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Image sensor package for camera with sensor shift actuation

Abstract

Various embodiments include an image sensor package for a camera with sensor shift actuation. The camera may include one or more actuators (e.g., a voice coil motor (VCM) actuator) for moving the image sensor package relative to a lens group of the camera. The image sensor package may include an image sensor and a substrate. The image sensor may be electrically connected to a ledge surface of a lower portion of the substrate, via one or more wire bond electrical interconnects.

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Background/Summary

(1) This application claims benefit of priority to U.S. Provisional Application Ser. No. 63/138,303, entitled "Image Sensor Package for Camera with Sensor Shift Actuation," filed Jan. 15, 2021, and which is hereby incorporated herein by reference in its entirety.

BACKGROUND

Technical Field

(1) This disclosure relates generally to architecture for an image sensor package for a camera with sensor shift actuation.

Description of the Related Art

(2) The advent of small, mobile multipurpose devices such as smartphones and tablet or pad devices has resulted in a need for high-resolution, small form factor cameras for integration in the devices. Some small form factor cameras may incorporate optical image stabilization (OIS) mechanisms that may sense and react to external excitation/disturbance by adjusting location of the optical lens on the X and/or Y axis in an attempt to compensate for unwanted motion of the lens. Some small form factor cameras may incorporate an autofocus (AF) mechanism whereby the object focal distance can be adjusted to focus an object plane in front of the camera at an image plane to be captured by the image sensor. In some such autofocus mechanisms, the optical lens is moved as a single rigid body along the optical axis of the camera to refocus the camera.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** illustrates a side cross-sectional view of an example camera having an image sensor package for sensor shift actuation, in accordance with some embodiments.

(2) FIG. **2** illustrates an exploded perspective view of an example image sensor package and flex circuit for use in a camera with sensor shift actuation, in accordance with some embodiments.

(3) FIGS. **3**A-**3**B illustrate side cross-sectional views of example flex circuits that may be coupled with an image sensor package for sensor shift actuation, in accordance with some embodiments. FIG. **3**A shows a flex circuit including a portion disposed below the image sensor. FIG. **3**B shows a flex circuit including a cut-out that at least partially encircles the image sensor.

(4) FIGS. **4**A-**4**B illustrate views of an example flexure arrangement that may be coupled with an image sensor package for sensor shift actuation, in accordance with some embodiments. FIG. **4**A shows an exploded perspective view of the example flexure arrangement and the image sensor package. In FIG. **4**B, the exploded perspective view is collapsed to show the image sensor package mounted on the flexure arrangement.

(5) FIG. **5** is a flowchart of an example method of assembling a camera having an image sensor package for sensor shift actuation, in accordance with some embodiments.

(6) FIG. **6** illustrates a schematic block diagram of a portion of an image sensor package that may be coupled with one or more actuators and/or one or more suspension arrangements, e.g., to enable sensor shift actuation, in accordance with some embodiments.

(7) FIG. **7** illustrates a schematic representation of an example device that may include a camera having an image sensor package for sensor shift actuation, in accordance with some embodiments.

(8) FIG. **8** illustrates a schematic block diagram of an example computer system that may include a camera having an image sensor package for sensor shift actuation, in accordance with some embodiments.

(9) This specification includes references to "one embodiment" or "an embodiment." The appearances of the phrases "in one embodiment" or "in an embodiment" do not necessarily refer to

the same embodiment. Particular features, structures, or characteristics may be combined in any suitable manner consistent with this disclosure.
(10) “Comprising.” This term is open-ended. As used in the appended claims, this term does not foreclose additional structure or steps. Consider a claim that recites: “An apparatus comprising one or more processor units . . . ” Such a claim does not foreclose the apparatus from including additional components (e.g., a network interface unit, graphics circuitry, etc.).
(11) “Configured To.” Various units, circuits, or other components may be described or claimed as “configured to” perform a task or tasks. In such contexts, “configured to” is used to connote structure by indicating that the units/circuits/components include structure (e.g., circuitry) that performs those task or tasks during operation. As such, the unit/circuit/component can be said to be configured to perform the task even when the specified unit/circuit/component is not currently operational (e.g., is not on). The units/circuits/components used with the “configured to” language include hardware—for example, circuits, memory storing program instructions executable to implement the operation, etc. Reciting that a unit/circuit/component is “configured to” perform one or more tasks is expressly intended not to invoke 35 U.S.C. § 112 (f) for that unit/circuit/component. Additionally, “configured to” can include generic structure (e.g., generic circuitry) that is manipulated by software and/or firmware (e.g., an FPGA or a general-purpose processor executing software) to operate in manner that is capable of performing the task(s) at issue. “Configure to” may also include adapting a manufacturing process (e.g., a semiconductor fabrication facility) to fabricate devices (e.g., integrated circuits) that are adapted to implement or perform one or more tasks.
(12) “First,” “Second,” etc. As used herein, these terms are used as labels for nouns that they precede, and do not imply any type of ordering (e.g., spatial, temporal, logical, etc.). For example, a buffer circuit may be described herein as performing write operations for “first” and “second” values. The terms “first” and “second” do not necessarily imply that the first value must be written before the second value.
(13) “Based On.” As used herein, this term is used to describe one or more factors that affect a determination. This term does not foreclose additional factors that may affect a determination. That is, a determination may be solely based on those factors or based, at least in part, on those factors. Consider the phrase “determine A based on B.” While in this case, B is a factor that affects the determination of A, such a phrase does not foreclose the determination of A from also being based on C. In other instances, A may be determined based solely on B.
(14) It will also be understood that, although the terms first, second, etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first contact could be termed a second contact, and, similarly, a second contact could be termed a first contact, without departing from the intended scope. The first contact and the second contact are both contacts, but they are not the same contact.
(15) The terminology used in the description herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used in the description and the appended claims, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will also be understood that the term “and/or” as used herein refers to and encompasses any and all possible combinations of one or more of the associated listed items. It will be further understood that the terms “includes,” “including,” “comprises,” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.
(16) As used herein, the term “if” may be construed to mean “when” or “upon” or “in response to determining” or “in response to detecting,” depending on the context. Similarly, the phrase “if it is

determined" or "if [a stated condition or event] is detected" may be construed to mean "upon determining" or "in response to determining" or "upon detecting [the stated condition or event]" or "in response to detecting [the stated condition or event]," depending on the context.

DETAILED DESCRIPTION

(17) Various embodiments include an image sensor package for a camera with sensor shift actuation. The camera may include one or more actuators (e.g., a voice coil motor (VCM) actuator) for moving the image sensor package relative to a lens group of the camera. The image sensor package may include an image sensor and a substrate. The image sensor may be electrically connected to a ledge surface of a lower portion of the substrate, via one or more wire bond electrical interconnects. In various embodiments, the wire bond arrangement disclosed herein may involve processes that reduce the risk of thermally demagnetizing the VCM actuator, relative to other camera designs that use flip chip arrangements that involve high-temperature flip chip processes.

(18) Reference will now be made in detail to embodiments, examples of which are illustrated in the accompanying drawings. In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be apparent to one of ordinary skill in the art that some embodiments may be practiced without these specific details. In other instances, well-known methods, procedures, components, circuits, and networks have not been described in detail so as not to unnecessarily obscure aspects of the embodiments.

(19) FIG. **1** illustrates a side cross-sectional view of an example camera **100** having an image sensor package for sensor shift actuation. The example X-Y-Z coordinate system shown in FIG. **1** may apply to embodiments discussed throughout this disclosure. According to various embodiments, the camera **100** may include one or more optical elements (e.g., lens group **102** and/or optical element(s) **104**) and an image sensor package (e.g., comprising image sensor **106**). The image sensor **106** may be configured to capture light **108** that has passed through the optical element(s), and generate image data based on the captured light **108**. As discussed in further detail herein, the camera **100** may include one or more actuators (e.g., actuator(s) **602** in FIG. **6**) for moving the image sensor **106** (and/or the image sensor package), e.g., relative to the lens group **102**. Thus, the camera **100** may be configured with sensor shift actuation, which may be used to provide autofocus (AF) and/or optical image stabilization (OIS) functionality. In some embodiments, lens group **102** may include one or more lens elements that define an optical axis. In some embodiments, optical element(s) **104** may include one or more lens groups and/or one or more light path folding elements (e.g., a prism, a mirror, etc., configured to fold, or redirect, a path of light).

(20) In some embodiments, the image sensor package may include the image sensor **106**, a substrate **110**, a carrier **112**, a stiffener **114**, and/or an optical element (e.g., an optical filter such as infrared cut-off filter (IRCF) filter **116**). The substrate **110** may be electrically connected to the image sensor **106** via one or more wire bond electrical interconnects **118**. As indicated in FIG. **1**, the substrate **110** may include an upper portion and a lower portion. The upper portion may include a first inner surface **120** that extends in a first direction orthogonal to an image plane defined by the image sensor **106** (e.g., the Z-axis direction). The lower portion may include a second inner surface **122** that extends in the first direction orthogonal to the image plane. In various embodiments, the second inner surface **122** may be closer to the image sensor **106**, relative to the first inner surface **120**. Furthermore, the lower portion may include a ledge surface **124** that extends, in a second direction parallel to the image plane (and/or orthogonal to the first direction) (e.g., the X-axis direction and/or the Y-axis direction), from the first inner surface **120** to the second inner surface **122**.

(21) According to some embodiments, the wire bond interconnect(s) **118** may include a first end portion that is bonded to the image sensor **106** (e.g., via one or more bond pads **126** on a top

surface of the image sensor **106**), and a second end portion that is bonded to the ledge surface **124** (e.g., via bond pad(s) **128**). In various embodiments, the image sensor package may include a plurality of wire bond interconnects **118**, each of which may have a respective first end portion bonded to the image sensor **106** and a respective second end portion bonded to the ledge surface **124**.

(22) In some embodiments, the camera **100** may include a flex circuit **130** (and/or a flexure, such as the flexure arrangement **400** described herein with reference to FIGS. **4**A-**4**B). The flex circuit **130** may be fixedly coupled with the substrate **110**. In some embodiments, the stiffener **114** may be fixedly coupled with the image sensor **106** and the flex circuit **130**, e.g., such that at least a portion of the flex circuit **130** is sandwiched between the stiffener **114** and the substrate **110**. In various embodiments, the stiffener **114** may be attached to a bottom of the image sensor **106**. The flex circuit **130** may be used to convey electrical signals **132**, e.g., between the substrate **110** and one or more other components of the camera **100** (and/or of a device that includes the camera, such as device **700** in FIG. **7** and/or computer system **800** in FIG. **8**). The electrical signals **132** may include power, control, and/or image signals, etc., in various embodiments. In some examples, image signals from the image sensor **106** may be conveyed to such other component(s) via the wire bond electrical interconnect(s) **118**, the substrate **110**, and/or the flex circuit **130**. In some embodiments, a portion of the flex circuit **130** may extend beyond an outer periphery of the camera **100**. In some examples, an enclosure **134** of the camera **100** may define at least a portion of the outer periphery of the camera **100**. The enclosure **134** may encase at least a portion of the camera **100**, e.g., as indicated in FIG. **1**. According to some embodiments, the flex circuit **130** may convey electrical signals **132** to external component(s) that are external to the camera **100**. Additionally, or alternatively, the flex circuit **130** may connected to another flex circuit (not shown), such that the flex circuit **130** is capable of conveying electrical signals **132** to the external component(s) via the other flex circuit. As discussed herein with reference to FIG. **2**, the flex circuit **130** may be configured to allow motion of the image sensor package enabled by the actuator(s). As discussed herein with reference to FIGS. **2** and **3**B, in some embodiments the flex circuit **130** may have a cut-out that enables positioning the image sensor **106** close to the substrate **110**, which may enable a camera size reduction in one or more directions (e.g., in the X-axis direction and/or the Y-axis direction).

(23) As previously mentioned, the image sensor package may include the carrier **112** in various embodiments. The carrier **112** may be fixedly coupled with the substrate **110**. In various embodiments, at least a portion of the actuator(s) may be coupled with the carrier **112**. As an example, the actuator(s) may comprise a voice coil motor (VCM) actuator. One or more magnets and/or one or more coils of the VCM actuator may be attached to the carrier **112**, e.g., as discussed herein with reference to FIG. **6**. Additionally, or alternatively, at least a portion of one or more suspension arrangements (e.g., suspension arrangement(s) **604** in FIG. **6**) may be coupled with the carrier **112**. For example, the suspension arrangement(s) may include one or more springs that are coupled to the carrier **112** and to one or more stationary structures, such that the suspension arrangement(s) suspend the image sensor package from the stationary structure(s) and allow motion of the image sensor package enabled by the actuator(s).

(24) According to various embodiments, the actuator(s) may be configured to move the image sensor package in one or multiple directions. As an example, the actuator(s) may be configured to move the image sensor package in at least one direction parallel to the optical axis of lens group **102** (e.g., the Z-axis direction), e.g., to enable AF motion. Additionally, or alternatively, the actuator(s) may be configured to move the image sensor package in one or more directions orthogonal to the optical axis of lens group **102** (e.g., the X-axis direction and/or the Y-axis direction), e.g., to enable OIS motion.

(25) In some embodiments, the IRCF **116** (and/or other optical element(s)) may be fixedly coupled with the substrate **110**. For example, the IRCF **116** may be attached to a top side of the upper

portion of the substrate **110**, as indicated in FIG. **1**. The image sensor **106** may be positioned, in the direction orthogonal to the image plane (e.g., the Z-axis direction), between the stiffener **114** and the IRCF **116**. A bottom side of the image sensor **106** may be fixedly attached to the stiffener **114**, and a top side (opposite the bottom side) of the image sensor **106** may face the IRCF **116**, which may be positioned in the path of light **104**, such that light passes through the IRCF **116** before reaching the image sensor **106**. In some embodiments, the image sensor **106** may be entirely encapsulated within a chamber that is at least partially defined by the substrate **110**, the stiffener **114**, and/or the IRCF **116**.
(26) According to various embodiments, the flex circuit **130** and the substrate **110** may be separately formed and then attached to one another, e.g., using an adhesive. In some non-limiting examples, the substrate **110** may comprise a ceramic substrate. However, according to some embodiments, the substrate **110** may be integrally formed with the flex circuit **130**, e.g., using an organic material, to produce what will be referred to herein as a "substrate-flex circuit hybrid structure" (or "hybrid structure" for brevity), where the term "hybrid" is used herein to characterize the multi-purpose use (flex circuit and substrate) of the structure. The hybrid structure may be a monolithic component that is formed of a single piece of material in some non-limiting embodiments. In some examples, use of the hybrid structure in the camera **100**, instead of separately formed flex circuit and substrate components, may allow for a reduction of one or more steps in the manufacturing process for the camera **100**.
(27) In some embodiments, the camera **100** and/or the image sensor package may include a fender **136** fixedly coupled with the stiffener **114** and/or the flex circuit **130**, e.g., as indicated in FIG. **1**. The fender **136** may comprise a bottom surface that defines an end stop (e.g., with an inner surface of the enclosure **134**) with respect to motion in the direction orthogonal to the image plane (the Z-axis direction).
(28) In some embodiments, the camera **100** and/or the image sensor package may include one or more electrical component(s) **138** that are fixedly coupled with the substrate **110**. For example, the electrical component(s) **138** may be mounted on the top surface of the substrate **110**. According to some embodiments, the flex circuit **130** may be configured to convey electrical signals **132** between the electrical component(s) **138** and one or more other components. Electrical signals **132** may be routed between the electrical component(s) **138** and the flex circuit **130** via the substrate **110** in some embodiments.
(29) FIG. **2** illustrates an exploded perspective view of an example image sensor package **200** and an example flex circuit **202** for use in a camera (e.g., camera **100** in FIG. **1**) with sensor shift actuation. In various embodiments, the image sensor package **200** may include an image sensor **204**, a substrate **206**, a stiffener **208**, one or more optical elements **210**, and/or one or more electrical components **212**. In some embodiments, the flex circuit **202** (or a portion of the flex circuit **202**) may be considered to be part of the image sensor package **200**. For example, the image sensor package **200** may include a portion of the flex circuit **202** that is fixedly coupled with the substrate **206** and/or the stiffener **208** in some embodiments. Unless otherwise specified herein, the description of the components in FIG. **2** may apply to same- or similarly-named components in FIG. **1**, and vice-versa.
(30) As indicated in FIG. **2**, a lower portion of the substrate **206** may comprise a ledge surface **214** to which an end portion of wire bond electrical interconnect(s) (e.g., wire bond electrical interconnect(s) **118**) may be bonded. Furthermore, another end portion of the wire bond electrical interconnect(s) may be bonded to the image sensor **204**, e.g., to an upper surface of the image sensor **204**. In various embodiments, an inner surface (e.g., inner surface **122** in FIG. **1**) of the substrate **206** may at least partially encircle the image sensor **204**. As indicated in FIG. **2**, the substrate **206** may entirely encircle the image sensor **204** in some embodiments.
(31) In some embodiments, the flex circuit **202** may comprise edges **216** that define a cut-out **218**. According to some embodiments, the cut-out **218** may be positioned, in a direction orthogonal to

an image plane of the image sensor **204**, along a plane that intersects the image sensor **204**. In some embodiments, the image sensor **204**, the substrate **206**, the stiffener **208**, the optical element(s) **210**, and/or the cut-out **218** may be concentrically aligned or otherwise be positioned along a same axis that is orthogonal to the image plane of the image sensor **204**.

(32) According to some embodiments, the flex circuit **202** may include a moveable end portion **220**, an intermediate portion **222**, and one or more fixed end portions **224**. The moveable end portion **220** may be fixedly coupled with the substrate **206**, such that the moveable end portion moves together (e.g., in lockstep) with the substrate **206** and the image sensor **204**. The fixed end portion(s) **224** may be fixedly attached to a stationary structure of the camera. The intermediate portion **222** may extend between the moveable end portion **220** and the fixed end portion(s) **224**, and may be configured to convey electrical signals between the moveable end portion **220** and the fixed end portion(s) **224**. The intermediate portion **222** may be flexible and contain at least one bend region that interconnects at least two straight regions, so as to allow motion of the image sensor package **200** in one or more degrees of freedom. For example, the arrangement of the flex circuit **202** depicted in FIG. **2** may be configured to allow motion of the image sensor package **200** in the X-, Y-, and Z-axis directions.

(33) In some embodiments, the moveable end portion **220** of the flex circuit **202** may comprise electrical connections **226** that may be connected to corresponding electrical connections (not shown) of the substrate **206**, so that electrical signals (e.g., electrical signals **132** in FIG. **1**) may be conveyed between the substrate **206** and the flex circuit **202**. In some embodiments, the fixed end portion(s) **224** may comprise electrical connections **228** that may be connected to corresponding electrical connections (not shown) of the stationary structure and/or of another flex circuit.

(34) In some embodiments, one or more of the bend region(s) of the intermediate portion **222** may be reinforced with a reinforcement material **230**, such that portions of the bend region(s) are multi-layered to mitigate cyclic wear of the intermediate portion **222** at such bend region(s).

(35) FIGS. **3**A-**3**B illustrate side cross-sectional views of example flex circuits **300***a* and **300***b* that may be coupled with an image sensor package for sensor shift actuation in a camera (e.g., camera **100** in FIG. **1**). FIG. **3**A shows a flex circuit **300***a* including a portion disposed below the image sensor **106**. FIG. **3**B shows a flex circuit **300***b* including a cut-out (e.g., cut-out **218** in FIG. **2**) that at least partially encircles the image sensor **106**.

(36) In some embodiments, an adhesive (e.g., glue) may be injected at one or more locations to underfill the substrate **110**. In FIG. **3**A, which shows the flex circuit **300***a* that does not include a cut-out, but rather includes a portion disposed below the image sensor **106**, the underfill results in a significant outer adhesive fillet **302** and a significant inner adhesive fillet **304**. The inner adhesive fillet **304** consumes space (e.g., in the X-axis direction and/or the Y-axis direction) that limits how close the image sensor **106** may be positioned relative to the substrate **110** and/or that may interfere with achieving a desired flatness of the image sensor **106** when attaching the image sensor **106**.

(37) The flex circuit **300***b* in FIG. **3**B comprises one or more inner edges **306** that define the cut-out previously described. In some embodiments, the inner edge(s) **306** of the flex circuit **300***b* may be flush with an inner surface of the lower portion of the substrate **110**. In some embodiments, the inner edge(s) **306** of the flex circuit **300***b* may be set back from the inner surface of the lower portion of the substrate **110**. In various embodiments, an inner surface of an inner edge **306** does not extend, towards the image sensor **106**, beyond the inner surface of the lower portion of the substrate **110**. In this arrangement, the inner edge(s) **306** provide a capillary stop that prevents flow of the adhesive beyond the inner edge(s) **306**, thus avoiding the formation of the inner adhesive fillet **302** of FIG. **3**A, and allowing for a reduction in a lateral gap between the image sensor **106** and the substrate **110**.

(38) FIGS. **4**A-**4**B illustrate views of an example flexure arrangement **400** that may be coupled with an image sensor package for sensor shift actuation in a camera (e.g., camera **100** in FIG. **1**). FIG. **4**A shows an exploded perspective view of the example flexure arrangement **400** and the

image sensor package. In FIG. **4**B, the exploded perspective view is collapsed to show the image sensor package mounted on the flexure arrangement **400**.

(39) In some embodiments, the flexure arrangement **400** may include an inner frame **402**, an outer frame **404**, and one or more flexure arms **406** that are connected to the inner frame **402** and to the outer frame **404**. The inner frame **402** may be fixedly coupled with the substrate **206**. For example, an upper surface of the inner frame **402** may be connected to the lower portion of the substrate **206**. Furthermore, the stiffener **208** may be fixedly coupled with the image sensor **204** and the inner frame **402**. In some embodiments, one or more electrical connections **408** on the inner frame **402** may be used to provide electrical interface(s) with the substrate **206** (e.g., via corresponding electrical connection(s) of the substrate **206**). The outer frame **404** may be fixedly coupled with a stationary structure of the camera. The inner frame **402** may be moveable in one or more directions relative to the outer frame **404**. The flexure arm(s) **406** may be configured to allow motion of the inner frame **402** and the image sensor package enabled by the actuator(s). In some embodiments, the inner frame **402** may be considered part of the image sensor package. Electrical traces on at least a portion of the flexure arm(s) **406** may be configured to convey electrical signals (e.g., electrical signals **132** in FIG. **1**) between the inner frame **402** and the outer frame **404**. In some embodiments, the outer frame **404** may have electrical connections **410** that enable the flexure arrangement **400** to electrically interface with one or more other components.

(40) FIG. **5** is a flowchart of an example method **500** of assembling a camera (e.g., camera **100** in FIG. **1**) having an image sensor package for sensor shift actuation. It should be appreciated that the method **500** may include more or fewer operations than those represented by the blocks **502-516** in FIG. **5**. Moreover, it should be appreciated that the order in which the operations represented by the depicted blocks may be different than the order indicated in the flowchart in FIG. **5**.

(41) At **502**, the method **500** may include attaching a carrier to a substrate and to at least a portion of a voice coil motor (VCM) for moving an image sensor of a camera relative, e.g., relative to a lens group of the camera.

(42) At **504**, the method **500** may include fixedly coupling the image sensor with the substrate. In some examples, coupling the image sensor with the substrate may include attaching a portion of a flex circuit (and/or a portion of a flexure arrangement) to a bottom surface of the substrate, at **506**. According to some embodiments, the flex circuit may comprise edges that define a cut-out that is sized to at least partially encircle the image sensor along a plane that intersects the image sensor. At least one of the edges, that define the cut-out, may be positioned such that an inner surface of the edge does not extend, towards the image sensor, beyond the inner surface of the substrate. Additionally, or alternatively, coupling the image sensor with the substrate may include attaching a stiffener to a bottom surface of the image sensor, at **508**. In some embodiments, coupling the image sensor with the substrate may include attaching the stiffener to the flex circuit (and/or the flexure arrangement), at **510**.

(43) At **512**, the method **500** may include connecting the image sensor to the substrate via one or more wire bond electrical interconnects. In some examples, connecting the image sensor to the substrate may include bonding a first end portion of the wire bond electrical interconnect(s) to the image sensor. Furthermore, connecting the image sensor to the substrate may include bonding a second end portion of the wire bond electrical interconnect(s) to a ledge surface of the substrate. According to some implementations, connecting the image sensor to the substrate via the wire bond electrical interconnects (at **512**) may occur during a time period after attaching the carrier to the substrate and to at least a portion of the VCM actuator (at **502**). For instance, the image sensor may be connected to the substrate via the wire bond electrical interconnects after a VCM module that includes the carrier and the substrate has been assembled.

(44) FIG. **6** illustrates a schematic block diagram of a portion of an image sensor package **600** that may be coupled with one or more actuators **602** and/or one or more suspension arrangements **604**, e.g., to enable sensor shift actuation in a camera (e.g., camera **100** in FIG. **1**). In various

embodiments, the actuator(s) **602** may comprise a voice coil motor (VCM) actuator that includes one or more magnets and one or more coils. In some embodiments, a magnet may be positioned proximate a coil, such that the coil is capable of electromagnetically interacting with the magnet when a drive current is supplied to the coil. Such electromagnetic interaction may produce Lorentz forces move the image sensor package.

(45) As indicated in FIG. **6**, in various embodiments a first portion **606** of the actuator(s) **602** may be fixedly coupled with the carrier **112**, and a second portion **608** of the actuator(s) **602** may be fixedly coupled with one or more stationary structures **610** of the camera. For example, each of the first portion **606** and the second portion **608** of the actuator(s) **602** may include magnet(s) and/or coil(s). FIG. **6** shows an example of the first portion **606** comprising a magnet **612** that is attached to the carrier **112**. As previously mentioned, some other camera designs that use a flip chip image sensor arrangement may require processes involving high temperatures that may cause the VCM actuator (e.g., at least partially due to the proximity of the magnet **612** to the image sensor connection site) to thermally demagnetize, thus potentially compromising the performance of the VCM actuator. By contrast, the wire bond arrangement disclosed herein may involve significantly lower temperatures, relative to flip chip processes, and thus the risk of thermally demagnetizing the VCM actuator may be reduced.

(46) In some embodiments, the suspension arrangement(s) **604** may include one or more springs, one or more suspension wires, and/or one or more flexures, etc. A portion of the suspension arrangement **604** may be attached to the carrier **112** in some embodiments. Another portion of the suspension **604** arrangement may be attached to the stationary structure(s) **610** in some embodiments. The suspension arrangement **604** may be configured to suspend the image sensor package **600** from the stationary structures(s) **610**. Furthermore, the suspension arrangement **604** may be configured to allow motion of the image sensor package **600** enabled by the actuator(s) **602**.

(47) FIG. **7** illustrates a schematic representation of an example device **700** that may include a camera (e.g., camera **100** in FIG. **1**) having an image sensor package for sensor shift actuation, in accordance with some embodiments. In some embodiments, the device **700** may be a mobile device and/or a multifunction device. In various embodiments, the device **700** may be any of various types of devices, including, but not limited to, a personal computer system, desktop computer, laptop, notebook, tablet, slate, pad, or netbook computer, mainframe computer system, handheld computer, workstation, network computer, a camera, a set top box, a mobile device, an augmented reality (AR) and/or virtual reality (VR) headset, a consumer device, video game console, handheld video game device, application server, storage device, a television, a video recording device, a peripheral device such as a switch, modem, router, or in general any type of computing or electronic device.

(48) In some embodiments, the device **700** may include a display system **702** (e.g., comprising a display and/or a touch-sensitive surface) and/or one or more cameras **704**. In some non-limiting embodiments, the display system **702** and/or one or more front-facing cameras **704***a* may be provided at a front side of the device **700**, e.g., as indicated in FIG. **7**. Additionally, or alternatively, one or more rear-facing cameras **704***b* may be provided at a rear side of the device **700**. In some embodiments comprising multiple cameras **704**, some or all of the cameras may be the same as, or similar to, each other. Additionally, or alternatively, some or all of the cameras may be different from each other. In various embodiments, the location(s) and/or arrangement(s) of the camera(s) **704** may be different than those indicated in FIG. **7**.

(49) Among other things, the device **700** may include memory **706** (e.g., comprising an operating system **708** and/or application(s)/program instructions **710**), one or more processors and/or controllers **712** (e.g., comprising CPU(s), memory controller(s), display controller(s), and/or camera controller(s), etc.), and/or one or more sensors **716** (e.g., orientation sensor(s), proximity sensor(s), and/or position sensor(s), etc.). In some embodiments, the device **700** may communicate with one or more other devices and/or services, such as computing device(s) **718**, cloud service(s)

720, etc., via one or more networks **722**. For example, the device **700** may include a network interface (e.g., network interface **710**) that enables the device **700** to transmit data to, and receive data from, the network(s) **722**. Additionally, or alternatively, the device **700** may be capable of communicating with other devices via wireless communication using any of a variety of communications standards, protocols, and/or technologies.

(50) FIG. **8** illustrates a schematic block diagram of an example computing device, referred to as computer system **800**, that may include or host embodiments of a camera (e.g., camera **100** in FIG. **1**) having an image sensor package for sensor shift actuation, e.g., as described herein with reference to FIGS. **1-7**. In addition, computer system **800** may implement methods for controlling operations of the camera and/or for performing image processing images captured with the camera. In some embodiments, the device **700** (described herein with reference to FIG. **7**) may additionally, or alternatively, include some or all of the functional components of the computer system **800** described herein.

(51) The computer system **800** may be configured to execute any or all of the embodiments described above. In different embodiments, computer system **800** may be any of various types of devices, including, but not limited to, a personal computer system, desktop computer, laptop, notebook, tablet, slate, pad, or netbook computer, mainframe computer system, handheld computer, workstation, network computer, a camera, a set top box, a mobile device, an augmented reality (AR) and/or virtual reality (VR) headset, a consumer device, video game console, handheld video game device, application server, storage device, a television, a video recording device, a peripheral device such as a switch, modem, router, or in general any type of computing or electronic device.

(52) In the illustrated embodiment, computer system **800** includes one or more processors **802** coupled to a system memory **804** via an input/output (I/O) interface **806**. Computer system **800** further includes one or more cameras **808** coupled to the I/O interface **806**. Computer system **800** further includes a network interface **810** coupled to I/O interface **806**, and one or more input/output devices **812**, such as cursor control device **814**, keyboard **816**, and display(s) **818**. In some cases, it is contemplated that embodiments may be implemented using a single instance of computer system **800**, while in other embodiments multiple such systems, or multiple nodes making up computer system **800**, may be configured to host different portions or instances of embodiments. For example, in one embodiment some elements may be implemented via one or more nodes of computer system **800** that are distinct from those nodes implementing other elements.

(53) In various embodiments, computer system **800** may be a uniprocessor system including one processor **802**, or a multiprocessor system including several processors **802** (e.g., two, four, eight, or another suitable number). Processors **802** may be any suitable processor capable of executing instructions. For example, in various embodiments processors **802** may be general-purpose or embedded processors implementing any of a variety of instruction set architectures (ISAs), such as the x86, PowerPC, SPARC, or MIPS ISAs, or any other suitable ISA. In multiprocessor systems, each of processors **802** may commonly, but not necessarily, implement the same ISA.

(54) System memory **804** may be configured to store program instructions **820** accessible by processor **802**. In various embodiments, system memory **804** may be implemented using any suitable memory technology, such as static random access memory (SRAM), synchronous dynamic RAM (SDRAM), nonvolatile/Flash-type memory, or any other type of memory. Additionally, existing camera control data **822** of memory **804** may include any of the information or data structures described above. In some embodiments, program instructions **820** and/or data **822** may be received, sent or stored upon different types of computer-accessible media or on similar media separate from system memory **804** or computer system **800**. In various embodiments, some or all of the functionality described herein may be implemented via such a computer system **800**.

(55) In one embodiment, I/O interface **806** may be configured to coordinate I/O traffic between processor **802**, system memory **804**, and any peripheral devices in the device, including network interface **810** or other peripheral interfaces, such as input/output devices **812**. In some

embodiments, I/O interface **806** may perform any necessary protocol, timing or other data transformations to convert data signals from one component (e.g., system memory **804**) into a format suitable for use by another component (e.g., processor **802**). In some embodiments, I/O interface **806** may include support for devices attached through various types of peripheral buses, such as a variant of the Peripheral Component Interconnect (PCI) bus standard or the Universal Serial Bus (USB) standard, for example. In some embodiments, the function of I/O interface **806** may be split into two or more separate components, such as a north bridge and a south bridge, for example. Also, in some embodiments some or all of the functionality of I/O interface **806**, such as an interface to system memory **804**, may be incorporated directly into processor **802**.
(56) Network interface **810** may be configured to allow data to be exchanged between computer system **800** and other devices attached to a network **824** (e.g., carrier or agent devices) or between nodes of computer system **800**. Network **824** may in various embodiments include one or more networks including but not limited to Local Area Networks (LANs) (e.g., an Ethernet or corporate network), Wide Area Networks (WANs) (e.g., the Internet), wireless data networks, some other electronic data network, or some combination thereof. In various embodiments, network interface **810** may support communication via wired or wireless general data networks, such as any suitable type of Ethernet network, for example; via telecommunications/telephony networks such as analog voice networks or digital fiber communications networks; via storage area networks such as Fibre Channel SANs, or via any other suitable type of network and/or protocol.
(57) Input/output devices **812** may, in some embodiments, include one or more display terminals, keyboards, keypads, touchpads, scanning devices, voice or optical recognition devices, or any other devices suitable for entering or accessing data by one or more computer systems **800**. Multiple input/output devices **812** may be present in computer system **800** or may be distributed on various nodes of computer system **800**. In some embodiments, similar input/output devices may be separate from computer system **800** and may interact with one or more nodes of computer system **800** through a wired or wireless connection, such as over network interface **810**.
(58) Those skilled in the art will appreciate that computer system **800** is merely illustrative and is not intended to limit the scope of embodiments. In particular, the computer system and devices may include any combination of hardware or software that can perform the indicated functions, including computers, network devices, Internet appliances, PDAs, wireless phones, pagers, etc. Computer system **800** may also be connected to other devices that are not illustrated, or instead may operate as a stand-alone system. In addition, the functionality provided by the illustrated components may in some embodiments be combined in fewer components or distributed in additional components. Similarly, in some embodiments, the functionality of some of the illustrated components may not be provided and/or other additional functionality may be available.
(59) Those skilled in the art will also appreciate that, while various items are illustrated as being stored in memory or on storage while being used, these items or portions of them may be transferred between memory and other storage devices for purposes of memory management and data integrity. Alternatively, in other embodiments some or all of the software components may execute in memory on another device and communicate with the illustrated computer system via inter-computer communication. Some or all of the system components or data structures may also be stored (e.g., as instructions or structured data) on a computer-accessible medium or a portable article to be read by an appropriate drive, various examples of which are described above. In some embodiments, instructions stored on a computer-accessible medium separate from computer system **800** may be transmitted to computer system **800** via transmission media or signals such as electrical, electromagnetic, or digital signals, conveyed via a communication medium such as a network and/or a wireless link. Various embodiments may further include receiving, sending or storing instructions and/or data implemented in accordance with the foregoing description upon a computer-accessible medium. Generally speaking, a computer-accessible medium may include a non-transitory, computer-readable storage medium or memory medium such as magnetic or optical

media, e.g., disk or DVD/CD-ROM, volatile or non-volatile media such as RAM (e.g. SDRAM, DDR, RDRAM, SRAM, etc.), ROM, etc. In some embodiments, a computer-accessible medium may include transmission media or signals such as electrical, electromagnetic, or digital signals, conveyed via a communication medium such as network and/or a wireless link.
(60) The methods described herein may be implemented in software, hardware, or a combination thereof, in different embodiments. In addition, the order of the blocks of the methods may be changed, and various elements may be added, reordered, combined, omitted, modified, etc. Various modifications and changes may be made as would be obvious to a person skilled in the art having the benefit of this disclosure. The various embodiments described herein are meant to be illustrative and not limiting. Many variations, modifications, additions, and improvements are possible. Accordingly, plural instances may be provided for components described herein as a single instance. Boundaries between various components, operations and data stores are somewhat arbitrary, and particular operations are illustrated in the context of specific illustrative configurations. Other allocations of functionality are envisioned and may fall within the scope of claims that follow. Finally, structures and functionality presented as discrete components in the example configurations may be implemented as a combined structure or component. These and other variations, modifications, additions, and improvements may fall within the scope of embodiments as defined in the claims that follow.

Claims

1. A camera, comprising: a lens group comprising one or more lens elements; an image sensor package comprising: an image sensor; and a substrate, wherein the image sensor is electrically connected to the substrate via one or more wire bond electrical interconnects; an actuator for causing a flex circuit to flex, wherein a first portion of the actuator moves together with a first portion of the flex circuit, the image sensor, and the substrate, and wherein a second portion of the actuator is fixedly attached to a stationary structure of the camera; and the first portion of the flex circuit fixedly coupled with the substrate, wherein the flex circuit is configured to: flex, upon activation of the actuator, to move the image sensor package relative to the lens group, and convey electrical signals between the substrate and one or more stationary components to which a second portion of the flex circuit is attached.
2. The camera of claim 1, wherein: the one or more lens elements define an optical axis; and the actuator is configured to move the image sensor package in at least one direction parallel to the optical axis and in directions orthogonal to the optical axis.
3. The camera of claim 1, wherein the first portion of the actuator is fixedly coupled with the substrate.
4. The camera of claim 1, wherein: the image sensor package further comprises: a carrier fixedly coupled with the substrate; the actuator comprises a voice coil motor (VCM) actuator; the first portion comprises one or more magnets attached to the carrier; and the second portion comprises one or more coils.
5. The camera of claim 1, wherein the substrate comprises: an upper portion, comprising: a first inner surface that extends in a first direction orthogonal to an image plane defined by the image sensor; and a lower portion, comprising: a second inner surface that extends in the first direction orthogonal to the image plane, wherein the second inner surface is closer to the image sensor, relative to the first inner surface; and a ledge surface that extends, in a second direction parallel to the image plane, from the first inner surface to the second inner surface.
6. The camera of claim 5, wherein the one or more wire bond electrical interconnects comprise: a first end portion that is bonded to the image sensor; and a second end portion that is bonded to the ledge surface.
7. The camera of claim 1, further comprising: a stiffener fixedly coupled with the image sensor and

the flex circuit, such that at least a portion of the flex circuit is sandwiched between the stiffener and the substrate.

8. The camera of claim 7, wherein: the stiffener is attached to a bottom of the image sensor.

9. The camera of claim 1, wherein: the flex circuit comprises edges that define a cut-out that is positioned, in a direction orthogonal to an image plane of the image sensor, along a plane that intersects the image sensor.

10. The camera of claim 1, wherein the first portion of the flex circuit comprises an inner frame, and wherein the second portion of the flex circuit comprises an outer frame, and wherein the flex circuit comprises: a flexure arrangement, comprising: one or more flexure arms that are connected to the inner frame and to the outer frame, wherein: the one or more flexure arms allow motion of the image sensor package enabled by the actuator; and electrical traces on at least a portion of the one or more flexure arms are configured to convey electrical signals between the inner frame and the outer frame; and a stiffener fixedly coupled with the image sensor and the inner frame.

11. A device, comprising: one or more processors; memory storing program instructions executable by the one or more processors to control operations of a camera; and the camera, comprising: a lens group comprising one or more lens elements; an image sensor package that is movable relative to the lens group, the image sensor package comprising: an image sensor; and a substrate, wherein the image sensor is electrically connected to the substrate via one or more wire bond electrical interconnects; a stiffener fixedly attached to a bottom side of the image sensor, wherein the bottom side is opposite a top side of the image sensor; and an optical element directly attached to a top side of the substrate, wherein the top side of the image sensor faces an optical filter; wherein the image sensor is entirely encapsulated within a chamber at least partially defined by the substrate, the stiffener, and the optical element; and an actuator for moving the image sensor package.

12. The device of claim 11, wherein: the one or more lens elements define an optical axis; and the actuator comprises a voice coil motor (VCM) actuator configured to move the image sensor package in at least one direction parallel to the optical axis.

13. The device of claim 12, wherein: the image sensor package further comprises: a carrier fixedly coupled with the substrate; and the VCM actuator comprises: one or more magnets attached to the carrier; and one or more coils attached to a stationary structure of the camera.

14. The device of claim 11, wherein the substrate comprises: an upper portion, comprising: a first inner surface that extends in a first direction orthogonal to an image plane defined by the image sensor; and a lower portion, comprising: a second inner surface that extends in the first direction orthogonal to the image plane, wherein the second inner surface is closer to the image sensor, relative to the first inner surface; and a ledge surface that extends, in a second direction parallel to the image plane, from the first inner surface to the second inner surface.

15. The device of claim 14, wherein the one or more wire bond electrical interconnects comprise: a first end portion that is bonded to the image sensor; and a second end portion that is bonded to the ledge surface.

16. The device of claim 11, wherein the optical element comprises an infrared cut-off filter (IRCF).

17. The device of claim 11, wherein the camera further comprises a flex circuit fixedly coupled with the substrate, wherein the flex circuit comprises edges that define a cut-out that is positioned, in a direction orthogonal to an image plane of the image sensor, along a plane that intersects the image sensor.

18. The device of claim 11, wherein: the substrate is integrally formed with a flex circuit using an organic material to produce a substrate-flex circuit hybrid structure; and the camera further comprises a stiffener attached to a bottom side of the image sensor and a bottom side of the substrate-flex circuit hybrid structure.

19. A method of assembling a camera, the method comprising: attaching a carrier to a substrate; attaching a first portion of a voice coil motor (VCM) actuator to the carrier; attaching a second portion of the VCM actuator to a stationary structure of the camera, wherein the VCM actuator is

for causing a flex circuit to move; connecting a first portion of the flex circuit to the substrate, wherein the flex circuit is configured to: move, upon activation of the VCM actuator, an image sensor of the camera and the substrate together with the first portion of the VCM actuator and the first portion of the flex circuit relative to a lens group of the camera, and convey electrical signals between the substrate and one or more stationary components to which a second portion of the flex circuit is attached, and connecting the image sensor to the substrate via one or more wire bond electrical interconnects, wherein: the connecting the image sensor to the substrate via the one or more wire bond electrical interconnects comprises: bonding a first end portion of the one or more wire bond electrical interconnects to the image sensor; and bonding a second end portion of the one or more wire bond electrical interconnects to the substrate.