraviolet

radiation, such as in the 300 to 550 nanometer range through a photographic mask or computer directed laser pattern and developed. Suitable UV light sources are carbon arc lamps, xenon arc lamps, mercury vapor lamps which may be doped with metal halides (metal halide lamps), fluorescent lamps, argon filament lamps, electronic flash
5 lamps and photographic floodlight lamps. Exposure is conducted to provide sufficient actinic energy to the element to permit a photochemical change in the image areas where the light sensitive composition is exposed through a mask and yet substantially prevent any photochemical change in the nonimage areas. The exposed photoresist is then developed to thereby form imagewise removed and imagewise nonremoved
10 portions of the photoresist such that the imagewise removed portions are above at least some conductive lines. Typical developer compositions can be alkaline or neutral in nature and have a pH range of from about 5 to about 12. Developers are preferably formed from aqueous solutions of hydroxides, phosphates, silicates metabisulfites and/or monoethanolamine. Such non-exclusively include alkali metal
15 hydroxide, mono-, di- and tri- alkali metal phosphate, sodium silicate, alkali metal metasilicate and alkali metabisulfite. The developers may also contain art recognized surfactants, buffers, solvents and other ingredients. Other developers can be composed of common organic solvents.

20 Next one removes the portions of the conductive foil underlying the imagewise removed portions of the photoresist without removing the underlying photosensitive dielectric composition. The conductive foil portion to be removed may be so removed by such known techniques as etching and laser ablation. Figure 3 shows the conductive foil with imagewise removed portion after removal of the balance of the
25 photoresist layer.

Next one imagewise exposes the underlying photosensitive dielectric composition to actinic radiation through the removed portions of the conductive foil in a manner described above using the conductive foil as a conformal mask. The exposed portions
30 12 of the dielectric layer are seen in Figure 4. Optionally the photosensitive dielectric

composition is heated to reduce developer solubility of the nonexposed portions thereof. Such may be at temperatures of from about 90 °C to about 170 °C for from about 1 minute to about 30 minutes. Thereafter the photosensitive dielectric composition is developed in a manner similar to that described above to thereby form
5 imagewise removed and imagewise nonremoved portions of the photosensitive dielectric composition such that the imagewise removed portions form vias 14 to the conductive lines 6 as seen in Figure 5.

The nonremoved portions of the photosensitive dielectric composition are then cured,
10 preferably thermally cured. Curing may be effected by heating at temperatures of from about 90 °C to about 250 °C for from about 10 minutes to about 120 minutes.

One then electrically connects the conductive lines through the vias to a part of the conductive foil. This is preferably done by plating a metal 16 through the vias from the
15 conductive lines 6 to a part of the conductive foil 2 as seen in Figure 6. Such may be done by performing an electroless metal plating through the vias from the conductive lines to a part of the conductive foil, optionally followed by performing a metal electroplating step, each of which steps are well known in the art. Optionally the vias may be filled by a conductive paste such as U-300 available from Epoxy Technology,
20 Inc. or organo-metallic compounds such Ormet available from Toranaga Technologies Inc. of Carlsbad, California. Thereafter the conductive foil is preferably patterned by means well known in the art to thereby produce a pattern of conductive foil lines.

Optionally the process steps may be repeated one or more times by attaching another photosensitive element onto the previously patterned conductive foil lines resulting from
25 the process as described above to form a multilayered structure. Optionally the entire process may be conducted one or more times on both sides of the substrate to provide a dual sided printed circuit board.

In another embodiment of the invention, the above photosensitive element is attached
30 onto a pattern of conductive lines 6 on the surface of a substrate 8 as previously

described in Figure 1. Thereafter, as seen in Figure 7, the entire conductive foil 2 is removed, such as by etching or laser ablation techniques leaving only the photosensitive dielectric composition 4 on and between the conductive lines 6 on the surface of a substrate 8. This preferably imparts a microroughened, matte surface to the photosensitive dielectric composition for better adhesion of later plated copper to the dielectric layer. As seen in Figure 8 and 9, the photosensitive dielectric composition 4 is then imagewise exposed to actinic radiation and developed to thereby form imagewise removed and imagewise nonremoved portions of the dielectric composition such that the imagewise removed portions are above at least some conductive lines thus forming vias 14 to the conductive lines 6. The nonremoved portions of the photosensitive dielectric composition are then cured. Then, as seen in Figure 10, an electrically conductive layer 18, such as copper, is formed on the dielectric composition, preferably by plating, and forms an electrical connection from the conductive lines 6 through the vias 16 to the electrically conductive layer 18. Thereafter the electrically conductive layer 18 is patterned by means well known in the art to produce a pattern of conductive lines from the electrically conductive layer material.

The following non-limiting examples serve to illustrate the invention.

EXAMPLE 1

A photosensitive resin was prepared by mixing, at room temperature and under yellow lights, two epoxy monomers, EPON 1001F by Shell Chemical Company at 8% by weight and Denacol EX-512 by Nagase Chemical at 16%, a styrene maleic anhydride oligomer, SMA 1000 by Elf Autochem Inc. at 24%, a photoacid, CD 1011 from Sartomer Company at 2.5%, 2-ethyl-4-methylimidazole (EMI) at 0.3%, and a solvent, methyl ethyl ketone (MEK) at 49.2%. This monomer mixture was coated on a copper foil substrate to a thickness of 50 to 100 μm . The coating was baked in a 90°C oven for 5 minutes to form a tack-free dry film. The photosensitive dry film backed by

copper foil prepared as above is laminated to a circuitized inner layer board by a hot roll laminator with the roll temperature at about 120°C. In the same step an additional layer of MacDermid Aqua Mer MP200 dry film photoresist is laminated on top of the copper foil. The ensemble is allowed to cool and the dry film photoresist is exposed to
5 UV light through an artwork which is primarily clear, with dark regions where vias are desired. The dry film photoresist is developed, exposing the copper foil where the vias will be created, underneath the areas that were covered by the dark regions of the mask. The exposed copper foil is then etched away using a cupric chloride etchant at 50°C. After rinsing and drying, the panel is exposed to UV at 1 J/cm². The exposed
10 panel is postbaked for 5 minutes at 140°C and, after cooling down, the panel is immersed in and sprayed with 10% monoethanolamine (MEA) aqueous solution at 50°C for 5 minutes to strip the dry film photoresist and develop the via holes of the photosensitive layer down to the copper pads in the next layer. The holes are desmeared with potassium permanganate, cleaned with conventional cleaning solutions,
15 rinsed, and dried. The panel is then baked at 170°C for 2 h to cure the dielectric layer. Following cure, the panel is plated with conventional electroless copper solutions followed by an additional electroplating of 1-2 mils of copper. Conductive vias between the two copper layers are thus formed. The outer layer circuitry is fabricated with conventional print and etch processes. A photoresist dry film is laminated onto
20 the copper plane and imaged through UV exposure and developing. The copper layer is etched with conventional copper etchants. After etching the photoresist film is stripped with conventional strippers and the panel cleaned with conventional cleaning solutions. The above process is repeated as many times as necessary to fabricate a printed wiring board having the desired number of build-up layers. The board is finally
25 finished with whatever additional layers such as solder mask, solder, electroless gold, etc. are desired.

EXAMPLE 2

A photosensitive resin was prepared by mixing, at room temperature and under yellow lights, two epoxy monomers, EPON 1163 by Shell Chemical Company at 16% by weight and Denacol EX-614B by Nagase Chemical at 8%, a styrene maleic anhydride oligomer, SMA 1000 by Elf Autochem Inc. at 24%, a photoacid, CD 1011 from Sartomer Company at 2%, 2-ethyl-4-methylimidazole (EMI) at 0.2%, and a solvent, methyl ethyl ketone (MEK) at 49.8%. This monomer mixture was coated on a copper foil substrate to a thickness of 50 to 100 μm . The coating was baked in a 90°C oven for 5 minutes to form a tack-free dry film. The photosensitive dry film backed by copper foil prepared as above is laminated to a circuitized inner layer board by a vacuum press at about 100°C. A MacDermid Aqua Mer MP200 dry film photoresist is laminated on top of the copper foil by a hot roll laminator at 115°C. The ensemble is allowed to cool and the dry film photoresist is exposed to UV light through an artwork which is primarily clear, with dark regions where vias are desired. The dry film photoresist is developed, exposing the copper foil where the vias will be created, underneath the areas that were covered by the dark regions of the mask. The exposed copper foil is then etched away using a cupric chloride etchant at 50°C. After rinsing and drying, the panel is exposed to UV at 1 J/cm². The exposed panel is postbaked for 5 minutes at 140°C and, after cooling down, the panel is immersed in and sprayed with 10% monoethanolamine (MEA) aqueous solution at 50°C for 5 minutes to strip the dry film photoresist and develop the via holes of the photosensitive layer down to the copper pads in the next layer. After cleaning, rinsing and drying the panel is baked at 170°C for 2 h to cure the dielectric layer. Following cure, the panel is plated with conventional electroless copper solutions followed by an additional electroplating of 1-2 mils of copper. Conductive vias between the two copper layers are thus formed.

The outer layer circuitry is fabricated with conventional print and etch processes. A photoresist dry film is laminated onto the copper plane and imaged through UV exposure and developing. The copper layer is etched with conventional copper etchants. After etching the photoresist film is stripped with conventional strippers and the panel cleaned with conventional cleaning solutions. The above process is repeated as many times as necessary to fabricate a printed wiring board having the desired

number of build-up layers. The board is finally finished with whatever additional layers such as solder mask, solder, electroless gold, etc. are desired.

EXAMPLE 3

- 5 A photosensitive resin was prepared by mixing, at room temperature and under yellow lights, one epoxy monomer, Denacol EX-512 by Nagase Chemical at 24%, a styrene maleic anhydride oligomer, SMA 1000 by Elf Autochem Inc. at 24%, a photoacid, CD 1011 from Sartomer Company at 2%, 2-ethyl-4-methylimidazole (EMI) at 0.2%, and a solvent, methyl ethyl ketone (MEK) at 49.8%. This monomer mixture was coated on
- 10 a glass substrate to a thickness of 50 to 100 μm . The coating was baked in a 90°C oven for 5 minutes to form a tack-free dry film. The photosensitive dry film backed by copper foil prepared as above is laminated to a circuitized inner layer board by a vacuum press at about 100°C. The copper foil is etched away using a cupric chloride etchant at 50°C. After rinsing and drying, the panel is exposed to UV through an
- 15 artwork with desired features at 1 J/cm². The exposed panel is postbaked for 5 minutes at 140°C and, after cooling down, developed with 10% monoethanolamine (MEA) aqueous solution at 50°C for about 3 minutes to extend the via holes of the photodielectric layer down to the copper pads in the next layer. After cleaning, rinsing and drying the panel is baked at 170°C for 2 hours to cure the dielectric layer .
- 20 Following cure, the panel is plated with conventional electroless copper solutions followed by an additional electroplating of 1-2 mils of copper. Conductive vias between the two copper layers are thus formed. The outer layer circuitry is fabricated with conventional print and etch processes. A photoresist dry film is laminated onto the copper plane and imaged through UV exposure and developing. The copper layer
- 25 is etched with conventional copper etchants. After etching the photoresist film is stripped with conventional strippers and the panel cleaned with conventional cleaning solutions. The above process is repeated as many times as necessary to fabricate a printed wiring board having the desired number of build-up layers. The board is finally
- 30 etc. are desired.

EXAMPLE 4

A photosensitive resin was prepared mixing, at room temperature and under yellow lights, two epoxy monomers, EPON 1001F by Shell Chemical Company at 8% by weight and Denacol EX-512 by Nagase Chemical at 16%, a styrene maleic anhydride oligomer, SMA 2000 by Elf Autochem Inc. at 24%, a photoacid, CD 1011 from Sartomer Company at 2%, 2-ethyl-4-methylimidazole (EMI) at 0.2%, and a solvent, methyl ethyl ketone (MEK) at 49.8%. This monomer mixture was coated on a glass substrate to a thickness of 50 to 100 μm . The coating was baked in a 90°C oven for 5 minutes to form a tack-free dry film. The photosensitive dry film backed by copper foil prepared as above is laminated to a circuitized inner layer board by a vacuum press at about 100°C. The copper foil is etched away using a cupric chloride etchant at 50°C. After rinsing and drying, the panel is exposed to UV through an artwork with clear areas where vias are desired with 1 J/cm². The exposed panel is postbaked for 5 minutes at 140°C and, after cooling down, developed with 10% monoethanolamine (MEA) aqueous solution at 50°C for about 3 minutes to extend the via holes of the photodielectric layer down to the copper pads in the next layer. After cleaning, rinsing and drying the panel is baked at 170°C for 2 h to cure the dielectric layer. Following cure, the panel is plated with conventional electroless copper plating solutions followed by a conventional electroplating of an additional 1 micron of copper. Conductive vias between the two copper layers are thus formed. Conventional dry-film photoresist is laminated onto the panel and exposed through a mask and developed using standard industry practices. The pattern on the mask is such as to leave photo-resist on the circuit wherever traces are not desired. Copper is now exposed only where circuitry is desired. An additional conventional electroplating step is now performed to increase the copper thickness an additional 1-2 mils in the exposed regions. The photoresist is stripped and 2 microns of copper are etched away everywhere and the panel cleaned with conventional cleaning solutions. This removes the thin copper layer that was beneath the photo-resist during the last plating step while leaving the bulk of much thicker copper that has just been plated up creating the

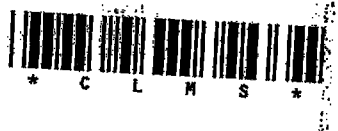
outer layer circuitry. The above process is repeated as many times as necessary to fabricate a printed wiring board having the desired number of build-up layers. The board is finished with whatever protective layers such as solder mask are desired.

- 5 From the above it can be seen that high density, built-up multilayer printed circuit boards can be produced by constructing microvias with positive working photoimageable dielectric materials.



What is claimed is:

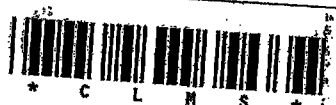
1. A process for producing a printed circuit board which comprises:
 - (a) attaching a photosensitive element onto a pattern of conductive lines on the surface of a substrate; which photosensitive element comprises a positive working
 - 5 photosensitive dielectric composition on a surface of a conductive foil, such that the photosensitive dielectric composition is positioned on the conductive lines;
 - (b) applying a layer of a photoresist onto an opposite surface of said foil;
 - (c) imagewise exposing the photoresist to actinic radiation; optionally heating the photosensitive dielectric composition to reduce developer solubility of the nonexposed
 - 10 portions thereof; and developing the photoresist to thereby form imagewise removed and imagewise nonremoved portions of the photoresist such that the imagewise removed portions are above at least some conductive lines;
 - (d) removing the portions of the conductive foil underlying the imagewise removed portions of the photoresist without removing the underlying photosensitive dielectric
 - 15 composition;
 - (e) overall exposing the photosensitive dielectric composition to actinic radiation through the removed portions of the conductive foil; optionally heating the photosensitive dielectric composition to reduce developer solubility of the nonexposed portions thereof; developing the photosensitive dielectric material to thereby remove
 - 20 only the portions of the photosensitive dielectric composition underlying the removed portions of the conductive foil, thereby forming vias to the conductive lines;
 - (f) curing the nonremoved portions of the photosensitive dielectric composition;
 - (g) electrically connecting the conductive lines through the vias to a part of the conductive foil; and
 - 25 (h) patterning the conductive foil to thereby produce a pattern of conductive foil lines.
2. The process of claim 1 further comprising repeating steps (a) through (h) at least once by attaching another photosensitive element according to step (a) onto the previously patterned conductive foil lines resulting from step (h).



3. The process of claim 1 wherein step (g) comprises plating a metal through the vias from the conductive lines to a part of the conductive foil.
4. The process of claim 1 wherein step (g) comprises performing an electroless metal
5 plating through the vias from the conductive lines to a part of the conductive foil.
5. The process of claim 1 wherein step (g) comprises performing an electroless metal plating through the vias from the conductive lines to a part of the conductive foil followed by performing a metal electroplating step.
- 10 6. The process of claim 1 wherein step (g) comprises filling the vias with a conductive paste or organometallic compound.
7. The process of claim 1 wherein step (f) is conducted by heating at a temperature of
15 from about 90° C to about 250° C.
8. The process of claim 1 wherein the foil comprises copper, copper alloys, aluminum or aluminum alloys.
- 20 9. The process of claim 1 wherein the conductive lines comprise copper, copper alloys, aluminum or aluminum alloys.
10. The process of claim 1 wherein the substrate comprises an insulating material.
- 25 11. The process of claim 1 wherein the photoresist is a negative working photosensitive composition.
12. The process of claim 1 wherein the photoresist is a positive working photosensitive composition.



13. The process of claim 1 wherein the substrate comprises a material selected from the group consisting of polyester, polyimide, epoxy, cyanate ester, silicon, gallium arsenide and teflon.
- 5 14. The process of claim 1 wherein the positive working photosensitive dielectric composition comprises at least one photoacid generator capable of generating an acid upon exposure to actinic radiation, at least one organic acid anhydride monomer or polymer, at least one epoxy, at least one nitrogen-containing curing catalyst, and an optional aromatic hydroxyl containing monomer, polymer or mixture thereof.
- 10 15. The process of claim 14 wherein the photoacid generator is an onium compound.
16. The process of claim 14 wherein the photoacid generator is selected from the group consisting of sulfonium compounds, iodonium compounds, diazonium
- 15 compounds, and organic compounds with photolabile halogen atoms, and mixtures thereof.
17. The process of claim 14 wherein the acid anhydride polymer has a number average molecular weight of from about 500 to about 50,000.
- 20 18. The process of claim 14 wherein the acid anhydride polymer is selected from the group consisting of styrene-maleic anhydride, styrene-alkyl methacrylate-itaconic anhydride, methyl methacrylate-butyl acrylate-itaconic anhydride, butyl acrylate-styrene-maleic anhydride, dodecenyl succinic anhydride, trimellitic anhydride,
- 25 chloroendic anhydride, phthalic anhydride, methylhexahydrophthalic anhydride, 1-methyl tetrahydrophthalic anhydride, hexahydrophthalic anhydride, methylnadic anhydride, methylbutenyltetrahydrophthalic anhydride, benzophenone tetracarboxylic dianhydride, methylcyclohexenedicarboxylic anhydride and mixtures thereof.



19. The process of claim 14 wherein the epoxy has a number average molecular weight ranging from about 100 to about 20,000, an epoxy equivalent weight of from about 50 to about 10,000, and an average number of epoxy groups per molecule of from about 1 to about 40.

5

20. The process of claim 14 wherein the epoxy comprises a diglycidyl ether of resorcinol, catechol, hydroquinone, biphenol, bisphenol A, bisphenol F, bisphenol K, tetrabromobisphenol A, phenol-formaldehyde novolac resins, alkyl substituted phenol-formaldehyde resins, phenol-hydroxybenzaldehyde resins, cresol-hydroxybenzaldehyde
10 resins, dicyclopentadiene-phenol resins, dicyclopentadiene-substituted phenol resins tetramethylbiphenol, tetramethyl-tetrabromobiphenol, and mixtures thereof.

21. The process of claim 14 wherein the nitrogen containing catalyst is selected from the group consisting of secondary amines, tertiary amines, phosphines and arsines and
15 blends thereof.

22. The process of claim 14 wherein the nitrogen containing catalyst is selected from the group consisting of imidazoles, imidazolidines, imidazolines, oxazoles, pyrroles, thiazoles, pyridines, pyrazines, morpholines, pyridazines, pyrimidines, pyrrolidines,
20 pyrazoles, quinoxalines, quinazolines, phthalazines, quinolines, purines, indazoles, indoles, indolazines, phenazines, phenarsazines, phenothiazines, pyrrolines, indolines, piperidines, piperazines and mixtures thereof.

23. The process of claim 14 wherein the aromatic hydroxyl containing compound is
25 selected from the group consisting of dihydroxy phenols, bi-phenols, bisphenols, halogenated bisphenols, alkylated bisphenols, trisphenols, phenol-aldehyde resins, halogenated phenol-aldehyde novolac resins, alkylated phenol-aldehyde novolac resins, phenol-hydroxybenzaldehyde resins, alkylated phenol-hydroxybenzaldehyde resins, the ethylene oxide, propylene oxide, butylene oxide adducts of dihydroxy phenols,
30 biphenols, bisphenols, halogenated bisphenols, alkylated bisphenols, trisphenols,

phenol-aldehyde novolac resins, halogenated phenol-aldehyde novolac resins, alkylated phenol-aldehyde novolac resins, cresol-aldehyde novolac resins, phenol-hydroxybenzaldehyde resins, cresol-hydroxybenzaldehyde resins, vinyl phenol polymers, and mixtures thereof.

5

24. A printed circuit board produced by the process of claim 1.



25. A printed circuit board produced by the process of claim 14.

10 26. A process for producing a printed circuit board which comprises:

(a) applying a layer of a positive working photosensitive dielectric composition onto a surface of a conductive foil thereby forming a photosensitive element;

(b) attaching the photosensitive element via the photosensitive dielectric composition onto a pattern of conductive lines on the surface of a substrate such that the

15 photosensitive dielectric composition is positioned on the conductive lines;

(c) applying a layer of a photoresist onto an opposite surface of said foil;

(d) imagewise exposing the photoresist to actinic radiation; optionally heating the photosensitive dielectric composition to reduce developer solubility of the nonexposed portions thereof; and developing the photoresist to thereby form imagewise removed

20 and imagewise nonremoved portions of the photoresist such that the imagewise removed portions are above at least some conductive lines;

(e) removing the portions of the conductive foil underlying the imagewise removed portions of the photoresist without removing the underlying photosensitive dielectric composition;

25 (f) overall exposing the photosensitive dielectric composition to actinic radiation through the removed portions of the conductive foil; optionally heating the photosensitive dielectric composition to reduce developer solubility of the nonexposed portions thereof;



developing the photosensitive dielectric material to thereby remove only the portions of the photosensitive dielectric composition underlying the removed portions of the conductive foil, thereby forming vias to the conductive lines;

(g) curing the nonremoved portions of the photosensitive dielectric composition;

5 (h) electrically connecting the conductive lines through the vias to a part of the conductive foil; and

(i) patterning the conductive foil to thereby produce a pattern of conductive foil lines.

27. The process of claim 26 further comprising repeating steps (a) through (i) at least
10 once by attaching another photosensitive element according to step (a) onto the previously patterned conductive foil lines resulting from step (i).

28. A process for producing a printed circuit board which comprises:

(a) attaching a photosensitive element onto a pattern of conductive lines on the surface
15 of a substrate; which photosensitive element comprises a positive working photosensitive dielectric composition on a surface of a conductive foil, such that the photosensitive dielectric composition is positioned on the conductive lines;

(b) removing the conductive foil;

(c) imagewise exposing a portion of the photosensitive dielectric composition to
20 actinic radiation; optionally heating the photosensitive dielectric composition to reduce developer solubility of the nonexposed portions thereof; and developing the dielectric composition to thereby form imagewise removed and imagewise nonremoved portions of the dielectric composition such that the imagewise removed portions are above at least some conductive lines;

25 (d) curing the nonremoved portions of the photosensitive dielectric composition;

(e) simultaneously forming an electrically conductive layer on the nonremoved portions of the dielectric composition and electrically connecting the conductive lines through the vias to the electrically conductive layer; and

(f) patterning the electrically conductive layer to thereby produce a pattern of
30 conductive lines.



29. The process of claim 28 further comprising repeating steps (a) through (f) at least once by attaching another photosensitive element according to step (a) onto the previously patterned conductive foil lines resulting from step (f).

5

30. A process for producing a printed circuit board which comprises:

(a) applying a layer of a positive working photosensitive dielectric composition onto a surface of a conductive foil thereby forming a photosensitive element;

10 (b) attaching the photosensitive element via the photosensitive dielectric composition onto a pattern of conductive lines on the surface of a substrate such that the photosensitive dielectric composition is positioned on the conductive lines;

(c) removing the conductive foil;

15 (d) imagewise exposing a portion of the photosensitive dielectric composition to actinic radiation; optionally heating the photosensitive dielectric composition to reduce developer solubility of the nonexposed portions thereof; and developing the dielectric composition to thereby form imagewise removed and imagewise nonremoved portions of the dielectric composition such that the imagewise removed portions are above at least some conductive lines;

(e) curing the nonremoved portions of the photosensitive dielectric composition;

20 (f) simultaneously forming an electrically conductive layer on the nonremoved portions of the dielectric composition and electrically connecting the conductive lines through the vias to the electrically conductive layer; and

(g) patterning the electrically conductive layer to thereby produce a pattern of conductive lines.

25

31. The process of claim 30 further comprising repeating steps (a) through (g) at least once by attaching another photosensitive element according to step (a) onto the previously patterned conductive foil lines resulting from step (h).