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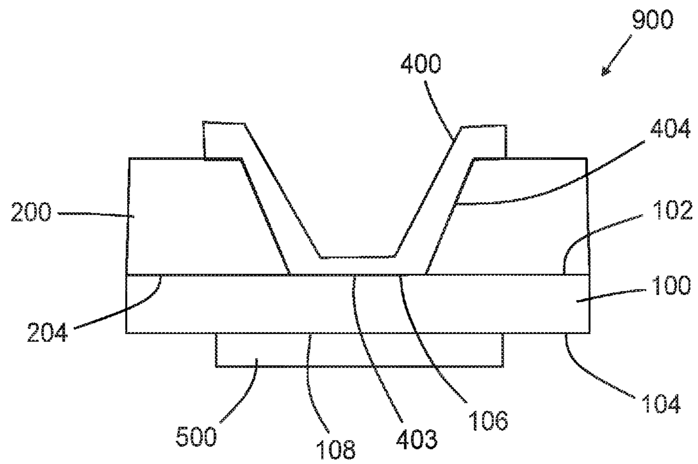

FIG. 1

(57) Abstract: Flexible capacitor constructions include a flexible bottom layer, a discontinuous flexible top layer, an electrically conductive top electrode, and an electrically conductive bottom electrode. The flexible bottom layer can be an adhesive layer. The discontinuous flexible top layer is disposed on the bottom layer and has a discontinuity in its surface that defines a via with sidewalls, and an exposed portion of the flexible bottom layer. The top electrode is disposed in the via and covers the sidewalls of the via, and the exposed portion of the flexible bottom layer. The electrically conductive bottom electrode is disposed on the flexible bottom layer, and is opposite and substantially aligned with the top electrode.

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FLEXIBLE CAPACITOR

Field of the Disclosure

The present disclosure relates to flexible capacitors that include flexible polymeric layers.

Background

A capacitor is a passive two-terminal electrical component that stores electrical energy in an electric field. Because of this effect, a capacitor was historically first known as a condenser. The effect of a capacitor is known as self capacitance. While it exists between any two electrical conductors of a circuit in sufficiently close proximity, a capacitor is designed to provide this effect for a variety of practical applications. Accordingly, the physical form and construction of practical capacitors vary widely, but most contain at least two electrical conductors often in the form of metallic plates or surfaces separated by a dielectric medium. The conductors may be foils, thin films, or sintered beads of metal or conductive electrolyte. The nonconducting dielectric acts to increase the capacitor's charge capacity. Materials commonly used as dielectrics include glass, ceramic, plastic film, paper, mica, and oxide layers. Capacitors are widely used as parts of electrical circuits in many common electrical devices. Unlike a resistor, an ideal capacitor does not dissipate energy.

Capacitors are widely used in wireless transceiver application circuits. Most of these capacitors serve the purposes of either constructively matching of filtering circuits or decoupling power supply lines. Usually, capacitors have, by far, the largest percentage of components that are necessary to complete a wireless transceiver application circuit.

In US Patent Publication No. 2012/0168207 (Oh et al.) a flexible multilayer thin film capacitor is described using a flexible metal substrate; a plurality of first internal electrode layers selectively applied on a first surface of the metal substrate using a metal material; a plurality of dielectric layers formed to be sequentially multi-layered on the whole surface of the first internal electrode layers using a dielectric material; a plurality of second internal electrode layers selectively applied on the dielectric layers using a metal material; a protecting layer applied on a surface of one of the plurality of second internal electrode layers; and a single pair of external electrodes connected to contact with the plurality of first internal electrode layers and the plurality of second internal electrode layers, respectively, and soldered on conductive inter-layer pads of a printed circuit board.

In Korea Patent KR 101254623 describes a manufacturing method for a flexible circuit substrate having a capacitor, and a flexible circuit substrate manufactured by the same, providing improved efficiency by processing a connecting pattern and a via hole with a serial process at one time.

Flexible LESDs (light emitting semiconductor devices) are described in the PCT Publication Nos. WO 2012/061184 and WO 2012/112873.

Summary

Disclosed herein are flexible capacitor constructions.

In some embodiments, the flexible capacitor construction comprises a flexible bottom layer, a discontinuous flexible top layer, an electrically conductive top electrode, and an electrically conductive bottom electrode. The flexible bottom layer has a first major surface and a second major surface, and can be an adhesive layer. The discontinuous flexible top layer is disposed on the second major surface of the bottom layer and has a first major surface and a second major surface, such that at least a portion of the first major surface of the flexible top layer is in contact with the second major surface of the flexible bottom layer, and a discontinuity in the first major surface of the flexible top layer defines a via therein, where the via comprises sidewalls, and an exposed portion of the second major surface of the flexible bottom layer. The electrically conductive top electrode is disposed in the via and covering at least portions of the second major surface of the flexible top layer adjacent the via, the sidewalls of the via, and the exposed portion of the second major surface of the flexible bottom layer. The electrically conductive bottom electrode is disposed on the first major surface of the flexible bottom layer, where the bottom electrode is opposite and substantially aligned with the top electrode, such that the top and bottom electrodes and the flexible bottom layer therebetween form a capacitor.

In other embodiments, the flexible capacitor construction comprises a flexible adhesive layer having a first major surface and a second major surface disposed between substantially aligned electrically conductive top and bottom electrodes. Each of the top and bottom electrode has a top major surface and a bottom major surface, such that the top and bottom electrodes and the flexible adhesive layer therebetween form a capacitor. In a top plan view, the flexible adhesive layer extends beyond at least one of the top and bottom electrodes. In some embodiments, the bottom major surface of the top electrode has a contact surface and a non-contact surface, where the contact surface is a portion of the bottom major surface of the top electrode that is in contact with the second major surface of the flexible adhesive layer, and the non-contact surface is a portion of the bottom surface of the top electrode that is not in contact with the second major surface of the flexible adhesive layer. The non-contact surface is spaced apart from the second major surface of the flexible adhesive layer, and a flexible polymeric dielectric layer, different from the flexible adhesive layer, fills the space between non-contact portion of the bottom surface of the top electrode and the second surface of the flexible adhesive layer.

In still other embodiments, the flexible capacitor construction comprises a flexible multilayer film comprising a plurality of flexible layers with at least one flexible adhesive layer and at least one flexible polymeric dielectric material layer, an electrically conductive top electrode disposed on a top side of the multilayer film, and an electrically conductive bottom electrode disposed on a bottom side of the multilayer film in substantial alignment with the top electrode. At least a portion of at least one layer in the plurality of flexible layers is disposed between the top and bottom electrodes and forming a capacitor, and at least one of the top and bottom electrodes is in direct contact with at least one flexible adhesive layer in the plurality of flexible layers. In some embodiments, at least one flexible adhesive layer in the plurality of flexible layers is an embedded layer of the multilayer film. In some embodiments, only one flexible adhesive layer in the plurality of layers is disposed between the top and bottom electrodes in a region of closest proximity between the top and bottom electrodes.

Brief Description of the Drawings

The present application may be more completely understood in consideration of the following detailed description of various embodiments of the disclosure in connection with the accompanying drawings.

Figure 1 shows a cross-sectional views of an embodiment of an article of this disclosure.

Figure 2 shows a cross-sectional view of an embodiment of a different article of this disclosure.

Figure 3 shows a cross-sectional view of an embodiment of a different article of this disclosure.

In the following description of the illustrated embodiments, reference is made to the accompanying drawings, in which is shown by way of illustration, various embodiments in which the disclosure may be practiced. It is to be understood that the embodiments may be utilized and structural changes may be made without departing from the scope of the present disclosure. The figures are not necessarily to scale. Like numbers used in the figures refer to like components. However, it will be understood that the use of a number to refer to a component in a given figure is not intended to limit the component in another figure labeled with the same number.

Detailed Description

Capacitors are widely used in wireless transceiver application circuits. Most of these capacitors serve the purposes of either constructively matching of filtering circuits or decoupling power supply lines. Usually, capacitors have, by far, the largest percentage of components that are necessary to complete a wireless transceiver application circuit. It is highly desirable to embed these capacitors in the substrate itself. Advantages include: soldering points for conventional surface-mount capacitors can be eliminated; neither electrode of the embedded capacitor is exposed to air; thickness is reduced since equivalent placed components are much thicker; and capacitance area can be flexed which makes this suitable for wearable-type of applications. Therefore, the need for flexible capacitors remains.

Disclosed herein are flexible capacitors that include flexible polymeric layers. The flexible polymeric layer includes an adhesive layer and may include additional flexible polymeric layers.

Unless otherwise indicated, all numbers expressing feature sizes, amounts, and physical properties used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the foregoing specification and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by those skilled in the art utilizing the teachings disclosed herein. The recitation of numerical ranges by endpoints includes all numbers subsumed within that range (e.g. 1 to 5 includes 1, 1.5, 2, 2.75, 3, 3.80, 4, and 5) and any range within that range.

As used in this specification and the appended claims, the singular forms "a", "an", and "the" encompass embodiments having plural referents, unless the content clearly dictates otherwise. For example, reference to "a layer" encompasses embodiments having one, two or more layers. As used in this specification and the appended claims, the term "or" is generally employed in its sense including "and/or" unless the content clearly dictates otherwise.

The term “adhesive” as used herein refers to polymeric compositions useful to adhere together two adherends. Examples of adhesives are pressure sensitive adhesives.

Pressure sensitive adhesive compositions are well known to those of ordinary skill in the art to possess properties including the following: (1) aggressive and permanent tack, (2) adherence with no more than finger pressure, (3) sufficient ability to hold onto an adherend, and (4) sufficient cohesive strength to be cleanly removable from the adherend. Materials that have been found to function well as pressure sensitive adhesives are polymers designed and formulated to exhibit the requisite viscoelastic properties resulting in a desired balance of tack, peel adhesion, and shear holding power. Obtaining the proper balance of properties is not a simple process.

Hot melt adhesives are thermoplastics applied in molten form (typically in the 65–180°C range) which solidify on cooling to form strong bonds between a wide range of adherends.

Thermoset adhesives are monomers, polymers or copolymers that when cured, change into a substantially infusible and insoluble product.

The terms “Tg” and “glass transition temperature” are used interchangeably. If measured, Tg values are determined by Differential Scanning Calorimetry (DSC) at a scan rate of 10°C/minute, unless otherwise indicated. Typically, Tg values for copolymers are not measured but are calculated using the well-known Fox Equation, using the monomer Tg values provided by the monomer supplier, as is understood by one of skill in the art.

The term “room temperature” refers to ambient temperature, generally 20-22°C, unless otherwise noted.

The term “(meth)acrylate” refers to monomeric acrylic or methacrylic esters of alcohols. Acrylate and methacrylate monomers or oligomers are referred to collectively herein as "(meth)acrylates”.

Unless otherwise indicated, "optically transparent" refers to an article, film or adhesive composition that has a high light transmittance over at least a portion of the visible light spectrum (about 400 to about 700 nm). Typically optically transparent articles, films or adhesive compositions have luminous transmittance of visible light of at least 80%.

Unless otherwise indicated, "optically clear" refers to an adhesive or article that has a high light transmittance over at least a portion of the visible light spectrum (about 400 to about 700 nm), and that exhibits low haze. Typically optically clear adhesives or articles have a luminous transmittance of visible light of at least 90% with a haze of less than 5%, often optically clear adhesives or articles have a luminous transmittance of visible light of at least 95% with a haze of less than 3%.

The term “adjacent” as used herein when referring to two layers means that the two layers are in proximity with one another with no intervening open space between them. They may be in direct contact with one another (e.g. laminated together) or there may be intervening layers.

The term “aliphatic” refers to hydrocarbon groups that include only alkyl and alkylene groups.

The term “alkyl” refers to a monovalent group that is a radical of an alkane, which is a saturated hydrocarbon. The alkyl can be linear, branched, cyclic, or combinations thereof and typically has 1 to 20 carbon atoms. In some embodiments, the alkyl group contains 1 to 18, 1 to 12, 1 to 10, 1 to 8, 1 to 6, or 1 to 4 carbon atoms. Examples of alkyl groups include, but are not limited to, methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, tert-butyl, n-pentyl, n-hexyl, cyclohexyl, n-heptyl, n-octyl, and ethylhexyl.

The term “alkylene” refers to a divalent group that is a radical of an alkane. The alkylene can be straight-chained, branched, cyclic, or combinations thereof. The alkylene often has 1 to 20 carbon atoms. In some embodiments, the alkylene contains 1 to 18, 1 to 12, 1 to 10, 1 to 8, 1 to 6, or 1 to 4 carbon atoms. The radical centers of the alkylene can be on the same carbon atom (i.e., an alkylidene) or on different carbon atoms.

The term “aromatic” refers to hydrocarbon groups that contain at least aryl and/or arylene groups, and may also include alkyl and/or alkylene groups.

The term “aryl” refers to a monovalent group that is aromatic and carbocyclic. The aryl can have one to five rings that are connected to or fused to the aromatic ring. The other ring structures can be aromatic, non-aromatic, or combinations thereof. Examples of aryl groups include, but are not limited to, phenyl, biphenyl, terphenyl, anthryl, naphthyl, acenaphthyl, anthraquinonyl, phenanthryl, anthracenyl, pyrenyl, perylenyl, and fluorenyl.

The term “arylene” refers to a divalent group that is carbocyclic and aromatic. The group has one to five rings that are connected, fused, or combinations thereof. The other rings can be aromatic, non-aromatic, or combinations thereof. In some embodiments, the arylene group has up to 5 rings, up to 4 rings, up to 3 rings, up to 2 rings, or one aromatic ring. For example, the arylene group can be phenylene.

In some embodiments of the current disclosure, the flexible capacitor construction comprises a flexible adhesive layer disposed between two electrodes, a top electrode and a bottom electrode. The flexible adhesive layer may comprise a pressure sensitive adhesive layer, a hot melt adhesive layer, or a thermoset adhesive layer. The compositions of the flexible adhesive layer are described in greater detail below. The flexible adhesive layer is a thermally conductive, dielectric layer. The flexible adhesive layer, when viewed from a top plan view, extends beyond at least one of the top and bottom electrodes. In some embodiments, the flexible adhesive layer extends beyond both the top electrode and the bottom electrode when viewed from a top plan view.

In some embodiments, the capacitor construction further comprises a flexible polymeric dielectric layer different from the flexible adhesive layer. In these embodiments, a portion of the top electrode is in direct contact with a top surface of the flexible adhesive layer, and a portion of the top electrode is spaced apart from the flexible adhesive layer. A flexible polymeric dielectric layer that is different from the adhesive layer, fills the space thus formed between the top electrode and the flexible adhesive layer.

This embodiment is shown in Figure 1. Figure 1 shows a cross sectional view of flexible capacitor construction 900. It should also be noted that flexible capacitor construction 900, includes the optional flexible polymeric dielectric layer different from the adhesive layer. Flexible capacitor construction 900 includes flexible adhesive layer 100 top electrode 400 and bottom electrode 500. Flexible capacitor construction 900 also includes optional flexible polymeric dielectric layer 200 which is different from flexible adhesive layer 100. Flexible adhesive layer 100 includes first major surface 102 and bottom major surface 104. The portion of the second major surface of adhesive layer 100 that contacts bottom electrode 500 is contact portion 108, and the portion of the first major surface of adhesive layer 100 that contacts top electrode 400 is contact portion 106. The portion of electrode 400 that contacts contact portion 106 is electrode contact portion 403. The portion of electrode 400 that does not contact adhesive layer 100 is electrode portion 404 which is spaced apart from the adhesive layer 100. Flexible polymeric dielectric layer 200 is located in this spaced apart region such that flexible polymeric dielectric layer 200 contacts flexible adhesive layer 100 in region 204 and also contacts the spaced apart electrode portion 404. As can be seen in Figure 1, even though Figure 1 is a cross sectional view and not a top view, flexible adhesive layer 100 extends beyond both top electrode 400 and bottom electrode 500.

Also disclosed herein are flexible capacitor constructions that comprise a flexible bottom layer with a first major surface and a second major surface, and a flexible discontinuous top layer with a first major surface and a second major surface disposed on the bottom layer, wherein segments of the top layer define a via, or a gap, between the segments of the top layer such that a portion or the second major surface of the bottom layer is exposed in the defined via. An electrically conductive first electrode is disposed in the via and covers at least portions of the second major surface of the top layer adjacent the via, the sidewalls of the via and the exposed portion of the second major surface of the bottom layer. An electrically conductive second electrode is disposed on the first major surface of the bottom layer opposite and substantially aligned with the first electrode, such that the first and second electrodes and the bottom layer therebetween form a capacitor. The flexible bottom layer, in many embodiments is an adhesive layer as is described in detail below. The adhesive layer may comprise a pressure sensitive adhesive, a hot melt adhesive, or a thermoset adhesive. The flexible bottom layer, in other embodiments, may comprise a thermoplastic layer that may not be suitable as a hot melt adhesive. The flexible top layer is typically a polymeric dielectric layer as is described in detail below.

This embodiment is illustrated by Figure 2 which is a cross sectional view of flexible capacitor construction 1000. In Figure 2, flexible capacitor construction 1000 comprises a flexible bottom layer

100 with a first major surface 104 and a second major surface102. Flexible discontinuous top layer 200 with a first major surface 204 and a second major surface 202, discontinuous top layer 200 being disposed on the bottom layer 100. Segments of the top layer define a via, or a gap 300, between the segments of the top layer such that a portion or the second major surface of the bottom layer, region 106, is exposed in the defined via 300. An electrically conductive first electrode 400 is disposed in the via 300 and covers at least portions of the second major surface of the top layer adjacent 202 the via 300, the sidewalls of the via 310, and the exposed portion of the second major surface of the bottom layer, region 106. In Figure 2, region 401 of first electrode 400 covers a portion of the second major surface 202 of the second major surface of top layer 200 at surface 402. The first electrode 400 contacts sidewalls 310 of the via at surfaces 404, and the first electrode 400 contacts the exposed region 106 of the second major surface of the bottom layer at region 403. An electrically conductive second electrode 500 is disposed on the first major surface of the bottom layer opposite and substantially aligned with the first electrode 400, such that the first electrode 400 and second electrode 500 and the bottom layer therebetween 100 form a capacitor.

Also disclosed is another embodiment of a flexible capacitor construction which is similar to that shown in Figure 2 as described above, except that instead of discrete layers 100 and 200, the flexible substrate and dielectric substrate comprises a flexible multilayer film comprising a plurality of flexible layers, where at least one of the flexible layers comprises a flexible adhesive layer and at least one the flexible layers comprises a flexible non-adhesive layer.

This embodiment is exemplified by Figure 3 which is a cross sectional view of a flexible capacitor construction 2000. Flexible capacitor construction 2000 comprises a flexible multilayer film 600, electrically conductive top electrode 630 disposed on the top side of the multilayer film 600, and electrically conductive bottom electrode 640 disposed on the bottom side of the multilayer film 600. Multilayer film 600 comprises a plurality of flexible layers 601-605, and 620-623. Of course, multilayer film 600 comprises at least two layers, and could comprise only two layers an adhesive layer and a non-adhesive layer, but in the embodiment shown in Figure 3 additional optional layers are included. In multilayer film 600, layers 620-623 are flexible adhesive layers and layers 601-605 are flexible non-adhesive layers. Compositions and descriptions of these layers is provided below. The top electrode 630 is separated from the bottom electrode 640 by embedded adhesive layer 621. Embedded adhesive layer 621 is located between the electrodes 630 and 640 at the point of closest proximity between the electrodes. Thus top electrode 630 is in direct contact with adhesive layer 621, and bottom electrode 640 is also in direct contact with adhesive layer 621. Adhesive layer 621 is shown as single layer, but adhesive layer 621 could be a multilayer article as long as the multilayer article is thermally conductive, dielectric and has outer adhesive surfaces that contact the electrodes 630 and 640. Also, in Figure 3, each of the adhesive layers 620, 621, 622, and 623 is shown in contact with at least one of the electrodes 630 and 640, but this need not be the case. In some embodiments, it may be desirable that at least one of the adhesive layers, for example layer 623, be in contact with at least one of the electrodes (640).

The adhesives suitable for use in the flexible capacitor constructions of this disclosure include pressure sensitive adhesives, hot melt adhesives and thermoset adhesives. While a wide range of adhesive materials are suitable, particularly suitable are ones which have a dielectric constant in a range from 2 to 5. In some embodiments, it may be desirable that the adhesive layer be optically transparent or even optically clear.

Pressure sensitive adhesives useful in the flexible capacitor constructions of the present disclosure include those based on natural rubbers, synthetic rubbers, styrene block copolymers, polyvinyl ethers, (meth)acrylates, poly-α-olefins, silicones, urethanes or ureas.

Useful natural rubber pressure sensitive adhesives generally contain masticated natural rubber, from 25 parts to 300 parts of one or more tackifying resins to 100 parts of natural rubber, and typically from 0.5 to 2.0 parts of one or more antioxidants. Natural rubber may range in grade from a light pale crepe grade to a darker ribbed smoked sheet and includes such examples as CV-60, a controlled viscosity rubber grade and SMR-5, a ribbed smoked sheet rubber grade. Tackifying resins used with natural rubbers generally include but are not limited to wood rosin and its hydrogenated derivatives; terpene resins of various softening points, and petroleum-based resins.

Another useful class of pressure sensitive adhesives are those comprising synthetic rubber. Such adhesives are generally rubbery elastomers, which are either self-tacky or non tacky and require tackifiers. Self-tacky synthetic rubber pressure sensitive adhesives include for example: butyl rubber, a copolymer of isobutylene with isoprene; polyisobutylene; homopolymers of isoprene; polybutadiene; or styrene/butadiene rubbers.

Styrene block copolymer pressure sensitive adhesives generally comprise elastomers of the A-B or A-B-A type, where A represents a thermoplastic polystyrene block and B represents a rubbery block of polyisoprene, polybutadiene, or poly(ethylene/butylene), and resins. Examples of the various block copolymers useful in block copolymer pressure sensitive adhesives include linear, radial, star and tapered styrene-isoprene block copolymers.

Polyvinyl ether pressure sensitive adhesives are generally blends of homopolymers of vinyl methyl ether, vinyl ethyl ether or vinyl iso-butyl ether, or blends of homopolymers of vinyl ethers and copolymers of vinyl ethers and acrylates to achieve desired pressure sensitive properties.

(Meth)acrylate pressure sensitive adhesives generally have a glass transition temperature of about -20°C. or less and may comprise from 100 to 80 weight percent of a C_3 -C_{12} alkyl ester component such as, for example, isooctyl acrylate, 2-ethyl-hexyl acrylate and n-butyl acrylate and from 0 to 20 weight percent of a polar component such as, for example, acrylic acid, methacrylic acid, ethylene vinyl acetate, N-vinyl pyrrolidone and styrene macromer. Typically, the (meth)acrylate pressure sensitive adhesives comprise from 0 to 20 weight percent of acrylic acid and from 100 to 80 weight percent of isooctyl acrylate. The (meth)acrylate pressure sensitive adhesives may be self-tacky or tackified. In some embodiments, the (meth)acrylate pressure sensitive adhesive may be a (meth)acrylate block copolymer pressure sensitive adhesive. Like the block copolymer adhesives described above, these pressure sensitive adhesives are of the ABA type where the A blocks are non-elastomeric blocks with a relatively high Tg such as methyl methacrylate blocks, and the B blocks are elastomeric or rubbery blocks.

Poly-α-olefin pressure sensitive adhesives, also called a poly(1-alkene) pressure sensitive adhesives, generally comprise either a substantially uncrosslinked polymer or a uncrosslinked polymer that may have radiation activatable functional groups grafted thereon as described in US Patent No. 5,209,971 (Babu, et al). The poly-α-olefin polymer may be self tacky and/or include one or more tackifying materials.

Silicone pressure sensitive adhesives, also called siloxane pressure sensitive adhesives, comprise two major components, a polymer or gum, and a tackifying resin. The polymer is typically a high molecular weight polydimethylsiloxane or polydimethyldiphenylsiloxane, that contains residual silanol functionality (SiOH) on the ends of the polymer chain, or a block copolymer comprising polydiorganosiloxane soft segments and urea terminated hard segments. The tackifying resin is generally a three-dimensional silicate structure that is endcapped with trimethylsiloxy groups ($OSiMe_3$) and also contains some residual silanol functionality. Examples of particularly suitable silicone pressure sensitive adhesives include the silicone urea block copolymer pressure sensitive adhesives described in US Patent No. 5,214,119 (Leir, et al) and silicone polyoxamide pressure adhesives described in US Patent No. 7,371,464 (Leir et al.).

Useful polyurethane and polyurea pressure sensitive adhesives include, for example, those disclosed in PCT Publication No. WO 00/75210 (Kinning et al.) and in US Patent Nos. 3,718,712 (Tushaus); 3,437,622 (Dahl); and 5,591,820 (Kydonieus et al.).

As described above, hot melt adhesives are thermoplastics applied in molten form (typically in the 65–180°C range) which solidify on cooling to form strong bonds between a wide range of adherends. Examples of suitable hot melt adhesive include: ethylene-vinyl acetate (EVA) copolymers; ethylene-acrylate copolymers (examples include ethylene *n*-butyl acrylate (EnBA), and ethylene-acrylic acid (EAA)); polyolefins (for example polyethylenes such as low density polyethylene (LDPE) and high density polyethylene (HDPE)), atactic polypropylene (PP or APP), poly-1-butene, and oxidized polyethylene); and polyurethanes (for example thermoplastic polyurethanes (TPU) which have a low Tg and are segmented copolymers prepared with long linear chains of flexible soft segments and short rigid hard segments).

Thermoset adhesives are monomers, polymers or copolymers that when cured, change into a substantially infusible and insoluble product. Thus unlike the hot melt adhesives described above which can undergo repeated heating and cooling cycles without being chemically changed, thermoset adhesives contain reactive components that react to irreversibly change into a substantially infusible and insoluble product.

Typically thermoset adhesives are classified as one part adhesives or two part adhesives. In one part thermoset adhesives, the reactive components are intermingled but do not react at room temperature for some amount of time. Typically the one part thermoset adhesives do not cure until energy is supplied either as heat or radiation. In two part adhesives, each part contains one of the reactive species and the two parts are kept separated until curing is desired. Thus, two part thermoset adhesives typically begin to react as soon as the two parts are mixed and do not require an additional input of energy.

Examples of suitable thermoset adhesives include epoxy resins, phenolics, and polyurethanes. Epoxy resins, also known as polyepoxides, are a class of reactive prepolymers and polymers which contain epoxide groups. Epoxy resins may be reacted (cross-linked) either with themselves through catalytic homopolymerisation, or with a wide range of co-reactants including polyfunctional amines, acids (and acid anhydrides), phenols, alcohols and thiols. These co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing. Among the suitable classes of epoxy resins include aromatic epoxy resins and aliphatic epoxy resins. Examples of aromatic epoxy resins are the diglycidyl ethers of bisphenol A (DGEBA) which is prepared by reacting epichlorohydrin with bisphenol A, and the diglycidyl ethers of bisphenol F (DGEBF) which is prepared by reacting epichlorohydrin with bisphenol F. Aliphatic epoxy resins are typically formed by glycidylation of aliphatic alcohols or polyols. The resulting resins may be monofunctional (e.g. dodecanol glycidyl ether), difunctional (butanediol diglycidyl ether), or higher functionality (e.g. trimethylolpropane triglycidyl ether). One specific class of aliphatic epoxy resins is cycloaliphatic epoxy resin, which contains one or more cycloaliphatic rings in the molecule (e.g. 3,4-epoxycyclohexylmethyl-3,4-epoxycyclohexane carboxylate).

Phenolic resins, also known as phenol-formaldehyde resins, are prepared by the reaction of phenol or a substituted phenol with formaldehyde. Phenol-formaldehyde resins, as a group, are formed by a step-growth polymerization reaction that can be either acid- or base-catalysed. Since formaldehyde exists predominantly in solution as a dynamic equilibrium of methylene glycol oligomers, the concentration of the reactive form of formaldehyde depends on temperature and pH. Phenol reacts with formaldehyde at the ortho and para sites (sites 2, 4 and 6) allowing up to 3 units of formaldehyde to attach to the ring. The initial reaction in all cases involves the formation of a hydroxymethyl phenol: $HOC_6H_5 + CH_2O \rightarrow HOC_6H_4CH_2OH$. The hydroxymethyl group is capable of reacting with either another free ortho or para site, or with another hydroxymethyl group. The first reaction gives a methylene bridge, and the second forms an ether bridge.

Polyurethane (PUR or PU) is a polymer composed of organic units joined by carbamate (urethane) links. Polyurethane polymers are traditionally and most commonly formed by reacting a di- or poly-isocyanate with a polyol. Both the isocyanates and polyols used to make polyurethanes contain, on average, two or more functional groups per molecule.

Typically the isocyanates used to make polyurethane have two or more isocyanate groups on each molecule. The most commonly used isocyanates are the aromatic diisocyanates, toluene diisocyanate (TDI) and methylene diphenyl diisocyanate, (MDI). Aliphatic and cycloaliphatic isocyanates can also used. The most important aliphatic and cycloaliphatic isocyanates are 1,6-hexamethylene diisocyanate (HDI), 1-isocyanato-3-isocyanatomethyl-3,5,5-trimethyl-cyclohexane (isophorone diisocyanate, IPDI), and 4,4′-diisocyanato dicyclohexylmethane, (H_{12}MDI or hydrogenated MDI).

Among the suitable polyols are polyether polyols, which are made by the reaction of epoxides with an active hydrogen containing compound, and polyester polyols, made by the polycondensation of multifunctional carboxylic acids and polyhydroxyl compounds.

The polyurethane reaction mixtures, whether one part or two part, often contain a polyurethane catalyst. Polyurethane catalysts can be classified into two broad categories, basic and acidic amine. Tertiary amine catalysts function by enhancing the nucleophilicity of the diol component. Alkyl tin carboxylates, oxides and mercaptide oxides function as mild Lewis acids in accelerating the formation of polyurethane. As bases, traditional amine catalysts include triethylenediamine (TEDA, also called DABCO, 1,4-diazabicyclo[2.2.2]octane), dimethylcyclohexylamine (DMCHA), and dimethylethanolamine (DMEA). A typical Lewis acidic catalyst is dibutyltin dilaurate.

The one part or two part thermoset adhesive is applied to a first substrate surface, a second substrate surface is contacted to it, and the thermoset is cured. In the case of one part thermosets, energy is applied, in the case of two part thermosets, the adhesive is permitted to cure at room temperature. The first substrate surface may be an electrode and the second substrate may be an electrode and dielectric layer as in Figures 1 and 2. Alternatively, the adhesive may either be in contact with an electrode and a dielectric layer as in Figure 3 or between two dielectric layers as in Figure 3.

Besides the polymeric components that comprise the adhesive layer of the flexible capacitor construction, the adhesive layer may also include a variety of additives as long as the additives do not adversely affect the desirable properties of the adhesive layer such as the adhesive properties, the flexibility, the dielectric nature or the thermal conductivity. Among the particularly suitable additives are particles which have a relatively high dielectric constant. Examples of particles that may suspended in the organic matrix of the adhesive layer include those with a dielectric constant of from 120 to 10,000. Suitable particles include metal oxide particles such as barium titanate ($BaTiO_3$), calcium copper titanate ($CaCu_3Ti_4O_{12}$), aluminum oxide (Al_2O_3), and the like. If present, the particles are typically present in an amount of from 0.1% to about 20% by weight, based upon the total weight of the adhesive layer.

The adhesive layer has a variety of desirable properties making it desirable for use in the flexible capacitor constructions of this disclosure. Among these properties are flexibility, relatively high dielectric constant, and high thermal conductivity. Typically the adhesive layer is relatively thin, aiding in its flexibility. In some embodiments the adhesive layer is between 2 and 50 micrometers thick, or even between 2 and 15 micrometers thick. Generally the dielectric constant of the adhesive layer is in a range from 0.25 to 100, or even in a range from 5 to 15.

As mentioned above, the adhesive layer is thermally conductive. Referring to Figures 1 and 2, generally the thermal conductivity of the adhesive layer (100) is greater than the thermal conductivity of the dielectric layer (200). In some embodiments, the adhesive layer has a thermal conductivity, reported in the units Watts/meter Kelvin or W/(m K), in a range from 0.25 W/(m K) to 5 W/(m K). A variety of methods can be used to measure the thermal conductivity of the adhesive layer, usually using needle probes as is well understood by one of skill in the art.

Again referring to Figures 1 and 2, additional properties of the adhesive layer (100) are related to the properties of the dielectric layer (200) and the processes used to prepare the flexible capacitor constructions of this disclosure. The processes used to prepare the flexible capacitor constructions of this disclosure are described in greater detail below. In many embodiments, the dielectric layer 200 is applied to the adhesive layer as continuous layer. This continuous layer is selectively etched to form the via. Typically a chemical etchant is used to effect the etching. In this process, portions of the dielectric layer are masked to prevent their etching. The adhesive layer 100, unlike the dielectric layer 200 is not etchable. In this way, when portions of dielectric layer 200 are completely etched away exposing the adhesive layer, the etching process does not keep going but rather halts. In this way the electrode, which is beneath the adhesive layer is not subject to damage by the etching process. Thus the adhesive layer, unlike the dielectric layer is not etchable by the etchant that is used to etch the dielectric layer. In some embodiments, this etchant comprises one or more of potassium hydroxide, monomethanol amine, and monoethylene glycol.

A wide range of materials are suitable for use in the flexible polymeric dielectric layers of the flexible capacitor constructions of this disclosure. Among the suitable polymeric materials include polyesters, polycarbonates, liquid crystal polymers, and polyimidies. Polyimides are particularly suitable. Examples of suitable polyimides include those available under the trade names KAPTON available from DuPont; APICAL available from Kaneka Texas Corp.; SKC Kolon PI available from SKC Kolon PI, Inc.; and UPILEX and UPISEL such as UPILEX S, UPILEX SN, and UPISEL VT available from Ube Industries, Japan. The polyimides UPILEX and UPISEL are prepared from monomers such as biphenyl tetracarboxylic dianhydride (BPDA) and phenyl diamine (PDA).

While the same dielectric materials can be used in the different embodiments of this disclosure, the nature of the dielectric polymer layer is different depending upon whether the flexible capacitor construction includes a single dielectric layer (200) as in Figures 1 and 2 or multiple layers of polymeric dielectric material (601-605) as in Figure 3.

In the embodiments which include a single layer of polymeric dielectric material (Figures 1 and 2) typically the average thickness of the polymeric dielectric material layer (200) is in a range from 12 micrometers to 125 micrometers. Generally, the dielectric constant of the polymeric dielectric material layer is in a range from 2 to 4.

As mentioned above, the polymeric dielectric material is etchable, permitting portions of the layer to etched away to form the via shown in Figures 1 and 2. Generally a chemical etchant is used. In some embodiments, this etchant comprises one or more of potassium hydroxide, monomethanol amine, and monoethylene glycol.

In the embodiments which include a multiple layers of polymeric dielectric material (Figure 3) typically the average thickness of each polymeric dielectric material layer (601-605) can vary over a broad range, typically each layer is in a range from 5 micrometers to 50 micrometers. Generally, the dielectric constant of each of the polymeric dielectric material layer is in a range from 2 to 4.

Also disclosed herein are methods for preparing flexible capacitor constructions. In some embodiments, the methods include providing a multilayer construction comprising a copper layer, an adhesive layer, and a polymeric dielectric layer. To this construction is selectively applied a resist layer to mask portions of the polymeric dielectric layer and the copper layer. The copper layer is plated with copper to form a bottom copper layer that will become bottom electrode (500). The construction is then chemically etched to remove portions of the polymeric dielectric layer to form the via 300. The selectively applied a resist layer is then removed along with the portions of the bottom copper layer that were covered by the selectively applied resist layer. The top surface containing via 300 is then sputtered with copper. To this construction is selectively applied a resist layer to mask the bottom copper layer and the edge portions of the sputtered copper layer. The sputtered copper layer is plated with copper to form a top copper layer that will become top electrode 400. The selectively applied resist layer is removed. The edge portions of the sputtered copper layer that were covered by the selectively applied a resist layer are then removed to generate an article of Figure 1 or 2.

This disclosure includes the following embodiments:

Among the embodiments are flexible capacitor constructions. Embodiment 1 includes a flexible capacitor construction comprising: a flexible bottom layer having a first major surface and a second major surface; a discontinuous flexible top layer disposed on the second major surface of the bottom layer and having a first major surface and a second major surface, such that at least a portion of the first major surface of the flexible top layer is in contact with the second major surface of the flexible bottom layer, and a discontinuity in first major surface of the flexible top layer defines a via therein, wherein the via comprises sidewalls, and an exposed portion of the second major surface of the flexible bottom layer; an electrically conductive top electrode disposed in the via and covering at least portions of the second major surface of the flexible top layer adjacent the via, the sidewalls of the via, and the exposed portion of the second major surface of the flexible bottom layer; and an electrically conductive bottom electrode disposed on the first major surface of the flexible bottom layer, wherein the bottom electrode is opposite and substantially aligned with the top electrode, such that the top and bottom electrodes and the flexible bottom layer therebetween form a capacitor.

Embodiment 2 is the flexible capacitor construction of embodiment 1, wherein the flexible bottom layer is an adhesive layer.

Embodiment 3 is the flexible capacitor construction of embodiment 2, wherein the adhesive layer is a pressure sensitive adhesive layer, a hot melt adhesive layer, or a thermoset adhesive layer.

Embodiment 4 is the flexible capacitor construction of embodiment 3, wherein the adhesive layer is a pressure sensitive adhesive layer comprising a natural rubber pressure sensitive adhesive, a synthetic rubber pressure sensitive adhesive, a styrene block copolymer pressure sensitive adhesive, a polyvinyl ether pressure sensitive adhesive, a (meth)acrylate pressure sensitive adhesive, a poly-α-olefin pressure sensitive adhesive, a silicone pressure sensitive adhesive, a urethane pressure sensitive adhesive, or a urea pressure sensitive adhesive.

Embodiment 5 is the flexible capacitor construction of embodiment 4, wherein the pressure sensitive adhesive layer is optically transparent.

Embodiment 6 is the flexible capacitor construction of embodiment 3, wherein the adhesive layer is a hot melt adhesive comprising an ethylene-vinyl acetate (EVA) copolymer hot melt adhesive, an ethylene-acrylate copolymer hot melt adhesive, a polyolefin hot melt adhesive, or a polyurethane hot melt adhesive.

Embodiment 7 is the flexible capacitor construction of embodiment 6, wherein the hot melt adhesive layer is optically transparent.

Embodiment 8 is the flexible capacitor construction of embodiment 3, wherein the adhesive layer is a thermoset adhesive layer comprising an epoxy resin thermoset adhesive, a phenolic thermoset adhesive, or a urethane thermoset adhesive.

Embodiment 9 is the flexible capacitor construction of embodiment 8, wherein the thermoset adhesive layer is optically transparent.

Embodiment 10 is the flexible capacitor construction of any of embodiments 1-9, wherein the flexible bottom layer comprises a plurality of particles dispersed in a polymeric adhesive matrix.

Embodiment 11 is the flexible capacitor construction of embodiment 10, wherein a particle concentration in the polymeric adhesive matrix is in a range from about 0.1% to about 20% by weight.

Embodiment 12 is the flexible capacitor construction of embodiment 10 or 11, wherein a dielectric constant of the particles is in a range from 120 to 10,000.

Embodiment 13 is the flexible capacitor construction of any of embodiments 10-12, wherein a dielectric constant of the polymeric adhesive matrix is in a range from 2 to 5.

Embodiment 14 is the flexible capacitor construction of any of embodiments 1-13, wherein a dielectric constant of the flexible bottom layer is in a range from 0.25 to 100.

Embodiment 15 is the flexible capacitor construction of any of embodiments 1-13, wherein a dielectric constant of the flexible bottom layer is in a range from 5 to 15.

Embodiment 16 is the flexible capacitor construction of any of embodiments 1-15, wherein an average thickness of the flexible bottom layer is in a range from 2 micrometers to 50 micrometers.

Embodiment 17 is the flexible capacitor construction of any of embodiments 1-15, wherein an average thickness of the flexible bottom layer is in a range from 2 micrometers to 15 micrometers.

Embodiment 18 is the flexible capacitor construction of any of embodiments 1-17, wherein the flexible bottom layer is thermally conductive.

Embodiment 19 is the flexible capacitor construction of any of embodiments 1-18, wherein the flexible bottom layer has a thermal conductivity in a range from 0.25 W/(m K) to 5 W/(m K).

Embodiment 20 is the flexible capacitor construction of any of embodiments 1-19, wherein a thermal conductivity of the flexible bottom layer is greater than a thermal conductivity of the flexible top layer.

Embodiment 21 is the flexible capacitor construction of any of embodiments 1-20, wherein the flexible top layer is a polymeric dielectric layer.

Embodiment 22 is the flexible capacitor construction of embodiment 21, wherein the polymeric dielectric layer comprises a polyester, a polycarbonate, a liquid crystal polymer, a polyimides, or a combination thereof.

Embodiment 23 is the flexible capacitor construction of any of embodiments 1-22, wherein an average thickness of the flexible top layer is in a range from 12 micrometers to 125 micrometers.

Embodiment 24 is the flexible capacitor construction of any of embodiments 1-23, wherein a dielectric constant of the flexible top layer is in a range from 2 to 4.

Embodiment 25 is the flexible capacitor construction of any of embodiments 1-24, wherein the flexible top layer is etchable by an etchant, but the flexible bottom layer is not etchable by an etchant.

Embodiment 26 is the flexible capacitor construction of embodiment 25, wherein the etchant is a chemical etchant.

Embodiment 27 is the flexible capacitor construction of embodiment 26, wherein the chemical etchant comprises one or more of potassium hydroxide, monoethanol amine and monoethylene glycol.

Embodiment 28 includes a flexible capacitor construction comprising: a flexible adhesive layer having a first major surface and a second major surface disposed between substantially aligned electrically conductive top and bottom electrodes wherein each of the top and bottom electrode has a top major surface and a bottom major surface, such that the top and bottom electrodes and the flexible adhesive layer therebetween form a capacitor and in a top plan view, the flexible adhesive layer extends beyond at least one of the top and bottom electrodes.

Embodiment 29 is the flexible capacitor construction of embodiment 28, wherein the first major surface of the flexible adhesive layer is in contact with at least a portion of the top surface of the bottom electrode in a first contact area and the second major surface of the flexible adhesive layer is in contact with at least a portion of the bottom surface of the top electrode in a second contact area, such that in a top plan view, the flexible adhesive layer extends beyond at least one of the first and second contact areas of the flexible adhesive layer.

Embodiment 30 is the flexible capacitor construction of embodiment 29, wherein in the top plan view, one of the first and second contact areas extends beyond the other one of the first and second contact areas of the adhesive layer.

Embodiment 31 is the flexible capacitor construction of any of embodiments 28-30, wherein the bottom major surface of the top electrode has a contact surface and a non-contact surface, wherein the contact surface is a portion of the bottom major surface of the top electrode that is in contact with the second major surface of the flexible adhesive layer, and the non-contact surface is a portion of the bottom surface of the top electrode that is not in contact with the second major surface of the flexible adhesive layer, wherein the non-contact surface is spaced apart from the second major surface of the flexible adhesive layer, and wherein a flexible polymeric dielectric layer, different from the flexible adhesive layer, fills the space between non-contact portion of the bottom surface of the top electrode and the second surface of the flexible adhesive layer.

Embodiment 32 is the flexible capacitor construction of any of embodiments 28-31, wherein the flexible adhesive layer is a pressure sensitive adhesive layer, a hot melt adhesive layer, or a thermoset adhesive layer.

Embodiment 33 is the flexible capacitor construction of embodiment 32, wherein the adhesive layer is a pressure sensitive adhesive layer comprising a natural rubber pressure sensitive adhesive, a synthetic rubber pressure sensitive adhesive, a styrene block copolymer pressure sensitive adhesive, a polyvinyl ether pressure sensitive adhesive, a (meth)acrylate pressure sensitive adhesive, a poly-α-olefin pressure sensitive adhesive, a silicone pressure sensitive adhesive, a urethane pressure sensitive adhesive, or a urea pressure sensitive adhesive.

Embodiment 34 is the flexible capacitor construction of embodiment 33, wherein the pressure sensitive adhesive layer is optically transparent.

Embodiment 35 is the flexible capacitor construction of embodiment 32, wherein the adhesive layer is a hot melt adhesive comprising an ethylene-vinyl acetate (EVA) copolymer hot melt adhesive, an ethylene-acrylate copolymer hot melt adhesive, a polyolefin hot melt adhesive, or a polyurethane hot melt adhesive.

Embodiment 36 is the flexible capacitor construction of embodiment 35, wherein the hot melt adhesive layer is optically transparent.

Embodiment 37 is the flexible capacitor construction of embodiment 32, wherein the adhesive layer is a thermoset adhesive layer comprising an epoxy resin thermoset adhesive, a phenolic thermoset adhesive, or a urethane thermoset adhesive.

Embodiment 38 is the flexible capacitor construction of embodiment 37, wherein the thermoset adhesive layer is optically transparent.

Embodiment 39 is the flexible capacitor construction of any of embodiments 28-38, wherein the flexible adhesive layer comprises a plurality of particles dispersed in a polymeric adhesive matrix.

Embodiment 40 is the flexible capacitor construction of embodiment 39, wherein a particle concentration in the polymeric adhesive matrix is in a range from about 0.1% to about 20% by weight.

Embodiment 41 is the flexible capacitor construction of embodiment 39 or 40, wherein a dielectric constant of the particles is in a range from 120 to 10,000.

Embodiment 42 is the flexible capacitor construction of any of embodiments 39-41, wherein a dielectric constant of the polymeric adhesive matrix is in a range from 2 to 5.

Embodiment 43 is the flexible capacitor construction of any of embodiments 28-42, wherein a dielectric constant of the flexible adhesive layer is in a range from 0.25 to 100.

Embodiment 44 is the flexible capacitor construction of any of embodiments 28-42, wherein a dielectric constant of the flexible adhesive layer is in a range from 5 to 15.

Embodiment 45 is the flexible capacitor construction of any of embodiments 28-44, wherein an average thickness of the flexible adhesive layer is in a range from 2 micrometers to 50 micrometers.

Embodiment 46 is the flexible capacitor construction of any of embodiments 28-44, wherein an average thickness of the flexible adhesive layer is in a range from 2 micrometers to 15 micrometers.

Embodiment 47 is the flexible capacitor construction of any of embodiments 28-46, wherein the flexible adhesive layer is thermally conductive.

Embodiment 48 is the flexible capacitor construction of any of embodiments 28-47, wherein the flexible adhesive layer has a thermal conductivity in a range from 0.25 W/(m K) to 5 W/(m K).

Embodiment 49 is the flexible capacitor construction of any of embodiments 31-48, wherein a thermal conductivity of the flexible adhesive layer is greater than a thermal conductivity of the flexible polymeric dielectric layer.

Embodiment 50 is the flexible capacitor construction of any of embodiments 31-49, wherein the flexible polymeric dielectric layer comprises a polyester, a polycarbonate, a liquid crystal polymer, a polyimides, or a combination thereof.

Embodiment 51 is the flexible capacitor construction of any of embodiments 31-50, wherein an average thickness of the flexible polymeric dielectric layer is in a range from 5 micrometers to 50 micrometers.

Embodiment 52 is the flexible capacitor construction of any of embodiments 31-51, wherein a dielectric constant of the flexible polymeric dielectric layer is in a range from 2 to 4.

Embodiment 53 is the flexible capacitor construction of any of embodiments 31-52, wherein the flexible polymeric dielectric layer is etchable by an etchant, but the flexible adhesive layer is not etchable by an etchant.

Embodiment 54 is the flexible capacitor construction of embodiment 53, wherein the etchant is a chemical etchant.

Embodiment 55 is the flexible capacitor construction of embodiment 54, wherein the chemical etchant comprises one or more of potassium hydroxide, monoethanol amine and monoethylene glycol.

Embodiment 56 includes a flexible capacitor construction comprising: a flexible multilayer film comprising a plurality of flexible layers comprising at least one flexible adhesive layer and at least one flexible polymeric dielectric material layer; an electrically conductive top electrode disposed on a top side of the multilayer film; and an electrically conductive bottom electrode disposed on a bottom side of the multilayer film in substantial alignment with the top electrode, at least a portion of at least one layer in the plurality of flexible layers disposed between the top and bottom electrodes and forming a capacitor, wherein at least one of the top and bottom electrodes is in direct contact with at least one flexible adhesive layer in the plurality of flexible layers.

Embodiment 57 is the flexible capacitor construction of embodiment 56, wherein each of the top and bottom electrodes is in direct contact with at least one flexible adhesive layer in the plurality of flexible layers.

Embodiment 58 is the flexible capacitor construction of embodiment 56, wherein each flexible adhesive layer in the plurality of flexible layers is in direct contact with at least one of the top and bottom electrodes.

Embodiment 59 is the flexible capacitor construction of any of embodiments 56-58, wherein at least one flexible adhesive layer in the plurality of flexible layers is in direct contact with both the top and bottom electrodes.

Embodiment 60 is the flexible capacitor construction of any of embodiments 56-59, wherein at least one flexible adhesive layer in the plurality of flexible layers is an embedded layer of the multilayer film.

Embodiment 61 is the flexible capacitor construction of any of embodiments 56-60, wherein only one flexible adhesive layer in the plurality of layers is disposed between the top and bottom electrodes in a region of closest proximity between the top and bottom electrodes.

Embodiment 62 is the flexible capacitor construction of any of embodiments 56-61, wherein the at least one flexible adhesive layer is a pressure sensitive adhesive layer, a hot melt adhesive layer, or a thermoset adhesive layer.

Embodiment 63 is the flexible capacitor construction of embodiment 62, wherein the at least one flexible adhesive layer is a pressure sensitive adhesive layer comprising a natural rubber pressure sensitive adhesive, a synthetic rubber pressure sensitive adhesive, a styrene block copolymer pressure sensitive adhesive, a polyvinyl ether pressure sensitive adhesive, a (meth)acrylate pressure sensitive adhesive, a poly-α-olefin pressure sensitive adhesive, a silicone pressure sensitive adhesive, a urethane pressure sensitive adhesive, or a urea pressure sensitive adhesive.

Embodiment 64 is the flexible capacitor construction of embodiment 63, wherein the pressure sensitive adhesive layer is optically transparent.

Embodiment 65 is the flexible capacitor construction of embodiment 62, wherein the at least one flexible adhesive layer is a hot melt adhesive comprising an ethylene-vinyl acetate (EVA) copolymer hot melt adhesive, an ethylene-acrylate copolymer hot melt adhesive, a polyolefin hot melt adhesive, or a polyurethane hot melt adhesive.

Embodiment 66 is the flexible capacitor construction of embodiment 65, wherein the hot melt adhesive layer is optically transparent.

Embodiment 67 is the flexible capacitor construction of embodiment 62, wherein the at least one flexible adhesive layer is a thermoset adhesive layer comprising an epoxy resin thermoset adhesive, a phenolic thermoset adhesive, or a urethane thermoset adhesive.

Embodiment 68 is the flexible capacitor construction of embodiment 67, wherein the thermoset adhesive layer is optically transparent.

Embodiment 69 is the flexible capacitor construction of any of embodiments 56-68, wherein the at least one flexible adhesive layer comprises a plurality of particles dispersed in a polymeric adhesive matrix.

Embodiment 70 is the flexible capacitor construction of embodiment 69, wherein a particle concentration in the polymeric adhesive matrix is in a range from about 0.1% to about 20% by weight.

Embodiment 71 is the flexible capacitor construction of embodiment 69 or 70, wherein a dielectric constant of the particles is in a range from 120 to 10,000.

Embodiment 72 is the flexible capacitor construction of any of embodiments 69-71, wherein a dielectric constant of the polymeric adhesive matrix is in a range from 2 to 5.

Embodiment 73 is the flexible capacitor construction of any of embodiments 56-72, wherein a dielectric constant of the at least one flexible adhesive layer is in a range from 0.25 to 100.

Embodiment 74 is the flexible capacitor construction of any of embodiments 56-72, wherein a dielectric constant of the flexible adhesive layer is in a range from 5 to 15.

Embodiment 75 is the flexible capacitor construction of any of embodiments 56-74, wherein an average thickness of the at least one flexible adhesive layer is in a range from 2 micrometers to 50 micrometers.

Embodiment 76 is the flexible capacitor construction of any of embodiments 56-74, wherein an average thickness of the at least one flexible adhesive layer is in a range from 2 micrometers to 15 micrometers.

Embodiment 77 is the flexible capacitor construction of any of embodiments 56-76, wherein the at least one flexible adhesive layer is thermally conductive.

Embodiment 78 is the flexible capacitor construction of any of embodiments 56-77, wherein the at least one flexible adhesive layer has a thermal conductivity in a range from 0.25 W/(m K) to 5 W/(m K).

Embodiment 79 is the flexible capacitor construction of any of embodiments 56-78, wherein a thermal conductivity of the flexible adhesive layer is greater than a thermal conductivity of the flexible polymeric dielectric layer.

Embodiment 80 is the flexible capacitor construction of any of embodiments 56-79, wherein the flexible polymeric dielectric layer comprises a polyester, a polycarbonate, a liquid crystal polymer, a polyimides, or a combination thereof.

Embodiment 81 is the flexible capacitor construction of any of embodiments 56-80, wherein an average thickness of the flexible polymeric dielectric layer is in a range from 12 micrometers to 125 micrometers.

Examples

These descriptive examples are merely for illustrative purposes only and are not meant to be limiting on the scope of the appended claims. The following abbreviations are used: pF = picoFarads; mm = millimeters; and wt% = weight %, or % by weight.

Etching Method

The general procedure for preparing the etchants includes first dissolving 37 wt% potassium hydroxide (KOH) in water by mixing, followed by the subsequent addition of 3.5 wt% ethylene glycol and 22 wt% ethanolamine. Samples can be subjected to selective etching by the use of selective etch masking through the use of an aqueous photoresist, such as HM-4056 from Hitachi Chemicals, Japan. The etching is controlled by timing, typically approximately 15 minutes.

Flexible Capacitor Preparation Method

To prepare a flexible capacitor a sample can be prepared in a series of steps by generating a three layer article with a polyimide layer, an adhesive layer, and a thin layer of copper. This article can be selectively masked on both the polyimide side and the copper side. Both sides can be laminated with dry film photoresist, such as HM4056 from Hitachi Chemicals, Ltd. creating a patterned etch mask on the polyimide side (which will become the electrode and via) and edge pads on the copper side using a photolithography process. The sample can then be subjected to the deposition of copper on the exposed copper surface of the copper side to generate a copper thickness of about 45 micrometers using an electroplating process. The sample can then subjected to a chemical etching process using the Etching Method described above to etch the exposed polyimide completely to create an etched via in the polyimide substrate. One advantage of the present disclosure is that the adhesive layer is not etched by the chemical etching process, and thus the chemical etching process stops once the polyimide layer is removed to expose a portion of the adhesive layer surface. The photoresist can be removed from both sides, and the portions of the copper layer that were covered by the photoresist and thus were not plated with copper can be removed to expose portions of the adhesive layer. The polyimide side can then be subjected to the deposition of copper to generate a thin copper layer using a copper sputter process. This article can be selectively masked on both the polyimide side and the copper side, with the copper side fully masked and the copper-clad polyimide side selectively masked. The polyimide side can then be subjected to the deposition of copper on the exposed copper surface to generate a copper thickness of about 45 micrometers using an electroplating process. The photoresist can be removed from both sides, and the portions of the copper layer on the polyimide side that were covered by the photoresist and thus were not plated with copper can be removed to expose portions of the polyimide layer. The resulting article can be an article as described by Figure 2.

Descriptive Examples 1-12

For Descriptive Examples 1-6 the above Flexible Capacitor Preparation Method could be followed using as the adhesive layer an epoxy adhesive layer (Descriptive Examples 1-3) or a phenolic adhesive layer (Descriptive Examples 4-6), where the thickness and estimated capacitance values are shown in Table 1 below. The typical dielectric constant values for the epoxy adhesive were assumed to be $\kappa = 6$, and for the phenolic adhesive was $\kappa = 8$.

Table 1: Calculated Capacitance Values for Adhesive Layers

Descriptive Example	Adhesive Type	Thickness (micrometers)	Estimated capacitance of the adhesive layer (pF/mm^2)
1	Epoxy	5	10.6
2	Epoxy	10	5.31
3	Epoxy	20	2.66
4	Phenolic	5	14.2
5	Phenolic	10	7.08
6	Phenolic	20	3.54

For Descriptive Examples 7-12 the above Flexible Capacitor Preparation Method could be followed using as the adhesive layer that contains 10% by weight of barium titanate particles in the epoxy adhesive layer (Descriptive Examples 7-9) or the phenolic adhesive layer (Descriptive Examples 10-12), where the thickness and estimated capacitance values are shown in Table 2 below. The effective dielectric constant values used for the epoxy/$BaTiO_3$ adhesive was $\kappa = 25.4$, and for the phenolic/$BaTiO_3$ adhesive was $\kappa = 27.2$.

Table 2: Calculated Capacitance Values for Adhesive Layers with $BaTiO_3$ Particles

Descriptive	Adhesive Type	Thickness	Estimated capacitance of adhesive layer

Example		(micrometers)	(pF/mm^2)
7	Epoxy/$BaTiO_3$	5	45
8	Epoxy/$BaTiO_3$	10	22.5
9	Epoxy/$BaTiO_3$	20	11.2
10	Phenolic/$BaTiO_3$	5	48.2
11	Phenolic/$BaTiO_3$	10	27.2
12	Phenolic/$BaTiO_3$	20	12.0

What is claimed is:

1. A flexible capacitor construction comprising:
a flexible bottom layer having a first major surface and a second major surface;
a discontinuous flexible top layer disposed on the second major surface of the bottom layer and having a first major surface and a second major surface, such that at least a portion of the first major surface of the flexible top layer is in contact with the second major surface of the flexible bottom layer, and a discontinuity in first major surface of the flexible top layer defines a via therein, wherein the via comprises sidewalls, and an exposed portion of the second major surface of the flexible bottom layer;
an electrically conductive top electrode disposed in the via and covering at least portions of the second major surface of the flexible top layer adjacent the via, the sidewalls of the via, and the exposed portion of the second major surface of the flexible bottom layer; and
an electrically conductive bottom electrode disposed on the first major surface of the flexible bottom layer, wherein the bottom electrode is opposite and substantially aligned with the top electrode, such that the top and bottom electrodes and the flexible bottom layer therebetween form a capacitor.

2. The flexible capacitor construction of claim 1, wherein the flexible bottom layer is an adhesive layer.

3. The flexible capacitor construction of claim 2, wherein the adhesive layer is a pressure sensitive adhesive layer, a hot melt adhesive layer, or a thermoset adhesive layer.

4. The flexible capacitor construction of claim 1, wherein the flexible bottom layer is thermally conductive.

5. A flexible capacitor construction comprising:
a flexible adhesive layer having a first major surface and a second major surface disposed between substantially aligned electrically conductive top and bottom electrodes wherein each of the top and bottom electrode has a top major surface and a bottom major surface, such that the top and bottom electrodes and the flexible adhesive layer therebetween form a capacitor and in a top plan view, the flexible adhesive layer extends beyond at least one of the top and bottom electrodes.

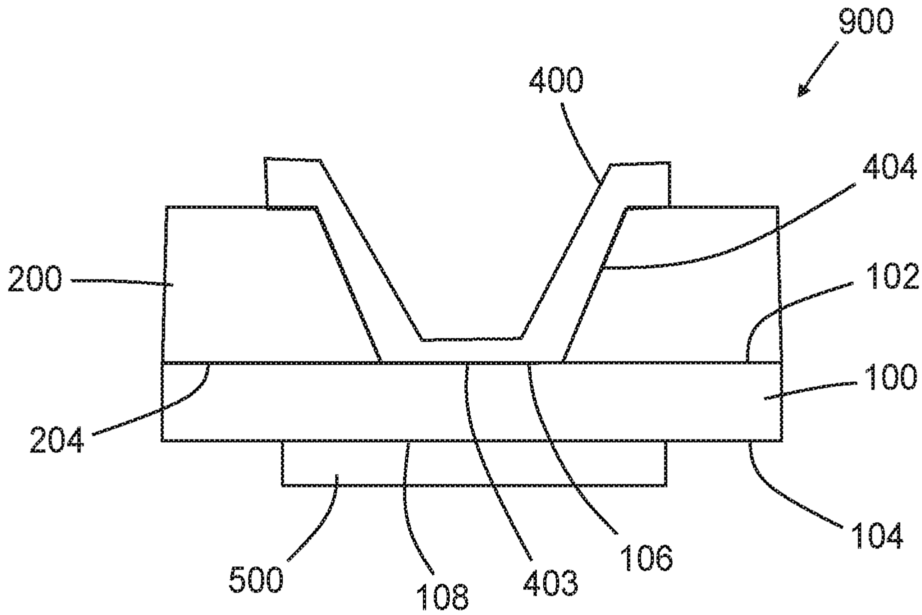
6. The flexible capacitor construction of claim 5, wherein the first major surface of the flexible adhesive layer is in contact with at least a portion of the top surface of the bottom electrode in a first contact area and the second major surface of the flexible adhesive layer is in contact with at least a portion of the bottom surface of the top electrode in a second contact area, such that in a top plan view, the flexible adhesive layer extends beyond at least one of the first and second contact areas of the flexible adhesive layer.

7. The flexible capacitor construction of claim 5, wherein the bottom major surface of the top electrode has a contact surface and a non-contact surface, wherein the contact surface is a portion of the bottom major surface of the top electrode that is in contact with the second major surface of the flexible adhesive layer, and the non-contact surface is a portion of the bottom surface of the top electrode that is not in contact with the second major surface of the flexible adhesive layer, wherein the non-contact surface is spaced apart from the second major surface of the flexible adhesive layer, and wherein a flexible polymeric dielectric layer, different from the flexible adhesive layer, fills the space between non-contact portion of the bottom surface of the top electrode and the second surface of the flexible adhesive layer.

8. A flexible capacitor construction comprising:
a flexible multilayer film comprising a plurality of flexible layers comprising at least one flexible adhesive layer and at least one flexible polymeric dielectric material layer;
an electrically conductive top electrode disposed on a top side of the multilayer film; and
an electrically conductive bottom electrode disposed on a bottom side of the multilayer film in substantial alignment with the top electrode, at least a portion of at least one layer in the plurality of flexible layers disposed between the top and bottom electrodes and forming a capacitor, wherein at least one of the top and bottom electrodes is in direct contact with at least one flexible adhesive layer in the plurality of flexible layers.

9. The flexible capacitor construction of claim 8, wherein each flexible adhesive layer in the plurality of flexible layers is in direct contact with at least one of the top and bottom electrodes.

10. The flexible capacitor construction of claim 8, wherein at least one flexible adhesive layer in the plurality of flexible layers is an embedded layer of the multilayer film.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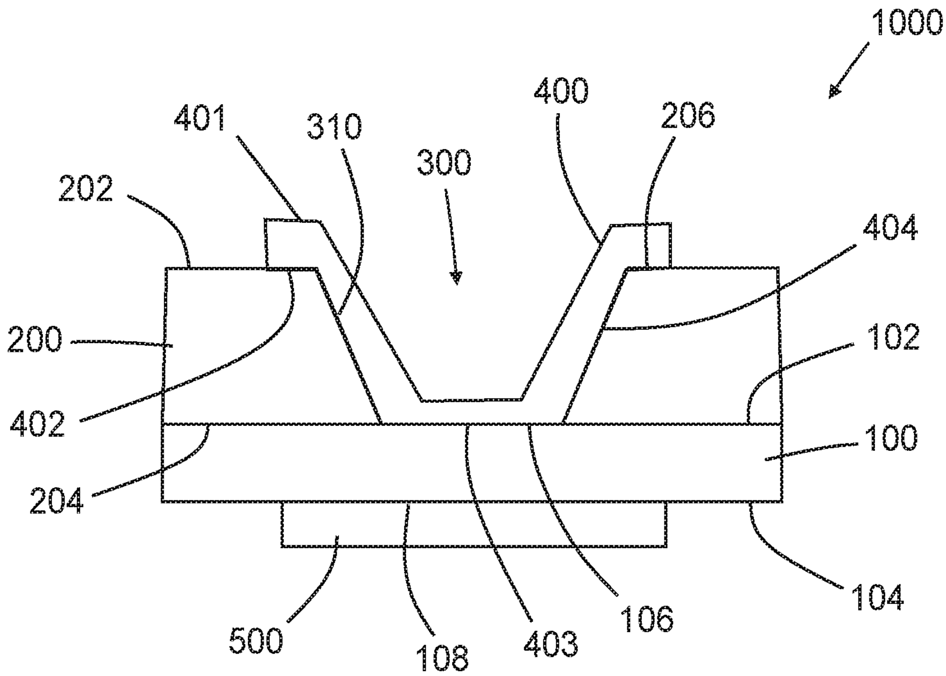
400
404
200
102
100
204
104
500
108
403
106

FIG. 1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200
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402
100
204
104
500
108
403
106

FIG. 2

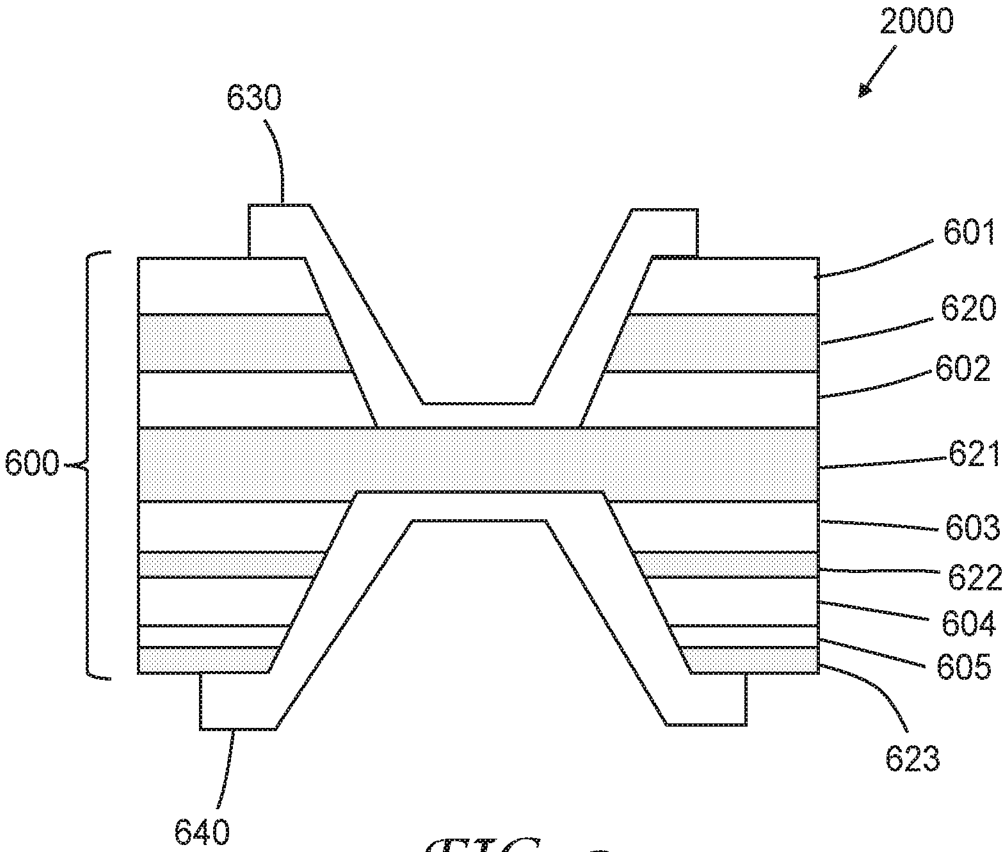

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2017/057847

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01G4/33 H01G4/01
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01G H01L H05K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2004 056097 A (NEC CORP) 19 February 2004 (2004-02-19) abstract figures 1, 2 paragraphs [0016] - [0038] -----	1-10
A	EP 1 014 399 A2 (MATSUSHITA ELECTRIC IND CO LTD [JP]) 28 June 2000 (2000-06-28) paragraphs [0042] - [0056]; figures 1-8 -----	1-10
A	JP 2002 100533 A (SONY CORP) 5 April 2002 (2002-04-05) abstract; figures 1-5 paragraphs [0070] - [0082] -----	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 March 2018	20/03/2018

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2017/057847

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JP 2002100533 A	05-04-2002	NONE	