SEMICONDUCTOR DEVICE AND METHOD OF FORMING AN INDUCTOR ON POLYMER MATRIX COMPOSITE SUBSTRATE

Field of the Invention

The present invention relates in general to semiconductor devices and, more particularly, to a semiconductor device and method of forming an inductor over a polymer matrix composite substrate.

Background of the Invention

Semiconductor devices are commonly found in modern electronic products. Semiconductor devices vary in the number and density of electrical components. Discrete semiconductor devices generally contain one type of electrical component, e.g., light emitting diode (LED), small signal transistor, resistor, capacitor, inductor, and power metal oxide semiconductor field effect transistor (MOSFET). Integrated semiconductor devices typically contain hundreds to millions of electrical components. Examples of integrated semiconductor devices include microcontrollers, microprocessors, charged-coupled devices (CCDs), solar cells, and digital micro-mirror devices (DMDs).

Semiconductor devices perform a wide range of functions such as high-speed calculations, transmitting and receiving electromagnetic signals, controlling electronic devices, transforming sunlight to electricity, and creating visual projections for television displays. Semiconductor devices are found in the fields of entertainment, communications, power conversion, networks, computers, and consumer products. Semiconductor devices are also found in military applications, aviation, automotive, industrial controllers, and office equipment.

Semiconductor devices exploit the electrical properties of semiconductor materials. The atomic structure of semiconductor material allows its electrical conductivity to be manipulated by the application of an electric field or base current or through the process of doping. Doping introduces impurities into the semiconductor material to manipulate and control the conductivity of the semiconductor device.

A semiconductor device contains active and passive electrical structures. Active structures, including bipolar and field effect transistors, control the flow of electrical current. By varying levels of doping and application of an electric field or base current, the transistor either promotes or restricts the flow of electrical current. Passive structures, including resistors, capacitors, and inductors, create a relationship between voltage and current necessary to perform a variety of electrical functions. The passive and active structures are electrically connected to form circuits, which enable the semiconductor device to perform high-speed calculations and other useful functions.

Semiconductor devices are generally manufactured using two complex manufacturing processes, i.e., front-end manufacturing, and back-end manufacturing, each involving potentially hundreds of steps. Front-end manufacturing involves the formation of a plurality of die on the surface of a semiconductor wafer. Each die is typically identical and contains circuits formed by electrically connecting active and passive components. Back-end manufacturing involves singulating individual die from the finished wafer and packaging the die to provide structural support and environmental isolation.

One goal of semiconductor manufacturing is to produce smaller semiconductor devices. Smaller devices typically consume less power, have higher performance, and can be produced more efficiently. In addition, smaller semiconductor devices have a smaller footprint, which is desirable for smaller end products. A smaller die size may be achieved by improvements in the front-end process resulting in die with smaller, higher density active and passive components. Back-end processes may result in semiconductor device packages with a smaller footprint by improvements in electrical interconnection and packaging materials.

Another goal of semiconductor manufacturing is to produce higher performance semiconductor devices. In high frequency applications, such as radio frequency (RF) wireless communications, integrated passive devices (IPDs) are often contained within the semiconductor device. Examples of IPDs include resistors, capacitors, and inductors. A typical RF system requires multiple IPDs in one or more semiconductor packages to perform the necessary electrical functions. The inductor is commonly formed over a sacrificial substrate for structural support. The sacrificial substrate is removed by a

grinding or etching process after formation of the inductor. The use of the sacrificial substrate adds processing steps, such as grinding and etching, as well as cost to the manufacturing process.

Summary of the Invention

A need exists to simplify the manufacturing process and reduce cost in forming an inductor. Accordingly, in one embodiment, the present invention is a method of making a semiconductor device comprising the steps of forming a polymer matrix composite substrate, forming a first insulating layer over a first surface of the polymer matrix composite substrate, forming a first conductive layer over the first insulating layer, forming a second insulating layer over the first insulating layer and first conductive layer, forming a second conductive layer over the second insulating layer and first conductive layer, forming a third insulating layer over the second insulating layer and second conductive layer, removing a portion of the third insulating layer to expose the second conductive layer, and forming a bump over the second conductive layer.

In another embodiment, the present invention is a method of making a semiconductor device comprising the steps of forming a molded substrate, forming a first conductive layer over the molded substrate, forming a first insulating layer over the molded substrate and first conductive layer, forming a second conductive layer over the first insulating layer and first conductive layer, forming a second insulating layer over the first insulating layer and second conductive layer, and forming an interconnect structure over the second conductive

layer.

In another embodiment, the present invention is a method of making a semiconductor device comprising the steps of forming a polymer matrix composite substrate, forming an inductor over the polymer matrix composite substrate, and forming an interconnect structure over the inductor.

In another embodiment, the present invention is a semiconductor device comprising a polymer matrix composite substrate and first conductive layer formed over the polymer matrix composite substrate. A first insulating layer is formed over the polymer matrix composite substrate and first conductive layer. A second conductive layer is formed over the first insulating layer and first conductive layer. A second insulating layer is formed over the first insulating layer and second conductive layer. An interconnect structure is formed over the second conductive layer.

Brief Description of the Drawings

FIG. 1 illustrates a PCB with different types of packages mounted to its surface;

FIGs. 2a-2c illustrate further detail of the representative semiconductor packages mounted to the PCB;

FIGs. 3a-3i illustrate a process of forming an IPD over a polymer matrix composite substrate;

FIGs. 4a-4e illustrate another process of forming an IPD over a planar surface of a polymer matrix composite substrate;

FIG. 5 illustrates another polymer matrix composite substrate with an IPD formed over a planar surface;

FIG. 6 illustrates a conductor wound to form an

inductor; and

FIGs. 7a-7n illustrate a process of forming an inductor over a polymer matrix composite substrate.

Detailed Description of the Drawings

The present invention is described in one or more embodiments in the following description with reference to the figures, in which like numerals represent the same or similar elements. While the invention is described in terms of the best mode for achieving the invention's objectives, it will be appreciated by those skilled in the art that it is intended to cover alternatives, modifications, and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims and their equivalents as supported by the following disclosure and drawings.

Semiconductor devices are generally manufactured using two complex manufacturing processes: front-end manufacturing and back-end manufacturing. Front-end manufacturing involves the formation of a plurality of die on the surface of a semiconductor wafer. Each die on the wafer contains active and passive electrical components, which are electrically connected to form functional electrical circuits. Active electrical components, such as transistors and diodes, have the ability to control the flow of electrical current. Passive electrical components, such as capacitors, inductors, resistors, and transformers, create a relationship between voltage and current necessary to perform electrical circuit functions.

Passive and active components are formed over the surface of the semiconductor wafer by a series of process steps including doping, deposition, photolithography, etching, and

planarization. Doping introduces impurities into the semiconductor material by techniques such as ion implantation or thermal diffusion. The doping process modifies the electrical conductivity of semiconductor material in active devices, transforming the semiconductor material into an insulator, conductor, or dynamically changing the semiconductor material conductivity in response to an electric field or base current. Transistors contain regions of varying types and degrees of doping arranged as necessary to enable the transistor to promote or restrict the flow of electrical current upon the application of the electric field or base current.

Active and passive components are formed by layers of materials with different electrical properties. The layers can be formed by a variety of deposition techniques determined in part by the type of material being deposited. For example, thin film deposition may involve chemical vapor deposition (CVD), physical vapor deposition (PVD), electrolytic plating, and electroless plating processes. Each layer is generally patterned to form portions of active components, passive components, or electrical connections between components.

The layers can be patterned using photolithography, which involves the deposition of light sensitive material, e.g., photoresist, over the layer to be patterned. A pattern is transferred from a photomask to the photoresist using light. The portion of the photoresist pattern subjected to light is removed using a solvent, exposing portions of the underlying layer to be patterned. The remainder of the photoresist is removed, leaving behind a patterned layer. Alternatively, some types of materials are patterned by directly depositing the material into the areas or voids formed by a previous deposition/etch process using techniques such as electroless and

electrolytic plating.

Depositing a thin film of material over an existing pattern can exaggerate the underlying pattern and create a non-uniformly flat surface. A uniformly flat surface is required to produce smaller and more densely packed active and passive components. Planarization can be used to remove material from the surface of the wafer and produce a uniformly flat surface. Planarization involves polishing the surface of the wafer with a polishing pad. An abrasive material and corrosive chemical are added to the surface of the wafer during polishing. The combined mechanical action of the abrasive and corrosive action of the chemical removes any irregular topography, resulting in a uniformly flat surface.

Back-end manufacturing refers to cutting or singulating the finished wafer into the individual die and then packaging the die for structural support and environmental isolation. To singulate the die, the wafer is scored and broken along non-functional regions of the wafer called saw streets or scribes. The wafer is singulated using a laser cutting tool or saw blade. After singulation, the individual die are mounted to a package substrate that includes pins or contact pads for interconnection with other system components. Contact pads formed over the semiconductor die are then connected to contact pads within the package. The electrical connections can be made with solder bumps, stud bumps, conductive paste, or wirebonds. An encapsulant or other molding material is deposited over the package to provide physical support and electrical isolation. The finished package is then inserted into an electrical system and the functionality of the semiconductor device is made available to the other system components.

FIG. 1 illustrates electronic device 50 having a chip

carrier substrate or printed circuit board (PCB) 52 with a plurality of semiconductor packages mounted on its surface. Electronic device 50 may have one type of semiconductor package, or multiple types of semiconductor packages, depending on the application. The different types of semiconductor packages are shown in FIG. 1 for purposes of illustration.

Electronic device 50 may be a stand-alone system that uses the semiconductor packages to perform one or more electrical functions. Alternatively, electronic device 50 may be a subcomponent of a larger system. For example, electronic device 50 may be a graphics card, network interface card, or other signal processing card that can be inserted into a computer. The semiconductor package can include microprocessors, memories, application specific integrated circuits (ASIC), logic circuits, analog circuits, RF circuits, discrete devices, or other semiconductor die or electrical components.

In FIG. 1, PCB 52 provides a general substrate for structural support and electrical interconnect of the semiconductor packages mounted on the PCB. Conductive signal traces 54 are formed over a surface or within layers of PCB 52 using evaporation, electrolytic plating, electroless plating, screen printing, or other suitable metal deposition process. Signal traces 54 provide for electrical communication between each of the semiconductor packages, mounted components, and other external system components. Traces 54 also provide power and ground connections to each of the semiconductor packages.

In some embodiments, a semiconductor device has two packaging levels. First level packaging is a technique for mechanically and electrically attaching the semiconductor die to an intermediate carrier. Second level packaging involves

mechanically and electrically attaching the intermediate carrier to the PCB. In other embodiments, a semiconductor device may only have the first level packaging where the die is mechanically and electrically mounted directly to the PCB.

For the purpose of illustration, several types of first level packaging, including wire bond package 56 and flip chip 58, are shown on PCB 52. Additionally, several types of second level packaging, including ball grid array (BGA) 60, bump chip carrier (BCC) 62, dual in-line package (DIP) 64, land grid array (LGA) 66, multi-chip module (MCM) 68, quad flat non-leaded package (QFN) 70, and quad flat package 72, are shown mounted on PCB 52. Depending upon the system requirements, any combination of semiconductor packages, configured with any combination of first and second level packaging styles, as well as other electronic components, can be connected to PCB 52. In some embodiments, electronic device 50 includes a single attached semiconductor package, while other embodiments call for multiple interconnected packages. By combining one or more semiconductor packages over a single substrate, manufacturers can incorporate pre-made components into electronic devices and systems. Because the semiconductor packages include sophisticated functionality, electronic devices can be manufactured using cheaper components and a streamlined manufacturing process. The resulting devices are less likely to fail and less expensive to manufacture resulting in a lower cost for consumers.

FIGs. 2a-2c show exemplary semiconductor packages. FIG. 2a illustrates further detail of DIP 64 mounted on PCB 52. Semiconductor die 74 includes an active region containing analog or digital circuits implemented as active devices, passive devices, conductive layers, and dielectric layers formed within the die and are electrically interconnected according to the

electrical design of the die. For example, the circuit may include one or more transistors, diodes, inductors, capacitors, resistors, and other circuit elements formed within the active region of semiconductor die 74. Contact pads 76 are one or more layers of conductive material, such as aluminum (Al), copper (Cu), tin (Sn), nickel (Ni), gold (Au), or silver (Ag), and are electrically connected to the circuit elements formed within semiconductor die 74. During assembly of DIP 64, semiconductor die 74 is mounted to an intermediate carrier 78 using a gold-silicon eutectic layer or adhesive material such as thermal epoxy or epoxy resin. The package body includes an insulative packaging material such as polymer or ceramic. Conductor leads 80 and wire bonds 82 provide electrical interconnect between semiconductor die 74 and PCB 52. Encapsulant 84 is deposited over the package for environmental protection by preventing moisture and particles from entering the package and contaminating die 74 or wire bonds 82.

FIG. 2b illustrates further detail of BCC 62 mounted on PCB 52. Semiconductor die 88 is mounted over carrier 90 using an underfill or epoxy-resin adhesive material 92. Wire bonds 94 provide first level packaging interconnect between contact pads 96 and 98. Molding compound or encapsulant 100 is deposited over semiconductor die 88 and wire bonds 94 to provide physical support and electrical isolation for the device. Contact pads 102 are formed over a surface of PCB 52 using a suitable metal deposition process such as electrolytic plating or electroless plating to prevent oxidation. Contact pads 102 are electrically connected to one or more conductive signal traces 54 in PCB 52. Bumps 104 are formed between contact pads 98 of BCC 62 and contact pads 102 of PCB 52.

In FIG. 2c, semiconductor die 58 is mounted face down

to intermediate carrier 106 with a flip chip style first level packaging. Active region 108 of semiconductor die 58 contains analog or digital circuits implemented as active devices, passive devices, conductive layers, and dielectric layers formed according to the electrical design of the die. For example, the circuit may include one or more transistors, diodes, inductors, capacitors, resistors, and other circuit elements within active region 108. Semiconductor die 58 is electrically and mechanically connected to carrier 106 through bumps 110.

BGA 60 is electrically and mechanically connected to PCB 52 with a BGA style second level packaging using bumps 112. Semiconductor die 58 is electrically connected to conductive signal traces 54 in PCB 52 through bumps 110, signal lines 114, and bumps 112. A molding compound or encapsulant 116 is deposited over semiconductor die 58 and carrier 106 to provide physical support and electrical isolation for the device. The flip chip semiconductor device provides a short electrical conduction path from the active devices on semiconductor die 58 to conduction tracks on PCB 52 in order to reduce signal propagation distance, lower capacitance, and improve overall circuit performance. In another embodiment, the semiconductor die 58 can be mechanically and electrically connected directly to PCB 52 using flip chip style first level packaging without intermediate carrier 106.

FIGs. 3a-3i illustrate, in relation to FIGs. 1 and 2a-2c, a process of forming an IPD structure over a polymer matrix composite, for example epoxy molding compound (EMC) substrate. In FIG. 3a, a chase mold 120 has upper plate 120a and lower plate 120b. A releasable tape 122 is applied to upper plate 120a of chase mold 120. An optional metal carrier 124 is mounted to lower plate 120b. Carrier 124 can also be silicon,

polymer, polymer composite, ceramic, glass, glass epoxy, beryllium oxide, tape, or other suitable low-cost, rigid material for structural support. Carrier 124 can be reusable in the manufacturing process. Alternatively, carrier 124 can be only one time usable, such as supporting tape and plastic liner. A releasable tape 126 is applied to carrier 124. Tape 122 and 126 are releasable by mechanical or thermal pressure. A laminated film 128 is formed over releasable tape 126. The film 128 can be metal, such as Cu and Al, or other electric conductive material with optional priming for better adhesion with encapsulant 132. An open area 130 is provided between upper plate 120a and lower plate 120b to dispense encapsulant material.

In FIG. 3b, an encapsulant material or molding compound 132 is dispensed into area 130, between upper plate 120a and lower plate 120b, using compressive molding, transfer molding, liquid encapsulant molding, or other suitable applicator. Encapsulant 132 can be a liquid, granular, or powder form, or sheet form of polymer composite material, such as epoxy resin with filler, epoxy acrylate with filler, or polymer with proper filler from 40% up to 95% content. When cured and removed from mold chase 120, encapsulant 132 forms an polymer matrix composite substrate wafer or panel 134 with laminated film 128, as shown in FIG. 3c. Alternatively, lamination film 128 can cover the full surface of substrate 134. The polymer matrix composite substrate 134 has high resistivity, low loss tangent, lower dielectric constant, coefficient of thermal expansion (CTE) matching the overlaying IPD structure, and good thermal conductivity.

In FIG. 3d, film layer 128 is patterned and etched to provide a first conductive layer 128a-128c, as well as to form

an indentation or shallow cavity 136 with surface 138 in polymer matrix composite substrate 134. Cavity 136 is optional with film layer 128 fully covering the surface of panel 134. The individual portions of conductive layer 128a-128c can be electrically common or electrically isolated depending on the connectivity of the individual semiconductor die.

In FIG. 3e, an optional planarization insulating layer 142 can be formed over polymer matrix composite substrate 134 and conductive layer 128 as one or more layers of silicon dioxide (SiO2), silicon nitride (Si3N4), silicon oxynitride (SiON), tantalum pentoxide (Ta2O5), aluminum oxide (Al2O3), polyimide, benzocyclobutene (BCB), polybenzoxazoles (PBO), WPR, or other suitable dielectric material, especially polymer photosensitive dielectric materials. The insulating layer 142 serves to planarize the surface of polymer matrix composite substrate 134 after removing laminated film 128 partially in order to improve step coverage of subsequent deposition and lithography processing steps. Alternatively, insulating layer 142 can be used as dielectric for IPD's capacitor component, as described below. The remaining IPD structure described in FIG. 3f-3i is shown without optional planarization layer 142.

In FIG. 3f, an optional resistive layer 146 is formed over conductive layer 128a and surface 138 of substrate 134 using PVD, CVD, or other suitable deposition process. In one embodiment, resistive layer 146 can be tantalum silicide (TaxSiy) or other metal silicides, TaN, nickel chromium (NiCr), titanium (Ti), titanium nitride (TiN), titanium tungsten (TiW), or doped poly-silicon having a resistivity between 5 and 100 ohm/sq.

An insulating or dielectric layer 148 is formed over resistive layer 146 using patterning with PVD, CVD, printing,

sintering, or thermal oxidation. The insulating layer 148 can be one or more layers of SiO2, Si3N4, SiON, Ta2O5, Al2O3, polyimide, BCB, PBO, or other suitable dielectric material. The overlapping between conductive layer 128a, resistive layer 146, and insulating layer 148 can have other embodiment. For example, resistive layer 146 can be fully inside conductive layer 128a.

In FIG. 3g, an insulating or passivation layer 150 is formed over conductive layer 128, resistive layer 146, and insulating layer 148 using spin coating, PVD, CVD, printing, sintering, or thermal oxidation. The insulating layer 150 can be one or more layers of SiO2, Si3N4, SiON, Ta2O5, Al2O3, polyimide, BCB, PBO, WPR, or other material having suitable insulating and structural properties, especially polymer photo sensitive dielectric materials. A portion of insulating layer 150 is removed to expose conductive layer 128, resistive layer 146, and insulating layer 148.

In FIG. 3h, an electrically conductive layer 152 is formed over conductive layer 128, insulating layers 148 and 150, and resistive layer 146 using patterning with PVD, CVD, sputtering, electrolytic plating, electroless plating process, or other suitable metal deposition process to form individual portions or sections 152a-152j. Conductive layer 152 can be one or more layers of Al, Cu, Sn, Ni, Au, Ag, Ti, TiW, or other suitable electrically conductive material. The individual portions of conductive layer 152a-152j can be electrically common or electrically isolated depending on the connectivity of the individual semiconductor die.

An insulating or passivation layer 154 is formed over insulating layer 150 and conductive layer 152 using spin coating, PVD, CVD, printing, sintering, or thermal oxidation.

The insulating layer 154 can be one or more layers of SiO2, Si3N4, SiON, Ta2O5, Al2O3, polyimide, BCB, PBO, or other material having suitable insulating and structural properties, especially polymer photo sensitive dielectric materials. A portion of insulating layer 154 is removed to expose conductive layer 152.

In FIG. 3i, an optional electrically conductive layer 156 is formed over conductive layer 152c using PVD, CVD, sputtering, electrolytic plating, electroless plating process, or other suitable metal deposition process. Conductive layer 156 can be one or more layers of Ti, TiW, NiV, Cr, CrCu, Al, Cu, Sn, Ni, Au, Ag, or other suitable electrically conductive material. In one embodiment, conductive layer 156 is an under bump metallization (UBM) containing a multi-layer metal stack with an adhesion layer, barrier layer, and seed or wetting layer. The adhesion layer is formed over conductive layer 152c and can be Ti, TiN, TiW, Al, or chromium (Cr). The barrier layer is formed over the adhesion layer and can be Ni, nickel vanadium (NiV), platinum (Pt), palladium (Pd), TiW, or chromium copper (CrCu). The barrier layer inhibits the diffusion of Cu into the active area of the die. The seed layer can be Cu, Ni, NiV, Au, or Al. The seed layer is formed over the barrier layer and acts as an intermediate conductive layer between conductive layer 152c and subsequent solder bumps or other interconnect structure. UBM 156 provides a low resistive interconnect to conductive layer 152c, as well as a barrier to solder diffusion and seed layer for solder wettability.

An electrically conductive bump material is deposited over UBM 156 using an evaporation, electrolytic plating, electroless plating, ball drop, or screen printing process. The bump material can be Al, Sn, Ni, Au, Ag, Pb, Bi, Cu, solder, and

combinations thereof, with an optional flux solution. For example, the bump material can be eutectic Sn/Pb, high-lead solder, or lead-free solder. The bump material is bonded to UBM 156 using a suitable attachment or bonding process. In one embodiment, the bump material is reflowed by heating the material above its melting point to form spherical balls or bumps 158. In some applications, bumps 158 are reflowed a second time to improve electrical contact to UBM 156. The bumps can also be compression bonded to UBM 156. Bumps 158 represent one type of interconnect structure that can be formed over UBM 156. The interconnect structure can also use bond wires, conductive paste, stud bump, micro bump, or other electrical interconnect. For example, bond wire 160 is formed over conductive layer 152j.

The structures described in FIGs. 3c-3i constitute a plurality of passive circuit elements or IPDs 162. In one embodiment, conductive layer 128a, resistive layer 146, insulating layer 148, and conductive layer 152a is a metal insulator metal (MIM) capacitor. Resistive layer 146 between conductive layer 152c and 152d is a resistor element in the passive circuit. The individual sections of conductive layer 152d-152i can be wound or coiled in plan-view to produce or exhibit the desired properties of an inductor. IPD 162 can have any combination of capacitors, resistors, and/or inductors.

The IPD structure 162 provides electrical characteristics needed for high frequency applications, such as resonators, high-pass filters, low-pass filters, band-pass filters, symmetric Hi-Q resonant transformers, matching networks, and tuning capacitors. The IPDs can be used as front-end wireless RF components, which can be positioned between the antenna and transceiver. The inductor can be a hi-Q balun,

transformer, or coil, operating up to 100 Gigahertz. In some applications, multiple baluns are formed over a same substrate, allowing multi-band operation. For example, two or more baluns are used in a quad-band for mobile phones or other global system for mobile (GSM) communications, each balun dedicated for a frequency band of operation of the quad-band device. A typical RF system requires multiple IPDs and other high frequency circuits in one or more semiconductor packages to perform the necessary electrical functions. Conductive layer 152j can be a ground plane for the IPD structure.

The IPD structure 162 formed over polymer matrix composite substrate 134 simplifies the manufacturing process and reduces cost. An optional temporary and reusable metal carrier is used to build the artificial molding compound wafer or panel. The polymer matrix composite substrate 134 provides high resistivity, low loss tangent, low dielectric constant, matching CTE with the IPD structure, and good thermal conductivity.

FIGs. 4a-4e illustrate, in relation to FIGs. 1 and 2a-2c, another process of forming an IPD structure over a polymer matrix composite or EMC substrate. In FIG. 4a, a chase mold 170 has upper plate 170a and lower plate 170b. A releasable tape 172 is applied to upper plate 170a of chase mold 170. A releasable tape 174 with optional adhesive properties is applied to lower plate 170b. Tape 172 and 174 are releasable by mechanical or thermal pressure. An encapsulant or molding compound 176 is dispensed into the open area between upper plate 170a and lower plate 170b using compressive molding, transfer molding, liquid encapsulant molding, or other suitable applicator. Encapsulant 176 can be a liquid, granular, or powder form of polymer composite material, such as epoxy resin with filler, epoxy acrylate with filler, or polymer with proper

filler from 40% up to 95% content. When cured and removed from mold chase 170, encapsulant 176 forms a polymer matrix composite substrate wafer or panel 178, as shown in FIG. 4b. The polymer matrix composite substrate 178 has high resistivity, low loss tangent, lower dielectric constant, CTE matching the overlaying IPD structure, and good thermal conductivity. An optional insulation layer 180 can be formed over polymer matrix composite substrate 178 as planarization layer with good insulation properties.

In FIG. 4c, an electrically conductive layer 182 is formed over interface and insulation layer 180 on substrate 178 using patterning with PVD, CVD, sputtering, electrolytic plating, electroless plating process, or other suitable metal deposition process to form individual portions or sections 182a-182c. Conductive layer 182 can be one or more layers of Al, Cu, Sn, Ni, Au, Ag, Ti, TiW, TiN, or other suitable electrically conductive material, with Ti, TiN, or TiW as an adhesive or barrier layer. The individual portions of conductive layer 182 can be electrically common or electrically isolated depending on the connectivity of the individual semiconductor die.

An optional resistive layer 184 is formed over conductive layer 182a and interface layer 180 of substrate 178 using PVD, CVD, or other suitable deposition process. In one embodiment, resistive layer 184 can be TaxSiy or other metal silicides, TaN, NiCr, Ti, TiN, TiW, or doped poly-silicon having a resistivity between 5 and 100 ohm/sq.

An insulating or dielectric layer 186 is formed over resistive layer 184 using patterning with PVD, CVD, printing, sintering, or thermal oxidation. The insulating layer 186 can be one or more layers of SiO2, Si3N4, SiON, Ta2O5, Al2O3, polyimide, BCB, PBO, or other suitable dielectric material.

An insulating or passivation layer 188 is formed over conductive layer 182, resistive layer 184, and insulating layer 186 using spin coating, PVD, CVD, printing, sintering, or thermal oxidation. The insulating layer 188 can be one or more layers of SiO2, Si3N4, SiON, Ta2O5, Al2O3, polyimide, BCB, PBO, WPR, or other material having suitable insulating and structural properties, especially polymer photo sensitive dielectric materials. A portion of insulating layer 188 is removed to expose conductive layer 182, resistive layer 184, and insulating layer 186.

In FIG. 4d, an electrically conductive layer 190 is formed over conductive layer 182, insulating layers 186 and 188, and resistive layer 184 using patterning with PVD, CVD, sputtering, electrolytic plating, electroless plating process, or other suitable metal deposition process to form individual portions or sections 190a-190j. Conductive layer 190 can be one or more layers of Al, Cu, Sn, Ni, Au, Ag, Ti, TiW, TiN, or other suitable electrically conductive material, with Ti, TiN, or TiW as an adhesive or barrier layer. The individual portions of conductive layer 190a-190j can be electrically common or electrically isolated depending on the connectivity of the individual semiconductor die.

An insulating or passivation layer 192 is formed over insulating layer 188 and conductive layer 190 using spin coating, PVD, CVD, printing, sintering, or thermal oxidation. The insulating layer 192 can be one or more layers of SiO2, Si3N4, SiON, Ta2O5, Al2O3, polyimide, BCB, PBO, WPR, or other material having suitable insulating and structural properties, especially polymer photo sensitive dielectric materials. A portion of insulating layer 192 is removed to expose conductive layer 190.

In FIG. 4e, an electrically conductive layer 194 is formed over conductive layer 190c using PVD, CVD, sputtering, electrolytic plating, electroless plating process, or other suitable metal deposition process. Conductive layer 194 can be one or more layers of Ti, TiW, NiV, Cr, CrCu, Al, Cu, Sn, Ni, Au, Ag, or other suitable electrically conductive material. In one embodiment, conductive layer 194 is a UBM containing a multi-layer metal stack with an adhesion layer, barrier layer, and seed or wetting layer. The adhesion layer is formed over conductive layer 190c and can be Ti, TiN, TiW, Al, or Cr. The barrier layer is formed over the adhesion layer and can be Ni, NiV, Pt, Pd, TiW, or CrCu. The barrier layer inhibits the diffusion of Cu into the active area of the die. The seed layer can be Cu, Ni, NiV, Au, or Al. The seed layer is formed over the barrier layer and acts as an intermediate conductive layer between conductive layer 190c and subsequent solder bumps or other interconnect structure. UBM 194 provides a low resistive interconnect to conductive layer 190c, as well as a barrier to solder diffusion and seed layer for solder wettability.

An electrically conductive bump material is deposited over UBM 194 using an evaporation, electrolytic plating, electroless plating, ball drop, or screen printing process. The bump material can be Al, Sn, Ni, Au, Ag, Pb, Bi, Cu, solder, and combinations thereof, with an optional flux solution. For example, the bump material can be eutectic Sn/Pb, high-lead solder, or lead-free solder. The bump material is bonded to UBM 194 using a suitable attachment or bonding process. In one embodiment, the bump material is reflowed by heating the material above its melting point to form spherical balls or bumps 196. In some applications, bumps 196 are reflowed a second time to improve electrical contact to UBM 194. The bumps

can also be compression bonded to UBM 194. Bumps 196 represent one type of interconnect structure that can be formed over UBM 194. The interconnect structure can also use bond wires, conductive paste, stud bump, micro bump, or other electrical interconnect. For example, bond wire 198 is formed over conductive layer 190j.

The structures described in FIGs. 4b-4e constitute a plurality of passive circuit elements or IPDs 200. In one embodiment, conductive layer 182a, resistive layer 184, insulating layer 186, and conductive layer 190a is a MIM capacitor. Resistive layer 184 between conductive layer 190c and 190d is a resistor element in the passive circuit. The individual sections of conductive layer 190d-190i can be wound or coiled in plan-view to produce or exhibit the desired properties of an inductor. IPD 200 can have any combination of capacitors, resistors, and/or inductors.

The IPD structure 200 provides electrical characteristics needed for high frequency applications, such as resonators, high-pass filters, low-pass filters, band-pass filters, symmetric Hi-Q resonant transformers, matching networks, and tuning capacitors. The IPDs can be used as front-end wireless RF components, which can be positioned between the antenna and transceiver. The inductor can be a hi-Q balun, transformer, or coil, operating up to 100 Gigahertz. In some applications, multiple baluns are formed over a same substrate, allowing multi-band operation. For example, two or more baluns are used in a quad-band for mobile phones or other GSM communications, each balun dedicated for a frequency band of operation of the quad-band device. A typical RF system requires multiple IPDs and other high frequency circuits in one or more semiconductor packages to perform the necessary electrical

functions. Conductive layer 190j can be a ground plane for the IPD structure. The IPD structure 200 formed over polymer matrix composite substrate 178 simplifies the manufacturing process and reduces cost. The polymer matrix composite substrate 178 provides high resistivity, low loss tangent, low dielectric constant, matching CTE with the IPD structure, and good thermal conductivity.

FIG. 5 illustrates another IPD structure formed over a polymer matrix composite substrate. Using a chase mold, a polymer matrix composite substrate wafer or panel 210 is formed in a similar manner as FIG. 4a. The polymer matrix composite substrate 210 has high resistivity, low loss tangent, lower dielectric constant, CTE matching the overlaying IPD structure, and good thermal conductivity.

An electrically conductive layer 212 is formed over substrate 210 using patterning with PVD, CVD, sputtering, electrolytic plating, electroless plating process, or other suitable metal deposition process to form individual portions or sections 212a-212c. Conductive layer 212 can be one or more layers of Al, Cu, Sn, Ni, Au, Ag, Ti, TiN, TiW, or other suitable electrically conductive material, with Ti, TiN, or TiW as an adhesive or barrier layer. The individual portions of conductive layer 212 can be electrically common or electrically isolated depending on the connectivity of the individual semiconductor die.

An insulating or passivation layer 218 is formed over conductive layer 212 using spin coating, PVD, CVD, printing, sintering, or thermal oxidation. The insulating layer 218 can be one or more layers of SiO_2, Si_3N_4, SiON, Ta_2O_5, Al_2O_3, polyimide, BCB, PBO, WPR, or other material having suitable insulating and structural properties, especially polymer photo

sensitive dielectric materials. A portion of insulating layer 218 is removed to expose conductive layer 212.

An electrically conductive layer 220 is formed over insulating layer 218 using patterning with PVD, CVD, sputtering, electrolytic plating, electroless plating process, or other suitable metal deposition process. Conductive layer 220 is an adhesion layer or barrier layer, such as Ti, TiW, TiN, TaxSiy, and TaN. Conductive layer 220 operates as a resistive layer for the IPD structure.

An electrically conductive layer 222 is formed over conductive layer 220 using patterning with PVD, CVD, sputtering, electrolytic plating, electroless plating process, or other suitable metal deposition process to form individual portions or sections 222a-222j. Conductive layer 222 can be one or more layers of Al, Cu, Sn, Ni, Au, Ag, or other suitable electrically conductive material. The individual portions of conductive layer 222a-222j are electrically common or electrically isolated depending on the connectivity of the individual semiconductor die.

An insulating or passivation layer 224 is formed over insulating layer 218 and conductive layers 220 and 222 using spin coating, PVD, CVD, printing, sintering, or thermal oxidation. The insulating layer 224 can be one or more layers of SiO2, Si3N4, SiON, Ta2O5, Al2O3, polyimide, BCB, PBO, WPR, or other material having suitable insulating and structural properties, especially polymer photo sensitive dielectric materials. A portion of insulating layer 224 is removed to expose conductive layer 222.

An electrically conductive layer 226 is formed over conductive layer 222c using PVD, CVD, sputtering, electrolytic plating, electroless plating process, or other suitable metal

deposition process. Conductive layer 226 can be one or more layers of Al, Cu, Sn, Ni, Au, Ag, or other suitable electrically conductive material. In one embodiment, conductive layer 226 is a UBM containing a multi-layer metal stack with an adhesion layer, barrier layer, and seed or wetting layer. The adhesion layer is formed over conductive layer 222c and can be Ti, TiN, TiW, Al, or Cr. The barrier layer is formed over the adhesion layer and can be Ni, NiV, Pt, Pd, TiW, or CrCu. The barrier layer inhibits the diffusion of Cu into the active area of the die. The seed layer can be Cu, Ni, NiV, Au, or Al. The seed layer is formed over the barrier layer and acts as an intermediate conductive layer between conductive layer 222c and subsequent solder bumps or other interconnect structure. UBM 226 provides a low resistive interconnect to conductive layer 222c, as well as a barrier to solder diffusion and seed layer for solder wettability.

An electrically conductive bump material is deposited over UBM 226 using an evaporation, electrolytic plating, electroless plating, ball drop, or screen printing process. The bump material can be Al, Sn, Ni, Au, Ag, Pb, Bi, Cu, solder, and combinations thereof, with an optional flux solution. For example, the bump material can be eutectic Sn/Pb, high-lead solder, or lead-free solder. The bump material is bonded to UBM 226 using a suitable attachment or bonding process. In one embodiment, the bump material is reflowed by heating the material above its melting point to form spherical balls or bumps 228. In some applications, bumps 228 are reflowed a second time to improve electrical contact to UBM 226. The bumps can also be compression bonded to conductive layer 226. Bumps 228 represent one type of interconnect structure that can be formed over UBM 226. The interconnect structure can also use

bond wires, conductive paste, stud bump, micro bump, or other electrical interconnect. For example, bond wire 230 is formed over conductive layer 222j.

The structures described in FIG. 5 constitute a plurality of passive circuit elements or IPDs 232. In one embodiment, conductive layer 212a, insulating layer 218, conductive layer 220, and conductive layer 222a is a MIM capacitor. The individual sections of conductive layer 222d-222i can be wound or coiled in plan-view to produce or exhibit the desired properties of an inductor. IPD 232 can have any combination of capacitors, resistors, and/or inductors.

The IPD structure 232 provides electrical characteristics needed for high frequency applications, such as resonators, high-pass filters, low-pass filters, band-pass filters, symmetric Hi-Q resonant transformers, matching networks, and tuning capacitors. The IPDs can be used as front-end wireless RF components, which can be positioned between the antenna and transceiver. The inductor can be a hi-Q balun, transformer, or coil, operating up to 100 Gigahertz. In some applications, multiple baluns are formed over a same substrate, allowing multi-band operation. For example, two or more baluns are used in a quad-band for mobile phones or other GSM communications, each balun dedicated for a frequency band of operation of the quad-band device. A typical RF system requires multiple IPDs and other high frequency circuits in one or more semiconductor packages to perform the necessary electrical functions. Conductive layer 190j can be a ground plane for the IPD structure.

The IPD structure 232 formed over polymer matrix composite substrate 210 simplifies the manufacturing process and reduces cost. The polymer matrix composite substrate 210

provides high resistivity, low loss tangent, low dielectric constant, matching CTE with the IPD structure, and good thermal conductivity.

FIG. 6 shows an exemplary inductor 242 formed with conductive layer 222.

FIGs. 7a-7n illustrate, in relation to FIGs. 1 and 2a-2c, a process of forming an inductor over a polymer matrix composite substrate. In FIG. 7a, a chase mold 250 has upper plate 250a and lower plate 250b. An optional releasable tape 252 is applied to upper plate 250a of chase mold 250. An optional metal carrier 254 is mounted to lower plate 250b. Carrier 254 can also be silicon, polymer, polymer composite, ceramic, glass, glass epoxy, beryllium oxide, tape, or other suitable low-cost, rigid material for structural support. Carrier 254 can be reusable in the manufacturing process. A releasable adhesive tape 256 is applied to carrier 254. Tape 252 and 256 are releasable by mechanical or thermal pressure.

In FIG. 7b, an encapsulant material or molding compound 260 is dispensed into the open area between upper plate 250a and lower plate 250b, using compressive molding, transfer molding, liquid encapsulant molding, or other suitable applicator. Encapsulant 260 can be a liquid, granular, or powder form of polymer composite material, such as epoxy resin with filler, epoxy acrylate with filler, or polymer with proper filler from 40% up to 95% content. When cured and removed from mold chase 250, encapsulant 260 forms a polymer matrix composite substrate wafer or panel 264, such as an EMC substrate, as shown in FIG. 7c.

FIG. 7d shows another method of forming the polymer matrix composite substrate. Chase mold 266 has upper plate 266a and lower plate 266b. An optional releasable tape 268 with

adhesive layer is applied to upper plate 266a of chase mold 266. An optional releasable tape 270 with adhesive layer is applied to lower plate 266b. Tape 268 and 270 are releasable by mechanical or thermal pressure. An encapsulant or molding compound 272 is dispensed into the open area between upper plate 266a and lower plate 266b using compressive molding, transfer molding, liquid encapsulant molding, or other suitable applicator. Encapsulant 272 can be a liquid, granular, or powder form of polymer composite material, such as epoxy resin with filler, epoxy acrylate with filler, or polymer with proper filler from 40% up to 95% content. When cured and removed from mold chase 266, encapsulant 272 forms a polymer matrix composite substrate wafer or panel 274, such as an EMC substrate, as shown in FIG. 7e. The polymer matrix composite substrate 264 and 274 each have high resistivity, low loss tangent, lower dielectric constant, CTE matching the overlaying IPD structure, and good thermal conductivity.

In FIG. 7f, a blanket insulating or passivation layer 276 is formed over a top surface of polymer matrix composite substrate 274 (or polymer matrix composite substrate 264) using spin coating, PVD, CVD, printing, sintering, or thermal oxidation. The insulating layer 276 can be one or more layers of SiO_2, Si_3N_4, SiON, Ta_2O_5, Al_2O_3, polyimide, BCB, PBO, WPR, or other material having suitable insulating and structural properties. Alternatively, insulating layer 276 is formed during the molding process in chase mold 250 or 266 with the interaction between the encapsulant and releasing tape.

FIG. 7g shows an alternate embodiment with the blanket insulating layer 276 formed over the top surface of polymer matrix composite substrate 274. In addition, a blanket insulating or passivation layer 278 is formed over a bottom

surface of polymer matrix composite substrate 274, opposite the top surface using spin coating, lamination, PVD, CVD, printing, sintering, or thermal oxidation. The insulating layer 278 can be one or more layers of SiO2, Si3N4, SiON, Ta2O5, Al2O3, polyimide, BCB, PBO, WPR, or other material having suitable insulating and structural properties. Alternatively, insulating layers 276 and 278 are formed during the molding process in chase mold 250 or 266 with the interaction between the encapsulant and releasing tape. The insulating layers 276 and 278 can be the same materials with the same or different thickness.

FIG. 7h shows an embodiment with the blanket insulating layer 276 formed over the top surface of polymer matrix composite substrate 274, and a blanket insulating or passivation layer 280 formed over insulating layer 276, using spin coating, PVD, CVD, printing, sintering, or thermal oxidation. The insulating layer 280 can be one or more layers of SiO2, Si3N4, SiON, Ta2O5, Al2O3, polyimide, BCB, PBO, or other material having suitable insulating and structural properties. The insulating layer 276 can be formed during the molding process in chase mold 250 or 266.

FIG. 7i shows an embodiment without an insulating layer over either the top surface or bottom surface of polymer matrix composite substrate 274.

Continuing with the embodiment of FIG. 7f, an electrically conductive layer 282 is formed over insulating layer 276 using patterning with PVD, CVD, sputtering, electrolytic plating, electroless plating process, or other suitable metal deposition process to form individual portions or sections 282a-282c, as shown in FIG. 7j. Conductive layer 282 can be one or more layers of Al, Cu, Sn, Ni, Au, Ag, Ti, TiN,

TiW, or other suitable electrically conductive material, with Ti, TiN, or TiW as an adhesive or barrier layer. The individual portions of conductive layer 282a-282c can be electrically common or electrically isolated depending on the connectivity of the individual semiconductor die. Although conductive layer 282 is shown over insulating layer 276 from FIG. 7f, the conductive layer can be similarly formed over the insulating layers and/or polymer matrix composite substrate 274 in the embodiments of FIGs. 7g-7i.

In FIG. 7k, an insulating or passivation layer 284 is formed over insulating layer 276 and conductive layer 282 using spin coating, PVD, CVD, printing, sintering, or thermal oxidation. The insulating layer 284 can be one or more layers of SiO2, Si3N4, SiON, Ta2O5, Al2O3, polyimide, BCB, PBO, WPR, or other material having suitable insulating and structural properties, especially polymer photo sensitive dielectric materials. The insulating layer 284 serves in part to planarize the surface of polymer matrix composite substrate 274 in part to improve step coverage of subsequent deposition and lithography processing steps.

In FIG. 7l, an electrically conductive layer 286 is formed over conductive layer 282a-282c and insulating layer 284 using patterning with PVD, CVD, sputtering, electrolytic plating, electroless plating process, or other suitable metal deposition process. Conductive layer 286 can be one or more layers of Al, Cu, Sn, Ni, Au, Ag, Ti, TiW, or other suitable electrically conductive material. Conductive layer 286 is an adhesion layer or barrier layer. The adhesion layer can be Ti, TiN, TiW, Al, or Cr. The barrier layer can be Ni, NiV, Pt, Pd, TiW, or CrCu. The barrier layer inhibits the diffusion of Cu into the active area of the die.

An electrically conductive layer 288 is formed over conductive layer 286 using patterning with PVD, CVD, sputtering, electrolytic plating, electroless plating process, or other suitable metal deposition process to form individual portions or sections 288a-288j. Conductive layer 288 can be one or more layers of Al, Cu, Sn, Ni, Au, Ag, or other suitable electrically conductive material. The individual portions of conductive layer 288a-288j are electrically common or electrically isolated depending on the connectivity of the individual semiconductor die.

In FIG. 7m, an insulating or passivation layer 292 is formed over insulating layer 284 and conductive layer 288 using spin coating, PVD, CVD, printing, sintering, or thermal oxidation. The insulating layer 292 can be one or more layers of SiO2, Si3N4, SiON, Ta2O5, Al2O3, polyimide, BCB, PBO, WPR, or other material having suitable insulating and structural properties, especially polymer photo sensitive dielectric materials. A portion of insulating layer 292 is removed to expose conductive layer 288c and 288j.

In FIG. 7n, an electrically conductive layer 294 formed over conductive layer 288c and 288j as a UBM containing a multi-layer metal stack with an adhesion layer, barrier layer, and seed or wetting layer. The adhesion layer can be Ti, TiN, TiW, Al, or Cr. The barrier layer can be Ni, NiV, Pt, Pd, TiW, or CrCu. The barrier layer inhibits the diffusion of Cu into the active area of the die. The seed layer can be Cu, Ni, NiV, Au, or Al. The seed layer is formed over the barrier layer and acts as an intermediate conductive layer between conductive layer 288c and 288j and subsequent solder bumps or other interconnect structure. UBM 294 provides a low resistive interconnect to conductive layer 288c and 288j, as well as a

barrier to solder diffusion and seed layer for solder wettability. Alternatively, conductive layer 294 can overlap the edge of the via in insulating layer 292.

An electrically conductive bump material is deposited over UBM 294 using an evaporation, electrolytic plating, electroless plating, ball drop, or screen printing process. The bump material can be Al, Sn, Ni, Au, Ag, Pb, Bi, Cu, solder, and combinations thereof, with an optional flux solution. For example, the bump material can be eutectic Sn/Pb, high-lead solder, or lead-free solder. The bump material is bonded to UBM 294 using a suitable attachment or bonding process. In one embodiment, the bump material is reflowed by heating the material above its melting point to form spherical balls or bumps 296. In some applications, bumps 296 are reflowed a second time to improve electrical contact to UBM 294. The bumps can also be compression bonded to UBM 294. Bumps 296 represent one type of interconnect structure that can be formed over UBM 294. The interconnect structure can also use bond wires, conductive paste, stud bump, micro bump, or other electrical interconnect.

The structure described in FIG. 7a-7n, more specifically conductive layer 288e-288i, constitutes an inductor formed over polymer matrix composite substrate 274. The individual sections of conductive layer 288e-288i can be wound or coiled in plan-view to produce or exhibit the desired properties of an inductor. The inductor structure 288e-288i provides electrical characteristics needed for high frequency applications, such as resonators, high-pass filters, low-pass filters, band-pass filters, symmetric Hi-Q resonant transformers, matching networks, and tuning capacitors. The inductor can be used as front-end wireless RF components, which

can be positioned between the antenna and transceiver. The inductor can be a hi-Q balun, transformer, or coil, operating up to 100 Gigahertz. In some applications, multiple baluns are formed over a same substrate, allowing multi-band operation. For example, two or more baluns are used in a quad-band for mobile phones or other GSM communications, each balun dedicated for a frequency band of operation of the quad-band device. A typical RF system requires multiple inductors and other high frequency circuits in one or more semiconductor packages to perform the necessary electrical functions.

The inductor structure 288e-288i formed over polymer matrix composite substrate 274 simplifies the manufacturing process and reduces cost. An optional temporary and reusable metal carrier is used to build the artificial molding compound wafer or panel. The polymer matrix composite substrate 274 provides high resistivity, low loss tangent, low dielectric constant, matching CTE with the IPD structure, and good thermal conductivity.

While one or more embodiments of the present invention have been illustrated in detail, the skilled artisan will appreciate that modifications and adaptations to those embodiments may be made without departing from the scope of the present invention as set forth in the following claims.

Claims

What is claimed:

1. A method of making a semiconductor device, comprising:

forming a polymer matrix composite substrate;

forming a first insulating layer directly on a first surface of the polymer matrix composite substrate;

forming a first conductive layer directly on the first insulating layer;

forming a second insulating layer over the first insulating layer and first conductive layer;

forming a second conductive layer over the second insulating layer and extending to the first conductive layer;

forming a third insulating layer over the second insulating layer and second conductive layer;

removing a portion of the third insulating layer to expose the second conductive layer; and

forming a bump over the second conductive layer.

2. The method of claim 1, wherein forming the polymer matrix composite substrate includes:

providing a chase mold having first and second plates;

applying a first releasable layer over the first plate;

forming a metal carrier over the second plate;

applying a second releasable layer over the metal carrier; and

depositing an encapsulant material between the first and second plates of the chase mold.

3. The method of claim 1, further including forming a third conductive layer between the first conductive layer and second conductive layer.

4. The method of claim 1, further including forming a fourth insulating layer over a second surface of the polymer matrix composite substrate, opposite the first surface of the polymer matrix composite substrate.

5. The method of claim 1, further including forming a fourth insulating layer over the first insulating layer prior to forming the first conductive layer.

6. The method of claim 1, wherein the second conductive layer is wound to exhibit inductive properties.

7. A method of making a semiconductor device, comprising:

forming a molded substrate by,

(a) providing a chase mold including first and second plates, and

(b) depositing an encapsulant material between the first and second plates;

forming a first conductive layer over the molded substrate;

forming a first insulating layer over the molded substrate and first conductive layer;

forming an integrated passive device including a second conductive layer over the first insulating layer and extending to the first conductive layer;

forming a second insulating layer over the first insulating layer and second conductive layer; and

forming an interconnect structure over the second conductive layer.

8. The method of claim 7, wherein forming the molded substrate includes:

applying a first releasable layer over the first plate; and

applying a second releasable layer over the second plate.

9. The method of claim 7, further including forming a third conductive layer between the first conductive layer and second conductive layer.

10. The method of claim 7, further including:

forming a third insulating layer over a first surface of the molded substrate prior to forming the first conductive layer; and

forming a fourth insulating layer over a second surface of the molded substrate, opposite the first surface of the molded substrate.

11. The method of claim 7, further including:

forming a third insulating layer over a first surface of the molded substrate prior to forming the first conductive layer; and

forming a fourth insulating layer over the third insulating layer.

12. The method of claim 7, wherein the second conductive layer is wound to exhibit inductive properties.

13. The method of claim 7, wherein the interconnect structure includes a bump or bond wire.

14. A method of making a semiconductor device, comprising:
forming a polymer matrix composite substrate by:
(a)providing a chase mold having first and second plates,
(b)applying a first releasable layer over the first plate,
(c)applying a second releasable layer over the second plate, and
(d)depositing an encapsulant material between the first and second plates of the chase mold;
forming an inductor over the polymer matrix composite substrate; and
forming an interconnect structure over the inductor.

15. The method of claim 14, further including:
forming a first conductive layer over the polymer matrix composite substrate;
forming a first insulating layer over the polymer matrix composite substrate and first conductive layer;
forming a second conductive layer over the first insulating layer and first conductive layer;
forming a second insulating layer over the first insulating layer and second conductive layer; and
forming the interconnect structure over the second conductive layer.

16. The method of claim 15, further including forming a third conductive layer between the first conductive layer and second conductive layer.

17. The method of claim 15, further including:

forming a third insulating layer over a first surface of the polymer matrix composite substrate prior to forming the first conductive layer; and

forming a fourth insulating layer over a second surface of the polymer matrix composite substrate, opposite the first surface of the polymer matrix composite substrate.

18. The method of claim 15, further including:

forming a third insulating layer over a first surface of the polymer matrix composite substrate prior to forming the first conductive layer; and

forming a fourth insulating layer over the third insulating layer.

19. A method of making a semiconductor device, comprising:

forming a polymer matrix composite substrate in a chase mold;

forming an inductor over the polymer matrix composite substrate; and

forming an interconnect structure over the inductor.

20. The method of claim 19, further including:

forming a first conductive layer over the polymer matrix composite substrate;

forming a first insulating layer over the polymer matrix composite substrate and first conductive layer;

forming the inductor over the first insulating layer and first conductive layer;

forming a second insulating layer over the first insulating layer and inductor; and

forming the interconnect structure over the inductor.

21. The method of claim 20, further including forming a third conductive layer between the first conductive layer and inductor.

22. The method of claim 20, further including:

forming a third insulating layer over a first surface of the polymer matrix composite substrate prior to forming the first conductive layer; and

forming a fourth insulating layer over a second surface of the polymer matrix composite substrate, opposite the first surface of the polymer matrix composite substrate.

23. The method of claim 20, further including:

forming a third insulating layer over a first surface of the polymer matrix composite substrate prior to forming the first conductive layer; and

forming a fourth insulating layer over the third insulating layer.

24. The method of claim 19, wherein forming the polymer matrix composite substrate includes:

providing the chase mold having first and second plates;

applying a first releasable layer over the first plate;

forming a metal carrier over the second plate;

applying a second releasable layer over the metal carrier; and

depositing an encapsulant material between the first and second plates.