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ISOLATION DEVICE WITH SAFETY FUSE

Abstract

This description relates generally to semiconductor devices. A semiconductor device can include first and second conductive layers that can be positioned over a substrate, and at least one dielectric layer between the first and second conductive layers. The at least one dielectric layer can be positioned over at least a portion of the second conductive layer, and the first conductive layer can be positioned over a portion of the least one dielectric layer. The semiconductor device can further include a third conductive layer that can be positioned over the substrate and can be conductively connected to the second conductive layer and the substrate. The third conductive layer includes a fusible link.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION [0001] This Application is a divisional of U.S. Pat. No. 12,XXX,XXX (application Ser. No. 17/512,415), which is hereby fully incorporated herein by reference.

TECHNICAL FIELD

[0002] This description relates generally to semiconductor devices and processes, and more specifically, but not exclusively, to an isolator device and methods of forming the same.

BACKGROUND

[0003] Isolation is used in electrical circuits to prevent a flow of direct currents and undesirable alternating currents between two parts of a system and also shield high voltage from one part of a system to the other part of a system to prevent electrical shock. While preventing a flow of undesirable currents between parts of a system, isolation may allow signal transfer between the isolated parts of the system. Isolation can be provided by integrated circuits (ICs) referred to as isolators. Isolators may be included in electronic systems for safety reasons and/or to protect electronic components of the systems. For example, where two systems need to communicate, but the two systems may have different potentials, communication may be through an isolator but allows no current flow between two systems with different voltages. Various types of isolators may include optical coupling, capacitive coupling, inductive coupling, or other types of coupling.

SUMMARY

[0004] In an example, a semiconductor device can include first and second conductive layers that can be positioned over a substrate, and at least one dielectric layer between the first and second conductive layers. The at least one dielectric layer can be positioned over at least a portion of the second conductive layer, and the first conductive layer can be positioned over a portion of the least one dielectric layer. The semiconductor device can further include a third conductive layer that can be positioned over the substrate and can be conductively connected to the second conductive layer and the substrate. The third conductive layer includes a fusible link.

[0005] In another example, a method of forming an IC can include forming first and second electrodes of a reactive device over a substrate, and forming an interconnect network that can conductively couple the first electrode to the substrate and to a first terminal of a fusible link. The first and second electrodes can be separated by a dielectric layer.

[0006] In a further example, an IC can include upper and lower electrodes located over a substrate, and separated by a dielectric layer. The lower electrode can be located directly between the upper electrode and the substrate. The IC can further include an interconnect network that can conductively connect the lower electrode to the substrate and to a first terminal of a fusible link.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is an example of a cross-sectional view of a semiconductor isolator device with a fuse.

[0008] FIG. 2 is an example of etched conductive layers representative of various fuse shapes.

[0009] FIG. 3 is an example of a method of forming a semiconductor isolator device.

[0010] FIGS. 4-26 is an example of a process flow for fabricating a semiconductor isolator device with a fuse.

DETAILED DESCRIPTION

[0011] This description relates generally to isolator devices. Isolator devices are packaged ICs with capacitors for isolating different devices, such as a low voltage device (e.g., a processor) and a high voltage device (e.g., a gate driver). Capacitors used in isolator devices can be referred to as isolation capacitors. Isolator devices generally include a lead frame and one or more dies. Input and output bond pads of the one or more dies can be attached to conductive leads of the lead frame using a respective bond wire, thereby coupling the one or more dies therein to one of the low and high voltage devices. The one or more dies can include an isolation capacitor, which can function as a safety capacitor, and thus protect a user (e.g., a human) on a low voltage side from excessive shocks on a high voltage side, such as lightning, high voltage electrostatic discharge (ESD) or excessive operation stress (EOS) events. However, another kind of EOS event can occur on the low voltage side between input pins and ground pins. During such an EOS event, for example, the low voltage device can have a voltage that is greater than its rated voltage and cause a circuit failure, which can cause the isolator device to receive excessive current from the low voltage device that is greater than an acceptable (or rated) amount for the isolator device. The excessive current can overheat the isolator device, which can lead to damage to the isolation capacitor by causing dielectric layers of the isolation capacitor to crack, thereby degrading the isolation capability of the isolation capacitor. If the isolation capability is sufficiently degraded, and the user comes into contact with the isolator device from the low voltage side during excessive shock events such as lightning, high voltage ESD, or EOS on the high voltage side, the excessive current can flow to the user and shock the user, which in some instances leads to a loss of human life

[0012] According to the examples herein, a semiconductor isolator device can be fabricated with a safety fuse to provide isolation capacitor protection to mitigate isolation capacitor degradation during an EOS event. The semiconductor isolator device as described herein can be coupled to a first device (e.g., a low voltage device) and a second device (e.g., a high voltage device) and galvanically isolate the first and second devices via one or more isolation capacitors. In some examples, the safety fuse is formed in a current path on an input conductive lead of the semiconductor isolator device. For example, the safety fuse can be formed in the current path between an input conductive lead and a ground conductive lead of a lead frame assembly of the semiconductor isolator device. A portion of the current path can be formed of conductive layers of the semiconductor isolator device through which a current received at the input conductive lead can flow through the semiconductor isolator device and make the device functional.

[0013] In some examples, a portion of a respective conductive layer of the conductive layers is etched according to a fuse pattern to form a current crowding portion corresponding to the safety fuse. The term “current crowding portion” as used herein can refer to a portion of a conductive layer that is connected to a terminal portion and when conducting current has a greater current density than does the terminal portion. Thus, the portion of the respective conductive layer can be etched based on the fuse pattern to form a current crowding area therein and can have a greater current density than non-etched portions of the respective conductive layer. Without implied limitation, an example of a current crowding portion is the narrow neck portion of a “dog bone” style fusible link, the neck portion having a constant width and spanning a nonzero distance between two wider terminal portions.

[0014] In some examples, the respective conductive layer (or a portion thereof) is representative of an input current bonding pad of the semiconductor isolator device, and thus the fuse can be formed in a portion of the bonding pad. By forming the fuse in the portion of the bonding pad, the fuse can reduce or eliminate degradation of the isolation capacitor during the EOS event as the excessive current would flow through the fuse and cause fusion (e.g., melting of the use) before flowing to the isolation capacitor since a current density is higher at the safety fuse. The high current density during an EOS event can melt the safety fuse and lead the safety fuse to become open and cutting off a current flow path. As such, the etched portion of the respective conductive layer that can be representative of the fuse can reduce or restrict an amount of current that can flow through the

isolator die. Thus, the fuse can limit a maximum current flow into the semiconductor isolator device, such that excessive current provided by the first device during the EOS event does not degrade the isolation capacitor, which can lead to a shock of the user. In some examples, the safety fuse is a poly fuse, a contact fuse, or a metal fuse.

[0015] Examples are described herein wherein a fuse is used isolator devices to limit an input current to an isolator device, such as during an EOS event. However, the examples herein should not be construed and/or limited to only such devices. The fuse can be used in any semiconductor device for restricting (or limiting) current that can be received by the semiconductor device or flow within the semiconductor device (e.g., between conductive layers).

[0016] FIG. 1 is an example of a cross-sectional view of an integrated circuit (IC) **100**, e.g. a semiconductor isolator device. Without implied limitation additional aspects of the IC **100** may be provided by U.S. Patent Application No. 2019/0378892 (“the ‘892 application”), incorporated herein by reference in its entirety. In some examples the IC **100** is implemented using a five-metal-level interconnect system, and shown while other examples are implemented in a six-metal-level interconnect system. The IC **100** can include a lead frame assembly (not shown) for mounting an isolator die **102**, which can be encapsulated in a molding compound. For clarity and brevity purposes, the lead frame assembly and the molding compound of the IC **100** have been omitted. In some other examples, the package may be a multi-chip module (MCM) small outline integrated circuit (SOIC) package. In other examples, a different package can be used for packaging the isolator die **102**. Thus, while examples are presented herein wherein a single isolator die is attached to the lead frame, in other examples, one or more dies that include the isolator die **102** can be attached to the lead frame and encapsulated in a single package.

[0017] The isolator die **102** includes a substrate **104**. In some examples, the substrate **104** includes a polysilicon or other conductive material in the form of a gate electrode of a transistor. In some examples, the substrate **104** includes silicon, or another semiconductor material such as gallium arsenide, or an epitaxial layer of semiconductor material, and may have various components, for example, metal-oxide-silicon (MOS) transistors, diodes, field effect transistors (FETs), bipolar transistors, resistors and capacitors formed within it. The isolator die **102** can include a lower metal layer **106** and an upper metal layer **108**. The lower metal layer **106** and the upper metal layer **108** are terminals of a device in which the lower metal layer **106** and the upper metal layer **108** may be reactively coupled when excited by an AC signal. In some examples, the upper metal layer **108** is representative of a top electrode of a parallel plate capacitor **110** and the lower metal layer **106** is representative of a bottom electrode of the capacitor **110**. In other examples, the upper metal layer **108** may represent a top electrode of an inductor, and the lower metal layer **106** is representative of a bottom electrode of the inductor. Without implied limitation, the following description refers to the capacitor example.

[0018] The capacitor **110** can function as a safety circuit element by providing DC isolation between circuits connected to the upper metal layer **108** and circuits connected to the lower metal layer **106**, and thus protect a user (e.g., a human) from excessive shock, such as from high voltage ESD or a circuit operating at high voltage. In some examples, the upper metal layer **108** also functions as a bond pad for bonding a wire **112**. A first end of the wire **112** can be bonded to the upper metal layer **108** by a ball bond **114**. A second end of the wire **112** can be bonded to a respective conductive package terminal, e.g. a lead of a lead frame assembly. In some examples, the respective conductive lead is coupled to a first device, for example, a high voltage device (e.g., a semiconductor driver device). Thus, in some examples, the capacitor **110** is referred to as a high-voltage (side) capacitor. In other examples, the second end of the wire **112** is bonded to another bond pad on another die located within a same package as the isolator die **102**, or to another isolation device.

[0019] As shown in FIG. 1, the isolator die **102** can include dielectric layers **116-132** including a PMD layer (pre-metal dielectric) **116**, IMD (intra-metal dielectric) layers **118**, **122**, **126**, and **130**,

and ILD (inter-level dielectric) layers **120**, **124**, **128** and **132**. Thus, in some examples, ILD and IMD layers can be arranged in an alternating pattern between the metal layers **106** and **108** to form the capacitor **110**. A number of dielectric layers between the metal layers **106** and **108** can define a thickness of a total dielectric for a respective capacitance value. Thus, a dielectric thickness of the capacitor **110** can correspond to a breakdown voltage of the capacitor **110**. As shown in the example of FIG. 1, the ILD layer **132** overlies the IMD layer **130**, which overlies the ILD layer **128**. The ILD layer **128** overlies the IMD layer **126** and this layer overlies the ILD layer **124**, as shown in FIG. 1. While the example of FIG. 1 shows five dielectric layers defining the dielectric thickness of the capacitor **110**, in other examples, more or less than five dielectric layers may be used, which can be a combination of ILD and/or IMD layers. As shown in FIG. 1, between the capacitor **110** and the substrate **104**, additional dielectric layers are positioned, including the PMD layer **116**, the IMD **118**, and the ILD **120**.

[0020] In the illustrated example, a metal stack **134** is connected between the substrate **104** and a fuse **156**. The metal stack **134** includes metal stack layers **136**, **138**, **140**, and **142**, which may be referred to as respectively being located at MET1, MET2, MET3 and MET4 levels, while the top metal level may be referred to as the MET5 level. In some examples, the lower metal layer **106** and the metal stack layer **138** are connected by an interconnection (not shown) at the same metal level. The metal stack **134** is also electrically connected to the lower metal layer **106** by an interconnection (not shown) that can be at any metal level. As described in greater detail below with respect to FIG. 2, the fuse **156** includes a first fuse head **158**, a second fuse head **160**, and a current crowding portion **162**. In the illustrated example the fuse **156** is located at the same level as the upper metal layer **108**, and the first fuse head is connected to the fifth via **152**. While the fuse **156** may be located at any metal level, in the illustrated example the fuse **156**, or a portion thereof such as the second fuse head **160**, can also function as a bond pad at the top metal level connected to a wire **164**.

[0021] To provide electrical continuity from the substrate to the fuse **156** the metal stack **134** includes vias **144**, **146**, **148**, **150**, and **152** located at corresponding VIA1, VIA2, VIA3 and VIA4 levels. In examples in which the IC **100** is implemented in an aluminum interconnect system, the vias **144**, **146**, **148**, **150**, and **152** may be formed of tungsten or another suitable metal. In examples in which the IC **100** is implemented using a copper interconnect system, the vias and metal levels may be copper formed by a damascene or dual-damascene process. In some examples, the via **144** lands on a transistor gate in the substrate **104**, in which case the via **146** may be referred to as a transistor contact. While the metal stack **134** is shown as a vertically stacked combination of metal layers and vias in which the MET1, MET2, MET3, and MET4 portions directly overlie or underlie each other, in various examples the metal stack **134** may be an interconnection network that includes an arbitrary combination of metal layers and vias to form a conductive path from the substrate **104** and the fuse **156**, and from the lower metal layer **106** and the fuse **156**.

[0022] Because the metal stack **134** enables current to flow between the substrate **104** and the fuse **156**, current may flow in some circumstances between the wire **164** and the substrate **104** by way of a current path **166**. An amount of current that can be carried along the current path **166** can be limited by a maximum current density that can be supported by the fuse **156**. Thus, a current density of current flowing along the current path **166** can be a function of a current flow area corresponding to a respective minimum cross-sectional area of a conductor in the current path **166**, e.g., the current crowding portion **162**.

[0023] In some examples, during operation excess current may flow through the metal stack **134**. For example, a transistor gate oxide in the substrate **104** may fail, e.g. by an ESD or EOS event, causing a low-resistance path to a grounded circuit node or a silicon substrate. In the absence of the fuse **156** energy may be transferred to the isolator die **102** that heats the substrate or interconnect layers sufficiently to cause damage such as cracks that may propagate into the capacitor **110**. Such cracks may cause a low-resistance path between the upper metal layer **108** and the lower metal

layer **106**, compromising the ability of the isolator die **102** to protect a person who may come in contact with the IC **100** or with other devices intended to be isolated from high voltage by the isolator die **102**.

[0024] However, the fuse **156** may provide backup isolation by fusing in the event of such an excess current event. The fuse **156** may be configured to support a current density that is representative of a maximum current flow through the capacitor **110** under intended operating conditions. But the current crowding portion **162** of the fuse **156** is configured such that in an excess current event the current density through the current crowding portion **162** exceeds the allowed maximum current, causing localized heating that fuses the current crowding portion, isolating the first fuse head **158** from the second fuse head **160**, thus ensuring high voltage is not coupled between the wire **112** and the wire **164**. In view of this operation, the fuse **156** may be referred to as a safety fuse. As described previously, the fuse **156** may be implemented alternatively in any metal layer or via layer, or in a polysilicon layer (not shown) of the substrate **104**.

[0025] For examples in which the fuse is implemented in a polysilicon layer, such layer can be doped with any suitable n-type or p-type impurities or can be undoped. For examples in which the fuse is implemented in a via layer, the current crowding portion may be implemented by a smaller number of vias in one via level relative to other via levels.

[0026] FIG. 2 is a top view of three example fuses **202**, **204**, and **206** that may serve as the fuse **156** (FIG. 1). Each of the fuses **202**, **204**, and **206** has a thin body portion between two taper portions that transition to each of two corresponding head portions. For example, the fuse **202** has a body portion **226** between head portions **214** and **220**, the fuse **204** has a body portion **228** between head portions **216** and **222**, and the fuse **206** has a body portion **230** between head portions **215** and **224**. The body portions **226**, **228**, and **230** may sometimes be referred to as fusible links, and the head portions may sometimes be referred to as terminals of the respective fuses. Current flowing through one of the fuses **202**, **204** and **206** is thus crowded in the body portion and taper portions relative to the head portions, and thus the body portion and taper portions may be collectively referred to sometimes as a current crowding portion, exemplified by current crowding portions **208**, **210** and **212**. By reducing a current flow cross-sectional area within the respective current crowding portion of each fuse **202**, **204**, and **206**, current crowding can lead to localized, melting and/or vaporization at the respective body portions **226**, **228**, and **230**, such as during an EOS or ESD event, as described herein.

[0027] The fuse **202** illustrates an example in which the taper portions have a maximum width equal to the head portions **214** and **220**, and the body portion **226** has a uniform cross-sectional area between the taper portions. The fuse **204** illustrates an example in which the taper portions have a maximum width smaller than the head portions **216** and **222**, and the body portion **228** has a uniform cross-sectional area between the taper portions. The fuse **206** illustrates an example in which the taper portions have a maximum width smaller than the head portions **218** and **224**, and the body portion **230** includes a notch, resulting in a portion of the body portion **230** having a first cross-sectional area and a portion having a second smaller cross-sectional area.

[0028] FIG. 3 is an example of a method **300** of forming an integrated circuit including a semiconductor isolator device such as the IC **100**, as shown in FIG. 1, e.g. using a 5-level metallization process. Thus, reference can be made to the example of FIGS. 1-2 in the example of FIG. 3. Additional details of forming one suitable example isolator device is provided by the '892 application. The method **300** can begin at **302** by forming a first dielectric layer (e.g., PMD layer **116**, FIG. 1) over a substrate (e.g., the substrate **104**, FIG. 1). At **302**, a first via, or contact (e.g., via **144**, FIG. 1) may also be formed within the first dielectric layer and connected to a gate electrode layer in an underlying substrate. At **304**, forming a second dielectric layer (e.g. IMD1 **118**, FIG. 1) over the first dielectric layer, and forming a metal layer (e.g. MET1 **136**, FIG. 1) within the second dielectric layer and connected to the first via. At **306**, forming a third dielectric layer (e.g. ILD1 **132**, FIG. 1) over the second dielectric first layer, and a second via (e.g. via **146**, FIG. 1) within the

third dielectric layer and connected to the first metal layer.

[0029] At **308** a fourth dielectric layer (e.g. IMD2 **122**, FIG. **1**) is formed over the third dielectric layer. A second metal layer (e.g. MET2 **138**, FIG. **1**) and a capacitor bottom plate (e.g. lower metal layer **106**, FIG. **1**) are formed within the fourth dielectric layer. The second metal layer is electrically connected to the second via, and to the capacitor bottom plate within the fourth dielectric layer. At **310** a fifth dielectric layer (e.g., ILD **124**, FIG. **1**) is formed over the fourth dielectric layer, and a third via (e.g. via **148**, FIG. **1**) is formed within the fifth dielectric layer and electrically connected to the second metal layer. At **312**, forming a sixth dielectric layer (e.g. IMD3 **126**, FIG. **1**), and forming a third metal layer (e.g. MET3 **140**, FIG. **1**) within the sixth dielectric layer and electrically connected to the third via. At **314** a seventh dielectric layer (e.g., ILD3 layer **128**, FIG. **1**) is formed over the sixth dielectric layer, and a fourth via (e.g. via **150**, FIG. **1**) is formed within the seventh dielectric layer and connected to the third metal layer. At **316**, forming an eighth dielectric layer (e.g. IMD4 **130**, FIG. **1**), and forming a metal layer (e.g. MET4 **142**, FIG. **1**) within the eighth dielectric layer and connected to the fourth via. At **318** a ninth dielectric layer (e.g., ILD4 layer **132**, FIG. **1**) is formed over the eighth dielectric layer, and a fifth via (e.g. via **152**, FIG. **1**) is formed within the ninth dielectric layer and connected to the fourth metal layer. [0030] At **320**, forming a capacitor top plate (e.g. top plate **108**, FIG. **1**) in a fifth metal level over the ninth dielectric layer and over the capacitor bottom plate. At **322**, forming a fuse (e.g. fuse **164**) over the and electrically connected to the first via. In one example the fuse is formed concurrently with step **320** at the same metal level as the capacitor top plate, but in other examples, the fuse may be formed at any other metal or gate electrode level. When formed at a top-level metal such as the fifth metal level, portions of the fuse may serve as interconnection terminals or bond pads. For example, the first fuse head **214** of the fuse **202** (FIG. **2**) may be electrically connected to the fifth via, and the second fuse head portion **220** may serve as a bond pad, for example, to which the wire **164** (FIG. **1**) is attached. Forming the fuse includes forming a corresponding body portion (e.g. body portion **226**, FIG. **2**). At **324** the fuse and the capacitor are connected between two terminals of a device package and sealed within the package.

[0031] In the method **300**, vias and metal layers (including the bottom and top plates and the fuse) may be formed by any suitable process. One such process includes aluminum metal layers, formed by subtractive etch, joined by tungsten vias formed by via fill and CMP. Another suitable process includes forming copper metal layers and vias by a damascene or double-damascene process. The scope of the disclosure includes future-developed metallization processes that are otherwise consistent with the disclosure. Furthermore, while illustrated as a 5-level metal process, the integrated circuit may include any number of metallization levels consistent with forming the capacitor **110**, for example, a 6-level metal process.

[0032] FIGS. **4-26** show stages of a method for fabricating a semiconductor isolator device, such as the IC **100**, as shown in FIG. **1**. Thus, reference can be made to the example of FIG. **1** in the example of FIGS. **4-26**. Without implied limitation, additional aspects are described in the '892 application for the specific implementation of a 5-level aluminum metallization process. As shown in FIG. **4**, at **400**, a PMD layer **402** (e.g. the PMD layer **116**, FIG. **1**), such as a silicon oxide-base dielectric, can be formed over a substrate **404**. In some examples, the substrate includes a gate electrode layer. As an example, the substrate **404** may include a polysilicon layer that resides over a MOS transistor. In some examples, at **400**, chemical-mechanical polishing (CMP) can be applied to a surface of the PMD layer **402** to planarize the surface of the PMD layer **402**. As shown in FIG. **5**, at **500**, the PMD layer **402** can be etched to form a first opening **406**.

[0033] At **600**, as shown in FIG. **6**, a first metal layer **408** can be deposited over the PMD layer **402**. The first metal layer **408** can fill the first opening **406** to form a first via **410** therein. In some examples, the first metal layer **408** is tungsten. Throughout this description via-fill metal may be described without implied limitation as tungsten while recognizing that other suitable transition metals may be used in addition or in the alternative. At **700**, the first metal layer **408** is polished by

CMP to remove the tungsten layer outside the opening **406**, so as to result in the structure, as shown in FIG. 7. For example, CMP can be applied to the tungsten layer **408** to strip away the tungsten layer **408** overlaying the PMD layer **402** while leaving the first via **410**.

[0034] As shown in FIG. 8, at **800**, a first metal layer **412** is deposited over the PMD layer **402**. The first metal layer **412** is etched at **900** to provide a first metal layer portion **414**, so as to result in the structure, as shown in FIG. 9. As shown in FIG. 10, at **1000**, a first IMD layer **416** is deposited over the first metal layer portion **414** and exposed portions of the PMD **402**. In some examples, as shown in FIG. 11, at **1100**, a first ILD layer **418**, e.g. including silicon oxide, is deposited over the first IMD layer **416**. In some examples, at **1100**, CMP is applied to a surface of the first ILD layer **418** to planarize the surface of the first ILD layer **418**. As shown in FIG. 12, at **1200**, the first ILD layer **418** can be etched to form a second opening **420** in the first ILD layer **418**.

[0035] At **1300**, as shown in FIG. 13, a second tungsten layer **422** can be deposited over the first ILD layer **418**. The tungsten layer **422** can fill the second opening **420** to form a second via **424** therein. As shown in FIG. 14, at **1400**, the tungsten layer **422** overlying the first ILD layer **418** can be polished so as to result in the structure as shown in FIG. 14. For example, CMP is applied to the tungsten layer **422** to strip away the tungsten layer **422** overlying the first ILD layer **418** while leaving the second via **424**. As shown in FIG. 15, at **1500**, a second metal layer **426** can be deposited over the first ILD layer **418**. In some examples, at **1600**, the second metal layer **426** is etched to form a capacitor bottom plate **428** and a second metal portion **430**, so as to result in the structure, as shown in FIG. 16. In some examples, at **1700**, a second IMD layer **432** is deposited over exposed portions of the first ILD layer **418**, so as to result in the structure, as shown in FIG. 17.

[0036] In some examples, at **1800**, during fabrication, steps **400-1000**, are repeated, so as to result in a structure as shown in FIG. 18. A number of times that the steps **400-1000** are repeated can be based on a capacitance for the semiconductor isolator device, and thus an application of the semiconductor isolator device. Thus, in some examples, during fabrication, a second ILD layer **434** is formed over the second dielectric layer **232**, the lower capacitor plate **428** and the second metal layer portion **430**. In some examples, during the fabrication, a second ILD layer **436** is formed over the second ILD layer **434**. In further examples, during the fabrication, a fourth ILD layer **438** is formed over the second ILD layer **436**, and a fourth IMD layer **440** can be formed over the fourth ILD layer **438**. As shown, at **1800**, during the fabrication, within the second ILD layer **434**, a third via **442** can be formed, and within the fourth ILD layer **438** a fourth via **444** can be formed. Moreover, during the fabrication, within the third IMD layer **436** and the fourth IMD layer **438** respective third and fourth metal layer portions **443** and **446** can be formed, so as to result in the structure, as shown in FIG. 18.

[0037] In some examples, at **1900**, as shown in FIG. 19, a fifth ILD layer **448** is deposited and etched to form a third opening **450**. At **2000**, steps **600-700** can be repeated, so as to result in the structure, as shown in FIG. 20. As such, a fifth via **452** can be formed in the third opening **450**, as shown in FIG. 20. In some examples, as shown in FIG. 21, at **2100**, a fifth metal layer **454** is deposited over the fifth ILD layer **448** and etched to form an upper capacitor plate **456** and fuse **458**. In some examples, at **2200**, a surface **460** of the fuse **458** is etched according to a fuse etching pattern to form a current crowding portion **462**. The current crowding portion **462** at the fuse **458** can function as a fusible link, and thus determine or define an amount of current that can be received at a corresponding pad, as described herein.

[0038] As shown in FIG. 22, the fuse **458** can be etched according to the fuse etching pattern, such that a width of the fuse **458** is reduced at a location along a length of the fuse **458**, thereby limiting an amount of current that can flow through the fuse **458** in contrast to non-etched portions of the fuse **458**. In some examples, the fuse **458** has an etch pattern similar to one of the etch patterns of the current crowding portions **214**, **216**, and **218**, as shown in FIG. 2. Accordingly, the fuse **458** can be etched to form the current crowding portion **462**, so as to result in an isolator die **464**, as shown

in FIG. 22. The isolator die **464** can correspond to the isolator die **102**, as shown in FIG. 1.

[0039] In some examples, at **2300**, as shown in FIG. 23, the isolator die **464** is attached to a lead frame assembly **466** that can include conductive leads **468** and a die mounting pad **470**. As shown in FIG. 23, the isolator die **464** can be attached to the die mounting pad **470**. An adhesive material can be used to secure the isolator die **464** to the die mounting pad **470**. For example, the adhesive material may be a polymeric type of material for attaching the isolator die **464** to the die mounting pad **470**. In other examples, a solder, another bonding agent, or attachment device can be used to secure the isolator die **464** to the die mounting pad **470**. In some examples, the upper capacitor plate **456** and fuse function as bond pads. In some examples, at **2400**, a first end of a bond wire **472** is bonded to the upper capacitor plate **456** by a ball bond **474**. In some examples, the first end of the bond wire **472** is bonded to the upper capacitor plate **456** by a stitch bond.

[0040] In some examples, at **2400**, a first end of a bond wire **476** is bonded to the fuse **458** by a ball bond **478**. In some examples, the first end of the bond wire **476** is bonded to the fuse **458** by a stitch bond. As shown in FIG. 25, at **2500**, second ends of the bond wires **472** and **476** can be coupled to a respective conductive lead of the conductive leads **468**. At **2600**, a structure, as shown in FIG. 25, can be encapsulated by a molding compound **480** to provide a packaged semiconductor isolator device **482**, as shown in FIG. 26. As an example, the molding compound **480** can be an epoxy based molding compounding. In some examples, the packaged semiconductor isolator device **480** includes the IC **100**, as shown in FIG. 1.

[0041] What has been described above are examples. It is, of course, not possible to describe every conceivable combination of components or methodologies, but one of ordinary skill in the art will recognize that many further combinations and permutations are possible. Accordingly, the disclosure is intended to embrace all such alterations, modifications, and variations that fall within the scope of this application, including the appended claims.

[0042] Modifications are possible in the described embodiments, and other embodiments are possible, within the scope of the claims.

Claims

1. A method of forming an integrated circuit, comprising: forming first and second electrodes of a reactive device over a substrate, the first and second electrodes separated by a dielectric layer; and forming an interconnect network that conductively couples the first electrode to the substrate and to a first terminal of a fusible link.
2. The method as recited in claim 1, wherein the fusible link is at a same metal level as the second electrode.
3. The method as recited in claim 1, wherein the interconnect network is implemented in a five-metal-level interconnect system.
4. The method as recited in claim 1, wherein the fusible link is connected to the first terminal and second terminal by tapered portions with a maximum width less than a width of the first and second terminals.
5. The method as recited in claim 1, wherein the connection to the substrate includes a connection to a transistor gate electrode.
6. The method as recited in claim 1, wherein the first and second electrodes include first and second plates of a parallel plate capacitor.
7. A method of forming a semiconductor device comprising: forming first and second conductive layers over a semiconductor substrate; forming at least one dielectric layer between the first and second conductive layers, wherein the at least one dielectric layer is positioned over at least a portion of the second conductive layer, and the first conductive layer is positioned over a portion of the at least one dielectric layer; forming a third conductive layer positioned over the substrate and conductively connected to the second conductive layer and the substrate, wherein the third

- conductive layer includes a fusible link; connecting a first wire between a first package terminal of a and the first conductive layer; and forming a second wire between a second package terminal and the fusible link.
- 8.** The method of claim 7, further comprising forming an interconnection network conductively connected to the third conductive layer to the second conductive layer.
- 9.** The method of claim 7, wherein the portion of the at least one dielectric layer is a first portion, and the third conductive layer is positioned over a second portion of the at least one dielectric layer.
- 10.** The method of claim 7, wherein the fusible link is located at a same metal layer as the first conductive layer.
- 11.** The method of claim 7, wherein the first and second package terminals are terminals of a molded plastic package.
- 12.** A method of forming an integrated circuit, comprising: forming first and second conductive layers positioned over a substrate; forming at least one dielectric layer between the first and second conductive layers, wherein the at least one dielectric layer is positioned over at least a portion of the second conductive layer, and the first conductive layer is positioned over a portion of the at least one dielectric layer; and forming a third conductive layer positioned over the substrate and conductively connected to the second conductive layer and the substrate, wherein the third conductive layer includes a fusible link having fuse body connected to two fuse terminals by corresponding tapered metal portions.
- 13.** The method of claim 12, further comprising forming an interconnection network conductively connected to the third conductive layer and to the second conductive layer.
- 14.** The method of claim 12, wherein the portion of the at least one dielectric layer is a first portion, and the third conductive layer is positioned over a second portion of the at least one dielectric layer.
- 15.** The method of claim 12, wherein the fusible link is located at a same metal layer as the first conductive layer.
- 16.** The method of claim 12, further comprising packaging the substrate in a device package, connecting a first wire between a first package terminal and the first conductive layer, and a connecting a second wire between a second package terminal and the fusible link.
- 17.** The method of claim 16, wherein the device package is a molded plastic package.
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