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APPARATUS INCLUDING INTEGRATED PADS AND METHODS OF MANUFACTURING THE SAME

Abstract

Semiconductor devices including electrically-isolated extensions and associated systems and methods are disclosed herein. An electrically-isolated extension may be coupled to a corresponding connection pad that is attached to a surface of a device. The electrically-isolated extensions may extend at least partially through one or more layers at or near the surface and toward a substrate or an inner portion thereof.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. patent application Ser. No. 18/380,118, filed Oct. 13, 2023; which is a continuation of U.S. patent application Ser. No. 17/408,343, filed Aug. 20, 2021, now U.S. Pat. No. 11,824,025; each of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present technology is directed to apparatuses, such as semiconductor devices including memory and processors, and several embodiments are directed to semiconductor devices that include connection pads.

BACKGROUND

[0003] The current trend in semiconductor fabrication is to manufacture smaller and faster devices with a higher density of components for computers, cell phones, pagers, personal digital assistants, and many other products. However, decrease in circuit size can lead to changes or weaknesses in structural integrity. For example, structures in the fabricated semiconductor device may delaminate and/or crack due to stress, temperature fluctuations, and/or mismatches in the coefficient of thermal expansion (CTE) for the corresponding materials of the structures in the device.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. 1A illustrates a bottom view of an apparatus in accordance with embodiments of the technology.

[0005] FIG. 1B illustrates a schematic cross-sectional view of the semiconductor device taken along a line 1B-1B of FIG. 1A in accordance with embodiments of the technology.

[0006] FIG. 2-FIG. 7 illustrate example phases for a manufacturing process in accordance with embodiments of the technology.

[0007] FIG. 8A-FIG. 8C illustrate a second example apparatus in accordance with embodiments of the technology.

[0008] FIG. 9A-FIG. 9C illustrate a third example apparatus in accordance with embodiments of the technology.

[0009] FIG. 10 is a flow diagram illustrating an example method of manufacturing an apparatus in accordance with an embodiment of the present technology.

[0010] FIG. 11 is a schematic view of a system that includes an apparatus configured in accordance with embodiments of the present technology.

DETAILED DESCRIPTION

[0011] In the following description, numerous specific details are discussed to provide a thorough and enabling description for embodiments of the present technology. One skilled in the relevant art, however, will recognize that the disclosure can be practiced without one or more of the specific details. In other instances, well-known structures or operations often associated with semiconductor devices are not shown, or are not described in detail, to avoid obscuring other aspects of the technology. In general, it should be understood that various other devices, systems, and methods in

addition to those specific embodiments disclosed herein may be within the scope of the present technology.

[0012] Several embodiments of semiconductor devices, packages, and/or assemblies in accordance with the present technology can include one or more electrically-isolated extensions (e.g., metallic structures, such as pegs, nails, spikes, nails, or the like) extending vertically inward from one or more pads (e.g., under-bump metallization (UBM), such as electrically-active pads, electrically-isolated pads, and/or thermal pads). The electrically-isolated extensions and the corresponding pads can be electrically isolated and disconnected from electrical circuits on the corresponding apparatus. Each electrically-isolated extension can extend vertically inward from a corresponding pad. For example, an apparatus (e.g., a semiconductor device, a package, and/or an assembly) can include a set of connection pads on a surface (e.g., a bottom surface) thereof. The electrically-isolated extension can be overlapped or hidden by a corresponding pad and extend upward or inward toward an inner portion of the apparatus. The electrically-isolated extension can extend at least partially through a passivation layer (e.g., a tetraethyl orthosilicate (TEOS) layer). In some embodiments, the electrically-isolated extension can extend completely through the passivation layer up to or at least partially through a barrier layer (e.g., a silicon nitride (SiN) layer) adjacent to or abutting the passivation layer.

[0013] The electrically-isolated extension can have a width that is less than one or more dimensions of the corresponding pad. In other words, the external portions of the pad can overhang or extend past external edges of the electrically-isolated extension. The electrically-isolated extension can have a length that is less than a distance measured between the inactive surface to the nearest distribution layer. For example, the electrically-isolated extensions can have the length that is less than lengths of through-silicon vias (TSVs). In some embodiments, the electrically-isolated extension length can be less than or up to a distance between the inactive surface to an apparatus/silicon substrate. In other embodiments, the electrically-isolated extension can extend partially into the apparatus substrate.

[0014] The electrically-isolated extension provides increased thermal dissipation for the apparatus. The electrically-isolated extension can include material (e.g., metallic material) that has better thermal conductivity than outer layers (e.g., the barrier layer and/or the passivation layer) of the apparatus. Accordingly, the electrically-isolated extension can increase the amount of thermal energy that is drawn out or removed through the corresponding pad (e.g., a thermal pad). The electrically-isolated extension can further improve the structural integrity of the apparatus. The electrically-isolated extension can increase the bond between the corresponding pad and the adjacent layer (e.g., the passivation/TEOS layer) and/or the rigidity in the corresponding portion. Accordingly, the electrically-isolated extension can reduce cracks or other structural failures in the adjacent layer.

[0015] FIG. 1A is a bottom view of an apparatus **100** (e.g., a semiconductor device, such as a chip, a package, and/or an assembly), and FIG. 1B is a schematic cross-sectional view of the apparatus **100** taken along a line 1B-1B of FIG. 1A in accordance with embodiments of the technology. Referring to FIG. 1A and FIG. 1B together, the apparatus **100** can include a surface **102** (e.g., a bottom surface) with a set of connection pads (e.g., UBMs). As an illustrative example, the apparatus **100** can have a thermal pad **104** and/or an electrical pad **106** disposed over the surface **102**. One or more of the pads, such as the thermal pad **104**, can have a dimension **108** (e.g., a width).

[0016] The apparatus **100** can have a substrate **112** (e.g., a wafer substrate, such as a silicon substrate). The apparatus **100** can have a barrier layer **114** (e.g., a SiN layer) disposed between the substrate **112** and a passivation layer **116** (e.g., a TEOS layer). The barrier layer **114** can overlap or cover the substrate **112** along a lateral plane. The barrier layer **114** may include a dielectric layer to electrically insulate one or more structures (e.g., metal layers, connectors, circuitry, or the like). The barrier layer **114** may also be configured to provide a barrier against chemicals (e.g., etching

agents) and/or elements (e.g., water molecules, sodium ions, etc.). The passivation layer **116** can overlap the substrate **112** and function as an electrical and/or a physical barrier. In some embodiments, the passivation layer **116** can function as a solder resist. The passivation layer **116** can have an exposed surface that corresponds to the surface **102** (e.g., the exposed surface of the apparatus **100** or the overall semiconductor substrate structure).

[0017] The apparatus **100** can include one or more electrically-isolated extensions **122** (e.g., structures, such as pegs, nails, spikes, nails, or the like) directly coupled to and extending from corresponding pad(s) toward an inner portion of the apparatus **100**. For the example illustrated in FIG. **1B**, the electrically-isolated extension **122** can include thermally conductive material (e.g., metallic material, such as copper) and extend along a vertical direction (e.g., inwardly or downward in FIG. **1B**) from a pad (e.g., the thermal pad **104**) toward the substrate **112**. The electrically-isolated extension **122** can be electrically isolated from circuits on the apparatus **100**. For example, the electrically-isolated extension **122** can be coupled (e.g., thermally, such as through direct contact and/or a thermally interfacing material) to the thermal pad **104**.

[0018] The electrically-isolated extension **122** can have an extension width **124** and an extension length **126**. The extension width **124** can be less than the pad width **108**. The electrically-isolated extension **122** can be overlapped or be covered by the corresponding pad (e.g., the thermal pad **104**). In other words, external portions of the coupled pad can overhang or laterally extend past external edges of the electrically-isolated extension **122**. The extension length **126** can be less than a separation distance from the surface **102** and an electrical circuit component in the apparatus **100**. The electrically-isolated extension **122** can extend at least partially into the passivation layer **116**, the barrier layer **114**, and/or the substrate **112**. For the example illustrated in FIG. **1B**, the electrically-isolated extension **122** can extend through the TEOS layer and up to the SiN layer disposed between the TEOS layer and the silicon substrate. The electrically-isolated extension **122** (e.g., peripheral surfaces thereof) can directly contact the barrier layer **114**.

[0019] The apparatus **100** can include one or more TSVs **132** coupled to the electrical pads **106**. The TSV **132** can include an electrically conductive structure (e.g., a copper peg, nail, spike, or the like) that extends vertically and at least partially into the substrate **112** of the apparatus **100**. The TSV **132** can electrically couple the corresponding electrical pad **106** to electrical circuit within the apparatus **100**.

[0020] The TSV **132** can be overlapped by and electrically coupled to the corresponding electrical pad **106**. In some embodiments, the TSV **132** can extend through an opening in the passivation layer **116**. For example, peripheral surface(s) of the TSV **132** can directly contact the passivation layer **116** that occupy the opening in the passivation layer **116**. In some embodiments, the opening can have a width or a dimension that is less than the pad width **108**. Also, the TSV **132** may further have a via width **134** that is less than the width of the opening and/or the pad width **108**. The TSV **132** can have a via length **136** that corresponds to the electrical coupling. The via length **136** can be greater than the extension length **126**.

[0021] FIG. **2**-FIG. **7** illustrate example phases for a manufacturing process in accordance with embodiments of the technology. The example phases can correspond to manufacturing the apparatus **100** of FIG. **1A**. FIG. **2** illustrates an intermediate structure **200** having a wafer-level substrate **202** (e.g., the substrate **112**) and a TSV structure **204**. The TSV structure **204** can correspond to the TSV **132** of FIG. **1A**, and the wafer-level substrate **202** can correspond to the substrate **112** of FIG. **1B**.

[0022] The wafer-level substrate **202** can have an uncovered surface **212**. The TSV structure **204** can extend below the uncovered surface **212** and partially into the wafer-level substrate **202**. The intermediate structure **200** can correspond to a phase after processing of the wafer-level substrate **202**. For example, the intermediate structure **200** can correspond to circuit formation (e.g., doping) on the wafer-level substrate **202**, grinding/thinning the silicon substrate, forming one or more patterning structures, creating voids in the patterning structures and/or the device wafer, filling (via,

e.g., metal deposition/plating) the voids with metallic material, and/or etching away protective or patterning layers.

[0023] FIG. 3 illustrates an intermediate structure **300** having the structure **200** of FIG. 2 covered with a barrier layer **302** and a passivation layer **304**. The barrier layer **302** can correspond to the barrier layer **114** of FIG. 1B, and the passivation layer **304** can correspond to the passivation layer **116** of FIG. 1B. For example, the barrier layer **114** can include a SiN layer, and the passivation layer **116** can include a TEOS layer.

[0024] In some embodiments, the manufacturing process can include depositing the barrier layer **302** onto the structure **200** (e.g., directly onto the uncovered surface **212** of FIG. 2) and then depositing the passivation layer **304** over the barrier layer **302**. For example, the barrier layer **302** and the passivation layer **304** can be deposited using corresponding chemical deposition and/or lamination processes. The barrier layer **302** can have a thickness less than a protrusion height of the TSV structure **204**. The barrier layer **302** can surround and/or conform to a portion of the TSV structure **204** protruding above the wafer-level substrate **202**. The passivation layer **304** may be applied with a thickness that covers a top portion of the TSV structure **204** and/or a corresponding portion of the barrier layer **302** over the top portion of the TSV structure **204**. The passivation layer **304** may be planarized.

[0025] FIG. 4 illustrates an intermediate structure **400** having the structure **300** of FIG. 3 with one or more extension openings/depressions **402** on a top surface thereof. The manufacturing process can include removal (using, e.g., chemical etching and/or mechanical removal techniques) of a portion of the passivation layer **304** at a predetermine location and/or depth to form each of the extension openings **402**. For example, the extension openings **402** can be formed with dimensions corresponding to the extension width **124** of FIG. 1B and/or the extension length **126** of FIG. 1B. The extension opening **402** may extend through the passivation layer **304** and down to the barrier layer **302**. Also, the extension opening **402** can be formed according to a predetermined shape (e.g., a cylindrical opening with a circular/oval cross-sectional shape or a polygonal cross-sectional shape) and/or a corresponding location.

[0026] FIG. 5 illustrates an intermediate structure **500** having the structure **400** of FIG. 4 with an extension structure **502** in each of the extension openings **402** of FIG. 4. The extension structure **502** can correspond to the electrically-isolated extension **122** of FIG. 1B. The extension structure **502** may be formed according to metal deposition or plating techniques. The extension structure **502** can occupy the extension openings **402** and have the shape associated with the extension opening **402**.

[0027] In some embodiments, the manufacturing process can iteratively repeat one or more processes associated with FIG. 3-FIG. 5. For example, the passivation layer **304** may be deposited or formed around the extension opening **402**. The extension opening **402** can be preserved or formed using a barrier or through controlling the deposition of the passivation layer **304**. Also, the passivation layer **304** and the extension structure **502** may be formed iteratively. For each iteration, a portion of the passivation layer **304** may be formed and a portion of the extension structure **502** may be deposited afterwards into the extension opening **402**. The iterative forming may be used to control patterns, shapes, and/or orientation of the extension structure **502**, such as by controlling and varying the size, location, and/or shape of the extension opening **402** across the iterations. Accordingly, the extension structure **502** can have a non-rectangular side-view shape, non-reflective shape across one or more axes, laterally extending portions, multiple internal members or portions, and/or separation spaces between internal members. In other embodiments, the extension structure **502** may be placed at a predetermined location after forming the barrier layer **302**, and the passivation layer **304** may be formed around the extension structure (such as by, e.g., flowing and curing passivation or epoxy material).

[0028] FIG. 6 can illustrate an intermediate structure **600** corresponding to the structure **500** of FIG. 5 with a top portion thereof removed. For example, the manufacturing process can include

chemical and/or mechanical removal processes (e.g., cutting, grinding, chemical-mechanical polishing (CMP), etc.) to remove a portion of the passivation layer **304**, the extension structure **502**, the TSV structure **204**, and/or the barrier layer **302** (e.g., the portion over the TSV structure **204**). As a result, the intermediate structure **600** can have the TSV structure **204** exposed on or through a top surface thereof. In some embodiments, the intermediate structure **600** can have a planar surface. In other words, top surfaces of the passivation layer **304**, the TSV structure **204**, and/or the extension structure **502** may be coplanar. Further, the TSV structure **204** may be located within an opening in the passivation layer **304**. The barrier layer **302** may also be located within the opening, with the barrier layer **302** contacting/surrounding the TSV structure **204**. Based on the removal, the electrically-isolated extension **122** of FIG. **1B** may be formed from the extension structure **502**, and the TSV **132** of FIG. **1B** may be formed from the TSV structure **204**.

[0029] FIG. **7** can illustrate the intermediate structure **600** with the set of pads (UBM) mounted thereon. The set of pads (e.g., the thermal pad **104** and/or the electrical pad **106**) may be mounted over the remaining/exposed extension structure **502** of FIG. **6** and/or the TSV structure **204** of FIG. **6**. The pads may be mounted based on bonding and/or attaching (via, e.g., adhesives) the set of pads to the corresponding extension structure **502** and/or TSV structure **204**. The apparatus **100** of FIG. **1A** may be formed based on mounting the set of pads to the intermediate structure **600**.

[0030] FIG. **8A**-FIG. **8C** illustrate a second example apparatus **800** (e.g., a semiconductor device, such as a chip, a package, and/or an assembly) in accordance with embodiments of the technology. FIG. **8A** can illustrate a bottom view of the apparatus **800**, FIG. **8B** can illustrate a cross-section view of the apparatus **800** taken along a line **8B-8B** of FIG. **8A**, and FIG. **8C** can illustrate a cross-section view of the apparatus **800** taken along a line **8C-8C** of FIG. **8B**.

[0031] The apparatus **800** can be similar to the apparatus **100** of FIG. **1A**. Referring to FIG. **8A** and FIG. **8B** together, the apparatus **800** can include a surface **802** (e.g., a bottom surface) with a set of connection pads (e.g., UBMs), such as a thermal pad **804** and/or an electrical pad **806** exposed/mounted thereon. The apparatus **800** can have a substrate **812** (e.g., a wafer substrate, such as a silicon substrate). The apparatus **800** can have a barrier layer **814** (e.g., a SiN layer) disposed between the substrate **812** and a passivation layer **816** (e.g., a TEOS layer). The apparatus **800** can further include a TSV **832**. The substrate **812**, the barrier layer **814**, the TSV **832**, and the passivation layer **816** can be similar in material, shape, location, orientation, or the like to the corresponding structures of the apparatus **100**.

[0032] The apparatus **800** can include a set of electrically-isolated extensions **822** each for one or more of the pads (e.g., one or more of the thermal pads **804**). For example, each set of electrically-isolated extensions **822** can be directly coupled (via, e.g., direct contact or an attachment mechanism, such as a thermally conductive adhesive) to one of the thermal pads **804**. Each set of electrically-isolated extensions **822** can include two or more structures (e.g., pins, pegs, etc.) overlapped by and extending from the corresponding pad toward the substrate **812**. The structures within each set of electrically-isolated extensions **822** can be arranged according to a predetermined pattern and have corresponding separation distances/spaces between pairs of adjacent structures. Each structure can have a predetermined shape (e.g., the cross-sectional shape and/or the side-view shape) that corresponds to the manufacturing process (e.g., the extension opening **402** of FIG. **4** and/or the iterative process described above). In some embodiments, the set of electrically-isolated extensions **822** can have lengths that corresponds to the extension length **126** of FIG. **1B**.

[0033] The set of electrically-isolated extensions **822** can have an extension width **824** that corresponds to a distance between opposing surfaces of structures located on opposing ends of the arrangement. The extension width **824** can be less than the pad width **808** and correspond to the extension width **124** of FIG. **1B**. In some embodiments, the apparatus **800** can include the set of electrically-isolated extensions **822** that match or correspond to the electrically-isolated extension **122** of FIG. **1B** for the apparatus **100** of FIG. **1**.

[0034] FIG. 9A-FIG. 9C illustrate a third example apparatus **900** (e.g., a semiconductor device, such as a chip, a package, and/or an assembly) in accordance with embodiments of the technology. FIG. 9A can illustrate a bottom view of the apparatus **900**, FIG. 9B can illustrate a cross-section view of the apparatus **900** taken along a line 9B-9B of FIG. 9A, and FIG. 9C can illustrate a cross-section view of the apparatus **900** taken along a line 9C-9C of FIG. 9B.

[0035] The apparatus **900** can be similar to the apparatus **100** of FIG. 1A. Referring to FIG. 9A and FIG. 9B together, the apparatus **900** can include a surface **902** (e.g., a bottom surface) with a set of connection pads (e.g., UBMs), such as a thermal pad **904** and/or an electrical pad **906** exposed/mounted thereon. The apparatus **900** can have a substrate **912** (e.g., a wafer substrate, such as a silicon substrate). The apparatus **900** can have a barrier layer **914** (e.g., a SiN layer) disposed between the substrate **912** and a passivation layer **916** (e.g., a TEOS layer). The apparatus **900** can further include a TSV **932**. The substrate **912**, the barrier layer **914**, the TSV **932**, and the passivation layer **916** can be similar in material, shape, location, orientation, or the like to the corresponding structures of the apparatus **100** and/or the apparatus **800** of FIG. 8A.

[0036] The apparatus **900** can include a set of electrically-isolated extensions **922** each for one or more of the pads (e.g., one or more of the thermal pads **904**). For example, each set of electrically-isolated extensions **922** can be directly coupled (via, e.g., direct contact or an attachment mechanism, such as a thermally conductive adhesive) to one of the thermal pads **904**. Each set of electrically-isolated extensions **922** can include two or more structures (e.g., pins, pegs, etc.) overlapped by and extending from the corresponding pad toward the substrate **912**. The structures within each set of electrically-isolated extensions **922** can be arranged according to a predetermined pattern and have corresponding separation distances/spaces between pairs of adjacent structures. Each structure can have a predetermined shape (e.g., the cross-sectional shape and/or the side-view shape) that corresponds to the manufacturing process (e.g., the extension opening **402** of FIG. 4 and/or the iterative process described above). In some embodiments, the set of electrically-isolated extensions **922** can have lengths that corresponds to the extension length **126** of FIG. 1B.

[0037] The set of electrically-isolated extensions **922** can have an extension width **924** that corresponds to a distance between opposing surfaces of structures located on opposing ends of the arrangement. The extension width **924** can be less than the pad width **908** and correspond to the extension width **124** of FIG. 1B. In some embodiments, the apparatus **900** can include the set of electrically-isolated extensions **922** that match or correspond to the electrically-isolated extension **122** of FIG. 1B for the apparatus **100** of FIG. 1.

[0038] In some embodiments, the set of electrically-isolated extensions **922** can include one or more cross-linking structures **928** connected to or integral with one or more of the vertically-extending structures. The cross-linking structures **928** can extend along a lateral direction. The cross-linking structures **928** can be located between the surface **902** and the substrate **912**. For example, the cross-linking structures **928** can extend horizontally and connect to the down-ward extension structures at 90° angles. The cross-linking structures **928** can be embedded in and directly contact the passivation layer **916**. In some embodiments, the cross-linking structures **928** can be a mesh structure, and the vertical structures can connect to the joint portions in the mesh.

[0039] FIG. 10 is a flow diagram illustrating an example method **1000** of manufacturing an apparatus (e.g., the apparatus **100** of FIG. 1A, the apparatus **800** of FIG. 8A, and/or the apparatus **900** of FIG. 9A) in accordance with an embodiment of the present technology. The method **1000** can include forming the electrically-isolated extension **122** of FIG. 1B.

[0040] At block **1002**, the method **1000** can include providing a semiconductor substrate (e.g., the substrate **112** of FIG. 1B, such as the wafer-level substrate **202** of FIG. 2). The substrate **112** can correspond to a process associated with FIG. 2 and the structure **200** of FIG. 2. The provided substrate may include the TSV structure **204** of FIG. 2 as described above. In some embodiments, providing the substrate **112** may include manufacturing the wafer-level substrate **202** as illustrated

at block **1004**, such as through semiconductor manufacturing processes (e.g., doping, thinning, or the like).

[0041] At block **1006**, the method **1000** can include forming protective layers. For example, forming the protective layers may include forming the barrier layer **302** of FIG. 3 and/or the passivation layer **304** of FIG. 3 over the substrate **112** (e.g., the wafer-level substrate **202** of FIG. 2 and/or the uncovered surface **212** of FIG. 2). The protective layers may be formed by depositing and/or laminating the layers over the substrate **112**. Forming the protective layers can correspond to the processes associated with FIG. 3 and the structure **300** of FIG. 3.

[0042] At block **1008**, the method **1000** can include forming depressions (e.g., the extension openings **402** of FIG. 4) in one or more of the protective layers for accommodating/forming extensions. For example, the extension openings **402** can be formed based on etching away or removing at least a portion of the passivation layer **304**, a portion of the barrier layer **302**, and/or a portion of the wafer-level substrate **202**. Forming the depressions can correspond to a process associated with FIG. 4 and the structure **400** of FIG. 4.

[0043] At block **1010**, the method **1000** can include forming extension structures. For example, the extension structures **502** of FIG. 5 may be formed in the extension openings **402**, such as by depositing or plating thermally-conductive material (e.g., metallic material) in the extension openings **402**. Forming the extensions can correspond to a process associated with FIG. 5 and structure **500** of FIG. 5.

[0044] In some embodiments, such as illustrated at block **1012**, the method **1000** can include exposing the TSVs. A portion of the structure **500** may be removed to expose the extension structures **502**. For example, a portion of the passivation layer **304**, a portion of the extension structure **502**, a portion of the TSV structure **204**, and/or a portion of the barrier layer **302** (e.g., the portion over and/or adjacent to the TSV structure **204**) by a chemical-mechanical polishing (CMP) process. Accordingly, exposing the TSVs can correspond to a planarization process associated with FIG. 6 and structure **600** of FIG. 6.

[0045] At block **1014**, the method **1000** can include attaching the connection pads (e.g., UBM), such as the electrical pads **106** FIG. 1A and/or the thermal pads **104** of FIG. 1A. The connection pads may be attached to/over the planarized surface (e.g., the surface **102** of FIG. 1A). The thermal pads **104** can be coupled (e.g., thermally coupled) or directly attached to the extension structures **502** (e.g., the electrically-isolated extensions **122**), and the electrical pads **106** can be coupled (e.g., electrically coupled) or directly attached to the TSV structures **204** (e.g., the TSVs **132**).

[0046] The electrically-isolated extensions **122** can provide increased stress relief on the passivation layer **304**, such as underneath the corresponding pad. The increased stress relief can prevent structural damages (e.g., cracks) in the passivation layer **304** and/or other structures in the apparatus. Moreover, the electrically-isolated extensions **122** can be formed based on leveraging existing processes (e.g., without increasing manufacturing complexities).

[0047] FIG. 11 is a schematic view of a system that includes an apparatus in accordance with embodiments of the present technology. Any one of the semiconductor devices described above with reference to FIGS. 1A-10 can be incorporated into any of a myriad of larger and/or more complex systems, a representative example of which is system **1190** shown schematically in FIG. 11. The system **1190** can include a semiconductor device **1100** ("device **1100**") (e.g., a semiconductor device, package, and/or assembly), a power source **1192**, a driver **1194**, a processor **1196**, and/or other subsystems or components **1198**. The device **1100** can include features generally similar to those devices described above. The resulting system **1190** can perform any of a wide variety of functions, such as memory storage, data processing, and/or other suitable functions. Accordingly, representative systems **1190** can include, without limitation, hand-held devices (e.g., mobile phones, tablets, digital readers, and digital audio players), computers, and appliances. Components of the system **1190** may be housed in a single unit or distributed over multiple, interconnected units (e.g., through a communications network). The components of the system

1190 can also include remote devices and any of a wide variety of computer-readable media. [0048] This disclosure is not intended to be exhaustive or to limit the present technology to the precise forms disclosed herein. Although specific embodiments are disclosed herein for illustrative purposes, various equivalent modifications are possible without deviating from the present technology, as those of ordinary skill in the relevant art will recognize. In some cases, well-known structures and functions have not been shown or described in detail to avoid unnecessarily obscuring the description of the embodiments of the present technology. Although steps of methods may be presented herein in a particular order, alternative embodiments may perform the steps in a different order. Similarly, certain aspects of the present technology disclosed in the context of particular embodiments can be combined or eliminated in other embodiments. Furthermore, while advantages associated with certain embodiments of the present technology may have been disclosed in the context of those embodiments, other embodiments can also exhibit such advantages, and not all embodiments need necessarily exhibit such advantages or other advantages disclosed herein to fall within the scope of the technology. Accordingly, the disclosure and associated technology can encompass other embodiments not expressly shown or described herein, and the invention is not limited except as by the appended claims.

[0049] Throughout this disclosure, the singular terms “a,” “an,” and “the” include plural referents unless the context clearly indicates otherwise. Similarly, unless the word “or” is expressly limited to mean only a single item exclusive from the other items in reference to a list of two or more items, then the use of “or” in such a list is to be interpreted as including (a) any single item in the list, (b) all of the items in the list, or (c) any combination of the items in the list. Additionally, the terms “comprising,” “including,” and “having” are used throughout to mean including at least the recited feature(s) such that any greater number of the same feature and/or additional types of other features are not precluded. Reference herein to “one embodiment,” “an embodiment,” “some embodiments” or similar formulations means that a particular feature, structure, operation, or characteristic described in connection with the embodiment can be included in at least one embodiment of the present technology. Thus, the appearances of such phrases or formulations herein are not necessarily all referring to the same embodiment. Furthermore, various particular features, structures, operations, or characteristics may be combined in any suitable manner in one or more embodiments.

Claims

1. An apparatus, comprising: a passivation layer covering a side of a semiconductor substrate; a connection pad disposed over the passivation layer of the semiconductor substrate; and an extension extending from the connection pad into the passivation layer, wherein the extension and the connection pad are electrically isolated from electrical circuit components of the semiconductor substrate.
2. The apparatus of claim 1, wherein the extension extends into the passivation layer by a length less than a distance between a surface of the passivation layer and the semiconductor substrate.
3. The apparatus of claim 1, wherein the extension has a length less than or equal to a thickness of the passivation layer, and wherein the semiconductor substrate corresponds to a semiconductor wafer.
4. The apparatus of claim 3, wherein the passivation layer includes a tetraethyl orthosilicate (TEOS) layer, and wherein at least a portion of a surface of the passivation layer comprises a surface of the semiconductor substrate.
5. The apparatus of claim 1, further comprising: a barrier layer disposed between the passivation layer and the semiconductor substrate; wherein the extension extends at least through the passivation layer to the barrier layer.
6. The apparatus of claim 5, wherein the extension extends at least partially through the barrier

layer.

7. The apparatus of claim 5, wherein the barrier layer comprises SiN.

8. The apparatus of claim 1, wherein the connection pad is a first connection pad, and further comprising: a second connection pad disposed over the passivation layer; and a through silicon via (TSV) directly coupled to the second connection pad and extending from the second connection pad through the passivation layer and into the semiconductor substrate, wherein the extension has a first length less than a second length of the TSV.

9. The apparatus of claim 1, wherein the extension includes a thermally conductive material and is thermally coupled to the connection pad.

10. The apparatus of claim 9, wherein the connection pad is a thermal pad configured to provide an external interface for removing thermal energy away from the semiconductor substrate.

11. The apparatus of claim 1, wherein: the connection pad has a first width; and the extension has a second width less than the first width.

12. The apparatus of claim 1, wherein the extension is one extension within a set of electrically-isolated extensions, extensions in the set of electrically-isolated extensions being: directly coupled to the connection pad, separated from each other by at least a separation distance, covered by the connection pad, and electrically isolated from the semiconductor substrate.

13. The apparatus of claim 12, wherein the set of electrically-isolated extensions includes at least one cross-linking structure extending between and connected to at least two adjacent extensions of the set of electrically-isolated extensions.

14. A semiconductor device, comprising: an active circuitry formed on a first side of a semiconductor substrate; an electrical pad over a second side of the semiconductor substrate and electrically coupled to the active circuitry; a thermal pad over the second side to the semiconductor substrate and electrically isolated from the active circuitry and the semiconductor substrate; and an extension extending from the thermal pad and toward an inner portion of the semiconductor substrate, wherein the extension is electrically isolated from the active circuitry and electrical circuit components of the semiconductor substrate.

15. The semiconductor device of claim 14, further comprising: an outer protective layer covering the semiconductor substrate; a barrier layer disposed between the outer protective layer and the semiconductor substrate; wherein the electrical pad and the thermal pad are attached over the outer protective layer and the semiconductor substrate; and the extension extends at least partially through the outer protective layer.

16. The semiconductor device of claim 15, wherein: the outer protective layer includes a tetraethyl orthosilicate (TEOS) layer; and the extension extends through the TEOS layer and up to the barrier layer.

17. The semiconductor device of claim 14, further comprising: a through silicon via (TSV) electrically coupled to the electrical pad and the active circuitry, the TSV having a TSV length that is greater than a length of the extension.

18. The semiconductor device of claim 14, the extension is one vertical extension within a set of vertical extensions, vertical extensions in the set of vertical extensions being: directly attached to the thermal pad, separated from each other by at least a lateral separation distance, arranged within an area under the thermal pad and having a width less than a width of the thermal pad, and electrically isolated from the active circuitry.

19. A method of manufacturing a semiconductor device, the method comprising: forming a protective outer layer over a side of a semiconductor substrate; forming a depression extending at least partially through the protective outer layer and toward the semiconductor substrate; forming an electrically-isolated extension in the depression, wherein the electrically-isolated extension is electrically isolated from electrical circuit components of the semiconductor substrate; and attaching a connection pad over the protective outer layer.

20. The method of claim 19, further comprising: forming a barrier layer over the semiconductor

substrate and a through-silicon via (TSV) before forming the protective outer layer; removing a portion of the barrier layer, a portion of the protective outer layer, a portion of the electrically-isolated extension, or a combination thereof to expose the TSV; attaching an electrical pad attached to the TSV; wherein: the connection pad is a thermal pad configured to provide an external thermal interface for removing thermal energy from the semiconductor device; the electrically-isolated extension includes a thermally conductive material and is thermally coupled to the thermal pad; and the protective outer layer is formed over the barrier layer and covers the TSV.
