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DEVICE PACKAGES WITH PARTIALLY MOLDED CONNECTORS

Abstract

A connector body such as a coaxial electrical connectors or fiber optic connector can be mounted above a device die that is encapsulated with molding material forming part of a molded device package by bonding the connector body to a redistribution structure formed on the device die. After the device die is molded, a lower portion of the connector body is surrounded by the molding material and an upper portion of the connector body is exposed at an exterior surface of the package. The redistribution structure can be configured to couple connector body to the device while preventing unwanted mechanical stress on the connector body and the device die.

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Background/Summary

TECHNICAL FIELD

[0001] Embodiments of the disclosure are related to electronic device packages which are at least partially formed by polymeric materials which encapsulate one or more components within the package.

BACKGROUND

[0002] Devices such as semiconductor integrated circuits are frequently encapsulated within molded polymer device packages which can protect the devices from mechanical damage and undesired contact with an external environment while providing macroscopic electrical contacts on one or more external surfaces of the package to allow for devices within the package to be interconnected with other devices. Such packages can incorporate carrier substrates such as printed circuit boards and can completely or partially encapsulate carrier substrates and semiconductor components. Some device packages include signal connectors configured to receive an electrical or other cable. Such connectors can include standard electrical connectors such as sub-miniature A (SMA), sub-miniature B (SMB), type N, and type F receptacles or corresponding plugs and can be integrated into device packages by mounting a connector on pads exposed at the surface of a device package (e.g., via surface-mount soldering techniques). Alternatively, a connector can be mounted directly on a surface of semiconductor die provided with suitable contact pads or mounted on a printed circuit board or other carrier substrate adjacent to one or more semiconductor device die or other components.

BRIEF SUMMARY

[0003] In an example embodiment, an electronic device package includes a device die having an upper surface and a lower surface, and a redistribution structure disposed on the upper surface of the device die. The redistribution structure includes one or more redistribution layers (RDLs) formed from electrically insulating material and having electrical interconnects routed within them. The package also includes a connector body disposed above the die and bonded to the redistribution structure. A volume of molding material encapsulates the die and the redistribution structure and surrounds a lower portion of the connector body such that an upper portion of the connector body is exposed at a surface of the device package.

[0004] In another example embodiment, a method includes bonding a connector body to a redistribution structure above a device die. The connector body is an electrical connector configured to be coupled to a coaxial electrical cable or a fiber optic connector configured to be coupled to an optical fiber. The redistribution structure includes one or more redistribution layers (RDLs) formed from electrically insulating material and having electrical interconnects routed within them. The method further includes encapsulating the device die and the redistribution structure within a volume of molding material such that a lower portion of the connector body is surrounded by the volume of molding material and the upper portion of the connector body is exposed at a surface of the device package.

Description

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0005] The present disclosure is illustrated by way of examples, embodiments and the like and is not limited by the accompanying figures, in which like reference numbers indicate similar elements. Elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. The figures along with the detailed description are incorporated and form part of the specification and serve to further illustrate examples, embodiments and the like, and explain

various principles and advantages, in accordance with the present disclosure, wherein:
[0006] FIG. **1**A is a cross-sectional view of an example device package according to one or more embodiments;
[0007] FIG. **1**B is a cross-sectional view showing a portion of the package of FIG. **1**A in greater detail;
[0008] FIG. **2** is a cross-sectional view of an example device package according to one or more embodiments that is related to the device package of FIG. **1**A;
[0009] FIG. **3** is a process flow illustration depicting an example process according to one or more embodiments suitable for forming the device package of FIG. **1**A;
[0010] FIG. **4** is a cross-sectional view of another example device package according to one or more embodiments;
[0011] FIG. **5** is a cross-sectional view of another example device package according to one or more embodiments.
DETAILED DESCRIPTION
[0012] The following detailed description provides examples for the purposes of understanding and is not intended to limit the invention or the application and uses of the same. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, or the following detailed description.
[0013] For simplicity and clarity of illustration, the drawing figures illustrate the general manner of construction, and descriptions and details of well-known features and techniques may be omitted to avoid unnecessarily obscuring the invention. Additionally, elements in the drawing figures are not necessarily drawn to scale. For example, the dimensions of some of the elements or regions in the figures may be exaggerated relative to other elements or regions to help improve understanding of embodiments of the invention. The connecting lines shown in the various figures contained herein are intended to represent exemplary functional relationships and/or physical couplings between the various elements. It should be noted that many alternative or additional functional relationships or physical connections may be present in one or more embodiments of the subject matter. Directional references such as “top,” “bottom,” “left,” “right,” “above,” “below,” and so forth, unless implied or stated otherwise, are not intended to require any preferred orientation, and are made with reference to the orientation of the corresponding figure or figures for purposes of illustration.
[0014] The terms “first,” “second,” “third,” “fourth” and the like in the description and the claims, if any, may be used for distinguishing between similar elements and not necessarily for describing a particular sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances such that the embodiments of the invention described herein are, for example, capable of operation in sequences other than those illustrated or otherwise described herein. Furthermore, the terms “comprise,” “include,” “have” and any variations thereof, are intended to cover non-exclusive inclusions, such that a process, method, article, or apparatus that comprises a list of elements is not necessarily limited to those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. The term “coupled,” as used herein, is defined as directly or indirectly connected in an electrical or non-electrical manner. As used herein the terms “substantial” and “substantially” mean sufficient to accomplish the stated purpose in a practical manner and that minor imperfections, if any, are not significant for the stated purpose.
[0015] It will be appreciated that the steps of various processes described herein are non-limiting examples of suitable processes according to embodiments and are for the purposes of illustration. Embodiments herein may use any suitable processes including those that omit steps of example processes described herein, perform those steps or similar steps in different orders, and the like. It will also be appreciated that well-known techniques and features may be omitted for clarity.
[0016] Unless explicitly stated otherwise, the terms “approximately” and “substantially”, when used herein to refer to measurable quantities including, but not limited to dimensions, shall mean

that a quantity is equal to a stated value or that two quantities are equal to each other to within an amount determined by accepted tolerances of the process(es) chosen to fabricate the relevant structure and/or an accepted measurement accuracy of the method(s) and/or measurement device(s) chosen to measure the dimensions or other properties described.

[0017] Conventional approaches for integrating macroscopic cable connectors with molded device packages include attaching connectors to the exterior of a package or bonding a connector to an otherwise unoccupied area of a carrier substrate such as a printed circuit board. However, such approaches can have disadvantages. As one example, connectors which are bonded to the exterior of a molded package can be susceptible to mechanical damage. In addition, lengthy electrical interconnections may be required to couple the connector to devices within the package which can degrade performance by introducing unwanted signal attenuation. In other approaches a connector may is disposed adjacent to one or more components on a printed circuit board or other substrate and the connector is partially molded together with the components on the substrate. However, such approaches can significantly increase the minimum footprint of the package. Accordingly, embodiments disclosed herein provide electronic device packages that include integrated signal connectors which can disposed directly above or below components within the package while providing strain relief which protects the connector and the die from unwanted mechanical stresses which can lead to device damage and/or degraded electrical performance while also reducing the minimum footprint area of the package compared to other approaches.

[0018] FIG. **1**A is a cross-sectional view of an example package according to one or more embodiments that includes an integrated connector body, non-limiting examples of which include coaxial electrical cable connectors such as SMA, SMB, type N, or type F receptacles and plugs. The package **100** includes a carrier substrate (the carrier **110**; e.g., a printed circuit board or any other suitable substrate) that has a lower surface **111** and an upper surface **112**. The carrier **110** can include electrical contacts (represented by solder bumps **115**) on its lower surface **111** that are suitable for use in coupling the carrier **110** to another assembly or device. A semiconductor device die or other electronic device die (the die **120** which has a lower surface **121** and an upper surface **122**) is bonded to the carrier **110** using any suitable material and process(es) including but not limited to soldering, direct bonding, adhesive bonding using electrically conductive or nonconductive adhesives, and the like. A die such as the die **120** and/or a connector body such as the connector body **140** can be electrically coupled to a carrier substrate such as the carrier **110** using any suitable methods, including but not limited to the use of wire bonds **136** as shown in FIG. **1**A. The carrier **110** includes electrical contacts (represented by solder bumps **115**) on its lower surface **111** that are suitable for use in coupling the carrier **110** to another assembly or device. It will be appreciated that, in one or more embodiments, a die such as the die **120** may be provided with electrical contacts on its bottom surface and can form an exposed surface of a device package without requiring a carrier substrate such as the carrier **110**. A die such as the die **120** can also be mechanically coupled to a carrier such as the carrier **110** using any suitable materials and methods including, but not limited to adhesive bonding using epoxy-based materials or other polymeric materials.

[0019] The package **100** includes a redistribution structure **130** that is disposed on the upper surface **122** of the die **120**. The redistribution structure **130** includes one or more redistribution layers. A redistribution layer (RDL) is a layer of insulating material through which electrically conductive interconnects **135** are routed. Interconnects such as the interconnects **135** can be used for various purposes including, but not limited to, electrically coupling portion of the die **120** to each other and to electrical contacts or other structures on or within the carrier **110**. A connector body **140** is disposed on an upper surface the redistribution structure **130** (the upper RDL surface **131**) and coupled to the die **120** via one or more interconnects **135**. Electrical connections to the connector body **140** formed by interconnects **135** can also mechanically couple the connector body **140** to the redistribution structure **130**. The redistribution structure **130** can allow the connector body **140** to be indirectly mechanically coupled to the die **120** in order to avoid unwanted mechanical stresses which might otherwise be experienced by the die **120** and/or the connector body **140** due to mismatches in thermal expansion between the connector body **140** and the die **120** or stresses which would otherwise be experienced when bonding the connector body **140** directly to the upper surface **122** of the die **120**.

[0020] In one or more embodiments, as shown in the example of FIG. **1**A, a redistribution structure such as redistribution structure **130** includes a first RDL such as the first RDL **132** and a second RDL such as the RDL **134**. In one or more such embodiments, the first RDL is characterized by a first elastic modulus and the second RDL is characterized by a second elastic modulus that is lower than the first elastic modulus. It will be appreciated that the relative thickness and elastic moduli of RDLs in a redistribution structure according to embodiments herein can be chosen to realize a desired combination of stiffness and mechanical compliance. It will be further appreciated that a redistribution structure according to embodiments herein can include any suitable number of RDLs in any suitable arrangement. In one or more embodiments, a first RDL such as the RDL **132** has a thickness less than 10 μm and a second RDL such as the RDL **134** has a thickness of greater than 10 μm. In one such embodiment, the first RDL has a thickness in the inclusive range of 3-5 μm and the second RDL has a thickness greater than 20 μm. It will also be understood that, in one or more embodiments, a connector body such as the connector body **140** can be bonded directly to suitable features such as contact pads on a die such as the die **120** without a redistribution structure such as the redistribution structure **130**.

[0021] In one or more embodiments a single RDL (e.g., the first RDL **132** or RDL **134**) is used between the die and the connector body. In such embodiments, suitable materials for the RDL include, but are not limited to, polyimide-based materials with a thickness of at least 6 μm (e.g., photosensitive polyimide films with a thickness in the inclusive range of 6-20 μm). For some applications, it is desirable that the modulus of such materials be approximately 3 GPa and that the cured film should have a breakdown voltage of approximately 100 V/μm or better.

[0022] In the example of FIG. **1**A, the connector body **140** includes lower portion **142** and an upper portion **144**. The lower portion **142** is encapsulated, along with the redistribution structure **130**, the die **120** and (at least) the upper surface **112** of the carrier **110** within a volume of molding material **150** which may be any suitable electrically-insulating polymeric material including, but not limited to an epoxy-based material. The molding material **150** may be formed as shown using any suitable methods. As one non-limiting example, the volume of molding material **150** is formed using a film-assisted molding process in which a molding insert protects the upper portion **144** of the connector body **140** from being molded, leaving it exposed as shown in FIG. **1**A at the surface **151** of the volume of molding material which forms a first exterior surface of the package **100**, with an opposite exterior surface of the package **100** formed by the lower surface **111** of the carrier **110**.

[0023] It will be appreciated that the connector body **140** is described as an electrical connector for purposes of illustration and that other connectors can be used. For example, in one or more embodiments, a connector body such as the connector body **140** is a fiber optic connector configured to be coupled to an optical fiber, non-limiting examples of which include an SC fiber connector, FC fiber connector, LC fiber connector, ST fiber connector and the like. In one or more such embodiments, a package such as the package **100** includes optoelectronic components configured to be coupled to the connector body and the package can include optical elements such as waveguides, lenses, and optical couplers, as non-limiting examples. Such components can be formed with one or more RDL layers of a redistribution structure such as the redistribution structure **130**, and/or on or within a die such as the die **120**, as non-limiting examples.

[0024] It will be further appreciated that RDLs such as the RDL **132** and the RDL **134**, along with interconnects **135** are depicted schematically for ease of understanding. For example, the relative dimensions of interconnects within RDLs and the relative dimensions of RDLs with respect to other features may be exaggerated for clarity. It will be understood that horizontal portions of interconnects such as the interconnects **135** and related interconnects described herein may be disposed on surfaces of one or more RDLs and that the thickness of such interconnects may be significantly less than the thickness(es) of the RDL(s) such that height variations corresponding to interconnects along the RDL surfaces may be small compared to the thickness(es) of the corresponding RDL(s).

[0025] FIG. **1**B shows a detailed view of the connector body **140** of FIG. **1**A. In the example of FIG. **1**B, the connector body **140** includes extensions **145** surrounding the lower portion **142** of the connector body **140**. Such extensions can enable the use of film-assisted molding (FAM) to form the volume of molding material **150** if dimensions of the connector body **140** are too small to support a molding insert during film-assisted model. For example, the width of the base of a connector body such as the connector body **140** may be less than a minimum clearance (as represented by the dimension **199**) required for a molding insert such as the molding insert **195** as shown in FIG. **1**B. It will be appreciated that relative dimensions of the connector body **140** and the extensions **145** are not to scale and may differ from other depictions as an aid to understanding. Extensions such as the extensions **145** can be formed in any suitable manner, using any suitable materials. For example, the extensions **145** can be formed by dispending and curing epoxy at connector base, injection molding, or another suitable process. In one or more embodiments, a connector body such as the connector body **140** can be bonded to a redistribution structure such as the redistribution structure **130** followed by formation of extensions such as the extensions **145** or in one or more other embodiments, the connector body may be provided with extensions before being bonded to the redistribution structure. It will be further understood that in one or more embodiments (e.g., embodiments described in connection with FIG. **2** below) extensions such as the extensions **145** are not necessary.

[0026] FIG. **2** is a partially exploded cross-sectional view of another example package according to one or more embodiments that includes an integrated connector body. The package **200** includes a die **220** (e.g., a die **120**) with a lower surface **221** and an upper surface **222** opposite the lower surface **221**. A redistribution structure **230** is disposed on the upper surface **221** of the redistribution structure **230** and includes electrically-conductive interconnects **235**, similarly to the redistribution structure **130** of FIG. **1**A. In this example the redistribution structure **230** includes a first RDL **232** (e.g., a first RDL **132**) and a second RDL **234** (e.g., an RDL **134**). The package **200** includes an aperture in **252** in the volume of molding material **250** with one or more interconnects **235** exposed on the upper RDL surface **231** of the redistribution structure **230**. The connector body **240** can be bonded to the exposed interconnects **235** within the aperture **252** before or after the die **220** and the redistribution structure **230** are encapsulated within the volume of molding material **250**.

[0027] FIG. **3** shows an example process suitable for forming a device package according to one or more embodiments. The process **300** includes the steps **310**, **320**, **330**, **340**, and **350** which are described in connection with forming the package **100** of FIG. **1**A. It will be appreciated that, for ease of understanding, certain elements may be committed such as descriptions of well-known techniques and fabrication processes. Furthermore, it will be understood that in one or more embodiments steps of the process **300**, other processes described herein and/or similar processes may be performed in a different order than described, that steps of the process **300** or other processes, or related steps may be omitted, and that additional steps can be added. It will be further understood that multiple process steps may be described as occurring in a single process step or that actions described as occurring in multiple steps may be performed in a single step.

[0028] At step **310**, the die **120** is received and the first RDL **132** is formed. The RDL **132** and subsequent RDLs may be formed by any suitable process. As an example, a suitable polymer film may be deposited or otherwise formed on the upper surface **122** of the die **120** followed by formation and patterning of a masking material such as photoresist in photolithographic process. A metal or other suitably conductive material can be deposited via sputtering, thermal evaporation, or a plating process to form a first portion of the interconnects **135**, followed by removal of the masking material to remove unwanted material deposited onto the masking material (i.e., an additive “lift-off” process). Alternatively, the interconnects **135** within the first RDL **132** can be patterned in a subtractive process in which metal is deposited over an entire area and then selectively removed (e.g., via wet chemical etching, sputter etching, and/or reactive ion etching, as non-limiting examples). Next at step **320**, the RDL **134** is formed and patterned above the RDL **132**. It will be understood that, in one or more embodiments, which include only one RDL, that step **320** is omitted.

[0029] It will be understood that descriptions of steps such as step **310** above are simplified for ease of understanding. Along these lines, it will be understood that RDLs such as the RDL **132** and the RDL **134** may be formed in multiple steps and interconnects such as interconnect **135** may be formed from multiple metal layers or metal alloy layers in multiple metal deposition steps. As one nonlimiting example, an RDL with embedded interconnects can be formed by depositing a metal seed layer over a die. Photoresist can then be patterned over the seed layer and used as a mask during electroplating of additional metal which can be the same metal as the seed layer or a different metal. The photoresist can then be removed and the residual seed layer can be etched away leaving only the desired interconnect features.

[0030] At step **330**, the connector body **140** is bonded to the redistribution structure **130** (formed by the RDL **132** and the RDL **134**). In one or more embodiments, a connector body such as the connector bod **140** is bonded to a redistribution structure **130** such as the redistribution structure **130** (at least in part) by being bonded to exposed interconnects **135** (i.e., interconnects **135** of the RDL **134**) which can also serve to electrically couple signal connections of the connector body to a die such as the die **120**. In one or more embodiments, a connector body can also be bonded to a redistribution structure using electrically conductive or electrically nonconductive adhesive.

[0031] At step **340**, the lower surface **121** of the die **120** is bonded to the carrier **110** using a bonding material **342** such as an adhesive which can be electrically conductive, highly resistive, or nonconducting. At step **340**, the extensions **145** are formed around the lower portion **142** of the connector body **140** as described above in connection with FIG. **1**B. In one or more embodiments, a connector body such as the connector body **140** is received with extensions such as the extensions **145** already formed, or the extensions are formed during an earlier step (e.g., at step **330**), or the extensions **145** are formed at a later step (e.g., the step **350** of the process **300**).

[0032] At step **350**, one or more interconnects **135** are coupled to electrical contacts on the carrier **110** (e.g., by the wire bonds **136**), thereby electrically coupling one or more signal lines of the connector body **140** to the die **120**. After step **350**, a molding process may be performed to encapsulate the die **120**, the redistribution structure **130** (i.e., the RDL **132** and the RDL **134**) and the lower portion **142** of the connector body **140** within the volume of molding material **150** as shown in FIG. **1**A.

[0033] Packages according to embodiments disclosed herein are not limited to a single die such as the die **120** or the die **220**. For instance, FIG. **4** is a cross-sectional view of an example device package (the package **400**) which includes a first die **420**A and a second die **420**B in a stacked arrangement with both die encapsulated within a volume of molding material **450** (e.g., molding material **150** or **250**). As shown, the die **420**A is disposed on a carrier **410** (e.g., a carrier **110**) and includes redistribution structure **430** with a first RDL **432** and a second RDL **434**. A connector body connector **440** (e.g., a connector body **140** or **240**) is bonded to interconnects **435** of the redistribution structure **430**.

[0034] A die such as the die **420**B can include a redistribution structure is similar to the redistribution structure **430**. In the example of FIG. **4**, additional interconnects **455**A and **455**B can electrically couple the die **420**B to an electrical contact or other structure on the carrier **410**, and to die **420**A (via interconnects **435** of the redistribution structure **430**), respectively. As an example, the through mold interconnects **455**A and **455**B are depicted as metal pillars which can be directly bonded metallized pads on the carrier **410** or interconnects **435**.

[0035] A multilayer package with two or more stacked die such as the package **400** can be fabricated using methods related to those described in connection with FIG. **3**. In one example, steps **310** through **350** (or steps **310** through **340**) of the process **300** can be performed followed by coupling the die **420**B to the die **420**A and to the carrier **410** via sufficiently-dimensions interconnects **455**A, **455**B, followed by a molding step to encapsulate the die **420**A, **420**B as pictured in FIG. **4**. The die **420**B can be bonded to the die **420**A and the carrier **410** prior to molding and the entire package **400** can be molded in a single film assisted molding step in which multiple molding inserts can be used to define the differing thickness of the molding material **450** over the die **420**B and surrounding the connector body **440**.

[0036] It will be understood that the relative thicknesses of the die **420**A, **420**B and the thickness of the molding material **450** between them are not necessarily to scale and that the interconnects **455**A, **455**B may be formed from any suitable materials. For example, the interconnects **455**A, **455**B can be solder bumps or metal pillars of differing heights (i.e., the interconnects **455**B are shorter than the interconnect **455**A). One or more of the interconnects **455**A, **455**B can be formed from two different structures which are configured to coalesce together or otherwise adhere to each other during bonding. As one non-limiting example the interconnect **455**A shown can be formed by solder bump on the die **420**B that fuses during bonding with a corresponding solder bump on the carrier **410**. Similarly, one or more of the interconnects **455**B can be formed by two corresponding solder bumps. As another non-limiting example, an interconnect **455**A or **455**B can be formed by a solder bump, a metal pillar, or another related structure on the die **420**B or the die **420**A and a corresponding volume of adhesive material on the opposite die.

[0037] It will be understood that nothing herein is intended to limit packages such as the package **400** to only two die and that any number of die, stacked in any suitable arrangement is possible using the devices and methods disclosed herein as well as other well-known methods including, but not limited to, film-assisted molding and the like. It will be further understood that nothing herein is intended to require that a second die such as the die **420**B is electrically or mechanically coupled to both another die such as the die **420**A or to a carrier such as the carrier **410**.

[0038] FIG. **5** is a cross-sectional view of another example package according to one or more embodiments. In the package **500**, a die **520** (e.g., a die **120**, **220**, or **420**) is encapsulated with a volume of molding material **550** and bonded to a carrier **510** that includes an aperture **515** that allows a connector body **540** (e.g., a connector body **140**, **240**, or **440**) to be oriented “face down” with respect to the carrier **510** such that it can be accessed through the aperture **515** in the carrier **510**. As shown, the die **520** is electrically and/or mechanically coupled to suitable contact pads or other structures on the carrier **510** via interconnects **555** (e.g., interconnects **455**A or **455**B).

[0039] A package such as the package **500**, in which a connector body is “face down” with respect to a carrier such as the carrier **510** can be fabricated using methods related to those described in connection with FIG. **3**. In one example, steps **310** through **330** of the process **300** can be performed. The die **520** can then be bonded “face down” to the carrier **510** via the interconnects **555** such that the connector body **540** protrudes through the aperture **515** in the carrier **510**. Afterward a molding process can be performed to encapsulate the die **520** with the volume of molding material **550**. In one or more embodiments, a molding insert may be used together with a film assisted molding process to prevent the molding material **550** from filling the aperture **515** in the carrier **510**.

EXAMPLES

[0040] Features of embodiments may be understood by way of one or more of the following examples.

[0041] Example 1: a device or method in which an electronic device package includes a device die having an upper surface and a lower surface and a redistribution structure disposed on the upper surface of the device die. The redistribution structure includes one or more redistribution layers (RDLs) formed from electrically insulating material and having electrical interconnects routed

within them. A connector body is disposed above the die and bonded to the redistribution structure, and a volume of molding material encapsulates the die and the redistribution structure and surrounds lower portion of the connector body such that an upper portion of the connector body is exposed at a first surface of the device package.
[0042] Example 2: the device or method of Example 1 where the connector body is an electrical connector configured to be coupled to a coaxial electrical cable.
[0043] Example 3: The device or method of Example 1 or Example where the redistribution structure includes a first RDL disposed on the upper surface of the device die and a second RDL disposed between the first RDL and the connector body.
[0044] Example 4: the device or method of any of Examples 1-3 where the lower portion of the connector body is encapsulated within the volume of molding material.
[0045] Example 5: the device or method of any of Examples 1-4 that further includes a carrier substrate having a lower surface and an upper surface opposite the upper surface; where the lower surface of the device die is bonded to the upper surface of the carrier substrate, where the lower surface of the carrier substrate includes a set of external electrical contacts that are exposed at a second surface of the device package, and where the electrical connector is electrically coupled to one or more of the external electrical interconnects via an electrical interconnect that passes through the carrier substrate and is electrically coupled to one or more electrical interconnects within the redistribution structure.
[0046] Example 6: the device or method of any of Examples 1-5 in which the device die is a first device die and the device package further includes a second device die disposed above the first device die and encapsulated within the volume of molding material, the second device die having a lower surface that faces the upper surface of the first device die, and an electrically conductive interconnect that passes through the volume of molding material and electrically couples an electrical contact on the lower surface of the second die to an electrical contact pad on the upper surface of the first device die.
[0047] Example 7: the device or method of any of Examples 1-6 that further includes a carrier substrate having a lower surface and an upper surface opposite the upper surface, the upper surface of the carrier substrate including a set of external electrical interconnects that are exposed at the first surface of the device package, where the lower surface of the carrier substrate is disposed on the volume of molding material above the device die and the redistribution structure, where the carrier substrate includes an aperture that surrounds the connector body, and where the electrical connector is electrically coupled to one or more of the external electrical interconnects via an electrical interconnect that passes through the volume of molding material and is electrically coupled to one or more electrical interconnects within the redistribution structure.
[0048] Example 8: the device or method of any of Examples 1-7 where the connector body is a fiber optic connector body configured to be coupled to an optical fiber. Other technical features may be readily apparent to one skilled in the art from the following figures, descriptions, and claims.
[0049] Example 9: the device or method of any of Examples 1-8 where the connector body is electrically coupled to the device die via an electrical interconnect that is exposed at the upper surface of the redistribution structure and passes through the first RDL and the second RDL.
[0050] Example 10: the device or method of any of Examples 1-9 where the first RDL is characterized by a first elastic modulus and the second RDL is characterized by a second elastic modulus that is lower than the first elastic modulus.
[0051] Example 11: The device or method of any of Examples 1-10 where the device die is a first device die and the device package further includes a second device die disposed above the first device die and encapsulated within the volume of molding material, the second device die having a lower surface that faces the upper surface of the first device die, and an electrically conductive interconnect that passes through the volume of molding material and electrically couples an

electrical contact pad on the lower surface of the second die to an electrical contact pad on the upper surface of the carrier substrate.
[0052] The preceding detailed description and examples are merely illustrative in nature and are not intended to limit the embodiments of the subject matter or the application and uses of such embodiments. As used herein, the word “exemplary” means “serving as an example, instance, or illustration.” Any implementation described herein as exemplary is not necessarily to be construed as preferred or advantageous over other implementations. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, or detailed description.
[0053] It should be understood that this invention is not limited in its application to the details of construction and the arrangement of components set forth in the preceding description or illustrated in the accompanying drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of “including,” “comprising,” or “having” and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Unless specified or limited otherwise, the terms “mounted,” “connected,” “supported,” and “coupled” and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, “connected” and “coupled” are not restricted to physical or mechanical connections or couplings.
[0054] The preceding discussion is presented to enable a person skilled in the art to make and use embodiments of the invention. Various modifications to the illustrated embodiments will be readily apparent to those skilled in the art, and the generic principles herein can be applied to other embodiments and applications without departing from embodiments of the invention. Thus, embodiments of the invention are not intended to be limited to embodiments shown but are to be accorded the widest scope consistent with the principles and features disclosed herein. The preceding detailed description is to be read with reference to the figures, in which like elements in different figures have like reference numerals. The Figures, which are not necessarily to scale, depict selected embodiments and are not intended to limit the scope of embodiments of the invention. Skilled artisans will recognize the examples provided herein have many useful alternatives and fall within the scope of embodiments of the invention.

Claims

1. An electronic device package comprising: a device die having an upper surface and a lower surface; a redistribution structure disposed on the upper surface of the device die, the redistribution structure including one or more redistribution layers (RDLs) formed from electrically insulating material and having electrical interconnects routed within them; a connector body disposed above the die and bonded to the redistribution structure; and a volume of molding material which encapsulates the die and the redistribution structure and surrounds lower portion of the connector body such that an upper portion of the connector body is exposed at a first surface of the device package.
2. The electronic device package of claim 1, wherein the connector body is an electrical connector configured to be coupled to a coaxial electrical cable.
3. The electronic device package of claim 1, wherein the redistribution structure comprises a first RDL disposed on the upper surface of the device die and a second RDL disposed between the first RDL and the connector body.
4. The electronic device package of claim 3, wherein the connector body is electrically coupled to the device die via an electrical interconnect that is exposed at the upper surface of the redistribution structure and passes through the first RDL and the second RDL.

5. The electronic device package of claim 3, wherein the first RDL is characterized by a first elastic modulus and the second RDL is characterized by a second elastic modulus that is lower than the first elastic modulus.
6. The electronic device package of claim 1, wherein the lower portion of the connector body is encapsulated within the volume of molding material.
7. The electronic device package of claim 1, further comprising a carrier substrate having a lower surface and an upper surface opposite the upper surface; wherein the lower surface of the device die is bonded to the upper surface of the carrier substrate; wherein the lower surface of the carrier substrate includes a set of external electrical contacts that are exposed at a second surface of the device package; and wherein the electrical connector is electrically coupled to one or more of the external electrical interconnects via an electrical interconnect that passes through the carrier substrate and is electrically coupled to one or more electrical interconnects within the redistribution structure.
8. The electronic device package of claim 1, wherein the device die is a first device die and the device package further comprises: a second device die disposed above the first device die and encapsulated within the volume of molding material, the second device die having a lower surface that faces the upper surface of the first device die; and an electrically conductive interconnect that passes through the volume of molding material and electrically couples an electrical contact on the lower surface of the second die to an electrical contact pad on the upper surface of the first device die.
9. The electronic device package of claim 1, further comprising: a carrier substrate having a lower surface and an upper surface opposite the upper surface, the upper surface of the carrier substrate including a set of external electrical interconnects that are exposed at a surface of the device package; wherein the lower surface of the carrier substrate is disposed on the volume of molding material above the device die and the redistribution structure; wherein the carrier substrate includes an aperture that surrounds the connector body; and wherein the electrical connector is electrically coupled to one or more of the external electrical interconnects via an electrical interconnect that passes through the volume of molding material and is electrically coupled to one or more electrical interconnects within the redistribution structure.
10. The electronic device package of claim 9, wherein the device die is a first device die and the device package further comprises: a second device die disposed above the first device die and encapsulated within the volume of molding material, the second device die having a lower surface that faces the upper surface of the first device die; and an electrically conductive interconnect that passes through the volume of molding material and electrically couples an electrical contact pad on the lower surface of the second die to an electrical contact pad on the upper surface of the carrier substrate.
11. The electronic device package of claim 1, wherein the connector body is a fiber optic connector body configured to be coupled to an optical fiber.
12. A method comprising: bonding a connector body to a redistribution structure above a device die, redistribution structure including one or more redistribution layers (RDLs) formed from electrically insulating material and having electrical interconnects routed within them; and encapsulating the device die and the redistribution structure within a volume of molding material such that a lower portion of the connector body is surrounded by the volume of molding material and the upper portion of the connector body is exposed at a surface of the device package; wherein the connector body is an electrical connector configured to be coupled to a coaxial electrical cable or a fiber optic connector configured to be coupled to an optical fiber.
13. The method of claim 12, wherein the redistribution structure comprises a first RDL disposed on the upper surface of the device die and a second RDL disposed between the first RDL and the connector body.
14. The method of claim 13, further comprising electrically coupling the connector body the device

die via an electrical interconnect that is exposed at the upper surface of the redistribution structure and passes through the first RDL and the second RDL.

15. The method of claim 13, wherein the first RDL is characterized by a first elastic modulus and the second RDL is characterized by a second elastic modulus that is lower than the first elastic modulus.

16. The method of claim 12, further comprising encapsulating the lower portion of the connector body within the volume of molding material.

17. The method of claim 12, further comprising a carrier substrate having a lower surface and an upper surface opposite the upper surface; wherein the lower surface of the device die is bonded to the upper surface of the carrier substrate; wherein the lower surface of the carrier substrate includes a set of external electrical contacts that are exposed at a second surface of the device package; and wherein the electrical connector is electrically coupled to one or more of the external electrical interconnects via an electrical interconnect that passes through the carrier substrate and is electrically coupled to one or more electrical interconnects within the redistribution structure.

18. The method of claim 12, wherein the device die is a first device die and the device package further comprises: a second device die disposed above the first device die and encapsulated within the volume of molding material, the second device die having a lower surface that faces the upper surface of the first device die; and an electrically conductive interconnect that passes through the volume of molding material and electrically couples an electrical contact on the lower surface of the second die to an electrical contact pad on the upper surface of the first device die.

19. The method of claim 12, further comprising: a carrier substrate having a lower surface and an upper surface opposite the upper surface, the upper surface of the carrier substrate including a set of external electrical interconnects that are exposed at the first surface of the device package; wherein the lower surface of the carrier substrate is disposed on the volume of molding material above the device die and the redistribution structure; wherein the carrier substrate includes an aperture that surrounds the connector body; and wherein the method further comprises electrically coupling the connector body to one or more of the external electrical interconnects via an electrical interconnect that passes through the volume of molding material and is electrically coupled to one or more electrical interconnects within the redistribution structure.

20. The method of claim 19, wherein the device die is a first device die and the device package further comprises: a second device die disposed above the first device die and encapsulated within the volume of molding material, the second device die having a lower surface that faces the upper surface of the first device die; and an electrically conductive interconnect that passes through the volume of molding material and electrically couples an electrical contact pad on the lower surface of the second die to an electrical contact pad on the upper surface of the carrier substrate.