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(54) **FLEXIBLE PACKAGE**

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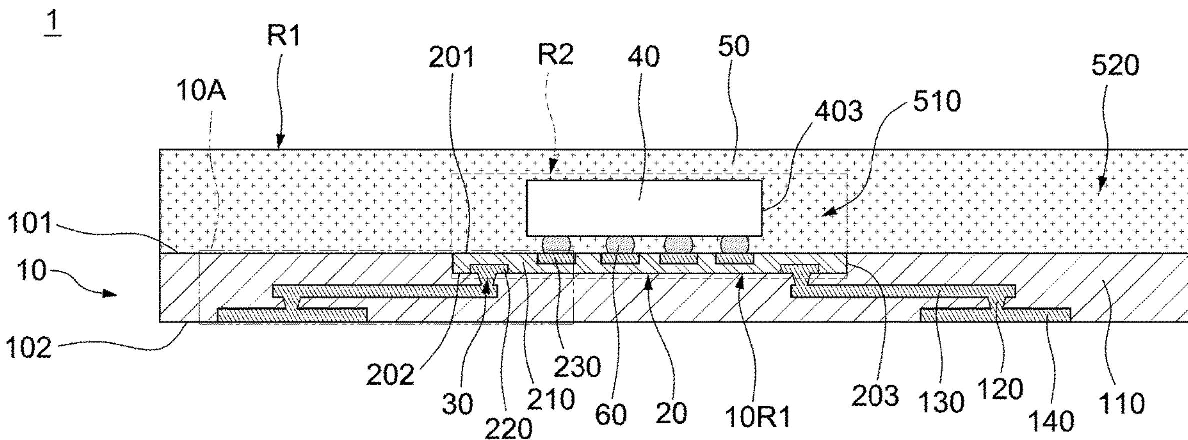
(57) **ABSTRACT**

A flexible package is provided. The flexible package includes a first carrier and a second carrier. The second carrier is electrically connected to the first carrier. The second carrier is at least partially embedded in the first carrier, and an electrical connection interface between the first carrier and the second carrier is within the first carrier.



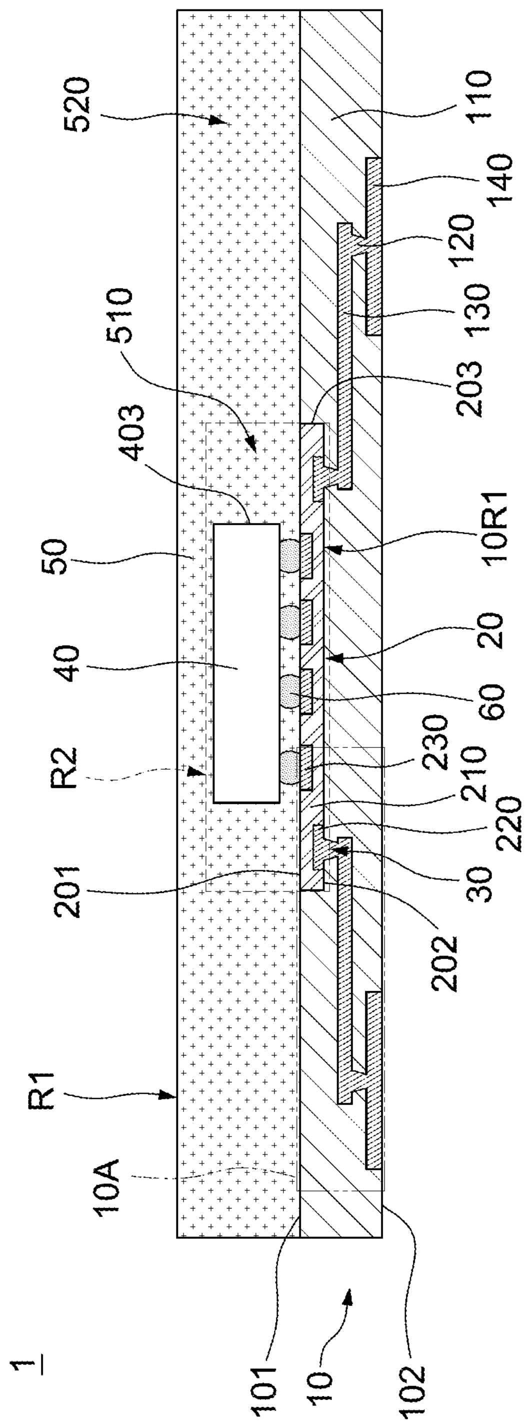


FIG. 1A

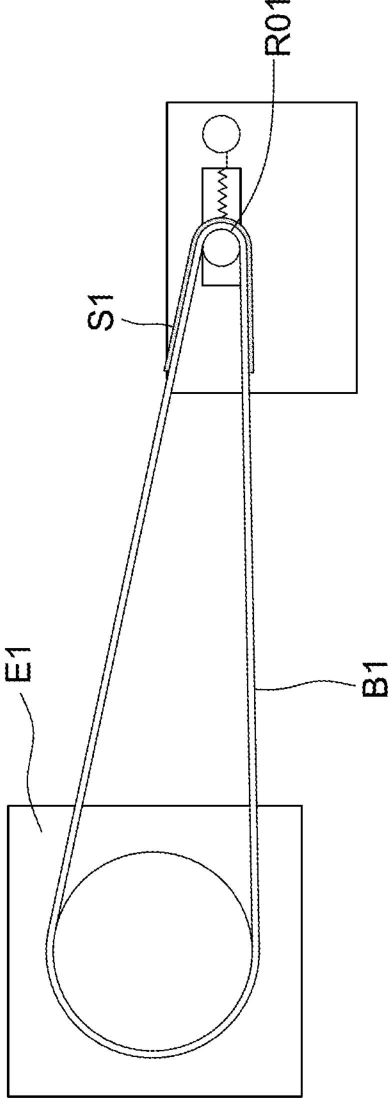


FIG. 1A1

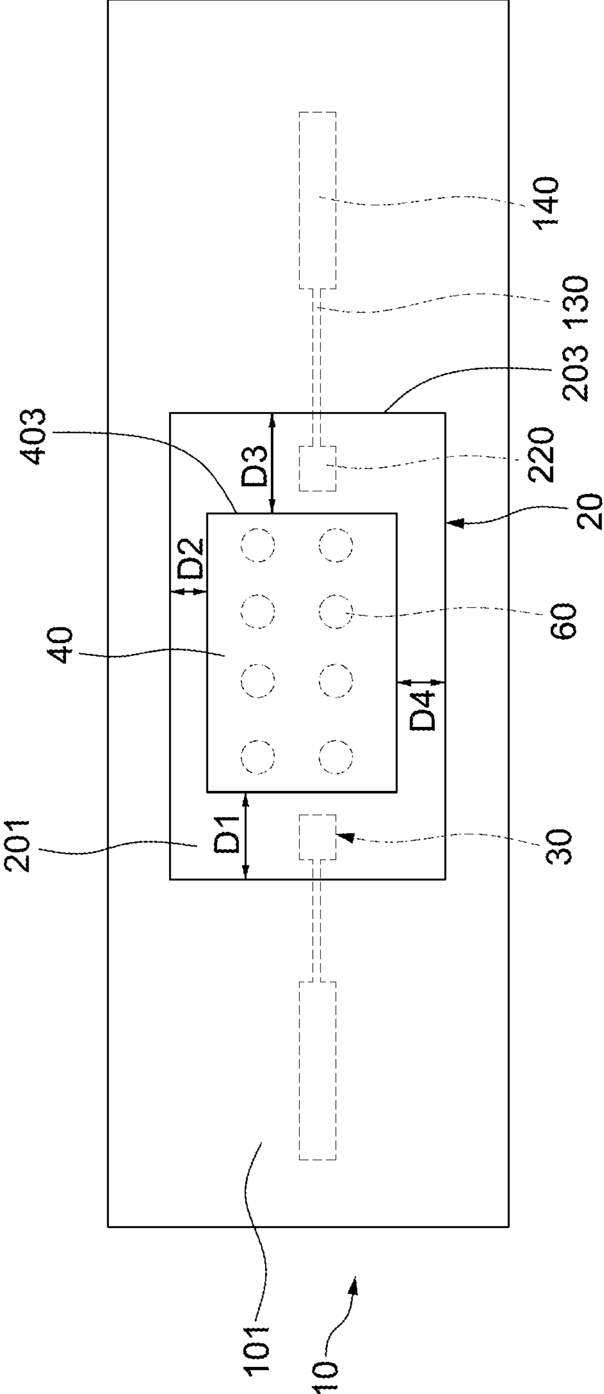


FIG. 1B

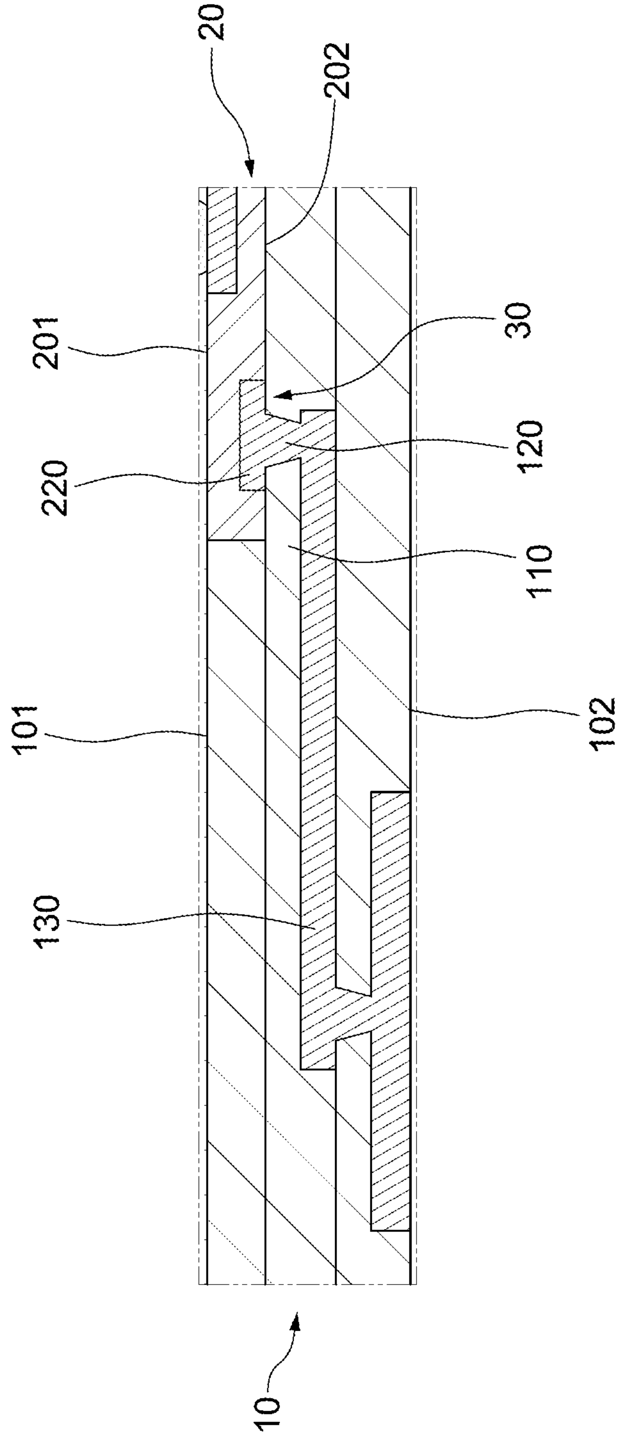


FIG. 1C

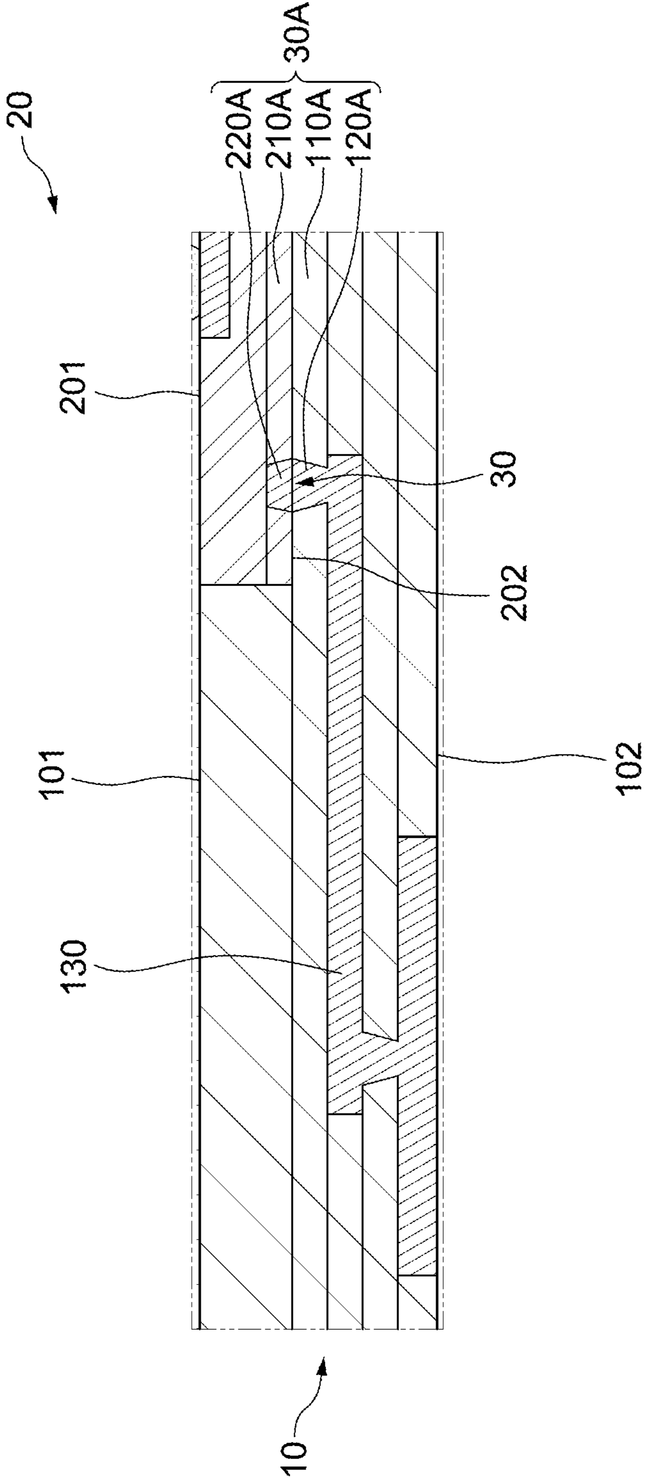


FIG. 1D

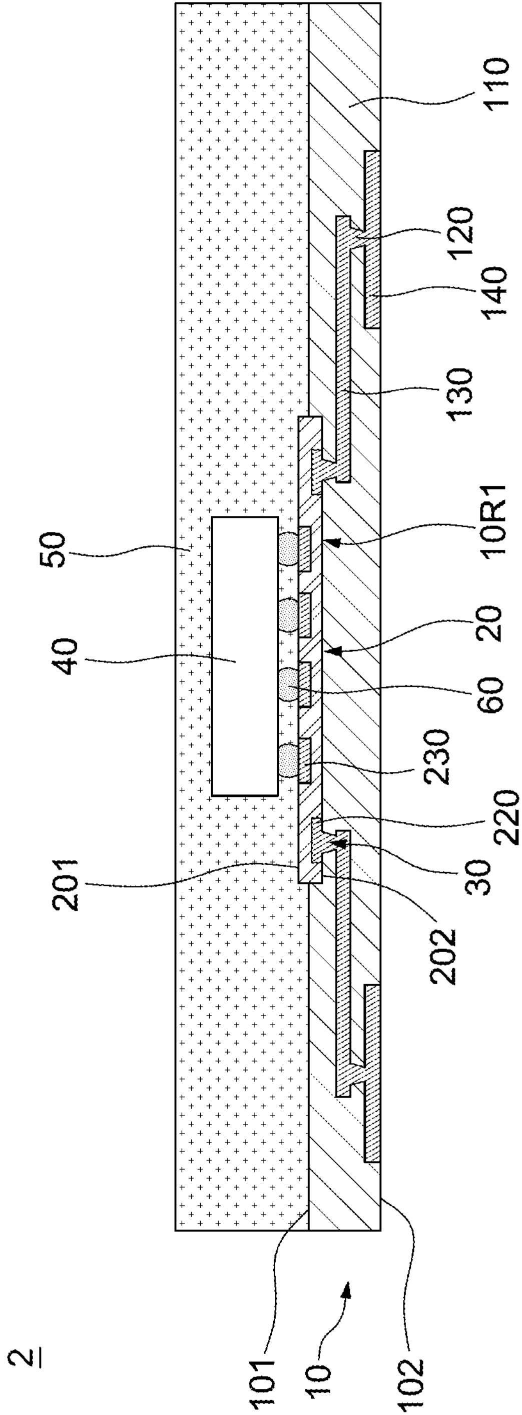


FIG. 2

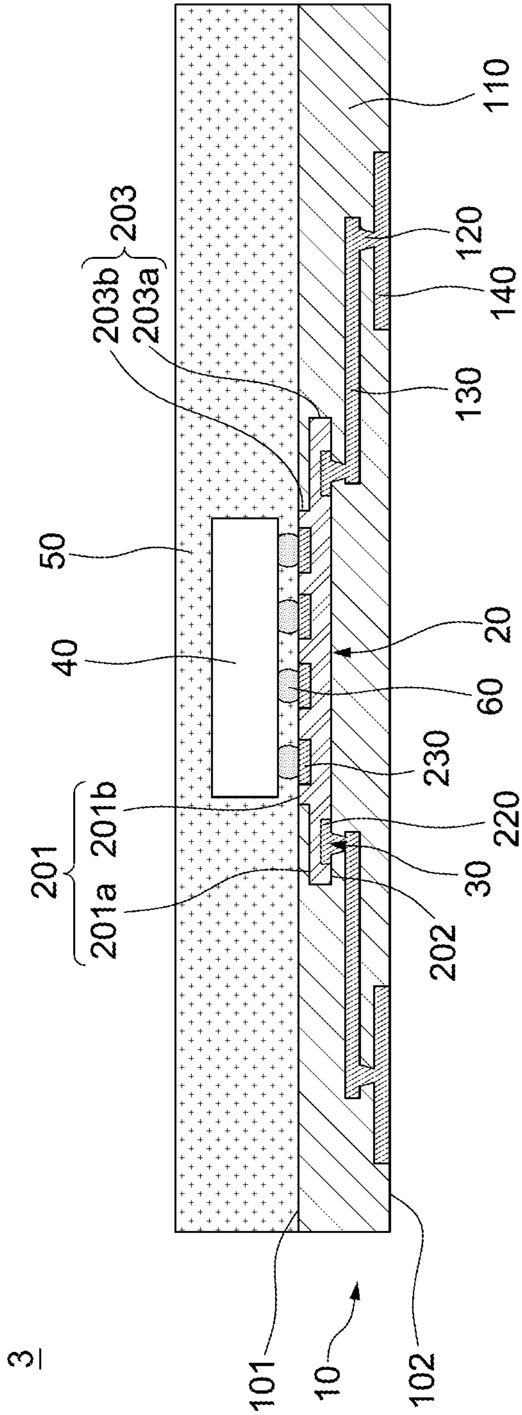


FIG. 3

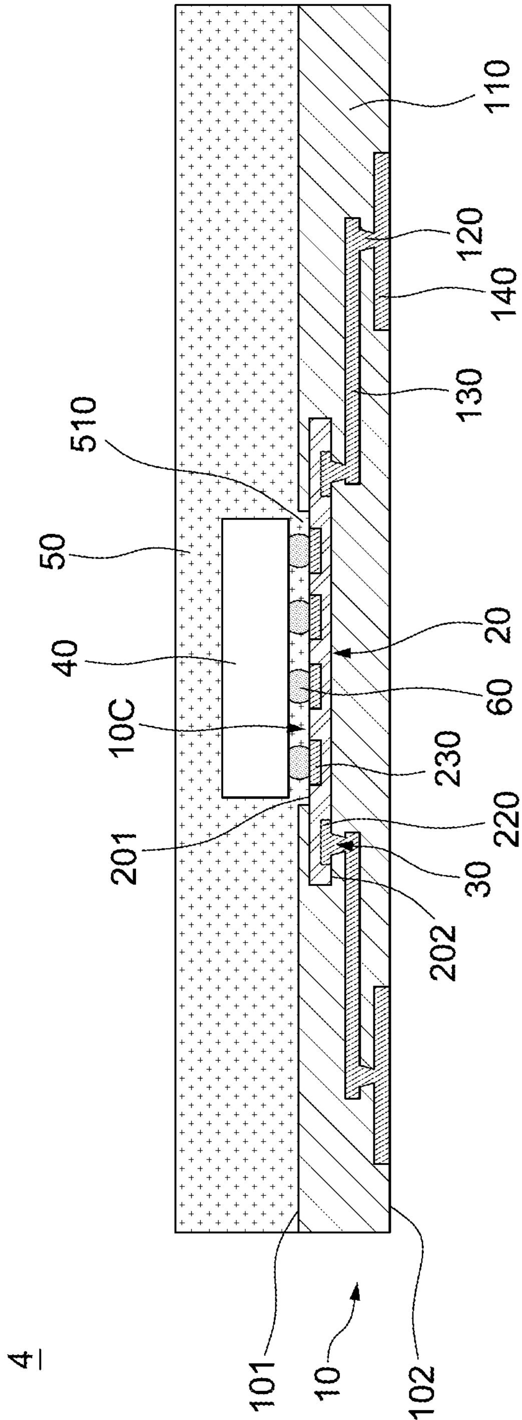


FIG. 4

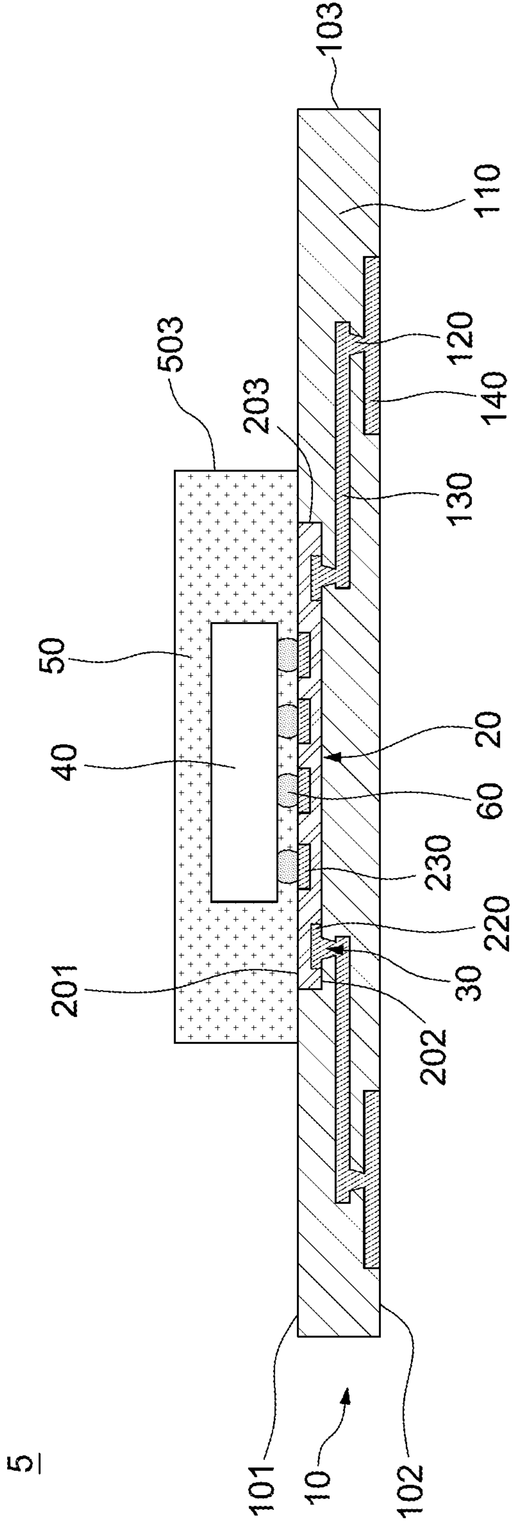


FIG. 5

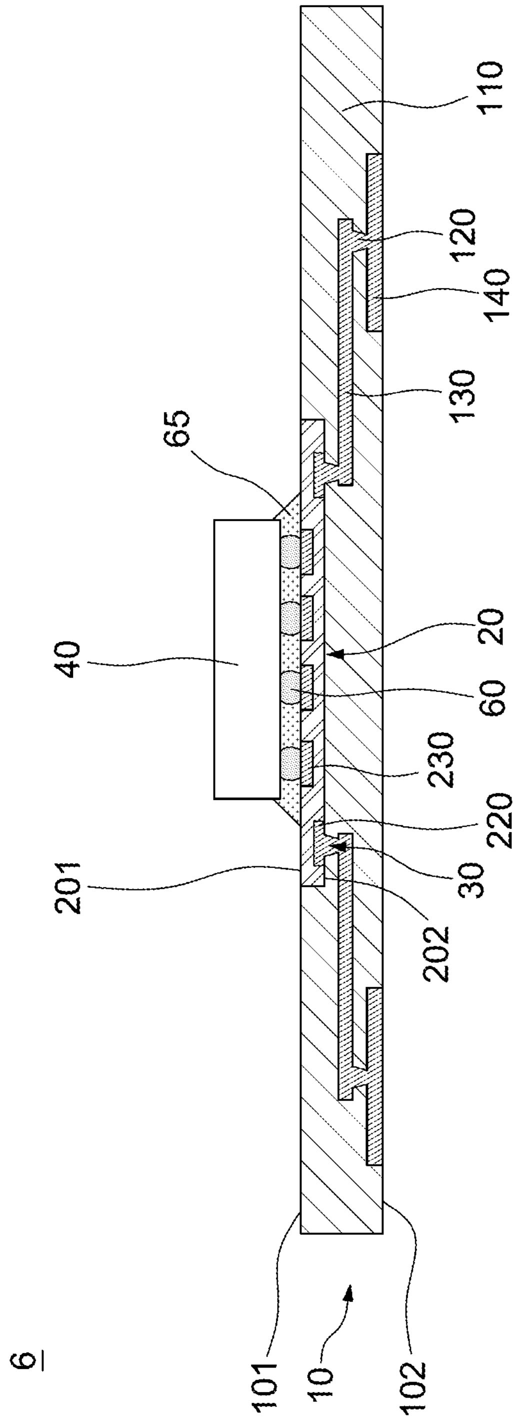


FIG. 6

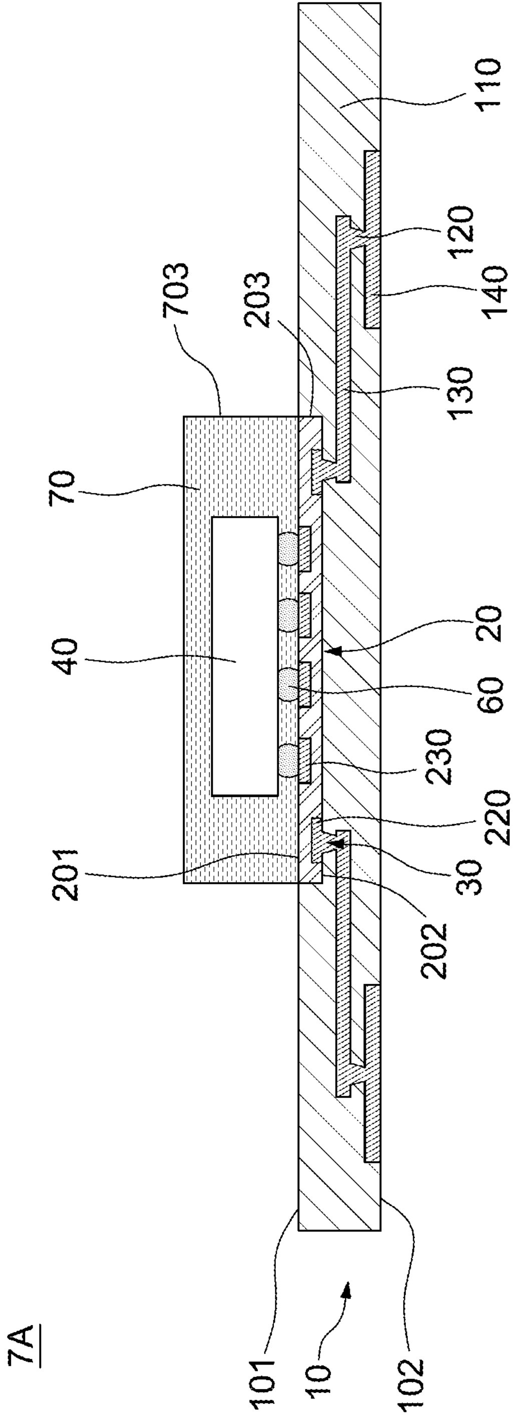


FIG. 7A

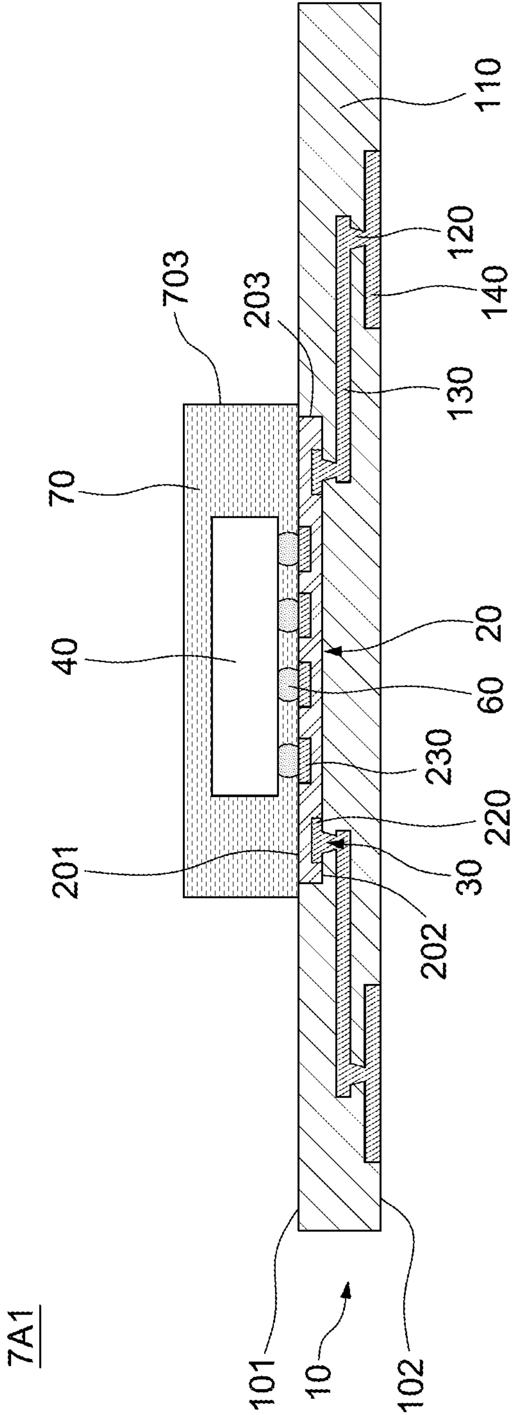


FIG. 7A1

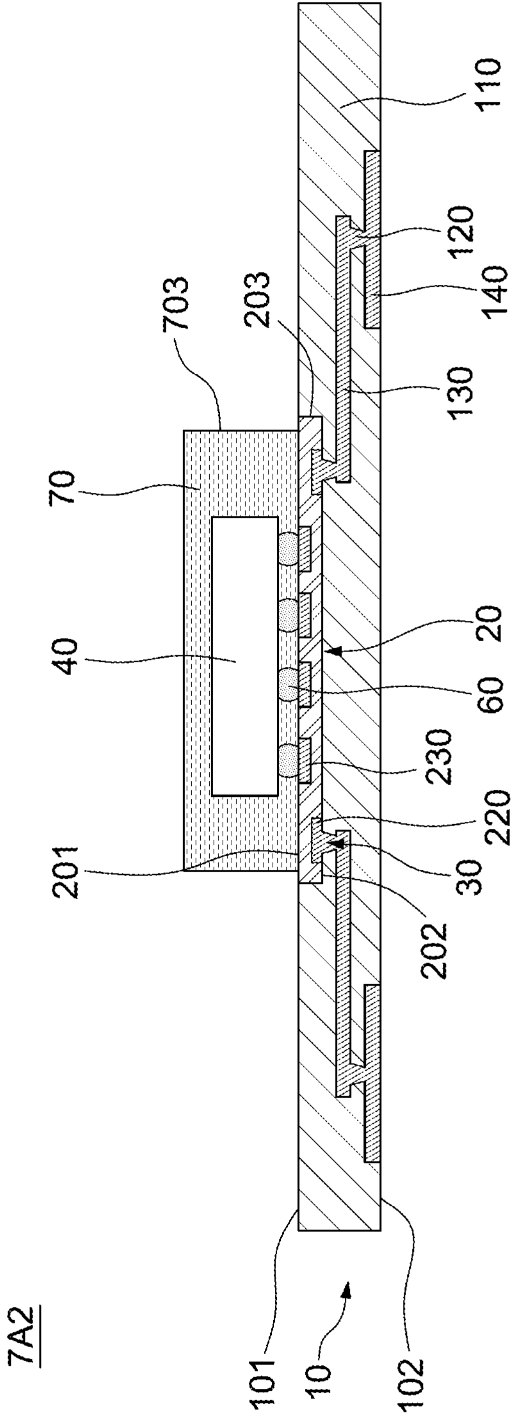


FIG. 7A2

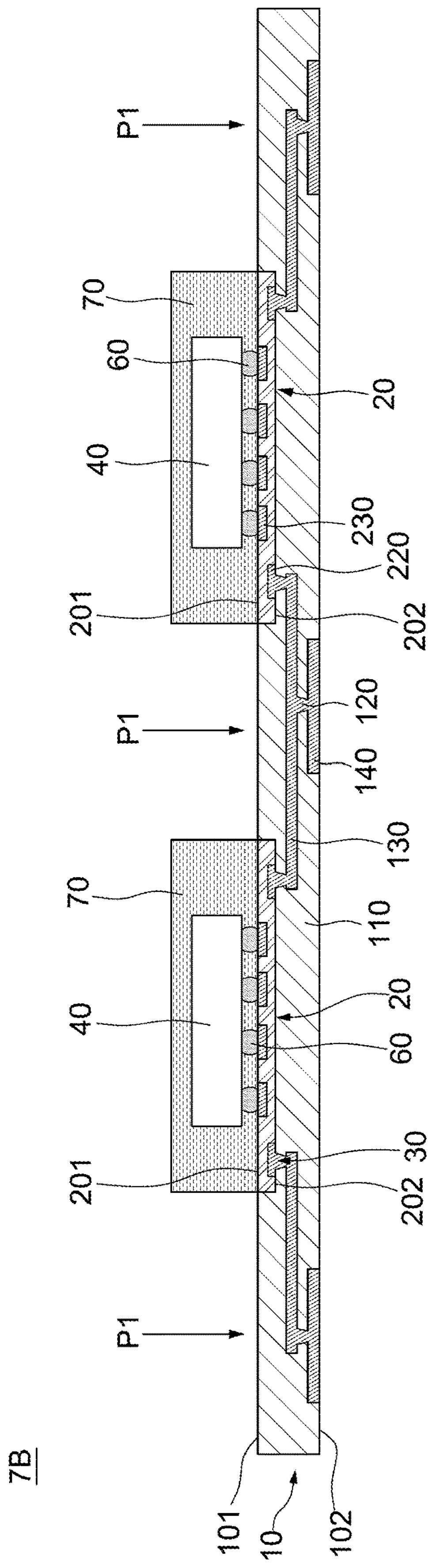


FIG. 7B

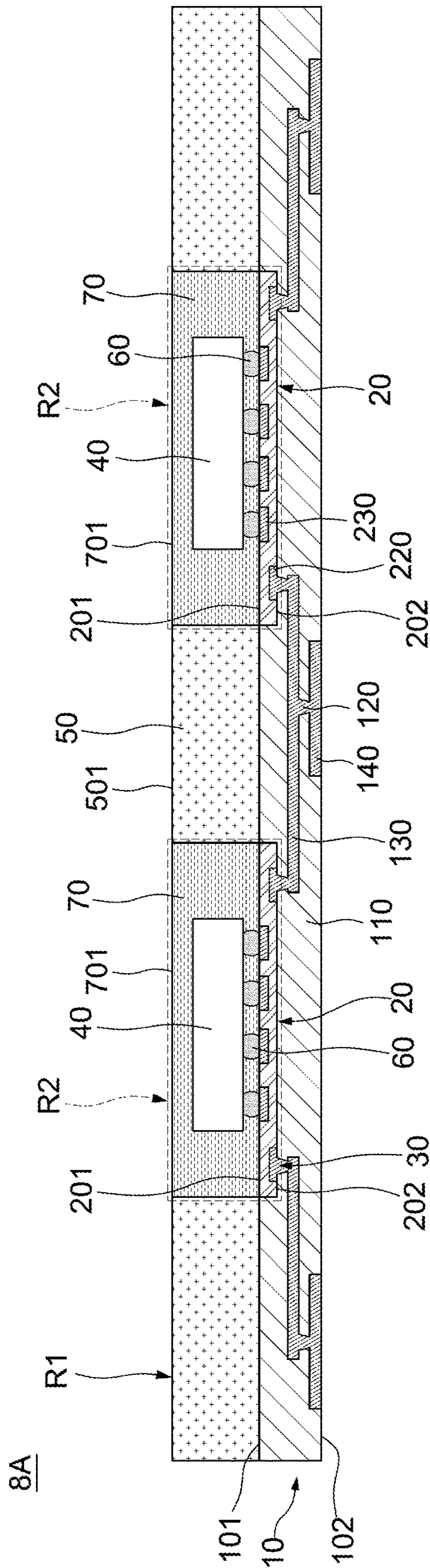


FIG. 8A

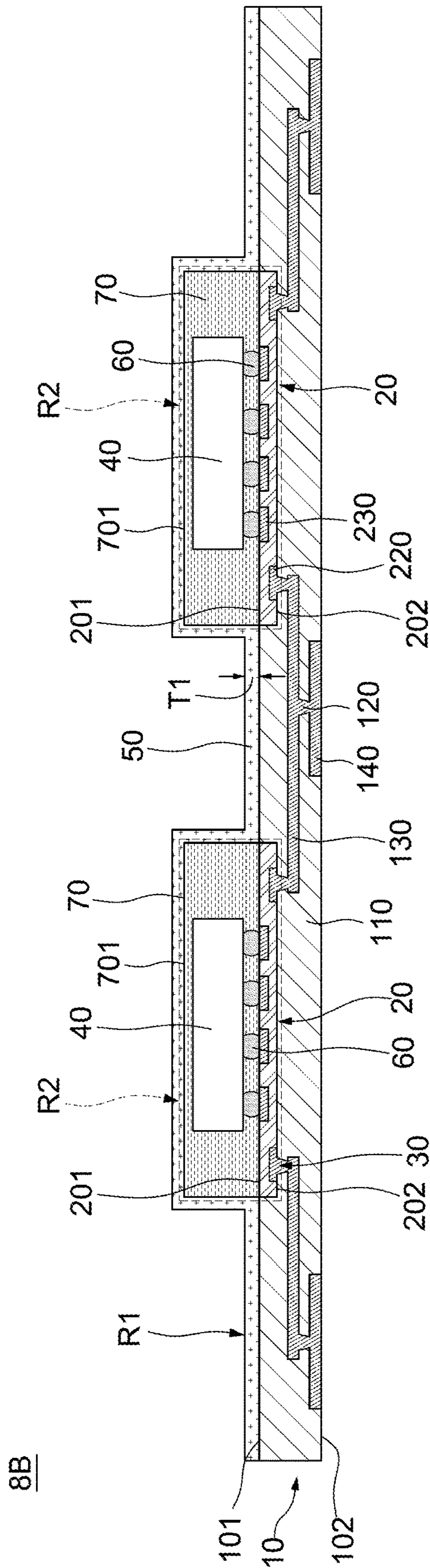


FIG. 8B

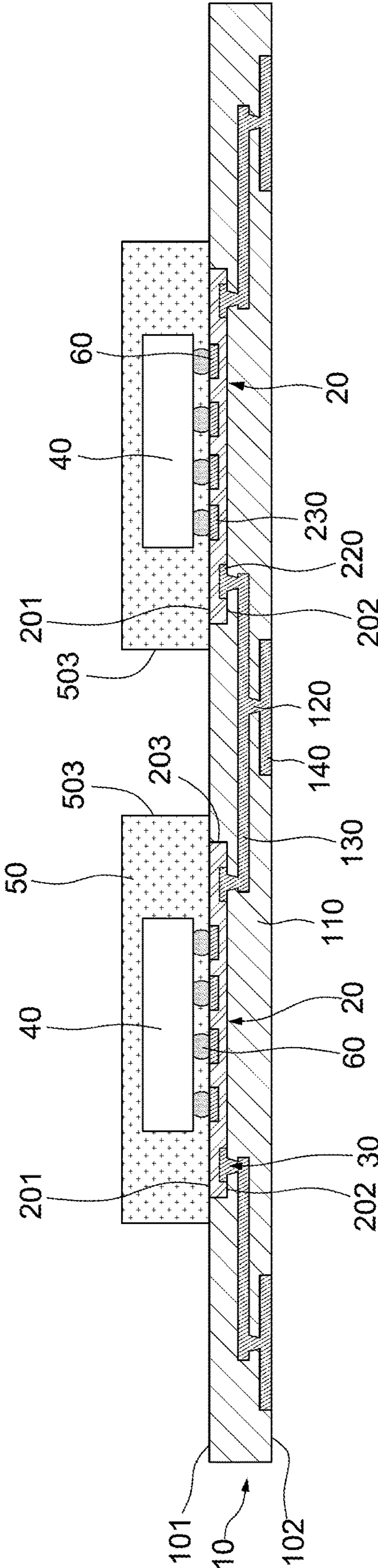


FIG. 9

FLEXIBLE PACKAGE

BACKGROUND

1. Technical Field

[0001] The present disclosure relates generally to a flexible package.

2. Description of the Related Art

[0002] Prominent technological trends in electronic devices, such as improved mobility, decreased size, and enhanced connectivity are changing the electronic device market. Wearable electronic devices constitute a current area of advancement. Such wearable electronic devices utilize a flexible substrate to package required semiconductor devices and/or modules. Other structures disposed over the flexible substrate may still be damaged. Therefore, it is desirable to develop a flexible package addressing such shortcomings.

SUMMARY

[0003] In one or more embodiments, a flexible package includes a first carrier and a second carrier. The second carrier is electrically connected to the first carrier. The second carrier is at least partially embedded in the first carrier, and an electrical connection interface between the first carrier and the second carrier is within the first carrier.

[0004] In one or more embodiments, a flexible package includes a carrier structure and an electronic component. The carrier structure includes a first region having a first hardness and a second region having a second hardness greater than the first hardness. The electronic component is embedded in the second region.

[0005] In one or more embodiments, a flexible package includes a first carrier, a second carrier, and an electronic component. The second carrier is electrically connected to the first carrier through a solder-free connection structure. The first carrier and the second carrier are configured to demonstrate different results after being subjected to a bending test. The electronic component is connected to the second carrier.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Aspects of the present disclosure are best understood from the following detailed description when read with the accompanying drawings. It is noted that various features may not be drawn to scale, and the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

[0007] FIG. **1**A is a cross-section of a flexible package in accordance with some embodiments of the present disclosure;

[0008] FIG. **1A1** is a schematic drawing of a device for performing a bending test in accordance with some embodiments of the present disclosure;

[0009] FIG. **1**B is a top view of a flexible package in accordance with some embodiments of the present disclosure;

[0010] FIG. **1**C is a cross-section of a portion of a flexible package in accordance with some embodiments of the present disclosure;

[0011] FIG. **1**D is a cross-section of a portion of a flexible package in accordance with some embodiments of the present disclosure;

[0012] FIG. **2** is a cross-section of a flexible package in accordance with some embodiments of the present disclosure;

[0013] FIG. **3** is a cross-section of a flexible package in accordance with some embodiments of the present disclosure;

[0014] FIG. **4** is a cross-section of a flexible package in accordance with some embodiments of the present disclosure;

[0015] FIG. **5** is a cross-section of a flexible package in accordance with some embodiments of the present disclosure;

[0016] FIG. **6** is a cross-section of a flexible package in accordance with some embodiments of the present disclosure;

[0017] FIG. **7**A is a cross-section of a flexible package in accordance with some embodiments of the present disclosure;

[0018] FIG. **7A1** is a cross-section of a flexible package in accordance with some embodiments of the present disclosure;

[0019] FIG. **7A2** is a cross-section of a flexible package in accordance with some embodiments of the present disclosure;

[0020] FIG. **7**B is a cross-section of a flexible package in accordance with some embodiments of the present disclosure;

[0021] FIG. **8**A is a cross-section of a flexible package in accordance with some embodiments of the present disclosure;

[0022] FIG. **8**B is a cross-section of a flexible package in accordance with some embodiments of the present disclosure; and

[0023] FIG. **9** is a cross-section of a flexible package in accordance with some embodiments of the present disclosure.

[0024] Common reference numerals are used throughout the drawings and the detailed description to indicate the same or similar elements. The present disclosure will be more apparent from the following detailed description taken in conjunction with the accompanying drawings.

DETAILED DESCRIPTION

[0025] FIG. **1**A is a cross-section of a flexible package **1** in accordance with some embodiments of the present disclosure. The flexible package **1** includes carriers **10** and **20**, an electronic component **40**, a protective element **50**, and one or more electrical contacts **60**.

[0026] The carrier **10** may have a surface **101** (also referred to as "a top surface") and a surface **102** (also referred to as "a bottom surface") opposite to the surface **101**. The carrier **10** may be or include a substrate. In some embodiments, the carrier **10** includes one or more dielectric layers **110**, one or more conductive vias **120**, one or more circuit layers **130**, and one or more conductive terminals **140**. The circuit layers **130** may be or include conductive layers or conductive patterns. In some embodiments, the conductive via **120** electrically connects the circuit layer **130** to the conductive terminal **140**. In some embodiments, the conductive via **120** electrically connects the circuit layer **130** to the carrier **20**. The conductive terminal **140** may be in

proximity to, adjacent to, or embedded in and exposed by the surface **102** for electrical connections. In some embodiments, the carrier **10** includes a flexible substrate. In some embodiments, the carrier **10** includes PI, LCP, or the like. In some embodiments, the carrier **10** may have a glass transition temperature (Tg) equal to or greater than about 300° C., e.g., from about 300° C. to about 450° C. In some embodiments, the carrier **10** has a tensile strength equal to or greater than about 200 MPa. In some embodiments, the carrier **10** includes a flexible printed circuit (FPC) board. In some embodiments, the conductive via **120**, the circuit layer **130**, and the conductive terminal **140** may independently include a conductive material such as a metal or metal alloy. Examples include gold (Au), silver (Ag), aluminum (Al), copper (Cu), or an alloy thereof.

[0027] The carrier **20** may include, for example, a printed circuit board, such as a paper-based copper foil laminate, a composite copper foil laminate, or a polymer-impregnated glass-fiber-based copper foil laminate. In some embodiments, the carrier **20** includes a ceramic material or a metal plate. In some embodiments, the carrier **20** may include a substrate, such as an organic substrate or a leadframe. In some embodiments, the carrier **20** may include a two-layer substrate which includes a core layer and a conductive material and/or structure disposed on a top surface and a bottom surface of the carrier **10**. The conductive material and/or structure may include a plurality of traces. In some embodiments, the carrier **20** includes a rigid substrate. In some embodiments, the carrier **20** includes BT, ABF, or the like. In some embodiments, the carrier **20** may have a glass transition temperature (Tg) less than about 300° C., e.g., from about 120° C. to about 280° C. In some embodiments, the CTE of the carrier **10** is equal to or greater than about 20 ppm/° C.

[0028] The carrier **20** may be electrically connected to the carrier **10**. In some embodiments, the carrier **20** is at least partially embedded in the carrier **10**. In some embodiments, as illustrated in FIG. **1**A, the carrier **20** is entirely embedded in the carrier **10**. The carrier **20** may have a surface **201** (also referred to as "a top surface") and a surface **202** (also referred to as "a bottom surface") opposite to the surface **201**. In some embodiments, the surface **201** of the carrier **20** substantially aligns or is coplanar with the surface **101** of the carrier **10**. In some embodiments, the carrier **20** includes at least one or more dielectric layers **210** and conductive terminals **220** and **230**. The carrier **20** may include an interconnection structure (not shown) electrically connected to the conductive terminals **220** and/or **230**, such as one or more conductive traces and/or one or more through vias. The conductive terminals **220** may be in proximity to, adjacent to, or embedded in and exposed by the surface **202** for electrical connections. The conductive terminals **230** may be in proximity to, adjacent to, or embedded in and exposed by the surface **201** for electrical connections. In some embodiments, at least one of the conductive terminal **220** is electrically connected to at least one of the conductive terminals **230** through the interconnection structure. In some embodiments, the conductive terminal **220** is electrically connected to the carrier **10**. In some embodiments, the interconnection structure and the conductive terminals **220** and **230** may independently include a conductive material such as a metal or metal alloy. Examples include Au, Ag, Al, Cu, or an alloy thereof.

[0029] In some embodiments, the carrier **20** is electrically connected to the carrier **10** through a solder-free connection structure. In some embodiments, the circuit layer **130** of the carrier **10** is electrically connected to the conductive terminal **220** of the carrier **20** through the solder-free connection structure. In some embodiments, an electrical connection interface **30** between the carrier **10** and the carrier **20** is within the carrier **10**.

[0030] In some embodiments, a hardness of the carrier **10** is less than a hardness of the carrier **20**. The term "hardness" hereinafter may refer to a resistance to deformation induced by an external force. The hardness may be defined by scratch hardness, indentation hardness, or the like. In some embodiments, the hardness of the carrier **10** and the carrier **20** may be defined by Young's modulus, tensile stress, Shore hardness, indentation depth, or other suitable properties. In some embodiments, the carrier **10** and the carrier **20** are configured to demonstrate different results after being subjected to a bending test. In some embodiments, the carrier **10** passes the bending test. In some embodiments, the carrier **20** fails the bending test.

[0031] FIG. **1A1** is a schematic drawing of a device for performing a bending test in accordance with some embodiments of the present disclosure. The bending test may be performed by the following process according to an international standard "IEC 62715-6-1". A sample S**1** (e.g., the carrier **10** and the carrier **20**) is disposed on a transporting belt B**1** which is driven by an engine E**1** to move and carry the sample S**1** to pass the roller region R**01**. Each time the sample S**1** passes the roller region R**01**, the sample S**1** is bent once by the curvature provided by the roller region R**01**, which refers to one bending cycle. The bending test is performed by bending the sample S**1** for 300 cycles. The sample S**1** is determined as passing the bending test if the internal circuitry of the sample S**1** remains on after **300** bending cycles, and the sample S**1** is determined as failing the bending test if the internal circuitry of the sample S**1** is not conducting after **300** bending cycles.

[0032] In some embodiments, a Young's modulus of the carrier **20** is different from a Young's modulus of the carrier **10**. In some embodiments, the Young's modulus of the carrier **20** is greater than or exceeds the Young's modulus of the carrier **10**. In some embodiments, a CTE of the carrier **20** is less than a CTE of the carrier **10**. In some embodiments, the CTE of the carrier **20** is equal to or less than about 20 ppm/° C. In some embodiments, a glass transition temperature (Tg) of the carrier **20** is less than a Tg of the carrier **10**.

[0033] The electronic component **40** may be disposed on and electrically connected to the carrier **20**. In some embodiments, one or more edges (e.g., at least an edge **403**) of the electronic component **40** may be recessed with respect to one or more edge (e.g., at least an edge **203**) of the carrier **20**. In some embodiments, the electronic component **40** is physically spaced apart from the carrier **10**. In some embodiments, the electronic component **40** is connected to the carrier **20**. In some embodiments, the carrier **20** is configured to serve as a rigid support for the electronic component **40**. In some embodiments, the carrier **20** is configured to prevent deformation of the electronic component **40**. In some embodiments, the carrier **20** is configured to prevent failure of electrical connection between the carrier **10** and the carrier **20** by preventing the electrical contacts **60** from being damaged or falling off the carrier **20**.

[0034] The protective element **50** may encapsulate the electronic component **40**. In some embodiments, the carrier **10** has a region **10**R**1** contacting the carrier **20** and spaced apart from the protective element **50**. In some embodiments, the protective element **50** has a Young's modulus equal to or less than about 100 MPa. In some embodiments, the Young's modulus of the protective element **50** is about 10 MPa to about 100 MPa. In some embodiments, the protective element **50** has a Tg from about −50° C. to about 25° C. In some embodiments, the protective element **50** is or includes an encapsulant. The encapsulant may include an epoxy resin having fillers, a molding compound (e.g., an epoxy molding compound or other molding compound), polyimide, a phenolic compound or material, a material with a silicone dispersed therein, or a combination thereof.

[0035] In some embodiments, the carriers **10** and **20** collectively form a carrier structure including a region R**1** and a region R**2** having a hardness greater than or exceeding the hardness of the region R**1**. In some embodiments, the region R**2** includes a rigid substrate (e.g., the carrier **20**) and an encapsulant portion (e.g., a portion **510** of the protective element **50** that is adjacent to or encapsulates the carrier **20**) connected to the rigid substrate. In some embodiments, the electronic component **40** is embedded in the region R**2**. In some embodiments, the electronic component **40** is electrically connected to the rigid substrate (e.g., the carrier **20**) and encapsulated by the encapsulant portion (e.g., the portion **510**). In some embodiments, the region R**1** includes a flexible substrate (e.g., the carrier **10**) and an encapsulant portion (e.g., a portion **520** of the protective element **50**) connected to the flexible substrate. In some embodiments, the flexible substrate (e.g., the carrier **10**) is electrically connected to the rigid substrate (e.g., the carrier **20**). In some embodiments, the encapsulant portion **510** and the encapsulant portion **520** are formed integrally.

[0036] The electrical contact **60** may electrically connect the electronic component **40** to the carrier **20**. In some embodiments, the electrical contacts **60** include conductive bumps (e.g., stud bumps), controlled collapse chip connection (C4) bumps, a ball grid array (BGA), or a land grid array (LGA). In some embodiments, the electrical contact **60** may be or may include Au, Ag, Cu, another metal, a solder alloy, or a combination of two or more thereof.

[0037] According to some embodiments of the present disclosure, with the design of the relatively rigid or hard carrier **20** that is at least partially embedded in the relatively flexible or soft carrier **10**, the carrier **10** can provide a flexible base for a wearable device which requires such flexibility, and the carrier **20** that electrically connects to the carrier **10** can provide rigid support for an electronic component **40** (e.g., by limiting or reducing the deformation of the electronic component **40**) as well as electrical connection between the electronic component **40** and the carrier **10**.

[0038] In addition, in some cases where a rigid carrier is disposed over and electrically connected to a flexible carrier through solder joints (e.g., solder balls), the connection between the solder joints and the flexible carrier may crack when the flexible carrier is bent to a relatively large extent. Such solder crack issues may result from the relatively large difference between the deformation of the rigid carrier and the flexible carrier. In contrast, according to some embodiments of the present disclosure, the relatively rigid or hard carrier **20** is electrically connected to the relatively flexible or soft carrier **10** through a solder-free connection structure embedded in the carrier **10**, the solder crack issues can be effectively prevented, and the electrical connection interface **30** between the carrier **10** and the carrier **20** is embedded in and well protected by the carrier **10**. Therefore, the reliability of the flexible package **1** can be improved.

[0039] Moreover, according to some embodiments of the present disclosure, with the design of the regions R1 and R2 of the carrier structure having different hardness, the electronic component **40** is embedded in the region R**2** that is configured to reduce deformation, such that the electronic component **40** is protected from damage, and the region R**1** can still provide a relatively high flexibility for the applications of the flexible package **1**.

[0040] Furthermore, according to some embodiments of the present disclosure, with the design of the Young's modulus of the protective element **50** and the characteristics of the carrier **10** when being subjected to a bending test, the protective element **50** can provide protection for the electronic component **40** and maintain flexibility compatible with that of the carrier **10**, as the flexible package **1** requires for its applications.

[0041] FIG. **1**B is a top view of a flexible package in accordance with some embodiments of the present disclosure. In some embodiments, FIG. **1**B is a top view of the flexible package **1** illustrated in FIG. **1**A, and some elements/components are omitted for clarity.

[0042] In some embodiments, an area of the electronic component **40** is less than an area of the carrier **20**. In some embodiments, a projection of the electronic component **40** is entirely within a top surface (e.g., the surface **201**) of the carrier **20**. In some embodiments, the electronic component **40** may have a dimension of about 3 mm×3 mm, and a distance (e.g., distances D**1**, D**2**, D**3** and/or D**4**) between an edge of the carrier **20** and an edge of the electronic component **40** is equal to or greater than about 100 μm, about 120 μm, or about 150 μm. In some embodiments, the distances D**1**, D**2**, D**3** and D**4** may be different, or at least two of the distances D**1**, D**2**, D**3** and D**4** can be substantially the same.

[0043] According to some embodiments of the present disclosure, with the design of the aforesaid ratio (A**1**/A**2**) of an area A**1** of the component **40** to an area A**2** of the carrier **20**, the relatively rigid carrier **20** can provide sufficient support and protection for the electronic component **40**, and thus solder crack issues which may result from a relatively large difference between the deformation of the carrier **10** and the carrier **20** can be prevented.

[0044] FIG. **1**C is a cross-section of a portion of a flexible package in accordance with some embodiments of the present disclosure. In some embodiments, FIG. **1**C is a cross-section of a portion **10**A of the flexible package **1** illustrated in FIG. **1**A.

[0045] In some embodiments, the carrier **10** includes a dielectric laminate (e.g., the dielectric layer **110**) and a conductive pattern or a conductive pad (e.g., the conductive via **120**) exposed by the dielectric laminate, and the carrier **20** includes a conductive pattern or a conductive pad (e.g., the conductive terminal **220**) contacting the conductive pattern or the conductive pad (e.g., the conductive via **120**) of the carrier **10**. In some embodiments, the carrier **10** is electrically connected to the carrier **20** through a solder-free connection structure including the conductive via **120** and the conductive terminal **220**. In some embodiments, the carrier **10** may be a build-up substrate including one or more

dielectric laminates (e.g., the dielectric layer **110**) and a conductive pattern or a conductive pad (e.g., the conductive via **120**) exposed by the dielectric laminate, and a conductive gel or a conductive paste (not shown) may be disposed between the carrier **10** and the carrier **20** to electrically connect the conductive pattern or the conductive pad of the carrier **10** to the conductive pattern or the conductive pad of the carrier **20**.

[0046] In some embodiments, the carrier **10** may be a build-up substrate which may be formed by forming one or more dielectric laminates (e.g., the dielectric layer **110**) on the carrier **20**, forming one or more through vias in the dielectric laminate to expose a conductive pattern or a conductive pad (e.g., the conductive terminal **220**) of the carrier **20**, and plating a conductive material or filling a conductive gel (or a conductive paste) in the through via to electrically connect the carrier **10** to the carrier **20**. The conductive via **120** may be formed of the plated conductive material or the conductive gel (or the conductive paste) filled in the through via.

[0047] FIG. **1**D is a cross-section of a portion of a flexible package in accordance with some embodiments of the present disclosure. In some embodiments, FIG. **1**D is a cross-section of a portion **10**A of the flexible package **1** illustrated in FIG. **1**A.

[0048] In some embodiments, the carrier **10** is electrically connected to the carrier **20** through a hybrid bond structure **30**A. In some embodiments, the hybrid bond structure **30**A is embedded in the carriers **10** and **20**. In some embodiments, the carrier **10** includes a dielectric layer **110**A and a hybrid bond pad **120**A, and the carrier **20** includes a dielectric layer **210**A and a hybrid bond pad **220**A. In some embodiments, the hybrid bond structure **30**A includes the dielectric layers **110**A and **210**A and the hybrid bond pads **120**A and **220**A. In some embodiments, the dielectric layer **110**A and the hybrid bond pad **120**A are embedded in the carrier **10**. In some embodiments, the dielectric layer **210**A and the hybrid bond pad **220**A are embedded in the carrier **20**. In some embodiments, the carrier **10** is electrically connected to the carrier **20** through a solder-free connection structure including the hybrid bond structure **30**A.

[0049] FIG. **2** is a cross-section of a flexible package **2** in accordance with some embodiments of the present disclosure. The flexible package **2** is similar to the flexible package **1** in FIG. **1**A, with differences therebetween as follows.

[0050] In some embodiments, the carrier **20** is partially embedded in the carrier **10**. In some embodiments, an elevation of a top surface (e.g., the surface **101**) of the carrier **10** is between an elevation of the top surface (e.g., the surface **201**) and an elevation of the bottom surface (e.g., the surface **202**) of the carrier **20**. In some embodiments, an elevation of the surface **201** is higher than or exceeds that of the surface **101** with respect to the surface **102** of the carrier **10**. In some embodiments, portions of lateral surfaces of the carrier **20** are encapsulated by the protective element **50**.

[0051] FIG. **3** is a cross-section of a flexible package **3** in accordance with some embodiments of the present disclosure. The flexible package **3** is similar to the flexible package **1** in FIG. **1**A, with differences therebetween as follows.

[0052] In some embodiments, the top surface (e.g., the surface **201**) of the carrier **20** includes a portion **201***a* (also referred to as "a stepped surface") covered by the carrier **10**. In some embodiments, the top surface (e.g., the surface **201**) of the carrier **20** includes a portion **201***b* (also referred to as "an elevated surface") substantially coplanar with the top surface (e.g., the surface **101**) of the carrier **10**. In some embodiments, the carrier **20** includes a stepped structure embedded in the carrier **10**. The stepped structure of the carrier **20** may be defined by the portions **201***a* and **201***b* of the surface **201**. In some embodiments, the stepped surface (e.g., the portion **201***a*) surrounds the elevated surface (e.g., the portion **201***b*). In some embodiments, the lateral surface (e.g., the edge **203**) of the carrier **20** has a portion **203***a* and a portion **203***b*, and the portion **203***b* is non-coplanar to the portion **203***a*. In some embodiments, the portion **203***a* is misaligned with the portion **203***b*. In some embodiments, the carrier **20** includes a portion (e.g., a recess defined by the portion **201***b* and the portion **203***b*) recessed from the lateral surface (e.g., the edge **203**) of the carrier **20**. In some embodiments, the portion **203***b* is recessed with respect to the portion **203***a*. In some embodiments, a portion of the carrier **10** extends into a space between the protective element **50** and the stepped surface of the carrier **20** to interlock with the carrier **20**.

[0053] According to some embodiments of the present disclosure, with the design of the stepped structure of the carrier **20**, the contact area or connection area between the carrier **10** and the carrier **20** can be increased. Therefore, an interlock connection may be formed between the carrier **10** and the carrier **20**, the bonding strength can be increased, and thus peeling issues from uneven deformation of the carriers **10** and **20** (e.g., due to CTE mismatch) can be mitigated or prevented.

[0054] FIG. **4** is a cross-section of a flexible package **4** in accordance with some embodiments of the present disclosure. The flexible package **4** is similar to the flexible package **1** in FIG. **1**A, with differences therebetween as follows.

[0055] In some embodiments, an elevation of the top surface (e.g., the surface **201**) of the carrier **20** is lower than an elevation of the top surface (e.g., the surface **101**) of the carrier **10** with respect to the surface **102** of the carrier **10**. In some embodiments, the carrier **10** defines an opening **10**C to expose a portion of the carrier **20**. In some embodiments, a portion of the electrical contact **60** is disposed within the opening **10**C. In some embodiments, a portion of the protective element **50** is disposed within the opening **10**C.

[0056] In some embodiments, the protective element **50** includes a protrusion (e.g., the portion **510**) embedded in the carrier **10**. In some embodiments, the protrusion (e.g., the portion **510**) of the protective element **50** contacts the carrier **20**. In some embodiments, the electrical contact **60** electrically connects the electronic component **40** to the carrier **20** and is encapsulated by the protrusion (e.g., the portion **510**) of the protective element **50**.

[0057] According to some embodiments of the present disclosure, with the design of the top surface of the carrier **10** and the top surface of the carrier **20** at different elevations, the possible peeling interface between the protective element **50** and the carrier **10** and the possible peeling interface between the protective element **50** and the carrier **20** are discontinuous. Therefore, even when peeling does occur at the interface between the protective element **50** and the carrier **10**, such peeling may be disrupted and/or stopped when reaching the discontinuous point between the carrier **10** and carrier **20**, and thus peeling between the protective element **50** and the carrier **20** may be prevented, such that the electrical connection between the electrical contacts **60** and the carrier **20** is protected from damage.

[0058] FIG. **5** is a cross-section of a flexible package **5** in accordance with some embodiments of the present disclosure. The flexible package **5** is similar to the flexible package **1** in FIG. **1**A, with differences therebetween as follows.

[0059] In some embodiments, the top surface (e.g., the surface **101**) of the carrier **10** has a first portion covered by the protective element **50** and a second portion exposed by the protective element **50**. In some embodiments, an edge **503** of the protective element **50** is directly above the surface **101** of the carrier **10**. In some embodiments, the edge **503** of the protective element **50** is recessed from an edge **103** of the carrier **10**. In some embodiments, the protective element **50** covers the interface between the carrier **10** and the carrier **20**, and thus cleavage or delamination between the carriers **10** and **20** can be prevented.

[0060] FIG. **6** is a cross-section of a flexible package **6** in accordance with some embodiments of the present disclosure. The flexible package **6** is similar to the flexible package **1** in FIG. **1**A, with differences therebetween as follows.

[0061] In some embodiments, the flexible package **6** includes an underfill **65** encapsulating the electrical contact **60**. In some embodiments, a portion of the top surface (e.g., the surface **201**) of the carrier **20** is exposed by the underfill **65**. In some embodiments, the underfill **65** includes an epoxy resin, a molding compound (e.g., an epoxy molding compound or other molding compound), polyimide, a phenolic compound or material, a material including a silicone dispersed therein, or a combination thereof. According to some embodiments of the present disclosure, the underfill **65** can protect the electrical contacts **60** from being damaged.

[0062] FIG. **7**A is a cross-section of a flexible package **7**A in accordance with some embodiments of the present disclosure. The flexible package **7**A is similar to the flexible package **1** in FIG. **1**A, with differences therebetween as follows.

[0063] In some embodiments, the flexible package **7**A includes a protective element **70** encapsulating the electronic component **40**. In some embodiments, the protective element **70** has a Young's modulus equal to or greater than about 100 MPa, and an edge **703** of the protective element **70** substantially aligns with an edge **203** of the carrier **20**. In some embodiments, the Young's modulus of the protective element **70** is about 5 GPa to about 20 GPa. In some embodiments, the protective element **70** has a Tg from about 100° C. to about 200° C.

[0064] According to some embodiments of the present disclosure, with the design of the relatively rigid or hard protective element **70** encapsulating the electronic component **40**, rigid support or resistance to deformation for the electronic component **40** is increased, and thus coverage of the protective element **70** can be reduced compared to that of the protective element **50**. In addition, according to some embodiments of the present disclosure, with the design of the edge **703** of the protective element **70** substantially aligned with the edge **203** of the carrier **20**, the flexible region of the flexible package **7**A can be increased.

[0065] FIG. **7A1** is a cross-section of a flexible package **7A1** in accordance with some embodiments of the present disclosure. The flexible package **7A1** is similar to the flexible package **7**A in FIG. **7**A, with differences therebetween as follows.

[0066] In some embodiments, one or more edges (e.g., at least the edge **703**) of the protective element **70** may exceed one or more edges (e.g., at least the edge **203**) of the carrier **20**. In some embodiments, the protective element **70** covers an interface between the carrier **10** and the carrier **20**, and thus cleavage or delamination between the carriers **10** and **20** can be prevented. In addition, according to some embodiments of the present disclosure, with the design of the edge **703** of the protective element **70** misaligned with the edge **203** of the carrier **20**, the possible peeling interface between the carrier **20** and the carrier **10** and the edge **703** of the protective element **70** are discontinuous. Therefore, even when peeling does occur at the interface between the carrier **20** and the carrier **10** when the flexible package **7A1** is bent, such peeling may be disrupted and/or stopped when reaching the discontinuous point under the protective element **70**, and thus peeling between the carrier **20** and the carrier **10** may be prevented.

[0067] FIG. **7A2** is a cross-section of a flexible package **7A2** in accordance with some embodiments of the present disclosure. The flexible package **7A2** is similar to the flexible package **7**A in FIG. **7**A, with differences therebetween as follows.

[0068] In some embodiments, one or more edges (e.g., at least the edge **703**) of the protective element **70** may be recessed with respect to one or more edges (e.g., at least the edge **203**) of the carrier **20**. According to some embodiments of the present disclosure, with the design of the edge **703** of the protective element **70** recessed with respect to the edge **203** of the carrier **20**, the flexible region of the flexible package **7A2** can be increased.

[0069] FIG. **7**B is a cross-section of a flexible package **7**B in accordance with some embodiments of the present disclosure. The flexible package **7**B is similar to the flexible package **7**A in FIG. **7**A, with differences therebetween as follows.

[0070] In some embodiments, the flexible package **7**B includes a carrier **10**, a plurality of carriers **20** embedded in the carrier **10**, a plurality of electronic components **40** each electrically connected to a corresponding carrier **20**, and a plurality of protective elements **70** each encapsulating a corresponding electronic component **40**. In some embodiments, the electronic components **40** are electrically connected through the carrier **10**. In some embodiments, the circuit layer **130** electrically connects the electronic components **40**. In some embodiments, one or more edges (e.g., at least the edge **703**) of the protective element **70** may be exceeding or recessed with respect to one or more edges (e.g., at least the edge **203**) of the carrier **20**.

[0071] According to some embodiments of the present disclosure, with the design of the protective elements **70** discretely arranged on and connected to separate positions of the flexible carrier **10**, stress (e.g., bending stress) can be redistributed to the less rigid portions P**1** of the carrier **10** between the protective elements **70**. Therefore, the electronic components **40** encapsulated by the protective elements **70** may be subject to less stress, and damage to the electronic components **40** further prevented.

[0072] FIG. **8**A is a cross-section of a flexible package **8**A in accordance with some embodiments of the present disclosure. The flexible package **8**A is similar to the flexible package **7**B in FIG. **7**B, with differences therebetween as follows.

[0073] In some embodiments, the flexible package **8** includes a carrier **10**, a plurality of carriers **20** embedded in the carrier **10**, a plurality of electronic components **40** each electrically connected to a corresponding carrier **20**, a plu-

rality of protective element **70** each encapsulating a corresponding electronic component **40**, and a protective element **50** encapsulating the protective elements **70**. In some embodiments, the protective element **70** is between the electronic component **40** and the protective element **50**, and a Young's modulus of the protective element **50** is less than a Young's modulus of the protective element **70**. In some embodiments, the protective element **50** contacts the protective elements **70**. In some embodiments, a top surface **501** of the protective element **50** substantially aligns with top surfaces **701** of the protective elements **70**. In other embodiments, the protective element **50** may cover the top surfaces **701** of the protective elements **70**. In some embodiments, the protective element **50** is spaced apart from the surface **201** of the carrier **20**. In some embodiments, one or more edges (e.g., at least the edge **703**) of the protective element **70** may be exceeding or recessed with respect to one or more edges (e.g., at least the edge **203**) of the carrier **20**.

[0074] In some embodiments, the carriers **10** and **20** collectively form a carrier structure including a region R**1** and a region R**2** having a hardness greater than or exceeding the hardness of the region R**1**. In some embodiments, the region R**1** includes the carrier **10** (e.g., the flexible carrier or substrate), and the region R**2** includes the carrier **20** (e.g., the rigid carrier or substrate). In some embodiments, the region R**1** includes the protective element **50** (e.g., the relatively flexible or soft protective element), and the region R**2** includes the protective element **70** (e.g., the relatively rigid or hard protective element).

[0075] FIG. **8**B is a cross-section of a flexible package **8**B in accordance with some embodiments of the present disclosure. The flexible package **8**B is similar to the flexible package **8**A in FIG. **8**A, with differences therebetween as follows.

[0076] In some embodiments, the protective element **50** is conformal with the profile of the protective elements **70**. In some embodiments, the protective element **50** has a substantially constant thickness Ti. In some embodiments, one or more edges (e.g., at least the edge **703**) of the protective element **70** may be exceeding or recessed with respect to one or more edges (e.g., at least the edge **203**) of the carrier **20**.

[0077] FIG. **9** is a cross-section of a flexible package **9** in accordance with some embodiments of the present disclosure. The flexible package **9** is similar to the flexible package **5** in FIG. **5**, with differences therebetween as follows.

[0078] In some embodiments, the flexible package **9** includes a carrier **10**, a plurality of carriers **20** embedded in the carrier **10**, a plurality of electronic components **40** each electrically connected to a corresponding carrier **20**, and a plurality of protective elements **50** each encapsulating a corresponding electronic component **40**. In some embodiments, the electronic components **40** are electrically connected through the carrier **10**. In some embodiments, the circuit layer **130** electrically connects the electronic components **40**. In some embodiments, edges **503** of adjacent protective elements **50** are spaced apart from each other. In some embodiments, an edge **203** of the carrier **20** is recessed from the edge **503** of the protective element **50**. In some embodiments, the protective element **50** covers the interface between the carrier **10** and the carrier **20**, and thus cleavage or delamination between the carriers **10** and **20** can be prevented.

[0079] As used herein, the terms "approximately," "substantially," "substantial" and "about" are used to describe and account for small variations. When used in conjunction with an event or circumstance, the terms can refer to instances in which the event or circumstance occurs precisely as well as instances in which the event or circumstance occurs to a close approximation. For example, when used in conjunction with a numerical value, the terms can refer to a range of variation less than or equal to ±10% of said numerical value, such as less than or equal to ±5%, less than or equal to ±4%, less than or equal to ±3%, less than or equal to ±2%, less than or equal to ±1%, less than or equal to ±0.5%, less than or equal to ±0.1%, or less than or equal to ±0.05%. For example, two numerical values can be deemed to be "substantially" or "about" the same if a difference between the values is less than or equal to ±10% of an average of the values, such as less than or equal to ±5%, less than or equal to ±4%, less than or equal to ±3%, less than or equal to ±2%, less than or equal to ±1%, less than or equal to ±0.5%, less than or equal to ±0.1%, or less than or equal to ±0.05%. For example, "substantially" parallel can refer to a range of angular variation relative to 0° that is less than or equal to ±10°, such as less than or equal to ±5°, less than or equal to ±4°, less than or equal to ±3°, less than or equal to ±2°, less than or equal to ±1°, less than or equal to ±0.5°, less than or equal to ±0.1°, or less than or equal to ±0.05°. For example, "substantially" perpendicular can refer to a range of angular variation relative to 90° that is less than or equal to ±10°, such as less than or equal to ±5°, less than or equal to ±4°, less than or equal to ±3°, less than or equal to ±2°, less than or equal to ±1°, less than or equal to ±0.5°, less than or equal to ±0.1°, or less than or equal to ±0.05°.

[0080] Two surfaces can be deemed to be coplanar or substantially coplanar if a displacement between the two surfaces is no greater than 5 μm, no greater than 2 μm, no greater than 1 μm, or no greater than 0.5 μm.

[0081] As used herein, the terms "conductive," "electrically conductive" and "electrical conductivity" refer to an ability to transport an electric current. Electrically conductive materials typically indicate those materials that exhibit little or no opposition to the flow of an electric current. One measure of electrical conductivity is Siemens per meter (S/m). Typically, an electrically conductive material is one having a conductivity greater than approximately 104 S/m, such as at least 105 S/m or at least 106 S/m. The electrical conductivity of a material can sometimes vary with temperature. Unless otherwise specified, the electrical conductivity of a material is measured at room temperature.

[0082] As used herein, the singular terms "a," "an," and "the" may include plural referents unless the context clearly dictates otherwise. In the description of some embodiments, a component provided "on" or "over" another component can encompass cases where the former component is directly on (e.g., in physical contact with) the latter component, as well as cases where one or more intervening components are located between the former component and the latter component.

[0083] While the present disclosure has been described and illustrated with reference to specific embodiments thereof, these descriptions and illustrations do not limit the present disclosure. It can be clearly understood by those skilled in the art that various changes may be made, and equivalent components may be substituted within the embodiments without departing from the true spirit and scope of the present disclosure as defined by the appended

claims. The illustrations may not necessarily be drawn to scale. There may be distinctions between the artistic renditions in the present disclosure and the actual apparatus, due to variables in manufacturing processes and the like. There may be other embodiments of the present disclosure which are not specifically illustrated. The specification and drawings are to be regarded as illustrative rather than restrictive. Modifications may be made to adapt a particular situation, material, composition of matter, method, or process to the objective, spirit and scope of the present disclosure. All such modifications are intended to be within the scope of the claims appended hereto. While the methods disclosed herein have been described with reference to particular operations performed in a particular order, it can be understood that these operations may be combined, sub-divided, or re-ordered to form an equivalent method without departing from the teachings of the present disclosure. Therefore, unless specifically indicated herein, the order and grouping of the operations are not limitations of the present disclosure.

What is claimed is:

1. A flexible package, comprising:

a first carrier; and

a second carrier electrically connected to the first carrier, wherein the second carrier is at least partially embedded in the first carrier, and an electrical connection interface between the first carrier and the second carrier is within the first carrier.

2. The flexible package as claimed in claim **1**, wherein a CTE or a glass transition temperature (Tg) of the second carrier is less than a CTE or a Tg of the first carrier.

3. The flexible package as claimed in claim **1**, wherein the second carrier has a top surface and a bottom surface opposite to the top surface, and an elevation of a top surface of the first carrier is between an elevation of the top surface and an elevation of the bottom surface of the second carrier.

4. The flexible package as claimed in claim **1**, wherein a top surface of the second carrier comprises a first portion covered by the first carrier.

5. The flexible package as claimed in claim **4**, wherein the second carrier has a lateral surface angled with the top surface, and the lateral surface has a first portion and a second portion non-coplanar to the first portion.

6. The flexible package as claimed in claim **4**, wherein the top surface of the second carrier further comprises a second portion substantially coplanar with a top surface of the first carrier.

7. The flexible package as claimed in claim **4**, wherein the first carrier has a top surface and a bottom surface opposite to the top surface, and an elevation of the top surface of the second carrier is lower than an elevation of the top surface of the first carrier with respect to the bottom surface of the first carrier.

8. The flexible package as claimed in claim **1**, further comprising an electronic component disposed on and electrically connected to the second carrier, wherein a projection of the electronic component is entirely within a top surface of the second carrier.

9. The flexible package as claimed in claim **8**, further comprising a first protective element encapsulating the electronic component, wherein the first carrier has a first region contacting the second carrier and spaced apart from the first protective element.

10. The flexible package as claimed in claim **9**, wherein the first protective element comprises a protrusion embedded in the first carrier.

11. The flexible package as claimed in claim **9**, wherein a top surface of the first carrier has a first portion covered by the first protective element and a second portion exposed by the first protective element.

12. The flexible package as claimed in claim **9**, an edge of the first protective element is substantially aligned with or recessed with respect to an edge of the second carrier.

13. The flexible package as claimed in claim **9**, further comprising a second protective element between the electronic component and the first protective element, wherein a Young's modulus of the first protective element is less than a Young's modulus of the second protective element.

14. A flexible package, comprising:

a carrier structure comprising a first region having a first hardness and a second region having a second hardness greater than the first hardness; and

an electronic component embedded in the second region.

15. The flexible package as claimed in claim **14**, wherein the first region comprises a first substrate, the second region comprises a second substrate electrically connected to the first substrate, and the first substrate and the second substrate have different hardness.

16. The flexible package as claimed in claim **15**, wherein the first region further comprises a first encapsulant connected to the first substrate, the second region further comprises a second encapsulant connected to the second substrate, the hardness of the second substrate is greater than the hardness of the first substrate, and a hardness of the second encapsulant is greater than a hardness of the first encapsulant.

17. The flexible package as claimed in claim **14**, wherein the first region comprises a first encapsulant, and the second region comprises a second encapsulant having a hardness different from a hardness of the first encapsulant.

18. A flexible package, comprising:

a first carrier;

a second carrier electrically connected to the first carrier through a solder-free connection structure, wherein the first carrier and the second carrier are configured to demonstrate different results after being subjected to a bending test; and

an electronic component connected to the second carrier.

19. The flexible package as claimed in claim **18**, wherein an electrical connection interface between the first carrier and the second carrier is within the first carrier.

20. The flexible package as claimed in claim **18**, wherein the first carrier comprises a dielectric laminate and a first conductive pattern exposed by the dielectric laminate, and the second carrier comprises a second conductive pattern contacting the first conductive pattern.

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