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Sensor temperature reducer for a sensor shift camera architecture

Abstract

A camera comprising: a camera enclosure; an optomechanical assembly fixedly coupled to the camera enclosure; an image sensor assembly movably coupled to the camera enclosure, the image sensor assembly comprising: a substrate, an image sensor coupled to the substrate, a flexible printed circuit board coupled to the substrate, a conductive stiffener plate coupled to the flexible printed circuit board, and a passive heat exchanger thermally coupled to the image sensor to dissipate heat away from the image sensor.

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Background/Summary

FIELD

(1) An aspect of the disclosure is directed to a passive heat exchanger for reducing peak sensor temperatures in sensor shift cameras. Other aspects are also described and claimed.

BACKGROUND

(2) The use of small portable multipurpose devices such as smartphones and tablet or pad devices has resulted in a need for high-resolution, small form factor or miniature cameras for integration in the devices. Some of these cameras may incorporate optical image stabilization (OIS) mechanisms that may sense and react to external excitation/disturbance by adjusting a location of the optical lens on the X and/or Y axis in an attempt to compensate for unwanted motion of the lens. In addition, the cameras may incorporate an autofocus (AF) mechanism whereby the object focal distance is adjusted to allow objects at different distances to be in sharp focus and captured by the digital image sensor. In some such autofocus mechanisms, the optical lens is moved relative to the digital image sensor along the optical axis of the camera to refocus the camera. Due to the small form factor of the cameras, however, unintended movements, which may occur when the device is dropped, can cause camera components to collide and become damaged resulting in reduced camera reliability.

SUMMARY

(3) In one aspect, the disclosure is directed to a heat dissipating mechanism in a camera module that dissipates heat from the sensor package within the camera module (e.g., image sensor) through a conductive path. Representatively, the camera assembly disclosed herein may include an image sensor assembly that moves while the optical components remain fixed. The image sensor assembly, however, takes in light and may be made up of a number of electronic components that causes the image sensor assembly to transmit a lot of heat. The moving image sensor may therefore be prone to overheating if the heat it is generated cannot be dissipated. The fastest way to dissipate heat is through a conductive pathway. This can be difficult with the moving image sensor architecture, however, because the sensor assembly is "floating" above the bottom enclosure wall. The image sensor therefore does not rest on a conductive surface that could otherwise provide a strong conduction path. To address this, aspects of the instant disclosure provide a passive heat exchanger or reduction mechanism that can create a conductive pathway from the moving image sensor to help dissipate heat from the moving image sensor and reduce peak sensor temperatures. For example, in some aspects, the heat exchange or reduction mechanism may reduce the peak sensor temperature so that it does not exceed seventy degrees.

(4) Representatively, an aspect of the disclosure is directed to a camera including a camera enclosure; an optomechanical assembly fixedly coupled to the camera enclosure; an image sensor assembly movably coupled to the camera enclosure, the image sensor assembly comprising: a substrate, an image sensor coupled to the substrate, a flexible printed circuit board coupled to the substrate, a conductive stiffener plate coupled to the flexible printed circuit board, and a passive heat exchanger thermally coupled to the image sensor to dissipate heat away from the image sensor. In one aspect, the passive heat exchanger includes a thermally conductive gel contacting the image sensor and the conductive stiffener plate to form a conductive pathway that dissipates the heat away from the image sensor. In another aspect, the passive heat exchanger comprises a layer of thermally conductive material contacting a bottom side of the image sensor and a top side of the conductive stiffener plate. In another aspect, the flexible printed circuit board extends entirely across a bottom side of the image sensor, and the passive heat exchanger comprises a layer of thermally conductive material contacting the bottom side of the image sensor and a top side of the flexible printed circuit board. In another aspect, a conductive stiffener plate is coupled to a bottom side of the flexible printed circuit board and extends entirely across the bottom side of the image sensor. In another aspect, a passive heat exchanger includes a thermally conductive gel connected to a bottom side of the image sensor and a top side of the camera enclosure. In another aspect, a flexible printed circuit board and the conductive stiffener plate extend entirely across a bottom side of the image sensor, and the passive heat exchanger includes a number of heat sink fins formed in a portion of the conductive stiffener plate directly below the image sensor. In some aspects, the passive heat exchanger includes a heat sink directly attached to a bottom side of the image sensor. In another aspect, the passive heat exchanger includes a heat sink attached to an interior side of the camera enclosure. In some aspects, the heat sink includes a number of heat sink fins formed in an interior side of the camera enclosure and directly below the image sensor.

(5) In another aspect, a camera image sensor assembly includes a substrate movably coupled to a camera enclosure; an image sensor coupled to the substrate and having a bottom side suspended over an interior side of the camera enclosure; a flexible printed circuit board coupled to the substrate; a stiffener plate coupled to the flexible printed circuit board; and a passive heat exchanger thermally coupled to the image sensor to dissipate heat away from the image sensor. In some aspects, the stiffener plate includes a conductive portion that at least partially overlaps the bottom side of the image sensor and the passive heat exchanger is a thermally conductive gel positioned between the conductive portion of the stiffener plate and the bottom side of the image sensor. In some aspects, the passive heat exchanger includes a layer of thermally conductive gel completely covering the bottom side of the image sensor, the flexible printed circuit board is connected to the layer of thermally conductive gel, and the stiffener plate comprises a conductive

material connected to the flexible printed circuit board. In some aspects, the flexible printed circuit board entirely overlaps the bottom side of the image sensor. In some aspects, the stiffener plate entirely overlaps the bottom side of the image sensor. In some aspects, the passive heat exchanger includes a thermally conductive gel extending from the bottom side of the image sensor to the interior side of the camera enclosure. In further aspects, the passive heat exchanger includes a heat sink positioned between the bottom side of the image sensor and the interior side of the camera enclosure. In another aspect, the heat sink is directly attached to the bottom side of the image sensor or the interior side of the camera enclosure. In still further aspects, the flexible printed circuit board and the stiffener plate entirely overlap the bottom side of the image sensor, and the passive heat exchanger comprises a number of heat sink fins formed in the stiffener plate. In some aspects, the passive heat exchanger comprises a number of heat sink fins formed in the interior side of the camera enclosure.
(6) The above summary does not include an exhaustive list of all aspects of the present disclosure. It is contemplated that the disclosure includes all systems and methods that can be practiced from all suitable combinations of the various aspects summarized above, as well as those disclosed in the Detailed Description below and particularly pointed out in the claims filed with the application. Such combinations have particular advantages not specifically recited in the above summary.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The embodiments are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings in which like references indicate similar elements. It should be noted that references to “an” or “one” embodiment in this disclosure are not necessarily to the same embodiment, and they mean at least one.
(2) FIG. **1** illustrates a cross-sectional side view of an example camera assembly.
(3) FIG. **2** illustrates a magnified cross-sectional side view of some representative aspects of the camera assembly of FIG. **1**.
(4) FIG. **3** illustrates a magnified cross-sectional side view of an aspect of a camera assembly.
(5) FIG. **4** illustrates a magnified cross-sectional side view of an aspect of a camera assembly.
(6) FIG. **5** illustrates a magnified cross-sectional side view of an aspect of a camera assembly.
(7) FIG. **6** illustrates a magnified cross-sectional side view of an aspect of the camera assembly of FIG. **5**.
(8) FIG. **7** illustrates a magnified cross-sectional side view of an aspect of a camera assembly.
(9) FIG. **8** illustrates a magnified cross-sectional side view of an aspect of a camera assembly.
(10) FIG. **9** illustrates a magnified cross-sectional side view of an aspect of a camera assembly.
(11) FIG. **10** illustrates a magnified cross-sectional side view of an aspect of a camera assembly.
(12) FIG. **11** illustrates an example computer system that may include a camera assembly as disclosed herein.
DETAILED DESCRIPTION
(13) In this section we shall explain several preferred aspects of the disclosure with reference to the appended drawings. Whenever the shapes, relative positions and other aspects of the parts described in the aspects are not clearly defined, the scope of the disclosure is not limited only to the parts shown, which are meant merely for the purpose of illustration. Also, while numerous details are set forth, it is understood that some aspects of the disclosure may be practiced without these details. In other instances, well-known structures and techniques have not been shown in detail so as not to obscure the understanding of this description.
(14) The terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting of the disclosure. Spatially relative terms, such as “beneath”, “below”,

“lower”, “above”, “upper”, and the like may be used herein for ease of description to describe one element's or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the exemplary term “below” can encompass both an orientation of above and below. The device may be otherwise oriented (e.g., rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

(15) As used herein, the singular forms “a”, “an”, and “the” are intended to include the plural forms as well, unless the context indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising” specify the presence of stated features, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, steps, operations, elements, components, and/or groups thereof.

(16) The terms “or” and “and/or” as used herein are to be interpreted as inclusive or meaning any one or any combination. Therefore, “A, B or C” or “A, B and/or C” mean “any of the following: A; B; C; A and B; A and C; B and C; A, B and C.” An exception to this definition will occur only when a combination of elements, functions, steps or acts are in some way inherently mutually exclusive.

(17) FIG. **1** illustrates a cross-sectional side view of a camera assembly or module within which any one or more of the aspects disclosed herein, alone or in combination, may be implemented. The example X-Y-Z coordinate system shown in FIG. **1** may be used to discuss aspects of the system and/or system components, and may apply to aspects described throughout the disclosure. Camera assembly **100** may include a camera housing or enclosure **102** having a wall that defines an enclosed space or chamber within which various components of the camera assembly are positioned or otherwise contained. Representatively, the various camera components may be positioned within the enclosed space and fixedly or movably connected to the enclosure **102**. For example, the camera components may include an optomechanical assembly **104** including a number of optics components that are contained or otherwise coupled to the enclosure **102**. The camera components may further include a sensor assembly **106** including a number of sensing components that are contained or otherwise coupled to the enclosure **102**. The camera components may further include an actuator **108** that is operable to move the sensor assembly **106** relative to the optomechanical assembly **104** and/or enclosure **102** to provide OIS and/or AF functionality. Representatively, in some aspects, the optomechanical assembly **104** may be fixedly connected to the enclosure **102** by the actuator **108**. The sensor assembly **106** may be movably connected to the enclosure **102** by actuator **108**. The actuator **108** may be operable to move the sensor assembly **106** relative to the fixed optomechanical assembly **104** and enclosure **102** to provide the OIS and/or AF functionality. In this aspect, in some cases, the optomechanical assembly **104** and/or its associated components may be considered a fixed portion of the camera **100** while the sensor assembly **106** and/or its associated components may be considered a moving portion of the camera assembly **100**.

(18) Referring now in more detail to the optomechanical assembly **104**, optomechanical assembly **104** may include a lens **110** (or lens group), a prism **112** and a support structure **114** that holds lens **110** in the desired arrangement relative to prism **112**. For example, support structure **114** may hold lens **110** and prism **112** in an arrangement in which lens **110** is positioned above prism **112**, and prism **112** is positioned above imaging assembly **104** (e.g., relative to the Z-axis). Lens **110** (or lens group) may include one or more lens elements having an optical axis (e.g., the Z-axis) along which the light entering the camera propagates and is directed toward prism **112**. For example, as shown by the arrow, the light may enter an object side **112**A of prism **112** (e.g., along the Z-axis) and be redirected along an optical path through prism **112** (e.g., along the X-axis) and out the image side **112**B of prism **112** towards the imaging assembly **106** (e.g., along the Z-axis). Optomechanical

assembly **104** may be fixedly connected to the camera enclosure **102** by actuator **108** as previously discussed.

(19) Representatively, actuator **108** may, in some aspects, be a voice coil motor (VCM) actuator assembly or module including a base portion **116** and a carrier portion **118**. Base portion **116** may be fixedly connected to the optomechanical assembly **104** and camera enclosure **102**. For example, base portion **116** may be a substantially rigid structure (e.g., a plastic structure) that defines a periphery within which optomechanical assembly **104** is disposed. Representatively, base portion **116** may have multiple sides that surround and attach to the sides of optomechanical assembly **104**. For example, one or more of the side walls of fixed base portion **116** may be attached to support structure **114** as shown in FIG. **1** to fixedly connect optomechanical assembly **104** to camera enclosure **102**. Carrier portion **118** may be movably connected to the base portion **116** and camera enclosure **102**. Carrier portion **118** may be moved relative to camera enclosure **102** and/or base portion **116** by actuating components (e.g., magnets and/or coils) of actuator **108**.

(20) Sensor assembly **106** may be movably connected to camera enclosure **102** by the movable carrier portion **118**. Representatively, sensor assembly **106** may be an image sensor package including a stack up of a substrate **120**, an image sensor **122**, a flexible printed circuit board **128**, a stiffener member or plate **126** and a cover **124**. The image sensor **122** may be arranged within an opening of substrate **120** and secured within the opening by attaching a top side **122**A of image sensor **122** to a bottom side **120**B of substrate **120**. Cover **124** may be positioned over image sensor **122** and attached to a top side **120**A of substrate **120** as shown. The flexible printed circuit board **128** and stiffener member or plate **126** may be stacked along the bottom side **120**B of substrate **120**. For example, flexible printed circuit board **128** may be attached to the bottom side **120**B of substrate **120**, and stiffener member or plate **126** may be attached to a bottom side of flexible printed circuit board **128**. In some aspects, flexible printed circuit board **128** may be made of a flexible polyimide material with copper traces. In still further aspects, stiffener member or plate **126** may be made of a stiffening material that can help to provide added rigidity and/or support to substrate **120**. In addition, in some aspects, the stiffening material may be conductive or include conductive traces or pathways. For example, stiffener member or plate **126** may be made of steel or copper, or another relatively rigid material with steel or copper traces or pathways. In some aspects, electronic components (e.g., diodes, capacitors, low-dropout regulators (LDOs), etc.) may also be attached, mounted, embedded, or otherwise coupled to, substrate **120** to assist with the sensing function of image sensor **122**. The movable carrier portion **118** may be connected to substrate **120** (e.g., mounted to top side **120**A of substrate **120**) and used to shift the sensor assembly **106** relative to optomechanical assembly **104** along multiple axes, e.g., to provide AF and/or OIS functionality. For example, carrier portion **118** may be a substantially rigid structure (e.g., a plastic structure) including a number of sides that define a periphery within which sensor assembly **106** is disposed. The carrier sides may be connected to opposite sides surfaces of sensor assembly **106** (e.g., sides of substrate **120**) to secure sensor assembly **106** to carrier portion **118**.

(21) During an AF and/or OIS operation, movable carrier portion **118** may displace or shift sensor assembly **106** relative to optomechanical assembly **104** (and camera enclosure **102**). For example, carrier portion **118** may displace or shift sensor assembly **106** in a direction parallel to the Z-axis, X-axis and/or Y-axis. To allow for such movements, sensor assembly **106** may be suspended by carrier portion **118** a distance (D**1**) above the bottom wall of enclosure **102** as shown. The spacing of sensor assembly **106** distance (D**1**) from a resting surface, however, can present challenges when trying to dissipate heat or otherwise prevent sensor assembly **106** from overheating. As previously discussed, due to the light transmission and the electronic components associated with sensor assembly **106**, sensor assembly **106** may be prone to overheating. Although heat dissipation from sensor assembly **106** may occur by convection across distance (D**1**), this is not the fastest means for heat dissipation. A conductive pathway from sensor assembly **106** will dissipate heat at a faster rate than a convective pathway. Sensor assembly **106**, however, is spaced a distance (e.g., distance

(D**1**)) from any fixed surface of camera assembly **100** that could be used to provide a conductive pathway for faster heat dissipation.

(22) This challenge is solved in camera assembly **100** by attaching a passive heat exchanger **130** to the moving sensor assembly **106**. Passive heat exchanger **130** includes a conductive material that forms a conductive pathway for dissipating heat from sensor assembly **106**. Representatively, passive heat exchanger **130** may be directly connected to image sensor **122** to form a conductive pathway that can transfer heat away from sensor **122** and toward enclosure **102**. For example, the conductive pathway may extend a substantial length of the distance (D**1**), or the entire length, such that any remaining pathway for heat transfer, for example by conduction, is substantially reduced to a distance (D**2**). In this aspect, passive heat exchanger **130** forms a conductive pathway that increases a rate of heat dissipation from image sensor **122** and a substantially reduced gap for dissipating the heat by convection the remaining distance (D**2**) to enclosure **102**.

(23) Referring now in more detail to the passive heat exchanger, FIG. **2** illustrates a magnified cross-sectional view of the image sensor assembly **106** including passive heat exchanger **130** of FIG. **1**. From this view, it can be seen that passive heat exchanger **130** is directly attached to the bottom side **122**B of image sensor **122**. The passive heat exchanger **130** is further directly attached to a top side of an extended portion **126**A of stiffener member or plate **126**. Representatively, stiffener member or plate **126** may include an extended portion **126**A that at least partially overlaps the bottom side **122**B of image sensor **122**. Passive heat exchanger **130** may be positioned within this overlapping region to provide a conductive pathway from image sensor **122** through stiffener plate or member **126**. Passive heat exchanger **130** may, for example, be any sort of thermally conductive material or structure that provides a conductive pathway from image sensor **122**. Representatively, in one aspect, passive heat exchanger **130** may be a soft and thermally conductive material such as a gel. The thermally conductive gel may be applied between the bottom side **122**B of image sensor **122** and the top side of stiffener plate or member **126** as shown. The soft thermal gel bridges the gap between image sensor **122** and member **126**. In this aspect, when the image sensor heats up, the thermal gel wicks the heat away from image sensor **122** and through member **126** along a conductive pathway **132**. As previously discussed, stiffener plate or member **126** may be made of, or otherwise include, a conductive material (e.g., a copper) as well. Thus, conductive pathway **132** extends through and to the bottom side of member **126**. Any heat remaining after passing along conductive pathway **132** through the gel and member **126** is dissipated the remaining distance (D**2**) by convention to enclosure **102**. As previously discussed, this remaining distance (D**2**) from member **126** to enclosure **102** is much smaller than the distance (D**1**) from image sensor **122** to enclosure **102**. The convective pathway (e.g., along arrow D**2**) that remains for heat transfer out of the system (e.g., to enclosure **102**) is therefore reduced resulting in a further improvement in the rate of heat dissipation from image sensor **122**. For example, passive heat exchanger **130** may dissipate heat from the moving image sensor **122** and reduce peak sensor temperatures. Representatively, in some aspects, passive heat exchanger **130** may reduce the peak sensor temperature so that it does not exceed seventy degrees.

(24) In some aspects, the thermal gel forming passive heat exchanger **130** may be confined to the region of image sensor **122** that is overlapped by the extended portion **126**A of member **126**. For example, the thermal gel may only partially cover the bottom side **122**B of sensor **122** and does not extend across the entire bottom side **122**B of sensor **122**. In addition, the thermal gel may have any thickness suitable for occupying the entire space between the bottom side **122**B of image sensor **122** and the top side of portion **126**A. In this aspect, as shown by the arrow, conductive pathway **132** may run entirely through thermal gel to the bottom side of member **126**. Still further, in some aspects, a thickness of the thermal gel and/or member **126** may be increased to increase the length of the conductive pathway **132** and further reduce the distance (D**2**) of the convective pathway to the enclosure **102**. It should further be understood that although a thermal gel is described, any sort of relatively soft thermally conductive material suitable for transferring heat from image sensor **122**

to member **126** could be used.

(25) Referring now to FIG. **3**, FIG. **3** illustrates a magnified cross-sectional side view of an aspect of a camera assembly. Representatively, camera assembly **300** is a magnified view of another aspect of an image sensor assembly and passive heat exchanger that could be implemented in the camera assembly previously discussed in reference to FIG. **1**. The image sensor assembly **106** is similar to the previously discussed image sensor assemblies in that it includes a substrate **120**, an image sensor **122**, a flexible printed circuit board **128**, a stiffener member or plate **126** and a cover **124**. The flexible printed circuit board **128** and stiffener member or plate **126** may be stacked along the bottom side of substrate **120**. For example, flexible printed circuit board **128** may be attached to the bottom side of substrate **120**, and stiffener member or plate **126** may be attached to the bottom side of flexible printed circuit board **128**, as previously discussed. In some aspects, stiffener member or plate **126** may be made of a stiffening material that can help to provide added rigidity to substrate **120**. In addition, in some aspects, the stiffening material may be conductive or include conductive traces or pathways. For example, stiffener member or plate **126** may be made of steel or copper, or another relatively rigid material with steel or copper traces or pathways. The movable carrier portion **118** may be connected to substrate **120** and used to shift the sensor assembly **106** relative to optomechanical assembly **104** (shown in FIG. **1**) along multiple axes, e.g., to provide AF and/or OIS functionality, as previously discussed.

(26) In image sensor assembly **106** of camera assembly **300**, however, the flexible printed circuit board **128** and the stiffener member or plate **126** entirely overlap, or extend entirely across, the bottom side **122**B of image sensor **122**. Representatively, flexible printed circuit board **128** includes extended portion **128**A and stiffener member or plate **126** includes extended portion **126**A that entirely overlap the image sensor **122**. In addition, passive heat exchanger **130** also entirely overlaps, or extends entirely across, the bottom side **122**B of image sensor **122**. For example, passive heat exchanger **130** may be a thermally conductive gel as previously discussed, that contacts and is applied entirely across the bottom side **122**B of image sensor **122**. The extended portion **128**A of flexible printed circuit board **128** extends across, and contacts, the bottom side of substrate **120** and the thermally conductive gel. The extended portion **126**A of stiffener member or plate **126** extends across, and contacts, the bottom side of flexible printed circuit board **128**. Similar to the previously discussed configuration, the stack up of the passive heat exchanger **130**, flexible printed circuit board **128** and stiffener member or plate **126** forms a conductive pathway (e.g., similar to conductive pathway **132**) for heat dissipation away from image sensor **122**. In addition, in some aspects, the increased surface area of sensor **122** that is in contact with the thermally conductive gel may further increase the rate of heat transfer away from image sensor **122**. As previously discussed, once the heat is transferred through the conductive pathway to the bottom side of stiffener member or plate **126**, it can pass through the convective pathway between plate **126** and enclosure **102**, to enclosure **102** and out of the system. The combination of the conductive pathway and reduced convective pathway helps to increase the rate of heat dissipation and reduce the peak sensor temperature.

(27) Referring now to FIG. **4**, FIG. **4** illustrates a magnified cross-sectional side view of an aspect of a camera assembly. Representatively, camera assembly **400** is a magnified view of another aspect of an image sensor assembly and passive heat exchanger that could be implemented in the camera assembly previously discussed in reference to FIG. **1**. The image sensor assembly **106** is similar to the previously discussed image sensor assemblies in that it includes a substrate **120**, an image sensor **122**, a flexible printed circuit board **128**, a stiffener member or plate **126** and a cover **124**. The flexible printed circuit board **128** and stiffener member or plate **126** may be stacked along the bottom side (e.g., along side **120**B of FIG. **1**) of substrate **120**. The movable carrier portion **118** may be connected to substrate **120** and used to shift the sensor assembly **106** relative to optomechanical assembly **104** along multiple axes, e.g., to provide AF and/or OIS functionality, as previously discussed.

(28) In image sensor assembly **106** of camera assembly **400**, however, the flexible printed circuit board **128** entirely overlaps, or extends entirely across, the bottom side **122**B of image sensor **122**. Representatively, flexible printed circuit board **128** includes extended portion **128**A that entirely overlaps the image sensor **122**. In addition, passive heat exchanger **130** also entirely overlaps, or extends entirely across, the bottom side **122**B of image sensor **122**. For example, passive heat exchanger **130** may be a thermally conductive gel as previously discussed, that is applied entirely across the bottom side **122**B of image sensor **122**. The extended portion **128**A of flexible printed circuit board **128** extends across, and contacts, the bottom side of substrate **120** and the thermally conductive gel In contrast to FIG. **3**, however, the stiffener member or plate **126** does not extend entirely across the bottom side of the flexible printed circuit board **128** and/or image sensor **122**. Rather, stiffener member or plate **126** only partially overlaps the bottom side of flexible printed circuit board **128** and image sensor **122**. For example, stiffener member of plate **126** may be similar to the stiffener member or plate **126** described in FIG. **2**. Similar to the previously discussed configuration, the stack up of the passive heat exchanger **130** and flexible printed circuit board **128** may form a conductive pathway for heat dissipation away from image sensor **122**. In some aspects, the conductive pathway may be similar to the conductive pathway **132** described in reference to FIG. **2** and extend in the Z-axis direction from the bottom side of image sensor **122**, through printed circuit board **128** to the bottom side of plate **126**. In other aspects, the conductive pathway may extend vertically (in the Z-axis direction) through the passive heat exchanger **130** and the flexible printed circuit board **128**, then horizontally (in the X-axis direction) through stiffener member or plate **126** contacting a portion of flexible printed circuit board **128** then out the bottom side of plate **126** (in the Z-axis direction). As previously discussed, once the heat is transferred through the conductive pathway to the bottom side of stiffener member or plate **126**, it can pass through the convective pathway between plate **126** and enclosure **102**, to enclosure **102** and out of the system. The combination of the conductive pathway and reduced convective pathway helps to increase the rate of heat dissipation and reduce the peak sensor temperature. In addition, in some aspects, the increased surface area contact between the thermally conductive gel and the image sensor **122** further increases the rate of heat dissipation away from image sensor **122**.
(29) Referring now to FIG. **5**, FIG. **5** illustrates a magnified cross-sectional side view of an aspect of a camera assembly. Representatively, camera assembly **500** is a magnified view of another aspect of an image sensor assembly and passive heat exchanger that could be implemented in the camera assembly previously discussed in reference to FIG. **1**. The image sensor assembly **106** is similar to the previously discussed image sensor assemblies in that it includes a substrate **120**, an image sensor **122**, a flexible printed circuit board **128**, a stiffener member or plate **126** and a cover **124**. The flexible printed circuit board **128** and stiffener member or plate **126** may be stacked along the bottom side **120**B of substrate **120**. The movable carrier portion **118** may be connected to substrate **120** and used to shift the sensor assembly **106** relative to optomechanical assembly **104** along multiple axes, e.g., to provide AF and/or OIS functionality, as previously discussed.
(30) In image sensor assembly **106** of camera assembly **500**, however, the passive heat exchanger **130** contacts and extends entirely from the bottom side **122**B of image sensor **122** to the interior side **102**A of enclosure **102**. In this aspect, the conductive pathway for dissipating heat away from image sensor **122** extends entirely from image sensor **122** to enclosure **102**. In this aspect, enclosure **102** wicks heat away from image sensor **122** by conduction. For example, passive heat exchanger **130** may be a thermally conductive gel as previously discussed. The thermally conductive gel may be soft enough not to restrict movement of image sensor **122**, yet firm enough and have enough of an adhesive characteristic to remain in contact with image sensor **122** and enclosure **102**. Representatively, the thermally conductive gel may be like an adhesive so that it sticks to the surfaces of the image sensor **122** and enclosure **102**. In this aspect, the thermally conductive gel moves with image sensor **122**, and stays in contact with image sensor **122** and enclosure **102**, such that it expands, contracts, etc. as image sensor **122** moves along the X, Y

and/or Z-axes. Representatively, as illustrated in FIG. **5**, when image sensor **122** moves along the Z-axis away from enclosure **102**, the thermal gel remains in contact with the bottom side **122**B of image sensor **122** and is caused to expand as shown. Similarly, if image sensor **122** is moved closer to interior side **102**A of enclosure **102** the thermal gel will compress. Still further, if image sensor **122** is moved horizontally along the X-axis, the thermal gel will be pulled in the direction of image sensor **122** while always maintaining contact with image sensor **122** and enclosure **102** as shown. As a result, regardless of the movement of image sensor **122**, there is always a conductive pathway across the entire space or gap between image sensor **122** and enclosure **102**. This, in turn, substantially increases the rate of heat dissipation away from sensor **122** and the reduction in peak sensor temperature.

(31) Referring now to FIG. **7**. FIG. **7** illustrates a magnified cross-sectional side view of an aspect of a camera assembly. Representatively, camera assembly **700** is a magnified view of another aspect of an image sensor assembly and passive heat exchanger that could be implemented in the camera assembly previously discussed in reference to FIG. **1**. The image sensor assembly **106** is similar to the previously discussed image sensor assemblies in that it includes a substrate **120**, an image sensor **122**, a flexible printed circuit board **128**, a stiffener member or plate **126** and a cover **124**. The flexible printed circuit board **128** and stiffener member or plate **126** may be stacked along the bottom side of substrate **120**. For example, flexible printed circuit board **128** may be attached to the bottom side of substrate **120**, and stiffener member or plate **126** may be attached to flexible printed circuit board **128**, as previously discussed. In some aspects, stiffener member or plate **126** may be made of a stiffening material that can help to provide added rigidity to substrate **120**. In addition, in some aspects, the stiffening material may be conductive or include conductive traces or pathways. For example, stiffener member or plate **126** may be made of a metal such as steel or copper. The movable carrier portion **118** may be connected to substrate **120** and used to shift the sensor assembly **106** relative to optomechanical assembly **104** (as illustrated in FIG. **1**) along multiple axes, e.g., to provide AF and/or OIS functionality, as previously discussed.

(32) In image sensor assembly **106** of camera assembly **700**, the flexible printed circuit board **128** and the stiffener member or plate **126** entirely overlap, or extend entirely across, the bottom side of image sensor **122**. In addition, passive heat exchanger **702** is formed within the portion of stiffener member or plate **126** overlapping image sensor **122**. Representatively, stiffener member or plate **126** may be a metal plate and passive heat exchanger **702** may be a heat sink **702** that is formed in the bottom side of the metal plate. The heat sink **702** may, for example, include a number of pins or fins **704** that are separated by spaces or channels **706** formed in the bottom side of stiffener member or plate **126**. For example, the pins or fins **704** may have a pin-fin or straight-fin type heat sink arrangement. Since the heat sink **702** is directly attached to the bottom side of sensor **122**, it will create a conductive pathway drawing heat away from image sensor **122** and to the pins or fins **702**. The increased surface area created by the pins or fins **704** will increase the convective surface area which further helps to increase the rate of heat dissipation away from the image sensor **122**. It is contemplated that although a certain number of pins or fins **704** and channels **706**, and a particular fin/channel arrangement, is shown any number of pins or fins **704** and channels **706** in any arrangement may be used.

(33) Referring now to FIG. **8**, FIG. **8** illustrates a magnified cross-sectional side view of an aspect of a camera assembly. Representatively, camera assembly **800** is a magnified view of another aspect of an image sensor assembly and passive heat exchanger that could be implemented in the camera assembly previously discussed in reference to FIG. **1**. The image sensor assembly **106** is similar to the previously discussed image sensor assemblies in that it includes a substrate **120**, an image sensor **122**, a flexible printed circuit board **128**, a stiffener member or plate **126** and a cover **124**. The flexible printed circuit board **128** and stiffener member or plate **126** may be stacked along the bottom side of substrate **120**. For example, flexible printed circuit board **128** may be attached to the bottom side of substrate **120**, and stiffener member or plate **126** may be attached to flexible

printed circuit board **128**, as previously discussed. In some aspects, stiffener member or plate **126** may be made of a stiffening material that can help to provide added rigidity to substrate **120**. In addition, in some aspects, the stiffening material may be conductive or include conductive traces or pathways. For example, stiffener member or plate **126** may be made of a metal such as steel or copper. The movable carrier portion **118** may be connected to substrate **120** and used to shift the sensor assembly **106** relative to optomechanical assembly **104** along multiple axes, e.g., to provide AF and/or OIS functionality, as previously discussed.

(34) Image sensor assembly **106** may further include passive heat exchanger **802** attached to the bottom side **122**B of image sensor **122**, similar to the previously discussed configuration of FIG. **7**. In this configuration, however, passive heat exchanger **802** is not formed within the stiffener member or plate **126**. Rather, passive heat exchanger **802** is a heat sink that is separate from the flexible printed circuit board **128** and the stiffener member or plate **126**, and directly attached to the bottom side **122**B of image sensor **122**. For example, flexible printed circuit board **128** and stiffener member or plate **126** are attached to the bottom side of substrate **120** but do not overlap image sensor **122**. The heat sink **802** is then directly attached to the bottom side **122**B of image sensor **122**, between the ends of the circuit board **128** and plate **126**. Representatively, heat sink **802** may include a number of pins or fins **804** that are separated by spaces or channels **806** formed in a metal plate or other conductive material that can then be attached to sensor **122**. For example, the pins or fins **804** may have a pin-fin or straight-fin type heat sink arrangement. Since the heat sink **802** is directly attached to the bottom side of sensor **122**, it will create a conductive pathway drawing heat away from image sensor **122** and to the pins or fins **804**. The increased surface area created by the pins or fins **804** will help to transfer the heat generated by the image sensor **122** to the air, where it is dissipated away from the image sensor **122**.

(35) Referring now to FIG. **9**, FIG. **9** illustrates a magnified cross-sectional side view of an aspect of a camera assembly. Representatively, camera assembly **900** is a magnified view of another aspect of an image sensor assembly and passive heat exchanger that could be implemented in the camera assembly previously discussed in reference to FIG. **1**. The image sensor assembly **106** is similar to the previously discussed image sensor assemblies in that it includes a substrate **120**, an image sensor **122**, a flexible printed circuit board **128**, a stiffener member or plate **126** and a cover **124**. The flexible printed circuit board **128** and stiffener member or plate **126** may be stacked along the bottom side of substrate **120** as previously discussed. The movable carrier portion **118** may be connected to substrate **120** and used to shift the sensor assembly **106** relative to optomechanical assembly **104** along multiple axes, e.g., to provide AF and/or OIS functionality, as previously discussed.

(36) Image sensor assembly **106** may further include passive heat exchanger **902**. In this configuration, however, passive heat exchanger **902** is attached to the interior side **102**A of enclosure **102**. For example, passive heat exchanger **902** may be a heat sink that is directly below image sensor **122** and attached to the interior side **102**A of enclosure **102**. Representatively, the heat sink may include a number of pins or fins **904** that are separated by spaces or channels **906** formed in a metal plate or other metal structure that can be attached or mounted to the interior side **102**A of enclosure **102**. For example, pins or fins **904** may have a pin-fin or straight-fin type heat sink arrangement. Since the heat sink **902** is positioned below image sensor **122**, heat emitted from image sensor **122** will reach heat sink **902** by way of convection across the gap or space and be transferred away from image sensor **122** to the enclosure **102**. The increased surface area created by the pins or fins **904** will help to wick away and transfer the heat generated by the image sensor **122** to the enclosure **102**.

(37) Referring now to FIG. **10**, FIG. **10** illustrates a magnified cross-sectional side view of an aspect of a camera assembly. Representatively, camera assembly **1000** is a magnified view of another aspect of an image sensor assembly and passive heat exchanger that could be implemented in the camera assembly previously discussed in reference to FIG. **1**. The image sensor assembly

106 is similar to the previously discussed image sensor assemblies in that it includes a substrate **120**, an image sensor **122**, a flexible printed circuit board **128**, a stiffener member or plate **126** and a cover **124**. The flexible printed circuit board **128** and stiffener member or plate **126** may be stacked along the bottom side of substrate **120** as previously discussed. The movable carrier portion **118** may be connected to substrate **120** and used to shift the sensor assembly **106** relative to optomechanical assembly **104** along multiple axes, e.g., to provide AF and/or OIS functionality, as previously discussed.

(38) Image sensor assembly **106** may further include passive heat exchanger **1002**. In this configuration, however, passive heat exchanger **1002** is formed into the interior side **102**A of enclosure **102**. For example, passive heat exchanger **1002** may be a heat sink that is directly below image sensor **122** and formed in the interior side **102**A of enclosure **102**. Representatively, the heat sink may include a number of pins or fins **1004** that are separated by spaces or channels **1006** formed in the interior side **102**A of enclosure **102**. For example, the pins or fins **1004** may have a pin-fin or straight-fin type heat sink arrangement. The pins or fins **1004** and channels **1006** may be formed within the enclosure **102** by a metal forming process. Since the heat sink **1002** is positioned below image sensor **122**, heat emitted from image sensor **122** will reach heat sink **1002** and be transferred away from image sensor **122** to the enclosure **102**. The increased surface area created by the pins or fins **1004** will help to transfer the heat generated by the image sensor **122** to the enclosure **102**.

(39) Referring now to FIG. **11**, FIG. **11** illustrates an example computer system that may include a camera, in accordance with aspects disclosed herein. Representatively, FIG. **11** illustrates an example computer system **1100** that may include one or multiple features, components, and/or functionality of the aspects described herein with reference to FIGS. **1-10**. The computer system **1100** may be configured to execute any or all of the aspects described herein. In some aspects, computer system **1100** 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, 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.

(40) Various aspects of a camera system as described herein, including aspects for actuating the camera system using a voice coil motor, as described herein may be executed in one or more computer systems **1100**, which may interact with various other devices. Note that any component, action, or functionality described above with respect to FIGS. **1-10** may be implemented on one or more computers configured as computer system **1100** of FIG. **11**. Representatively, computer system **1100** may include one or more processors **1110** coupled to a system memory **1120** via an input/output (I/O) interface **1130**. Computer system **1100** may further include a network interface **1140** coupled to I/O interface **1130**, and one or more input/output devices **1150**, such as cursor control device **1160**, keyboard **1170**, and display(s) **1180**. In some cases, it is contemplated that aspects may be implemented using a single instance of computer system **1100**, while in other embodiments multiple such systems, or multiple nodes making up computer system **1100**, may be configured to host different portions or instances of aspects disclosed herein. For example, in one aspect, some elements may be implemented via one or more nodes of computer system **1100** that are distinct from those nodes implementing other elements.

(41) In various aspects, computer system **1100** may be a uniprocessor system including one processor **1110**, or a multiprocessor system including several processors **1110** (e.g., two, four, eight, or another suitable number). Processors **1110** may be any suitable processor capable of executing instructions. For example, in various aspects, processors **1110** 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 **1110** may commonly, but not necessarily, implement the same ISA.

(42) System memory **1120** may be configured to store camera control program instructions **1122** and/or camera control data accessible by processor **1110**. In various aspects, system memory **1120** 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. In the illustrated aspect, program instructions **1122** may be configured to implement a lens control application **1124** incorporating any of the functionality described above. Additionally, existing camera control data **1132** of memory **1120** may include any of the information or data structures described above. In some aspects, program instructions and/or data may be received, sent or stored upon different types of computer-accessible media or on similar media separate from system memory **1120** or computer system **1100**. While computer system **1100** is described as implementing the functionality of functional blocks of previous Figures, any of the functionality described herein may be implemented via such a computer system.

(43) In one aspect, I/O interface **1130** may be configured to coordinate I/O traffic between processor **1110**, system memory **1120**, and any peripheral devices in the device, including network interface **1140** or other peripheral interfaces, such as input/output devices **1150**. In some embodiments, I/O interface **1130** may perform any necessary protocol, timing or other data transformations to convert data signals from one component (e.g., system memory **1120**) into a format suitable for use by another component (e.g., processor **1110**). In some embodiments, I/O interface **1130** 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 aspects, the function of I/O interface **1130** 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 **1130**, such as an interface to system memory **1120**, may be incorporated directly into processor **1110**.

(44) Network interface **1140** may be configured to allow data to be exchanged between computer system **1100** and other devices attached to a network **1185** (e.g., carrier or agent devices) or between nodes of computer system **1100**. Network **1185** 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 **1140** 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.

(45) Input/output devices **1150** may, in some aspects, 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 **1100**. Multiple input/output devices **1150** may be present in computer system **1100** or may be distributed on various nodes of computer system **1100**. In some aspects, similar input/output devices may be separate from computer system **1100** and may interact with one or more nodes of computer system **1100** through a wired or wireless connection, such as over network interface **1140**.

(46) As shown in FIG. **11**, memory **1120** may include program instructions **1122**, which may be processor-executable to implement any element or action described above. In one embodiment, the program instructions may implement the methods described above. In other embodiments, different elements and data may be included. Note that data may include any data or information described above.

(47) Those skilled in the art will appreciate that computer system **1100** 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 **1100** 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.

(48) While certain aspects have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad disclosure, and that the disclosure is not limited to the specific constructions and arrangements shown and described, since various other modifications may occur to those of ordinary skill in the art. The description is thus to be regarded as illustrative instead of limiting. For example, although the drawings illustrate a combination of aspects and elements, any one or more of the aspects or elements may be optional and/or combined with aspects or elements from other drawings. In addition, to aid the Patent Office and any readers of any patent issued on this application in interpreting the claims appended hereto, applicants wish to note that they do not intend any of the appended claims or claim elements to invoke 35 U.S.C. 112(f) unless the words “means for” or “step for” are explicitly used in the particular claim.

Claims

1. A camera comprising: a camera enclosure; an optomechanical assembly fixedly coupled to the camera enclosure; an image sensor assembly movably coupled to the camera enclosure, the image sensor assembly comprising: a substrate, an image sensor coupled to the substrate, a flexible printed circuit board coupled to the substrate, a conductive stiffener plate coupled to the flexible printed circuit board, and a passive heat exchanger comprising a thermally conductive gel contacting the image sensor and the conductive stiffener plate to form a conductive pathway that dissipates heat away from the image sensor.
2. The camera of claim 1 wherein the passive heat exchanger contacts a bottom side of the image sensor and a top side of the conductive stiffener plate.
3. A camera image sensor assembly comprising: a substrate movably coupled to a camera enclosure; an image sensor coupled to the substrate and having a bottom side suspended over an interior side of the camera enclosure; a flexible printed circuit board coupled to the substrate; a stiffener plate coupled to the flexible printed circuit board; and a passive heat exchanger comprising a thermally conductive gel contacting the image sensor and the stiffener plate to dissipate heat away from the image sensor.
4. The camera image sensor assembly of claim 3 wherein the stiffener plate comprises a conductive portion that at least partially overlaps the bottom side of the image sensor and the thermally conductive gel is positioned between the conductive portion of the stiffener plate and the bottom side of the image sensor.