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### Chip package structure with metal-containing layer

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#### Abstract

A chip package structure is provided. The chip package structure includes a first wiring substrate comprising a substrate, a first pad, a second pad, and an insulating layer. The first pad and the second pad are respectively over a first surface and a second surface of the substrate, the first surface is opposite to the second surface, the insulating layer is over the first surface and partially covers the first pad, and the first pad is wider than the second pad. The chip package structure includes a nickel-containing layer over the first pad. The chip package structure includes a conductive protection layer over the nickel-containing layer. The conductive protection layer has a curved surface, and a recess is surrounded by the curved surface and an inner wall of the insulating layer over the first pad.

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**Inventors:** Chen; Yu-Huan (Taoyuan, TW), Hsu; Kuo-Ching (New Taipei, TW), Chen; Chen-Shien (Zhubei, TW)

**Applicant:** Taiwan Semiconductor Manufacturing Company, Ltd. (Hsinchu, TW)

**Family ID:** 1000008749929

**Assignee:** TAIWAN SEMICONDUCTOR MANUFACTURING COMPANY, LTD.  
(Hsinchu, TW)

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*Primary Examiner:* Vu; Hung K

*Attorney, Agent or Firm:* McClure, Qualey & Rodack, LLP

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## Background/Summary

**PRIORITY CLAIM AND CROSS-REFERENCE** (1) This application is a Continuation of U.S. application Ser. No. 17/744,884, filed on May 16, 2022 (now U.S. Pat. No. 12,002,746), which is a Divisional of U.S. application Ser. No. 16/893,467, filed on Jun. 5, 2020 (now U.S. Pat. No. 11,335,634), which claims the benefit of U.S. Provisional Application No. 62/893,874, filed on Aug. 30, 2019, and entitled “CHIP PACKAGE STRUCTURE AND METHOD FOR FORMING THE SAME”, the entirety of which is incorporated by reference herein.

## BACKGROUND

(1) Semiconductor devices are used in a variety of electronic applications, such as personal computers, cell phones, digital cameras, and other electronic equipment. Semiconductor devices are typically fabricated by sequentially depositing insulating layers or dielectric layers, conductive layers, and semiconductor layers over a semiconductor substrate, and patterning the various material layers using photolithography processes and etching processes to form circuit components and elements thereon.

(2) Many integrated circuits are typically manufactured on a semiconductor wafer. The dies of the wafer may be processed and packaged at the wafer level, and various technologies have been developed for wafer level packaging.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

(1) Aspects of the present disclosure are best understood from the following detailed description when read with the accompanying figures. It should be noted that, in accordance with standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

(2) FIGS. 1A-1M are cross-sectional views of various stages of a process for forming a chip package structure, in accordance with some embodiments.

(3) FIGS. 2A-2B are cross-sectional views of various stages of a process for forming a chip package structure, in accordance with some embodiments.

(4) FIG. 3 is a cross-sectional view of a chip package structure, in accordance with some embodiments.

(5) FIGS. 4A-4H are cross-sectional views of various stages of a process for forming a chip package structure, in accordance with some embodiments.

(6) FIGS. 5A-5B are cross-sectional views of various stages of a process for forming a chip package structure, in accordance with some embodiments.

(7) FIG. 6 is a cross-sectional view of a chip package structure, in accordance with some embodiments.

(8) FIG. 7 is a cross-sectional view of a chip package structure, in accordance with some embodiments.

(9) FIG. 8 is a cross-sectional view of a chip package structure, in accordance with some embodiments.

(10) FIG. 9 is a cross-sectional view of a chip package structure, in accordance with some embodiments.

### DETAILED DESCRIPTION

(11) The following disclosure provides many different embodiments, or examples, for implementing different features of the subject matter provided. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. For example, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed between the first and second features, such that the first and second features may not be in direct contact. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

(12) Furthermore, spatially relative terms, such as “beneath,” “below,” “lower,” “above,” “upper”

and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. The spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. The apparatus may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly. It should be understood that additional operations can be provided before, during, and after the method, and some of the operations described can be replaced or eliminated for other embodiments of the method.

(13) Some embodiments of the disclosure are described. Additional operations can be provided before, during, and/or after the stages described in these embodiments. Some of the stages that are described can be replaced or eliminated for different embodiments. Additional features can be added to the semiconductor device structure. Some of the features described below can be replaced or eliminated for different embodiments. Although some embodiments are discussed with operations performed in a particular order, these operations may be performed in another logical order.

(14) FIGS. 1A-1M are cross-sectional views of various stages of a process for forming a chip package structure, in accordance with some embodiments. As shown in FIG. 1A, a wiring substrate **110** is provided, in accordance with some embodiments. The wiring substrate **110** includes a substrate **111**, through substrate vias (or plated through holes, PTH) **112**, wiring layers **113a**, **113b**, **114a** and **114b**, pads **115a** and **115b**, conductive vias **116a** and **116b**, and insulating layers **117a**, **117b**, **118a** and **118b**, in accordance with some embodiments.

(15) The substrate **111** has surfaces **111a** and **111b**, in accordance with some embodiments. The surface **111a** is opposite to the surface **111b**, in accordance with some embodiments. In some embodiments, the substrate **111** is made of an insulating material such as a fiber material, a polymer material, or a glass material. The fiber material includes, for example, a glass fiber material.

(16) In some other embodiments, the substrate **111** is made of a semiconductor material or a conductive material, in accordance with some embodiments. The semiconductor material includes, for example, silicon or germanium. The conductive material includes, for example, a metal material.

(17) The through substrate vias **112** pass through the substrate **111**, in accordance with some embodiments. The wiring layers **113a** and **113b** are formed over the surfaces **111a** and **111b** respectively, in accordance with some embodiments. The through substrate vias **112** electrically connect the wiring layer **113a** to the wiring layer **113b**, in accordance with some embodiments.

(18) If the substrate **111** is made of a semiconductor material or a conductive material, an insulating layer (not shown) is formed between the substrate **111** and the through substrate vias **112** and between the substrate **111** and the wiring layers **113a** and **113b** to electrically insulate the substrate **111** from the through substrate vias **112** and the wiring layers **113a** and **113b**, in accordance with some embodiments.

(19) The wiring layer **114a**, the pads **115a**, the conductive vias **116a**, and the insulating layers **117a** and **118a** are formed over the surface **111a**, in accordance with some embodiments. The wiring layer **114a** and the conductive vias **116a** are in the insulating layer **117a**, in accordance with some embodiments. The pads **115a** are over the insulating layer **117a**, in accordance with some embodiments. The conductive vias **116a** are electrically connected between the wiring layers **113a** and **114a** and between the wiring layer **114a** and the pads **115a**, in accordance with some embodiments.

(20) The insulating layer **118a** is formed over the insulating layer **117a** and the pads **115a**, in accordance with some embodiments. The insulating layer **118a** has openings **P1**, in accordance with some embodiments. The openings **P1** respectively expose the pads **115a** thereunder, in accordance with some embodiments. The insulating layer **118a** partially covers the pads **115a**, in accordance with some embodiments.

(21) The wiring layer **114b**, the pads **115b**, the conductive vias **116b**, and the insulating layers **117b** and **118b** are formed over the surface **111b**, in accordance with some embodiments. The wiring layer **114b** and the conductive vias **116b** are in the insulating layer **117b**, in accordance with some embodiments. The pads **115b** are over the insulating layer **117b**, in accordance with some embodiments. The conductive vias **116b** are electrically connected between the wiring layers **113b** and **114b** and between the wiring layer **114b** and the pads **115b**, in accordance with some embodiments.

(22) The insulating layer **118b** is formed over the insulating layer **117b** and the pads **115b**, in accordance with some embodiments. The insulating layer **118b** has openings **P2**, in accordance with some embodiments. The openings **P2** respectively expose the pads **115b**, in accordance with some embodiments. The insulating layer **118b** partially covers the pads **115b**, in accordance with some embodiments.

(23) In some embodiments, the pad **115b** is wider than the pad **115a**. That is, a width **W1** of the pad **115b** is greater than a width **W2** of the pad **115a**, in accordance with some embodiments. The pad **115b** is used to bond with a wiring substrate (e.g., a printed circuit board), in accordance with some embodiments. The pad **115a** is used to bond with a chip, in accordance with some embodiments. The width **W1** ranges from about 200  $\mu\text{m}$  to about 600  $\mu\text{m}$ , in accordance with some embodiments. The width **W2** ranges from about 20  $\mu\text{m}$  to about 110  $\mu\text{m}$ , in accordance with some embodiments. In some embodiments, a (maximum) width **W3** of the opening **P2** is greater than a (maximum) width **W4** of the opening **P1**.

(24) The through substrate vias **112**, the wiring layers **113a**, **113b**, **114a** and **114b**, the pads **115a** and **115b**, and the conductive vias **116a** and **116b** are made of a conductive material such as a metal material or an alloy thereof, in accordance with some embodiments. The metal material includes aluminum, copper or tungsten.

(25) As shown in FIG. 1B, a nickel-containing layer **122** is formed over top surfaces **115b1** of the pads **115b**, in accordance with some embodiments. The nickel-containing layer **122** covers the entire exposed portion of the top surface **115b1**, which is exposed by the opening **P2**, in accordance with some embodiments. The nickel-containing layer **122** is in the openings **P2**, in accordance with some embodiments. The nickel-containing layer **122** is made of nickel or alloys thereof, in accordance with some embodiments. The nickel-containing layer **122** is formed using a plating process such as an electroless plating process, in accordance with some embodiments.

(26) As shown in FIG. 1B, a palladium-containing layer **124** is formed over the nickel-containing layer **122**, in accordance with some embodiments. The palladium-containing layer **124** is in the openings **P2**, in accordance with some embodiments. The palladium-containing layer **124** has a thickness **T1** ranging from about 0.02  $\mu\text{m}$  to about 0.1  $\mu\text{m}$ , in accordance with some embodiments. The palladium-containing layer **124** is made of palladium or alloys thereof, in accordance with some embodiments. The palladium-containing layer **124** is formed using a plating process such as an electroless plating process, in accordance with some embodiments.

(27) As shown in FIG. 1B, a gold-containing layer **126** is formed over the palladium-containing layer **124**, in accordance with some embodiments. The gold-containing layer **126** is in the openings **P2**, in accordance with some embodiments. The gold-containing layer **126** has a thickness **T2** ranging from about 0.02  $\mu\text{m}$  to about 0.1  $\mu\text{m}$ , in accordance with some embodiments. The gold-containing layer **126** is made of gold or alloys thereof, in accordance with some embodiments. The gold-containing layer **126** is formed using a plating process such as an immersion plating process, in accordance with some embodiments.

(28) As shown in FIG. 1B, a conductive protection layer **130** is formed over the gold-containing layer **126**, in accordance with some embodiments. In some embodiments, a porosity of the conductive protection layer **130** is lower than a porosity of the palladium-containing layer **124** and lower than a porosity of the gold-containing layer **126**. That is, the conductive protection layer **130** has a structure, which is denser than that of the palladium-containing layer **124** and the gold-

containing layer **126**, in accordance with some embodiments.

(29) In some embodiments, a thickness **T3** of the conductive protection layer **130** is greater than a sum of the thickness **T1** of the palladium-containing layer **124** and the thickness **T2** of the gold-containing layer **126**. In some embodiments, the conductive protection layer **130** is thinner than the insulating layer **118b** over the pads **115b**.

(30) The thickness **T3** ranges from about 1  $\mu\text{m}$  to about 25  $\mu\text{m}$ , in accordance with some embodiments. The thickness **T3** ranges from about 1  $\mu\text{m}$  to about 10  $\mu\text{m}$ , in accordance with some embodiments. The conductive protection layer **130** covers an entire top surface **122a** of the nickel-containing layer **122**, in accordance with some embodiments.

(31) If the conductive protection layer **130** is not formed, the nickel atoms in the nickel-containing layer **122** may be affected by deflux solutions used in subsequent deflux processes, and may tend to migrate through the palladium-containing layer **124** and the gold-containing layer **126** and to be oxidized. Since the conductive protection layer **130** is denser and thicker than the palladium-containing layer **124** and the gold-containing layer **126**, the conductive protection layer **130** may separate the nickel-containing layer **122** from the deflux solutions. Therefore, the conductive protection layer **130** may improve the adhesion between the pads **115b** and conductive bumps, which are subsequently formed between, and connected between, the pads **115b** and a chip. The formation of the conductive protection layer **130** may strengthen the conductive bumps.

(32) Since the conductive protection layer **130** may provide a stronger protection to the nickel-containing layer **122**, the deflux solution having stronger removal ability for flux layers may be used to remove the flux layers more completely. Therefore, the yield of the removal process of the flux layers may be improved.

(33) In some embodiments, a distance **D1** between a top surface **118b1** of the insulating layer **118b** and a top surface **115b1** of the pad **115b** is greater than a distance **D2** between a top surface **132** of the conductive protection layer **130** and the top surface **115b1** of the pad **115b**. That is, the top surface **132** is lower than the top surface **118b1**, in accordance with some embodiments.

(34) The conductive protection layer **130**, the gold-containing layer **126**, the palladium-containing layer **124**, and the nickel-containing layer **122** are made of different materials, in accordance with some embodiments. The conductive protection layer **130** is made of a metal material (e.g., tin) or an alloy thereof (e.g., tin alloy), in accordance with some embodiments. The conductive protection layer **130** is formed using a printing process or an electroless plating process, in accordance with some embodiments.

(35) As shown in FIG. 1C, a reflow process is performed over the conductive protection layer **130**, in accordance with some embodiments. During the reflow process, the gold-containing layer **126** and the palladium-containing layer **124** are dissolved in the conductive protection layer **130**, and an intermetallic compound layer **C** is formed between the conductive protection layer **130** and the nickel-containing layer **122**, in accordance with some embodiments. The intermetallic compound layer **C** may improve the adhesion between the conductive protection layer **130** and the nickel-containing layer **122**.

(36) The intermetallic compound layer **C** is structurally denser than the conductive protection layer **130**, the gold-containing layer **126**, and the palladium-containing layer **124**, in accordance with some embodiments. In some embodiments, a thickness **T4** of the intermetallic compound layer **C** is greater than the sum of the thickness **T1** of the palladium-containing layer **124** and the thickness **T2** of the gold-containing layer **126** (as shown in FIG. 1B). Therefore, the intermetallic compound layer **C** provides a greater protection to the nickel-containing layer **122** than the palladium-containing layer **124** and the gold-containing layer **126**, in accordance with some embodiments. As a result, the intermetallic compound layer **C** and the conductive protection layer **130** may together protect the nickel-containing layer **122** from damage during subsequent processes.

(37) The intermetallic compound layer **C** is made of materials of the conductive protection layer **130** and the nickel-containing layer **122**, in accordance with some embodiments. The intermetallic

compound layer C includes a compound material, in accordance with some embodiments. The compound material includes, for example, tin and nickel, such as Ni.sub.3Sn.sub.4.

(38) After the reflow process, the conductive protection layer **130** has a (maximum) thickness **T3'**, in accordance with some embodiments. The thickness **T3'** is greater than the sum of the thickness **T1** of the palladium-containing layer **124** and the thickness **T2** of the gold-containing layer **126** (as shown in FIG. **1B**), in accordance with some embodiments. The thickness **T3'** is greater than the thickness **T3** (as shown in FIG. **1B**), in accordance with some embodiments.

(39) The thickness **T3'** ranges from about 1  $\mu\text{m}$  to about 25  $\mu\text{m}$ , in accordance with some embodiments. The thickness **T3'** ranges from about 1  $\mu\text{m}$  to about 10  $\mu\text{m}$ , in accordance with some embodiments. In some embodiments, the (reflowed) conductive protection layer **130** is thinner than the insulating layer **118b** over the pads **115b**.

(40) The conductive protection layer **130** has a curved top surface **134**, in accordance with some embodiments. In some embodiments, the distance **D1** between the top surface **118b1** of the insulating layer **118b** and the top surface **115b1** of the pad **115b** is greater than a (maximum) distance **D3** between the curved top surface **134** and the top surface **115b1**.

(41) In some embodiments, a recess **R1** is surrounded by the conductive protection layer **130** and the insulating layer **118b** over the pads **115b**. The entire conductive protection layer **130** over one of the pads **115b** is in the corresponding opening **P2**, in accordance with some embodiments. That is, the conductive protection layer **130** does not extend out of the corresponding opening **P2**, which prevents the conductive protection layer **130** from contacting carrier substrates in subsequent processes, in accordance with some embodiments.

(42) The designs for the purpose of preventing the conductive protection layer **130** from contacting carrier substrates in subsequent processes include that the conductive protection layer **130** is thinner than the insulating layer **118b** over the pads **115b** (as shown in FIG. **1B**), the top surface **132** is lower than the top surface **118b1** (as shown in FIG. **1B**), and the distance **D1** between the top surface **118b1** of the insulating layer **118b** and the top surface **115b1** of the pad **115b** is greater than a (maximum) distance **D3** between the curved top surface **134** and the top surface **115b1** (as shown in FIG. **1C**). In some other embodiments (not shown), the curved top surface **134** (or the top surface **132**) is higher than the top surface **118b1** according to design requirements.

(43) As shown in FIG. **1D**, the wiring substrate **110** is flipped upside down and is disposed over a carrier substrate **140**, in accordance with some embodiments. The carrier substrate **140** is configured to provide temporary mechanical and structural support during subsequent processing steps, in accordance with some embodiments. The carrier substrate **140** includes glass, silicon oxide, aluminum oxide, metal, a combination thereof, or the like, in accordance with some embodiments. The carrier substrate **140** includes a metal frame, in accordance with some embodiments.

(44) As shown in FIG. **1D**, a conductive layer **150** is formed over the pads **115a**, in accordance with some embodiments. The conductive layer **150** includes solder balls, in accordance with some embodiments. The conductive layer **150** is made of a conductive material, such as metal (e.g., tin) or alloys thereof (e.g., tin alloy), in accordance with some embodiments. The formation of the conductive layer **150** includes forming a solder material layer (not shown) over the pads **115a**; and reflowing the solder material layer to form the conductive layer **150**, in accordance with some embodiments.

(45) As shown in FIG. **1E**, a thermo-compression process is performed over the conductive layer **150** to flatten a top surface **152** of the conductive layer **150**, in accordance with some embodiments. As shown in FIG. **1F**, a flux material layer **160** is formed over the conductive layer **150** and a top surface **118a1** of the insulating layer **118a**, in accordance with some embodiments. The flux material layer **160** is used to secure the bonding between the conductive layer **150** and conductive bumps over a chip in a subsequent chip bonding process so as to increase the yield of the chip bonding process.

(46) In some embodiments, the flux material layer **160** includes tartaric acid, a resin, an amine, and/or a solvent. In some embodiments, the amine is an alkyl substituted amine, an ethanol amine, an ethoxylated amine, or a propoxylated amine. In some embodiments, a surfactant is used, sometimes referred to as a flow modifier. The specific surfactant depends upon compatibility with the flux material layer **160**. In some embodiments, the surfactant is anionic such as long chain alkyl carboxylic acids, such as lauric acids, steric acids, or the like. The flux material layer **160** is formed using a dipping process or a jetting process, in accordance with some embodiments.

(47) As shown in FIG. 1G, a chip **170** is provided, in accordance with some embodiments. The chip **170** includes a semiconductor substrate **172**, a dielectric layer **174**, conductive pads **176**, and an interconnection layer **178**, in accordance with some embodiments.

(48) The semiconductor substrate **172** has a front surface **172a** and a back surface **172b** opposite to the front surface **172a**, in accordance with some embodiments. In some embodiments, active elements (e.g. transistors, diodes, or the like) and/or passive elements (e.g. resistors, capacitors, inductors, or the like) are formed over the front surface **172a** or in the semiconductor substrate **172** adjacent to the front surface **172a**.

(49) In some embodiments, the semiconductor substrate **172** is made of at least an elementary semiconductor material including silicon or germanium in a single crystal, polycrystal, or amorphous structure. In some other embodiments, the semiconductor substrate **172** is made of a compound semiconductor, such as silicon carbide, gallium arsenide, gallium phosphide, indium phosphide, indium arsenide, an alloy semiconductor, such as SiGe, or GaAsP, or a combination thereof. The semiconductor substrate **172** may also include multi-layer semiconductors, semiconductor on insulator (SOI) (such as silicon on insulator or germanium on insulator), or a combination thereof.

(50) The dielectric layer **174** is formed over the front surface **172a**, in accordance with some embodiments. The dielectric layer **174** is made of a polymer material, such as a polybenzoxazole (PBO) layer, a polyimide layer, a benzocyclobutene (BCB) layer, an epoxy layer, a photo-sensitive material layer, or another suitable material.

(51) The conductive pads **176** are formed in the dielectric layer **174**, in accordance with some embodiments. The conductive pads **176** are electrically connected to devices (not shown) formed in/over the semiconductor substrate **172**, in accordance with some embodiments. The conductive pads **176** are made of a conductive material, such as copper (Cu), copper alloy, aluminum (Al), aluminum alloy, tungsten (W), tungsten alloy, titanium (Ti), titanium alloy, tantalum (Ta) or tantalum alloy, in accordance with some embodiments.

(52) The interconnection layer **178** is formed over the dielectric layer **174**, in accordance with some embodiments. The interconnection layer **178** includes dielectric layers (not shown) and conductive interconnection structures (not shown) in the dielectric layers, in accordance with some embodiments.

(53) As shown in FIG. 1G, conductive bumps **180** are formed over the interconnection layer **178**, in accordance with some embodiments. The conductive interconnection structures of the interconnection layer **178** are electrically connected to the conductive bumps **180** and the conductive pads **176**, in accordance with some embodiments.

(54) The conductive bumps **180** are made of a conductive material, such as tin (Sn) or alloys thereof, in accordance with some embodiments. In some other embodiments, the conductive bumps **180** are made of copper (Cu), copper alloy, aluminum (Al), aluminum alloy, tungsten (W), tungsten alloy, titanium (Ti), titanium alloy, tantalum (Ta) or tantalum alloy.

(55) As shown in FIG. 1G, a flux material layer **190** is formed over the conductive bumps **180** and a surface **178a** of the interconnection layer **178**, in accordance with some embodiments. The flux material layer **190** is used to secure the bond between the conductive bumps **180** and the conductive layer **150** (as shown in FIG. 1F) in a subsequent chip bonding process so as to increase the yield of the chip bonding process, in accordance with some embodiments.



(56) In some embodiments, the flux material layer **190** includes tartaric acid, a resin, an amine, and/or a solvent. In some embodiments, the amine is an alkyl substituted amine, an ethanol amine, an ethoxylated amine, or a propoxylated amine. In some embodiments, a surfactant is used, sometimes referred to as a flow modifier. The specific surfactant depends upon compatibility with the flux material layer **190**. In some embodiments, the surfactant is anionic such as long chain alkyl carboxylic acids, such as lauric acids, steric acids, or the like. The flux material layer **190** is formed using a dipping process or a jetting process, in accordance with some embodiments.

(57) As shown in FIG. 1H, the chip **170** is bonded to the wiring substrate **110** through conductive bumps **210** and a flux layer **220**, in accordance with some embodiments. The flux layer **220** surrounds the conductive bumps **210**, in accordance with some embodiments.

(58) The conductive bumps **210** are between, and connected to, the pads **115a** and the chip **170**, in accordance with some embodiments. The conductive bumps **210** are formed from the conductive layer **150** and the conductive bumps **180**, in accordance with some embodiments. The flux layer **220** is formed from the flux material layers **160** and **190**, in accordance with some embodiments.

(59) The conductive protection layer **130** is thinner than the conductive bump **210**, in accordance with some embodiments. That is, the (maximum) thickness  $T3'$  of the conductive protection layer **130** is less than a thickness  $T5$  of the conductive bump **210**, in accordance with some embodiments.

(60) As shown in FIG. 1I, the flux layer **220** is removed, in accordance with some embodiments. The removal process of the flux layer **220** includes a dipping process or a jetting process, in accordance with some embodiments. For example, in the dipping process, the wiring substrate **110** is dipped in a deflux solution F accommodated in a tank E, in accordance with some embodiments. The flux layer **220** may dissolve in the deflux solution F, in accordance with some embodiments.

(61) The conductive protection layer **130** and the intermetallic compound layer C separate the nickel-containing layer **122** from the deflux solution F, in accordance with some embodiments. The conductive protection layer **130** is in direct contact with the deflux solution F, in accordance with some embodiments.

(62) The deflux solution F includes aqueous liquids (e.g., deionized water) and solvents such as hydrofluorocarbons (HFC's), hydrochlorofluorocarbons (HCFC's), chlorofluorocarbons, alcohols, terpenes, and combinations thereof, in accordance with some embodiments.

(63) As shown in FIG. 1J, the wiring substrate **110** is disposed over a carrier substrate **230**, in accordance with some embodiments. The carrier substrate **230** is configured to provide temporary mechanical and structural support during subsequent processing steps, in accordance with some embodiments. The carrier substrate **230** includes glass, silicon oxide, aluminum oxide, metal, a combination thereof, or the like, in accordance with some embodiments. The carrier substrate **230** includes a metal frame, in accordance with some embodiments.

(64) As shown in FIG. 1J, an underfill layer **240** is formed between the chip **170** and the wiring substrate **110**, in accordance with some embodiments. The underfill layer **240** includes an insulating material, such as a polymer material, in accordance with some embodiments.

(65) As shown in FIG. 1J, a molding layer **250** is formed over the wiring substrate **110**, the chip **170** and the underfill layer **240**, in accordance with some embodiments. The molding layer **250** encapsulates the chip **170**, in accordance with some embodiments. The molding layer **250** surrounds the chip **170**, the conductive bumps **210**, and the underfill layer **240**, in accordance with some embodiments. The molding layer **250** is made of an insulating material, such as a polymer material, in accordance with some embodiments.

(66) As shown in FIG. 1K, the wiring substrate **110** is flipped upside down and is disposed over a carrier substrate G, in accordance with some embodiments. The carrier substrate G is configured to provide temporary mechanical and structural support during subsequent processing steps, in accordance with some embodiments. The carrier substrate G includes glass, silicon oxide, aluminum oxide, metal, a combination thereof, or the like, in accordance with some embodiments. The carrier substrate G includes a metal frame, in accordance with some embodiments.

(67) As shown in FIG. 1K, conductive structures **260a** are formed over the conductive protection layer **130**, in accordance with some embodiments. The conductive structures **260a** are made of a conductive material such as metal (e.g., Sn) or alloys thereof, in accordance with some embodiments. In some embodiments, the conductive structures **260a** and the conductive protection layer **130** are made of the same conductive material such as tin or tin alloy.

(68) As shown in FIGS. 1K and 1L, a reflow process is performed over the conductive structures **260a** and the conductive protection layer **130** to melt and mix the conductive structures **260a** and the conductive protection layer **130** together so as to form conductive bumps **260**, in accordance with some embodiments.

(69) In some embodiments, a distance **D4** between a top surface **262** of the conductive bumps **260** and the top surface **115b1** of the pads **115b** is greater than the distance **D1** between the top surface **118b1** of the insulating layer **118b** and the top surface **115b1**. The conductive bump **260** is wider and thicker than the conductive bump **210**, in accordance with some embodiments. Therefore, the conductive bumps **260** are able to be bonded with a wiring substrate with larger pads than that of the chip **170** in subsequent processes, in accordance with some embodiments.

(70) As shown in FIG. 1L, a cutting process is performed over the wiring substrate **110** along cutting lines A to cut through the wiring substrate **110** and the molding layer **250** to form chip package structures **270**, in accordance with some embodiments.

(71) As shown in FIG. 1M, the chip package structure **270** is bonded to a wiring substrate **280** through the conductive bumps **260**, in accordance with some embodiments. The wiring substrate **280** includes a printed circuit board or another suitable wiring substrate. The wiring substrate **280** includes an insulating layer **282**, wiring layers **284**, conductive vias **286**, and pads **288**, in accordance with some embodiments.

(72) The wiring layers **284** and the conductive vias **286** are in the insulating layer **282**, in accordance with some embodiments. The pads **288** are over the insulating layer **282**, in accordance with some embodiments. The conductive vias **286** are electrically connected between the wiring layers **284** and between the wiring layer **284** and the pads **288**, in accordance with some embodiments.

(73) The wiring layers **284**, the conductive vias **286**, and the pads **288** are made of a conductive material such as a metal material or an alloy thereof, in accordance with some embodiments. The metal material includes aluminum, copper or tungsten.

(74) In this step, a chip package structure (or board-level package structure) **100** is substantially formed, in accordance with some embodiments. The chip package structure **100** includes the chip package structure **270**, the conductive bumps **260**, and the wiring substrate **280**, in accordance with some embodiments. The chip package structure **100** is a ball grid array (BGA) package structure, in accordance with some embodiments.

(75) FIGS. 2A-2B are cross-sectional views of various stages of a process for forming a chip package structure, in accordance with some embodiments. As shown in FIG. 2A, after the step of FIG. 1J, a cutting process is performed over the wiring substrate **110** along cutting lines A to cut through the wiring substrate **110** and the molding layer **250** to form chip package structures **290**, in accordance with some embodiments.

(76) As shown in FIG. 2B, a wiring substrate **280a** is provided, in accordance with some embodiments. The wiring substrate **280a** is similar to the wiring substrate **280** of FIG. 1M, except that the wiring substrate **280a** further includes resilient contact structures **289**, in accordance with some embodiments. The resilient contact structures **289** are mounted to the pads **288**, in accordance with some embodiments.

(77) As shown in FIG. 2B, the chip package structure **290** is bonded to the wiring substrate **280a** through the conductive protection layer **130** and the resilient contact structures **289**, in accordance with some embodiments. The resilient contact structures **289** are in direct contact with the conductive protection layer **130**, in accordance with some embodiments. The resilient contact

structures **289** are resilient metal strips, in accordance with some embodiments.

(78) In this step, a chip package structure (or board-level package structure) **200** is substantially formed, in accordance with some embodiments. The chip package structure **200** includes the chip package structure **290** and the wiring substrate **280a**, in accordance with some embodiments. The chip package structure **200** is a land grid array (LGA) package structure, in accordance with some embodiments.

(79) FIG. **3** is a cross-sectional view of a chip package structure (or board-level package structure) **300**, in accordance with some embodiments. As shown in FIG. **3**, the chip package structure **300** is similar to the chip package structure **200** of FIG. **2B**, except that the resilient contact structures **289** of the chip package structure **300** penetrate into the conductive protection layer **130**, in accordance with some embodiments. The conductive protection layer **130** may secure the resilient contact structures **289** to the pads **115b** to improve the yield of the chip package structure **300**. The chip package structure **300** is a land grid array (LGA) package structure, in accordance with some embodiments.

(80) FIGS. **4A-4H** are cross-sectional views of various stages of a process for forming a chip package structure, in accordance with some embodiments. As shown in FIG. **4A**, after the step of FIG. **1I**, the wiring substrate **110** is disposed over the carrier substrate **230**, in accordance with some embodiments. As shown in FIG. **4A**, a portion of the conductive layer **150** is not bonded to the chip **170**, in accordance with some embodiments.

(81) As shown in FIG. **4A**, an underfill layer **240** is formed between the chip **170** and the wiring substrate **110**, in accordance with some embodiments. As shown in FIG. **4A**, a flux layer **420** is formed over the portion of the conductive layer **150** and the top surface **118a1** of the insulating layer **118a**, in accordance with some embodiments.

(82) In some embodiments, the flux layer **420** includes tartaric acid, a resin, an amine, and/or a solvent. In some embodiments, the amine is an alkyl substituted amine, an ethanol amine, an ethoxylated amine, or a propoxylated amine. In some embodiments, a surfactant is used, sometimes referred to as a flow modifier. The specific surfactant depends upon compatibility with the flux layer **420**. In some embodiments, the surfactant is anionic such as long chain alkyl carboxylic acids, such as lauric acids, steric acids, or the like. The flux layer **420** is formed using a dipping process or a jetting process, in accordance with some embodiments.

(83) As shown in FIG. **4B**, a device **430** is bonded to the wiring substrate **110** through a conductive bump **410**, in accordance with some embodiments. The conductive bump **410** is partially formed from the portion of the conductive layer **150**, in accordance with some embodiments. The device **430** includes an active device or a passive device such as a resistor, a capacitor, or an inductor, in accordance with some embodiments.

(84) As shown in FIG. **4C**, the flux layer **420** is removed using a deflux process, in accordance with some embodiments. As shown in FIG. **4C**, a molding layer **440** is formed over the wiring substrate **110**, the chip **170**, the underfill layer **240**, the device **430**, and the conductive bump **410**, in accordance with some embodiments. The molding layer **440** encapsulates the chip **170** and the device **430**, in accordance with some embodiments.

(85) The molding layer **440** surrounds the chip **170**, the conductive bumps **210**, the underfill layer **240**, the device **430**, and the conductive bump **410**, in accordance with some embodiments. The molding layer **440** is made of an insulating material, such as a polymer material, in accordance with some embodiments.

(86) As shown in FIG. **4D**, the wiring substrate **110** is flipped upside down and is disposed over a carrier substrate **450**, in accordance with some embodiments. The carrier substrate **450** is configured to provide temporary mechanical and structural support during subsequent processing steps, in accordance with some embodiments. The carrier substrate **450** includes glass, silicon oxide, aluminum oxide, metal, a combination thereof, or the like, in accordance with some embodiments. The carrier substrate **450** includes a metal frame, in accordance with some

embodiments.

(87) As shown in FIG. 4D, a flux layer **460** is formed over a portion of the conductive protection layer **130**, in accordance with some embodiments. In some embodiments, the flux layer **460** includes tartaric acid, a resin, an amine, and/or a solvent. In some embodiments, the amine is an alkyl substituted amine, an ethanol amine, an ethoxylated amine, or a propoxylated amine.

(88) In some embodiments, a surfactant is used, sometimes referred to as a flow modifier. The specific surfactant depends upon compatibility with the flux layer **460**. In some embodiments, the surfactant is anionic such as long chain alkyl carboxylic acids, such as lauric acids, steric acids, or the like. The flux layer **460** is formed using a dipping process or a jetting process, in accordance with some embodiments.

(89) As shown in FIG. 4E, a device **470** is bonded to the wiring substrate **110** through a conductive bump **480**, in accordance with some embodiments. The conductive bump **480** is partially formed from the portion of the conductive protection layer **130**, in accordance with some embodiments. The device **470** includes an active device or a passive device such as a resistor, a capacitor, or an inductor, in accordance with some embodiments.

(90) As shown in FIG. 4F, the flux layer **460** is removed using a deflux process, in accordance with some embodiments. As shown in FIG. 4G, the steps of FIGS. 1K-1L is performed to form the conductive bumps **260** and to form chip package structures (or board-level package structures) **400**, in accordance with some embodiments. As shown in FIG. 4H, the step of FIG. 1M is performed to bond the chip package structure **400** to the wiring substrate **280** through the conductive bumps **260**, in accordance with some embodiments.

(91) In this step, a chip package structure **490** is substantially formed, in accordance with some embodiments. The chip package structure **490** includes the chip package structure **400**, the conductive bumps **260**, and the wiring substrate **280**, in accordance with some embodiments. The chip package structure **490** is a ball grid array (BGA) package structure, in accordance with some embodiments.

(92) FIGS. 5A-5B are cross-sectional views of various stages of a process for forming a chip package structure, in accordance with some embodiments. As shown in FIG. 5A, after the step of FIG. 4F, a cutting process is performed over the wiring substrate **110** along cutting lines A to cut through the wiring substrate **110** and the molding layer **440** to form chip package structures **510**, in accordance with some embodiments.

(93) As shown in FIG. 5B, the chip package structure **510** is bonded to the wiring substrate **280a** through the conductive protection layer **130** and the resilient contact structures **289**, in accordance with some embodiments. The resilient contact structures **289** are in direct contact with the conductive protection layer **130**, in accordance with some embodiments. The resilient contact structures **289** are resilient metal strips, in accordance with some embodiments. The resilient contact structures **289** penetrate into the conductive protection layer **130**, in accordance with some embodiments.

(94) In this step, a chip package structure (or board-level package structure) **520** is substantially formed, in accordance with some embodiments. The chip package structure **520** includes the chip package structure **510** and the wiring substrate **280a**, in accordance with some embodiments. The chip package structure **520** is a land grid array (LGA) package structure, in accordance with some embodiments.

(95) FIG. 6 is a cross-sectional view of a chip package structure **600**, in accordance with some embodiments. As shown in FIG. 6, the chip package structure **600** is similar to the chip package structure **100** of FIG. 1M, except that the chip package structure **600** further has an adhesive layer **610** and a heat-spreading lid **620**, in accordance with some embodiments. The chip package structure **600** does not have the molding layer **250** of the chip package structure **100**, in accordance with some embodiments.

(96) The adhesive layer **610** is formed over the wiring substrate **110**, in accordance with some

embodiments. The adhesive layer **610** surrounds the chip **170** and the underfill layer **240**, in accordance with some embodiments. The adhesive layer **610** has a ring shape, in accordance with some embodiments. The heat-spreading lid **620** is disposed over the chip **170** and the adhesive layer **610**, in accordance with some embodiments.

(97) The adhesive layer **610** is made of polymer, such as epoxy or silicone, in accordance with some embodiments. The adhesive layer **610** is formed using a dispensing process, in accordance with some embodiments. The heat-spreading lid **620** is made of a high thermal conductivity material, such as a metal material (aluminum or copper), an alloy material (e.g., stainless steel), or aluminum-silicon carbide (AlSiC), in accordance with some embodiments.

(98) FIG. 7 is a cross-sectional view of a chip package structure **700**, in accordance with some embodiments. As shown in FIG. 7, the chip package structure **700** is similar to the chip package structure **100** of FIG. 1M, except that the chip package structure **700** further has an adhesive layer **710**, a heat-spreading ring **720**, an adhesive layer **730** and a heat-spreading plate **740**, in accordance with some embodiments. The chip package structure **700** does not have the molding layer **250** of the chip package structure **100**, in accordance with some embodiments.

(99) The adhesive layer **710** is formed over the wiring substrate **110**, in accordance with some embodiments. The adhesive layer **710** surrounds the chip **170** and the underfill layer **240**, in accordance with some embodiments. The adhesive layer **710** has a ring shape, in accordance with some embodiments. The heat-spreading ring **720** is disposed over the adhesive layer **710**, in accordance with some embodiments.

(100) The adhesive layer **730** is formed over the heat-spreading ring **720**, in accordance with some embodiments. The adhesive layer **730** has a ring shape, in accordance with some embodiments. The heat-spreading plate **740** is disposed over the adhesive layer **730** and the chip **170**, in accordance with some embodiments.

(101) The adhesive layers **710** and **730** are made of polymer, such as epoxy or silicone, in accordance with some embodiments. The adhesive layers **710** and **730** are formed using a dispensing process, in accordance with some embodiments.

(102) The heat-spreading ring **720** and the heat-spreading plate **740** are made of a high thermal conductivity material, such as a metal material (aluminum or copper), an alloy material (e.g., stainless steel), or aluminum-silicon carbide (AlSiC), in accordance with some embodiments.

(103) FIG. 8 is a cross-sectional view of a chip package structure **800**, in accordance with some embodiments. As shown in FIG. 8, the chip package structure **800** is similar to the chip package structure **300** of FIG. 3, except that the chip package structure **800** further has an adhesive layer **610** and a heat-spreading lid **620**, in accordance with some embodiments.

(104) The chip package structure **800** does not have the molding layer **250** of the chip package structure **300**, in accordance with some embodiments. The resilient contact structures **289** pass through the conductive protection layer **130**, in accordance with some embodiments. The resilient contact structures **289** are in direct contact with the intermetallic compound layer C, in accordance with some embodiments.

(105) The adhesive layer **610** is formed over the wiring substrate **110**, in accordance with some embodiments. The adhesive layer **610** surrounds the chip **170** and the underfill layer **240**, in accordance with some embodiments. The adhesive layer **610** has a ring shape, in accordance with some embodiments. The heat-spreading lid **620** is disposed over the chip **170** and the adhesive layer **610**, in accordance with some embodiments.

(106) The adhesive layer **610** is made of polymer, such as epoxy or silicone, in accordance with some embodiments. The adhesive layer **610** is formed using a dispensing process, in accordance with some embodiments. The heat-spreading lid **620** is made of a high thermal conductivity material, such as a metal material (aluminum or copper), an alloy material (e.g., stainless steel), or aluminum-silicon carbide (AlSiC), in accordance with some embodiments.

(107) FIG. 9 is a cross-sectional view of a chip package structure **900**, in accordance with some

embodiments. As shown in FIG. 9, the chip package structure **900** is similar to the chip package structure **300** of FIG. 3, except that the chip package structure **900** further has an adhesive layer **710**, a heat-spreading ring **720**, an adhesive layer **730** and a heat-spreading plate **740**, in accordance with some embodiments. The chip package structure **900** does not have the molding layer **250** of the chip package structure **300**, in accordance with some embodiments.

(108) The adhesive layer **710** is formed over the wiring substrate **110**, in accordance with some embodiments. The adhesive layer **710** surrounds the chip **170** and the underfill layer **240**, in accordance with some embodiments. The adhesive layer **710** has a ring shape, in accordance with some embodiments. The heat-spreading ring **720** is disposed over the adhesive layer **710**, in accordance with some embodiments.

(109) The adhesive layer **730** is formed over the heat-spreading ring **720**, in accordance with some embodiments. The adhesive layer **730** has a ring shape, in accordance with some embodiments. The heat-spreading plate **740** is disposed over the adhesive layer **730** and the chip **170**, in accordance with some embodiments.

(110) The adhesive layers **710** and **730** are made of polymer, such as epoxy or silicone, in accordance with some embodiments. The adhesive layers **710** and **730** are formed using a dispensing process, in accordance with some embodiments.

(111) The heat-spreading ring **720** and the heat-spreading plate **740** are made of a high thermal conductivity material, such as a metal material (aluminum or copper), an alloy material (e.g., stainless steel), or aluminum-silicon carbide (AlSiC), in accordance with some embodiments.

(112) Processes and materials for forming the chip package structures **200**, **300**, **490**, **520**, **600**, **700**, **800** and **900** may be similar to, or the same as, those for forming the chip package structure **100** described above.

(113) In accordance with some embodiments, chip package structures and methods for forming the same are provided. The methods (for forming the chip package structure) form a conductive protection layer over a nickel-containing layer over pads before deflux processes to protect the nickel-containing layer from being oxidized during deflux processes. Therefore, the adhesion between the pads and conductive bumps subsequently formed between the pads and a chip is improved. As a result, the yield of the chip package structure is improved.

(114) In accordance with some embodiments, a chip package structure is provided. The chip package structure includes a first wiring substrate including a substrate, a first pad, a second pad, and an insulating layer. The first pad and the second pad are respectively over a first surface and a second surface of the substrate, the insulating layer is over the first surface and partially covers the first pad, and the first pad is wider than the second pad. The chip package structure includes a nickel-containing layer over the first pad. The chip package structure includes a conductive protection layer over the nickel-containing layer. The conductive protection layer includes tin, and a recess is surrounded by the conductive protection layer and the insulating layer over the first pad. The chip package structure includes a chip over the second surface of the substrate. The chip package structure includes a conductive bump between the second pad and the chip.

(115) In accordance with some embodiments, a chip package structure is provided. The chip package structure includes a first wiring substrate including a substrate, a first pad, a second pad, and an insulating layer. The first pad and the second pad are respectively over a first surface and a second surface of the substrate, and the insulating layer partially covers the first pad. The chip package structure includes a conductive protection element covering the first pad, wherein a bottommost end of the conductive protection element is closer to the first pad than a bottommost surface of the insulating layer, and the conductive protection layer includes tin. The chip package structure includes a metal-containing layer between the first pad and the conductive protection element. The conductive protection element and the metal-containing layer are made of different materials. The chip package structure includes a chip bonded to the second pad.

(116) In accordance with some embodiments, a chip package structure is provided. The chip

package structure includes a first wiring substrate including a substrate, a first pad, a second pad, and an insulating layer. The first pad and the second pad are respectively over a first surface and a second surface of the substrate, and the insulating layer partially covers the first pad. The chip package structure includes a tin-containing protection element covering the first pad. The tin-containing protection element is thinner than the insulating layer. The chip package structure includes a metal-containing layer between the tin-containing protection element and the first pad. The chip package structure includes a chip bonded to the second pad.

(117) The foregoing outlines features of several embodiments so that those skilled in the art may better understand the aspects of the present disclosure. Those skilled in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions, and alterations herein without departing from the spirit and scope of the present disclosure.

## Claims

1. A chip package structure, comprising: a first wiring substrate comprising a substrate, a first pad, a second pad, and an insulating layer, wherein the first pad and the second pad are respectively over a first surface and a second surface of the substrate, the first surface is opposite to the second surface, the insulating layer is over the first surface and partially covers the first pad, and the first pad is wider than the second pad; a nickel-containing layer over the first pad; and a conductive protection layer over the nickel-containing layer, wherein the conductive protection layer has a curved surface, and a recess is surrounded by the curved surface and an inner wall of the insulating layer over the first pad.
2. The chip package structure as claimed in claim 1, wherein the conductive protection layer comprises tin.
3. The chip package structure as claimed in claim 1, further comprising: a chip over the second surface of the substrate and electrically connected to the second pad.
4. The chip package structure as claimed in claim 3, further comprising: a conductive bump between the second pad and the chip.
5. The chip package structure as claimed in claim 1, further comprising: a second wiring substrate, wherein the first wiring substrate is over the second wiring substrate, the second wiring substrate comprises a second substrate and a resilient contact structure mounted to the second substrate, and the resilient contact structure is in direct contact with the conductive protection layer.
6. The chip package structure as claimed in claim 5, wherein the resilient contact structure is a resilient metal strip.
7. The chip package structure as claimed in claim 5, wherein the resilient contact structure penetrates into the conductive protection layer.
8. The chip package structure as claimed in claim 7, wherein a portion of the conductive protection layer is between the resilient contact structure and the nickel-containing layer.
9. The chip package structure as claimed in claim 5, wherein a first portion of the resilient contact structure is in the recess, and a second portion of the resilient contact structure is outside of the recess.
10. The chip package structure as claimed in claim 1, further comprising: an intermetallic compound layer between the conductive protection layer and the nickel-containing layer, wherein the intermetallic compound layer comprises tin and nickel.
11. A chip package structure, comprising: a first wiring substrate comprising a substrate, a first pad, a second pad, and an insulating layer, wherein the first pad and the second pad are respectively over

a first surface and a second surface of the substrate, the first surface is opposite to the second surface, and the insulating layer partially covers the first pad; a conductive protection element covering the first pad, wherein the conductive protection element comprises tin; a chip bonded to the second pad; and a second wiring substrate, wherein the first wiring substrate is over the second wiring substrate, the second wiring substrate comprises a second substrate and a resilient contact structure mounted to the second substrate, and the resilient contact structure extends into the insulating layer and is electrically connected to the conductive protection element.

12. The chip package structure as claimed in claim 11, wherein the resilient contact structure further extends into the conductive protection element.

13. The chip package structure as claimed in claim 11, wherein the resilient contact structure has a J-shape in a cross-sectional view of the second wiring substrate.

14. The chip package structure as claimed in claim 11, wherein a portion of the conductive protection element is between the resilient contact structure and the first pad.

15. The chip package structure as claimed in claim 11, wherein a first sidewall of the substrate and a second sidewall of the insulating layer are vertically aligned with each other.

16. The chip package structure as claimed in claim 11, wherein the resilient contact structure is closer to the first pad than a bottommost surface of the insulating layer.

17. A chip package structure, comprising: a first wiring substrate comprising a first substrate, a first pad, a second pad, and an insulating layer, wherein the first pad and the second pad are respectively over a first surface and a second surface of the first substrate, the first surface is opposite to the second surface, and the insulating layer partially covers the first pad; a tin-containing protection element covering the first pad, wherein the tin-containing protection element is in the insulating layer and has a curved bottom surface; and a second wiring substrate, wherein the first wiring substrate is over the second wiring substrate, the second wiring substrate comprises a second substrate and a contact structure mounted to the second substrate, the contact structure is in contact with the curved bottom surface, and the insulating layer surrounds a top portion of the contact structure.

18. The chip package structure as claimed in claim 17, further comprising: a chip bonded to the second pad.

19. The chip package structure as claimed in claim 17, wherein the tin-containing protection element is wider than the contact structure.

20. The chip package structure as claimed in claim 17, wherein the contact structure is closer to the first pad than a bottommost surface of the insulating layer.

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