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Kuo et al.

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(54) **OPTICAL SENSING SYSTEM AND ASSOCIATED ELECTRONIC DEVICE**

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H04B 10/40	(2013.01)
A61B 5/00	(2006.01)

(52) **U.S. Cl.**

CPC ***A61B 5/02427*** (2013.01); ***A61B 5/721*** (2013.01); ***H04B 10/40*** (2013.01)

(58) **Field of Classification Search**

CPC A61B 5/02416; A61B 5/02427; A61B 5/02433; A61B 5/721

See application file for complete search history.

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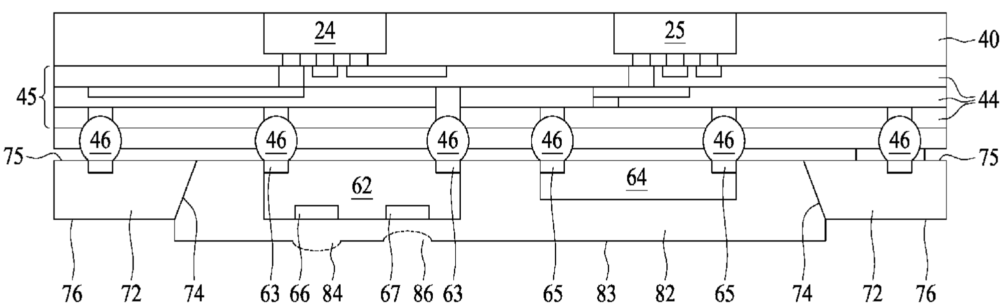
(57) **ABSTRACT**

An optical sensing system is disclosed. The optical sensing system includes a printed circuit board (PCB), a supporter and an optical sensor. The PCB includes a top surface, a bottom surface and a through cavity, wherein the through cavity extends downwardly from the top surface to the bottom surface. The supporter has a top surface and a bottom surface. The optical sensor is bonded and coupled to the top surface of the supporter, wherein the optical sensor includes a primary optic structure. Wherein the supporter is flipped over and bonded to the PCB with the top surface facing the through cavity, so that the optical sensor is coupled to the PCB and at least partially extends to the through cavity. Associated electronic devices are also disclosed.

20 Claims, 16 Drawing Sheets



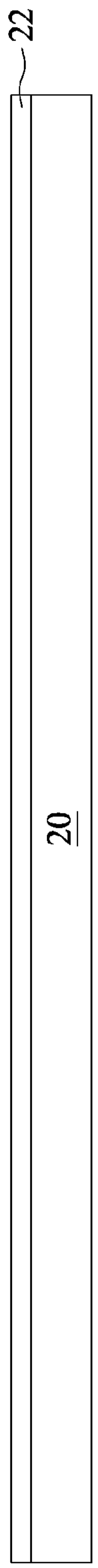


FIG. 1

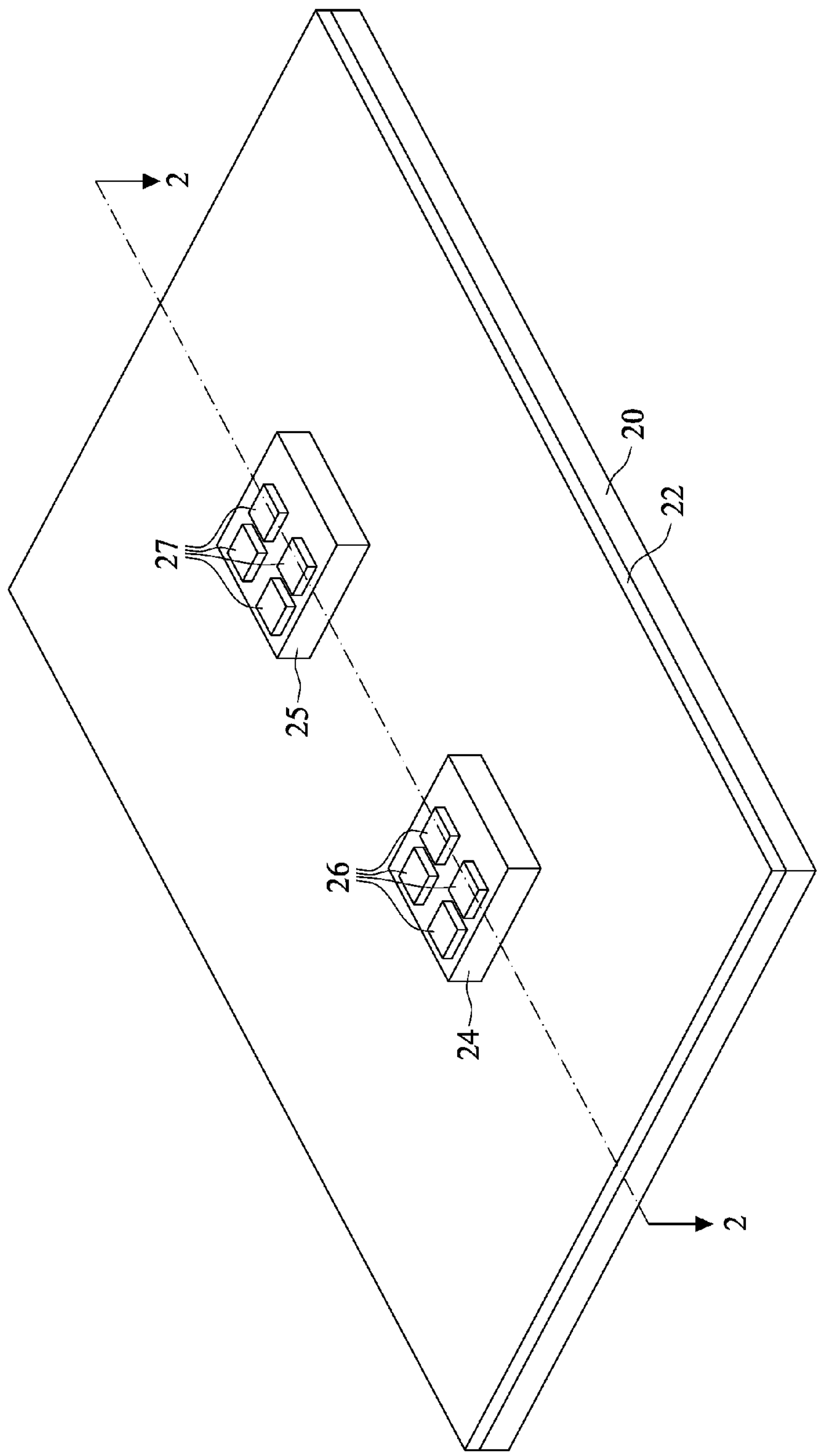


FIG. 2A

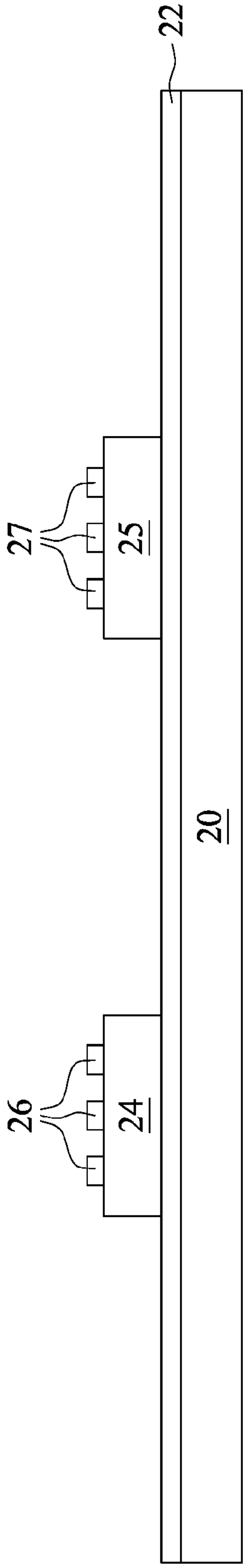


FIG. 2B

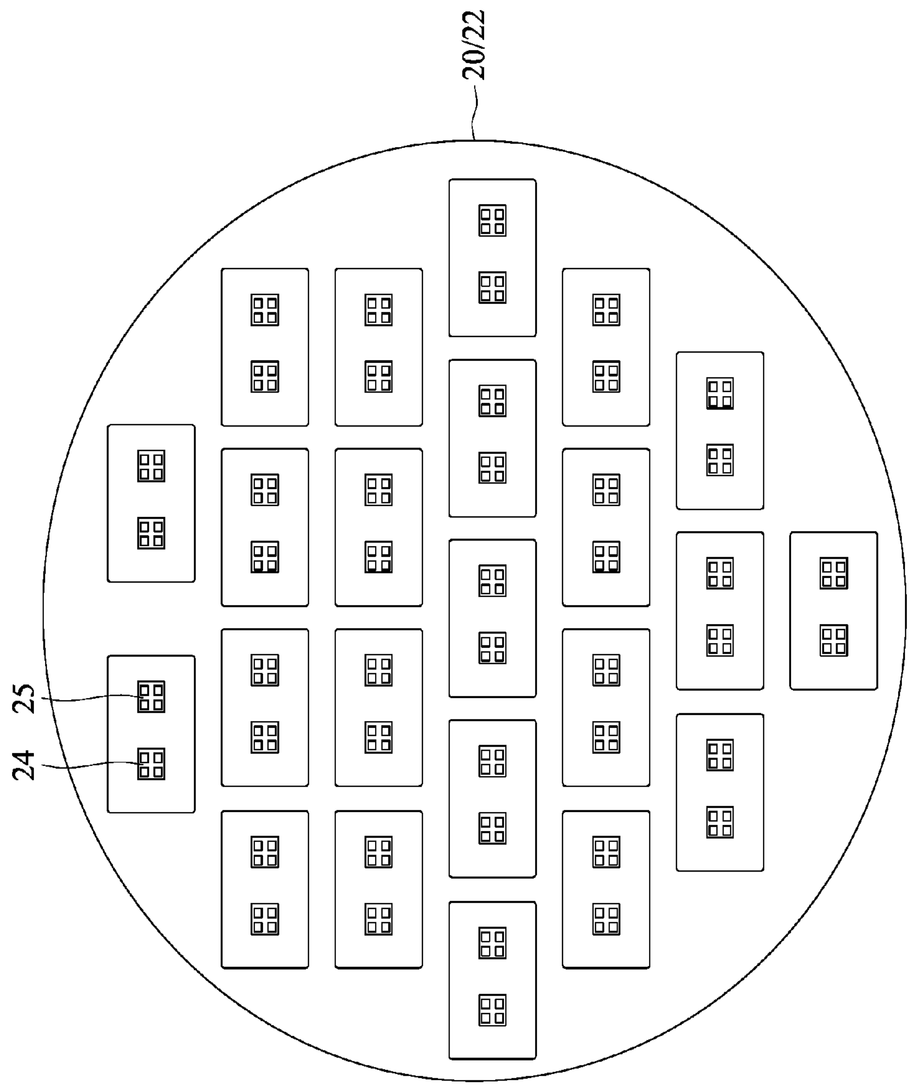


FIG. 2C

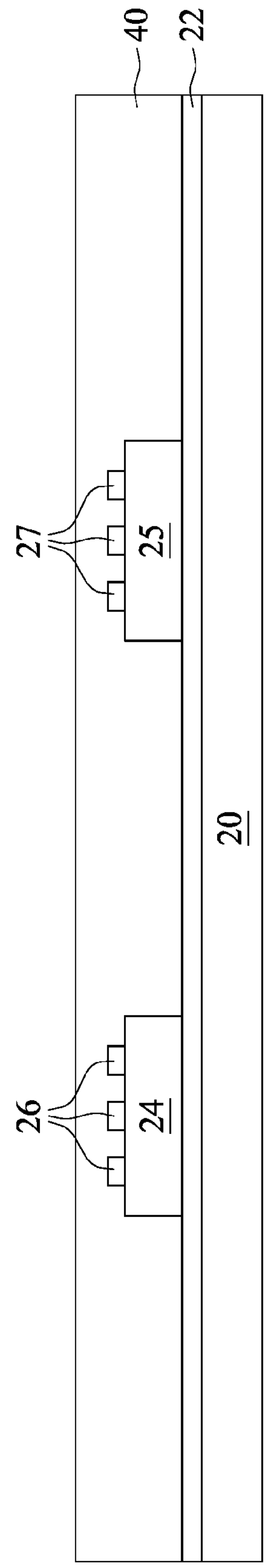


FIG. 3

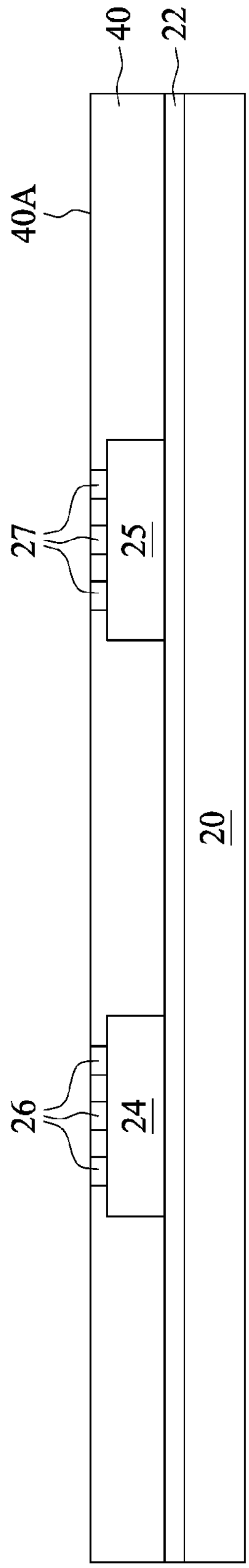


FIG. 4

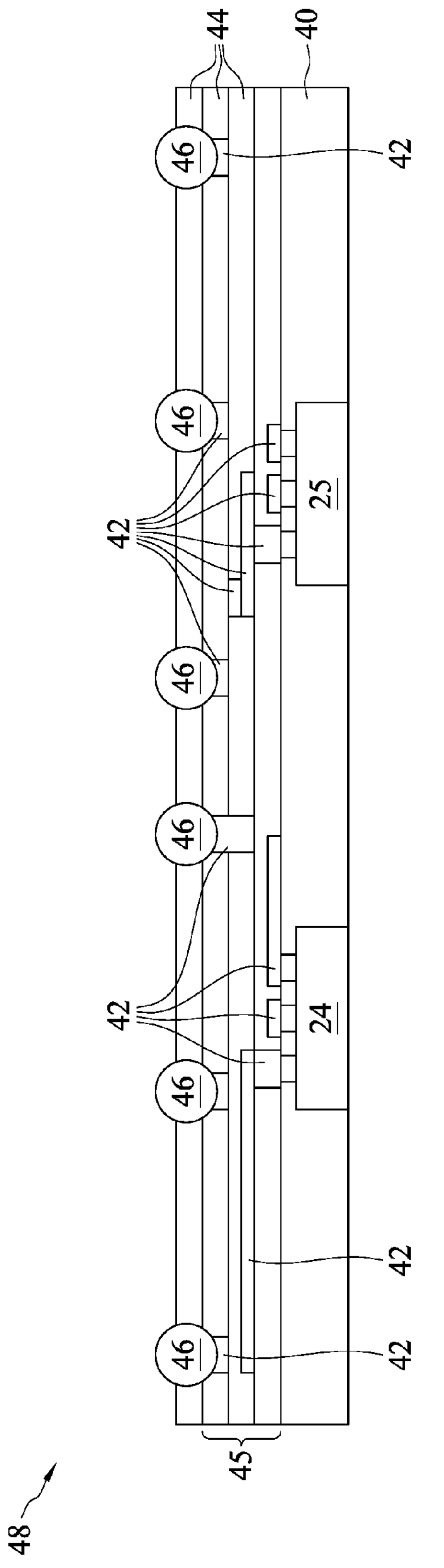


FIG. 5

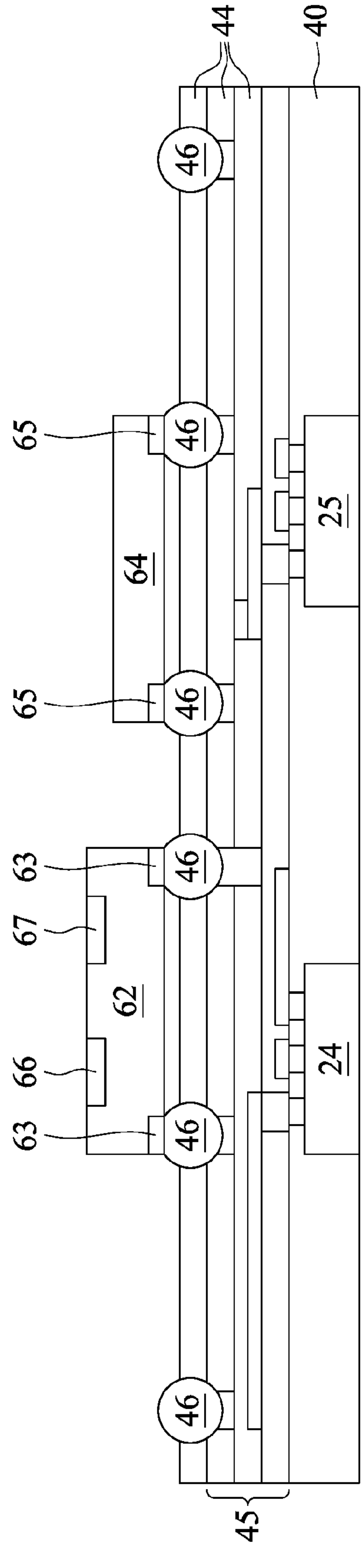


FIG. 6

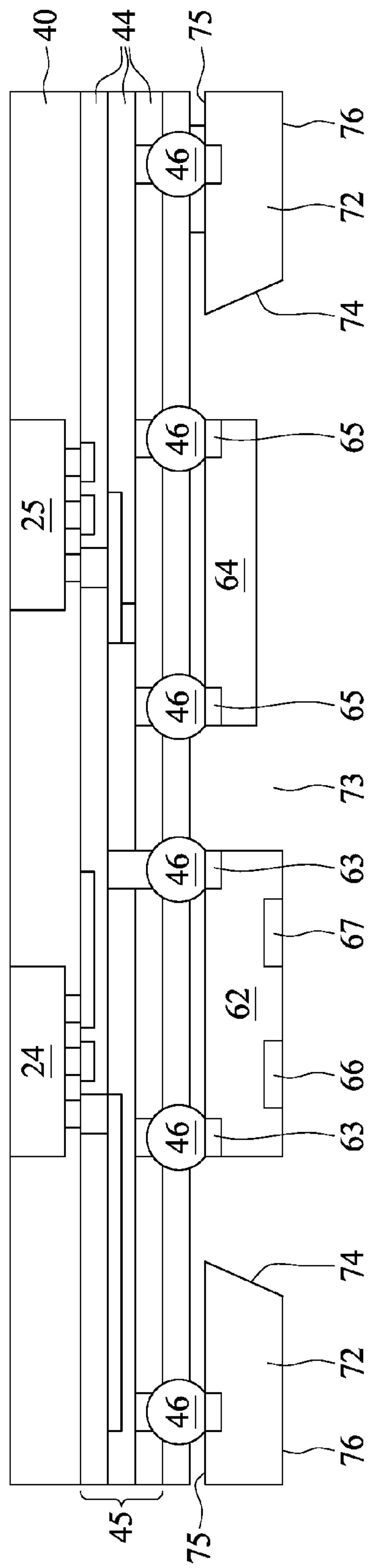

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FIG. 7

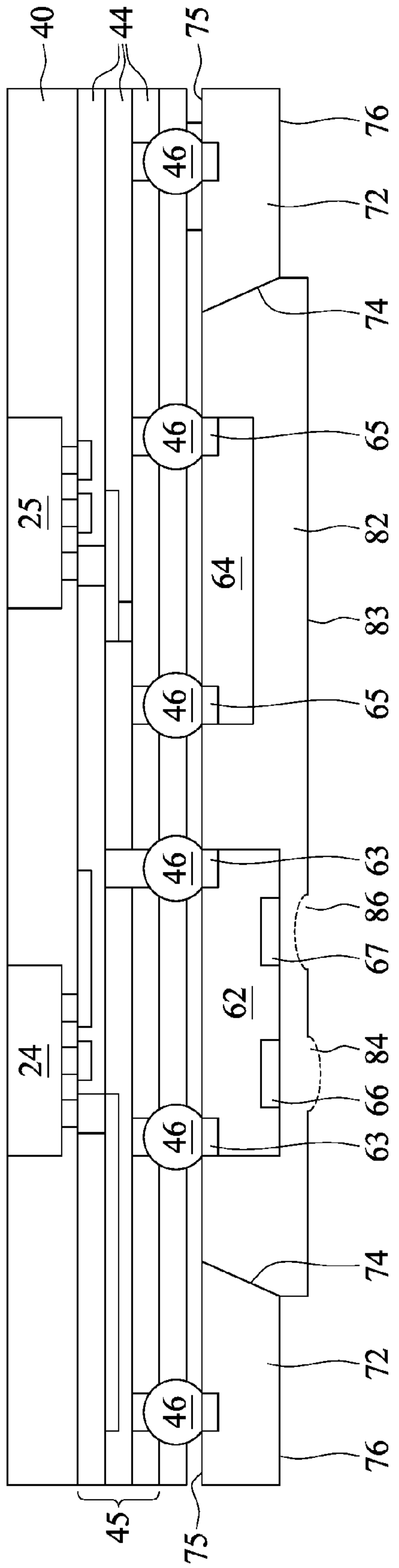

FIG. 8

FIG. 9

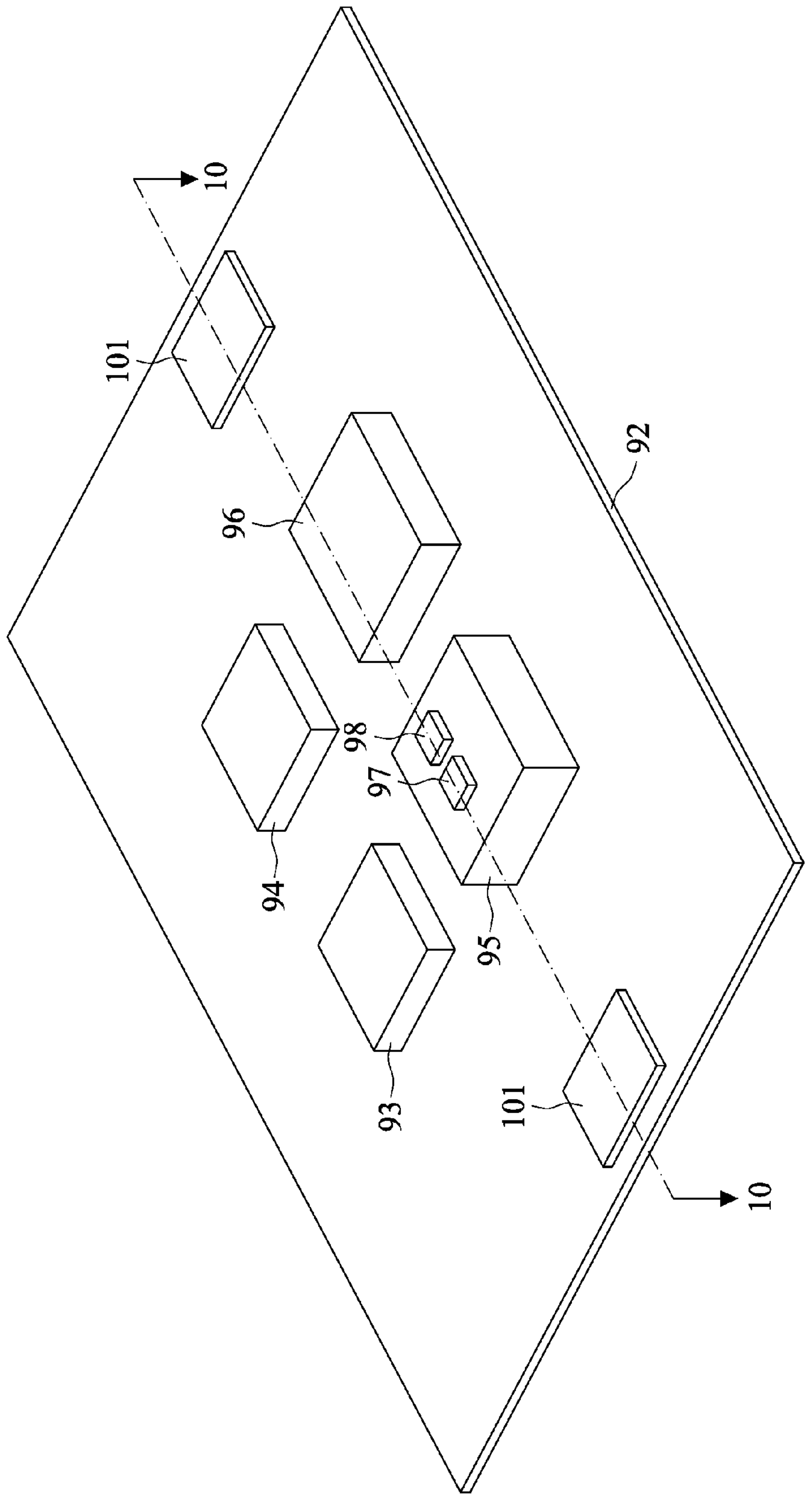

FIG. 10

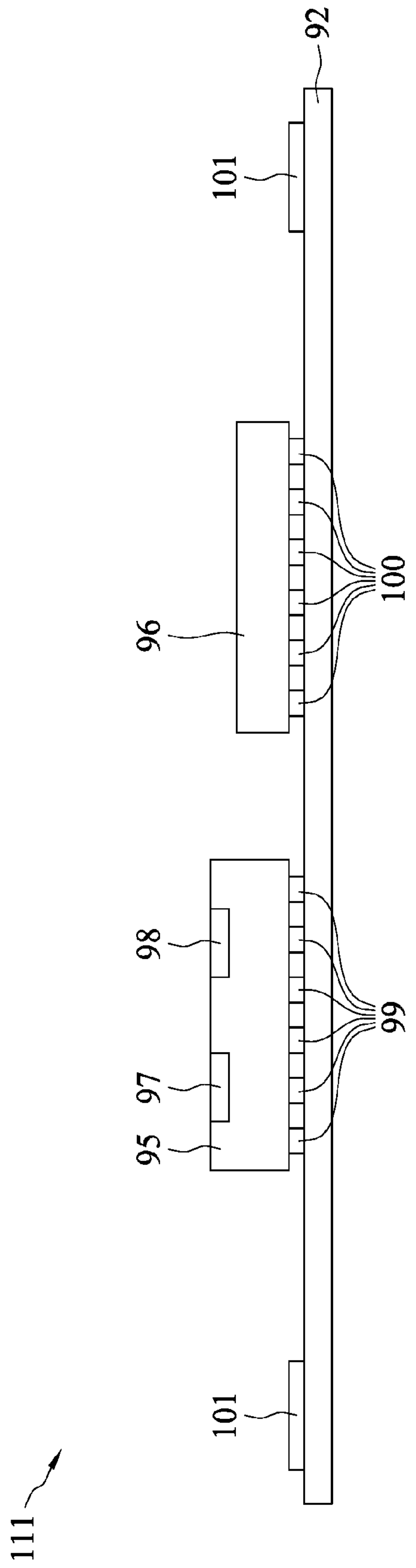

FIG. 11

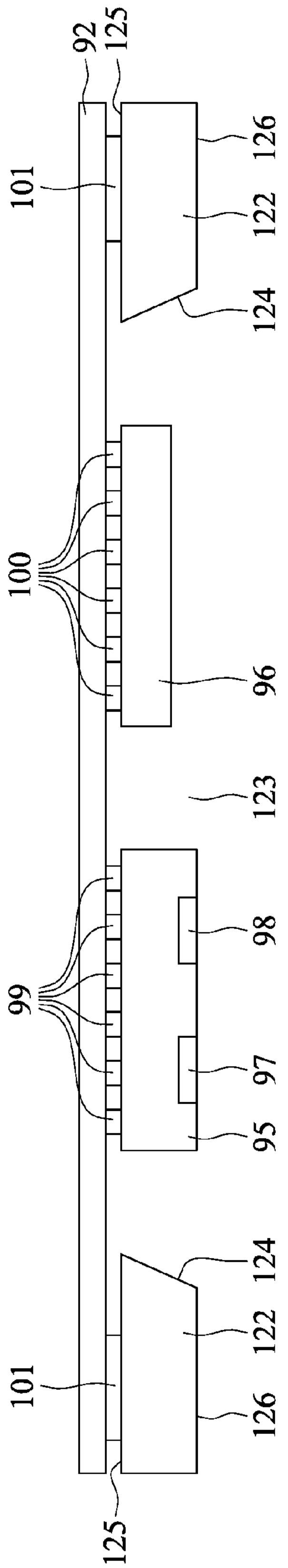

FIG. 12

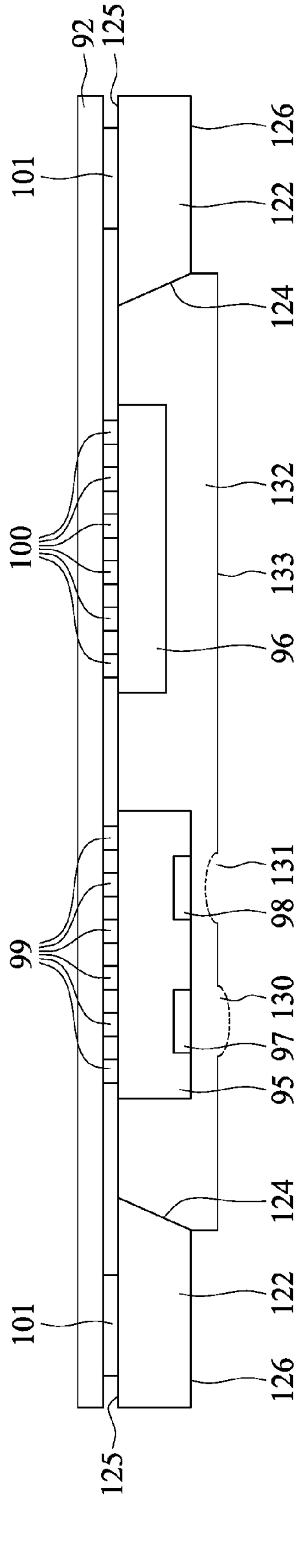
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FIG. 13

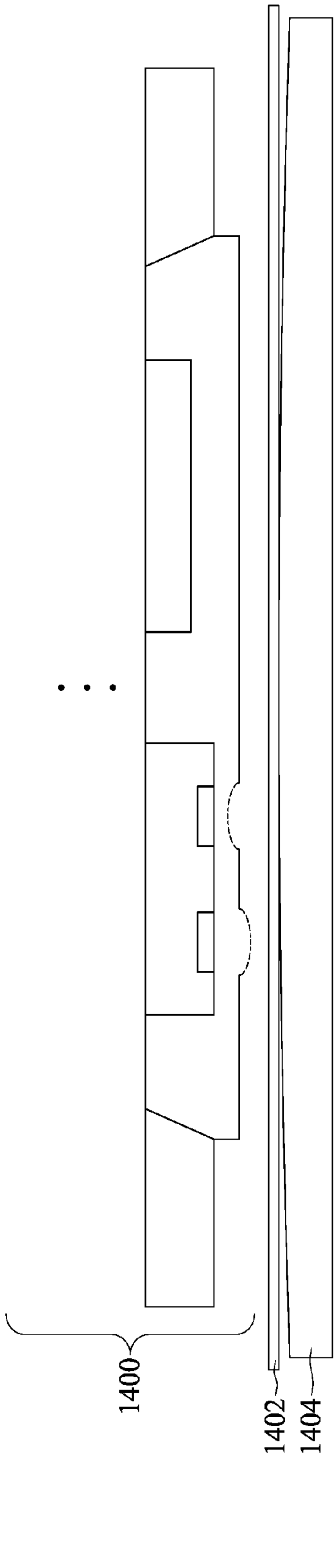

FIG. 14

OPTICAL SENSING SYSTEM AND ASSOCIATED ELECTRONIC DEVICE

BACKGROUND

Photoplethysmography (PPG) is a technology for measuring physiological parameters by shining light at a specific wavelength into the body and measuring the return signal (either through an extremity such as a finger or from reflections of the body). Unfortunately, PPGs are very sensitive to noise and cannot distinguish between the different factors including heart rate, breath rate and body motion, affecting the blood flow.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIGS. **1** through **8** are schematic views illustrating intermediate stages in the manufacturing of an optical sensing system in accordance with some exemplary embodiments of the present disclosure;

FIGS. **9** through **13** are schematic views illustrating intermediate stages in the manufacturing of an optical sensing system in accordance with some exemplary embodiments of the present disclosure; and

FIG. **14** is a cross-sectional view illustrating the integration of an optical sensing system into an electronic device in accordance with some exemplary embodiments.

DETAILED DESCRIPTION

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

Further, spatially relative terms, such as "beneath," "below," "lower," "above," "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. The spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. The apparatus may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly.

Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the disclosure are

approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviation found in the respective testing measurements. Also, as used herein, the term "about" generally means within 10%, 5%, 1%, or 0.5% of a given value or range. Alternatively, the term "about" means within an acceptable standard error of the mean when considered by one of ordinary skill in the art. Other than in the operating/working examples, or unless otherwise expressly specified, all of the numerical ranges, amounts, values and percentages such as those for quantities of materials, durations of times, temperatures, operating conditions, ratios of amounts, and the likes thereof disclosed herein should be understood as modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the present disclosure and attached claims are approximations that can vary as desired. At the very least, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Ranges can be expressed herein as from one endpoint to another endpoint or between two endpoints. All ranges disclosed herein are inclusive of the endpoints, unless specified otherwise.

In the present disclosure, an optical sensing system is presented. In an exemplary embodiment, the optical sensing system includes at least a sensor electrically connected to a printed circuit board (PCB), wherein a cavity of the PCB accommodates at least a portion of the sensor, and a secondary optical lens is formed on a material filling and encompassing gaps between the PCB cavity and the sensor. The compact optical sensing system allows for a reduced form factor of final products and provides for cost effective solution applicable to various optical sensing purposes. The intermediate stages of forming the optical sensing system are illustrated. The variations of the embodiments are discussed. Throughout the various views and illustrative embodiments, like reference numbers are used to designate like elements.

FIGS. **1** through **8** are schematic views illustrating intermediate stages in the manufacturing of an optical sensing system in accordance with some exemplary embodiments of the present disclosure. FIG. **1** is a cross-sectional view illustrating a carrier **20**, and an adhesive layer **22** on the carrier **20**. The carrier **20** may be a glass carrier, a ceramic carrier, or the like. The adhesive layer **22** may be formed of an adhesive such as an adhesive film.

FIG. **2**A is a three-dimensional perspective view illustrating the placement of dies **24** and **25** over the carrier **20**. The die **24** is placed over the carrier **20** by the side of the die **25**. In some embodiments, the dies **24** and **25** are attached to the adhesive layer **22**, which is adhered to the carrier **20**. The dies **24** and **25** may be a logic device die including logic transistors therein. The die **24** may include power management integrated circuits (PMICs) specifically designed to manage the power consumption of a system. In particular, a PMIC may process the raw voltage from a power supply, such as a battery, and in turn supply regulated voltages to drive a plurality of off-chip power consumption entities separate from the PMIC. A typical PMIC may include many high-power on-chip modules for driving off-chip power consumption entities, such as switched-mode battery chargers (SMBC's), back light display drivers (WLED's), buck regulators, audio amplifiers, and flash LED drivers. The on-chip modules may dissipate considerable power when processing power to or from the off-chip entities. The die **25** may include a microcontroller unit (MCU). The MCU is a computer with a smaller scale on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals.

Electrical connectors **26** and **27** are formed as the top portions of the die **24** and die **25** respectively, and are electrically coupled to the PMICs in the die **24** and the MCU in the die **25**. In some embodiments, the electrical connectors **26** and **27** include metal pillars (such as copper pillars), which may be pre-formed before the device die **24** and die **25** are placed over the carrier **20**. The metal pillars may be solder-free, and may comprise vertical walls. In some embodiments, dielectric layers are formed at the top surfaces of the die **24** and die **25**, with metal pillars having at least lower portions, or entireties, in the dielectric layer. The top surfaces of the dielectric layers may also be substantially level with the top ends of the electrical connectors **26** and **27**. The dielectric layers may be comprised of polyimide, polybenzoxazole (PBO), an oxide layer, a nitride layer, or multi-layers thereof. When the dielectric layers are not formed, the metal pillars protrude above the top surfaces of the die **24** and die **25**. In this embodiment, the dielectric layers are not depicted in the FIG. **2**A and subsequent drawings.

FIG. **2**B is a cross-sectional view illustrating the placement of the dies **24** and **25** over the carrier **20** taken along the lines **2-2** of FIG. **2**A. The dies **24** and **25** are attached to the adhesive layer **22**, which is adhered to the carrier **20**. The thicknesses of the dies **24**, **25** and the heights of electrical connectors **26** and **27** are controlled so that the top ends of the metal pillars of the dies **24** and **25** are substantially level with each other. Furthermore, since the dies **24** and **25** are placed on the adhesive **22**, the back surfaces of the dies **24** and **25** are level with each other.

FIG. **2**C illustrates a top view of the structure in FIGS. **2**A and **2**B. In some embodiments, the placement of the dies **24** and **25** is at a wafer level, and hence there are a plurality of dies **24** and **25** placed over the carrier **20**. FIG. **2**C illustrates that the carrier **20** has a round top-view shape. In alternative embodiments, the carrier **20** may also have a rectangular top-view shape, and the die **24** and die **25** may be laid out as an array. In FIG. **2**C, the rectangles (not marked) encircling each groups of the dies **24** and **25** define boundaries of the respective packages formed in subsequent steps.

Referring to FIG. **3**, a molding material **40** is dispensed and molded on the dies **24** and **25**. The molding material **40** fills the gaps between the dies **24** and **25**, and may be in contact with the adhesive layer **22**. Furthermore, the molding material **40** may be filled into the gaps between the electrical connectors **26** and **27** if the dielectric layers are not formed on the top surface of the dies **24** and **25**. The molding material **40** is comprised of a polymer in some embodiments. For example, the molding material **40** may include a molding compound, a molding underfill, an epoxy, or a resin. A top surface of the molding material **40** is higher than the top ends of the electrical connectors **26** and **27**. The bottom surface of the molding material **40** is substantially level with the back surfaces of the dies **24** and **25**. After being dispensed, the molding material **40** is cured.

Next, a planarization step, which may be a grinding step or a Chemical Mechanical Polish (CMP) operation, is performed to thin the molding material **40**. The planarization step may be completed until the top ends of the electrical connectors **26** and **27** are exposed. The resulting structure is shown in FIG. **4**. The top ends of the electrical connectors **26** and **27** in the dies **24** and **25** are level with each other, and are level with a top surface **40**A of the molding material **40**. In some embodiments in which no dielectric layer is formed, the molding material **40** encircles, and is in contact with, each of the electrical connectors **26** and **27**. In alternative embodiments in which the dielectric layers are formed, the top ends of the electrical connectors **26** and **27** are level with each other, and are substantially level with the surfaces of the dielectric layers and the top surface **40**A of the molding material **40**.

Next, referring to FIG. **5**, a redistribution layer (RDL) **45** is formed over the molding material **40**. The RDL **45**, sometimes also referred to as a re-distribution line, includes dielectric layers **44** and a plurality of connection patterns **42** reside therein. At least a portion of the connection patterns **42** is electrically connected to, and may interconnect, the electrical connectors **26** and **27**. There may be one, two, three, or more dielectric layers **44**, each including a plurality of connection patterns **42** at the same level. The connection patterns **42** further include vias that interconnect the connection patterns in neighboring redistribution layers. The connection patterns **42** in the bottom redistribution layer and the respective dielectric layer **44** have a bottom surface in contact with the top ends of the electrical connectors **26** and **27** and the top surface **40**A of the molding material **40**. In some embodiments, the RDL **45** are formed by forming and patterning the dielectric layers **44**, and forming the connection patterns **42** in the openings in the patterned dielectric layers **44**. In alternative embodiments, the RDL **45** is formed by depositing metal layers, patterning the metal layers, and filling the gaps between the connection patterns **42** with the dielectric layers **44**. In yet alternative embodiments, the RDL **45** may be formed using damascene processes. The RDL **45** may be comprised of copper, nickel, palladium, aluminum, tungsten, or the like. The dielectric layers **44** may comprise photo-sensitive materials such as polyimide, PBO, or the like, which may be patterned without using additional photo resists. The dielectric layers **44** may also be formed of a non-organic material or materials such as oxides and/or nitrides.

FIG. **5** also illustrates the formation of electrical connectors **46** in accordance with some exemplary embodiments. The formation of the connectors **46** may include placing solder balls on exposed portions of the connection patterns **42**, and reflowing the solder balls. In alternative embodiments, the formation of the connectors **46** includes performing a plating step to form copper or solder regions over the exposed portions of the connection patterns **42**. The connectors **46** may also include metal pillars, or metal pillars and solder caps, which may also be formed through plating. In some embodiments, the combined structure including the dies **24**, **25**, the molding material **40**, the overlying RDL **45** and the connectors **46** is referred to as an Integrated Fan Out (InFO) assembly or a fan-out package **48**. The carrier **20** is detached from the package **48** and the adhesive layer **22** may be removed in the subsequent operations. The fan-out package **48** occupies a portion of a wafer that includes a plurality of fan-out packages, and the wafer is die-sawed along scribe lines into a plurality of fan-out packages.

FIG. **6** is a cross-sectional view illustrating the placement of sensors **62** and **64** over the fan-out package **48** in accordance with some exemplary embodiments. In this embodiment, the sensor **62** may be a measuring device designed for measuring heart rate, i.e. an optical heart rate sensor. The optical heart rate sensor **62**, for example, is employed to improve physical and mental condition efficiently and safely. The user can employ an optical heart rate sensor **62** to monitor his heart rate level during exercising, for example, and avoid excessive stress. An optical heart rate sensor can also be utilized in slimming since it has been scientifically shown that the most efficient way to burn fat stored in the body is to exercise at a given heart rate (about 55 to 65%) of a person's maximum heart rate. An example optical heart rate sensor has more than one light emitting diode that provides light source projected to skin through a lens element **66**. An optical detector mounted close to the light source can detect the movement of blood under the skin of the wrist based on light reflected from the skin. The optical detector can detects blood movement by receiving a portion of the emitting light through a lens element **67**. The portion of the emitting light can be the initial light emitted by the light emitting diodes subtracted by an amount absorbed by skin. The lens elements **66** and **67** may be referred to as the first or primary optic as well.

The sensor **64** may be a motion sensor for correcting artifacts sensed by the optical heart rate sensor **62** due to user's motion. The motion sensor **64** may be a MEMS-based multi-dimensional accelerometer. For example, the motion sensor **64** may be a three dimensional accelerometer composed of three accelerometers disposed along ee orthogonal measurement axis and providing three dimensional acceleration data representative of the acceleration to which the device is subjected. The optical heart rate sensor **62** and motion sensor **64** may be bonded to fan-out package **48** by electrically connecting bond pads **63** and **65** to the electrical connectors **46**.

FIG. **7** is a cross-sectional view illustrating the bonding of fan-out package **48** onto a PCB **72** in accordance with some exemplary embodiments. As shown in FIG. **7**, the fan-out package **48** with the optical heart rate sensor **62** and motion sensor **64** bonded thereto is directly mounted onto a PCB **72** using a flip-chip technique through the electrical connectors **46**. The PCB **72** includes a continuous cavity **73** defined by a sidewall **74** of the PCB **72**. The continuous cavity **73** provides a space for accommodating the optical heart rate sensor **62** and motion sensor **64** bonded to the fan-out package **48**. In this embodiment, the continuous cavity **73** is a through cavity, which extends downwardly from a top surface **75** to a bottom surface **76** of the PCB **72** as shown in FIG. **7**.

A dimension of the through cavity **73** may be determined according to a dimension of the optical heart rate sensor **62** and motion sensor **64** that extends into the through cavity **73** of the PCB **72**. As a consequence, the entire optical sensing system including the fan-out package **48**, the optical heart rate sensor **62**, the motion sensor **64** and the PCB **72** can have a compact form factor which is thinner. When the optical sensing system is integrated into a device, such as a wrist watch including a heart rate measurement function, the thinner optical sensing system allow for a reduced thickness of the wrist watch. In addition, a distance between user's skin and the primary optic of the optical heart rate sensor **62** may be incidentally reduced through the optical sensing system shown in FIG. **7**, thereby improving the accuracy and sensitivity of the optical sensing system. In order to receive more light reflected from user's skin, the sidewall **74** of cavity **73** of the PCB **72** may be intentionally tilted toward the bottom surface **76**. However, this is not a limitation of the present disclosure. In some embodiments, the sidewall **74** of cavity **73** of the PCB **72** may be perpendicular to the top surface **75** and the bottom surface **76**.

In order to further enhance performance of the optical sensing system, a secondary optic structure may be employed. FIG. **8** is a cross-sectional view illustrating the forming of a secondary optic **82** onto the primary optic of the optical heart rate sensor **62** in accordance with some exemplary embodiments. In accordance with the present disclosure, different categories or types of secondary optics **82** may be used to apply optical properties of the underlying construction material and incorporate different specialized geometries that turn the primary optic of the optical heart rate sensor **62** into a more useful one. The secondary optics **82** includes a convex structure **84** protruding from a bottom surface **83** of the secondary optics **82**. When the light is emitted from the light source, the concave structure **86** can receive the light reflected from the skin. A central point of the convex structure **84** is located at a pathway that a perpendicular light emitted from the light source behind the lens element **66** passes through in order to more evenly distribute emitted light on user's skin. The secondary optics **82** further includes a concave structure **86** recessed into the bottom surface **83** of the secondary optics **82**. A central point of the concave structure **86** is located at a pathway that a perpendicular light reflected from the skin passes through in order to increase total amount of incident light for the lens element **67**.

The convex structure **84** and concave structure **86** may be formed on a material filling and encompassing gaps between the PCB cavity **73** and the optical heart rate sensor **62** and the motion sensor **64** as shown in FIG. **8**. The material may be comprised of any polymers including Polycarbonate (PC), Polyethylene terephthalate Resin (PET) and Polymethylmethacrylate (PMMA), and glass. Moreover, the bottom surface **83**, the convex structure **84** and the concave structure **86** can be fabricated by using single molding process to simplify manufacturing process and save cost. In some embodiments, a distance between the primary optics and the secondary optics, or for example, a distance between a light emitting diode and the convex lens is designed to be about 500 micrometer in order to retain the compactness of the package.

In some embodiments, the concept of the present disclosure may be reflected in an optical sensing system having a more generic structure. FIGS. **9** through **13** are schematic views illustrating intermediate stages in the manufacturing of an optical sensing system in accordance with some exemplary embodiments of the present disclosure. FIG. **9** is a cross-sectional view illustrating a PCB **92**. The PCB **92** shown in FIG. **9** is similar to that in FIG. **8**.

FIG. **10** is a three-dimensional perspective view illustrating the placement of dies **93-96** over the PCB **92**. The dies **93-96** may be placed over the PCB **92** side by side as shown in FIG. **10**. In some embodiments, the dies **93-96** may be placed over the PCB **92** in other arrangements. The dies **93-96** may be bonded and electrically connected to the PCB **92** through bonding pads. In some embodiments, the PCB **92** may be replaced by any other types of carrier including conductive patterns therein. The dies **93** and **94** may be a logic device die including logic transistors therein. The die **93** may include power management integrated circuits (PMICs) specifically designed to manage the power consumption of a system. In particular, a PMIC may process the raw voltage from a power supply, such as a battery, and in turn supply regulated voltages to drive a plurality of off-chip power consumption entities separate from the PMIC. A typical PMIC may include many high-power on-chip modules for driving off-chip power consumption entities, such as switched-mode battery chargers (SMBC's), back light display drivers (WLED's), buck regulators, audio amplifiers, and flash LED drivers. The on-chip modules may dissipate considerable power when processing power to or from the off-chip entities. The die **94** may include a microcontroller unit (MCU). The MCU is a computer with a smaller scale on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals.

The die **95** may be a measuring device designed for measuring heart rate, i.e. an optical heart rate sensor. The optical heart rate sensor **95**, for example, is employed to improve physical and mental condition efficiently and safely. The user can employ an optical heart rate sensor **95** to monitor his heart rate level during exercising, for example, and avoid excessive stress. An optical heart rate sensor can also be utilized in slimming since it has been scientifically shown that the most efficient way to burn fat stored in the body is to exercise at a given heart rate (about 55 to 65%) of a person's maximum heart rate. An example optical heart rate sensor has two light emitting diodes that provide light source projected to skin through a lens element **97**. An optical detector mounted close to the light source can detect the movement of blood under the skin of the wrist based on light reflected from the skin. The optical detector can detects blood movement by emitting light onto skin and measuring the amount of light absorbed by skin through a lens element **98**. The lens elements **97** and **98** may be referred to as the first or primary optic as well.

The sensor **96** may be a motion sensor for correcting artifacts sensed by the optical heart rate sensor **95** due to user's motion. The motion sensor **96** may be a MEMS-based multi-dimensional accelerometer. For example, the motion sensor **96** may be a three dimensional accelerometer composed of three accelerometers disposed along three orthogonal measurement axis and providing three dimensional acceleration data representative of the acceleration to which the device is subjected. In FIG. **11**, the optical heart rate sensor **95** and motion sensor **96** may be bonded to the PCB **92** by electrically connecting bond pads **99** and **100** to conductive connectors the PCB **92** and forms a PCB bridge **111**.

FIG. **12** is a cross-sectional view illustrating the bonding of the PCB bridge **111** onto a PCB **122** in accordance with some exemplary embodiments. As shown in FIG. **12**, the flipped PCB bridge **111** with the optical heart rate sensor **95** and motion sensor **96** bonded thereto is directly mounted onto a PCB **122** through electrical connectors **101**. The PCB **122** includes a continuous cavity **123** defined by a sidewall **124** of the PCB **122**. The continuous cavity **123** provides a space for accommodating the optical heart rate sensor **95** and motion sensor **96** bonded to the PCB **92**. In this embodiment, the continuous cavity **123** is a through cavity, which extends downwardly from a top surface **125** to a bottom surface **126** of the PCB **122** as shown in FIG. **12**.

A dimension of the through cavity **123** may be determined according to a dimension of the optical heart rate sensor **95** and motion sensor **96** that extends into the through cavity **123** of the PCB **122**. As shown in FIG. **12**, the optical heart rate sensor **95** possesses a thickness greater than that of the motion sensor **96** and the dies **93**, **94** (see FIG. **10**), and thus the dimension of the through cavity **123** (i.e., a distance between the top surface **125** and a bottom surface **126** of the PCB **122**) is determined by the thickness-limiting element, i.e., the heart rate sensor **95**. In some embodiments, the dimension of the through cavity **123** can be from about 1 mm to about 1.2 mm. As a consequence, the entire optical sensing system including the PCB bridge **111** and the PCB **122** can have a compact form factor which is thinner. When the optical sensing system is integrated into a device, such as a wrist watch including a heart rate measurement function, the thinner optical sensing system allow for a reduced thickness of the wrist watch. In addition, a distance between user's skin and the primary optic of the optical heart rate sensor **95** may be incidentally reduced through the optical sensing system shown in FIG. **12**, thereby improving the accuracy and sensitivity of the optical sensing system. In order to receive more light reflected from user's skin, the sidewall **124** of cavity **123** of the PCB **122** may be intentionally tilted toward the bottom surface **126**. However, this is not a limitation of the present disclosure. In some embodiments, the sidewall **124** of cavity **123** of the PCB **122** may be perpendicular to the top surface **125** and the bottom surface **126**.

In order to further enhance performance of the optical sensing system, a secondary optic structure may be employed. FIG. **13** is a cross-sectional view illustrating the forming of a secondary optic **132** onto the primary optic of the optical heart rate sensor **95** in accordance with some exemplary embodiments. In accordance with the present disclosure, different categories or types of secondary optics **132** may be used to apply optical properties of the underlying construction material and incorporate different specialized geometries that turn the primary optic of the optical heart rate sensor **95** into a more useful one. The secondary optics **132** includes a convex structure **130** protruding from a bottom surface **133** of the secondary optics **132**. A central point of the convex structure **130** is located at a pathway that a perpendicular light emitted from the light source behind the lens element **97** passes through in order to more evenly distribute emitted light on user's skin. The secondary optics **132** further includes a concave structure **131** recessed into the bottom surface **133** of the secondary optics **132**. When the light is emitted from the light source, the concave structure **131** can receive the light reflected from the skin. A central point of the concave structure **131** is located at a pathway that a perpendicular light reflected from the skin passes through in order to increase total amount of incident light for the lens element **98**.

The convex structure **130** and concave structure **131** may be formed on a material filling and encompassing gaps between the PCB cavity **123** and the optical heart rate sensor **95** and the motion sensor **96** as shown in FIG. **12**. The material may be comprised of any polymers including Polycarbonate (PC), Polyethylene terephthalate Resin (PET) and Polymethylmethacrylate (PMMA), and glass. Moreover, the bottom surface **133**, the convex structure **130** and the concave structure **131** can be fabricated by using single molding process to simplify manufacturing process and save cost.

FIG. **14** is a cross-sectional view illustrating the integration of an optical sensing system into an electronic device in accordance with some exemplary embodiments. An optical sensing system **1400** may be the optical sensing system shown in FIG. **7**, **8**, **12** or **13**. The optical sensing system **1400** may be integrated into an electronic device, such as an electronic wrist watch or a heart rate monitor. The electronic device includes a housing, and a flat glass **1402** is located at a bottom surface of the housing. When a user wears the electronic device, the flat glass **1402** of the electronic device contacts with skin of the user **1404** so that the optical sensing system **1400** can obtain a sensing result through the flat glass **1402**. Since the secondary optic structure is embedded in the optical sensing system **1400**, the bottom surface of the electronic device can be simple and thin without too much further process on it. Please note that the flat glass **1402** may be replaced by any other flat transparent materials. For example, in some embodiments, the transparent material may be a flat sapphire glass.

Some embodiments of the present disclosure provide an optical sensing system, including: a printed circuit board

(PCB) including a top surface, a bottom surface and a through cavity, wherein the through cavity extends downwardly from the top surface to the bottom surface; a supporter having a top surface and a bottom surface; and an optical sensor bonded and coupled to the top surface of the supporter, wherein the optical sensor includes a primary optic structure; wherein the supporter is flipped over and bonded to the PCB with the top surface facing the through cavity, so that the optical sensor is coupled to the PCB and at least partially extends to the through cavity.

In some embodiments of the present disclosure, the optical sensing system further includes a secondary optic structure at least disposed over the primary optic structure of the optical sensor.

In some embodiments of the present disclosure, the secondary optic structure includes a convex structure located at a pathway that a perpendicular light emitted from a light source behind the primary optic structure passes through.

In some embodiments of the present disclosure, the secondary optic structure further includes a concave structure, and when light is emitted from the light source and bounces off an object, the concave structure receives light reflected from the object.

In some embodiments of the present disclosure, the secondary optic structure further fills and encompasses gaps between the through cavity and the optical sensor.

In some embodiments of the present disclosure, the optical sensor is a heart rate sensor.

In some embodiments of the present disclosure, the optical sensing system further includes a motion sensor bonded and coupled to the top surface of the supporter, and the motion sensor is at least partially extends to the through cavity.

In some embodiments of the present disclosure, the optical sensing system further includes a die bonded and coupled to the supporter, wherein the die includes a power management integrated circuits (PMICs) or a microcontroller unit (MCU).

In some embodiments of the present disclosure, the die is bonded and coupled to the top surface of the supporter.

In some embodiments of the present disclosure, a sidewall of the through cavity is tilted toward the bottom surface of the PCB.

Some embodiments of the present disclosure provide an optical sensing system, including: a printed circuit board (PCB) including a top surface, a bottom surface and a through cavity, wherein the through cavity extends downwardly from the top surface to the bottom surface; a chip package including a top surface and a bottom surface, wherein a plurality of electrical connectors is located at the bottom surface of the chip package; and an heart rate sensor bonded and coupled to the bottom surface of the chip package, wherein the heart rate sensor includes a primary optic structure, a light source and a photo diode; wherein the chip package is bonded to the PCB through the electrical connectors and with the bottom surface facing the through cavity, so that the heart rate sensor is coupled to the PCB and at least partially extends to the through cavity.

In some embodiments of the present disclosure, the optical sensing system further includes a secondary optic structure at least disposed over the primary optic structure of the heart rate sensor, wherein the secondary optic structure includes a convex structure and a concave structure.

In some embodiments of the present disclosure, the secondary optic structure further fills and encompasses gaps between the through cavity and the heart rate sensor.

In some embodiments of the present disclosure, the chip package is a fan-out package and includes a power management integrated circuit (PMIC) die and a microcontroller unit (MCU) die.

In some embodiments of the present disclosure, a sidewall of the through cavity is tilted toward the bottom surface of the PCB.

Some embodiments of the present disclosure provide an electronic device, including: a housing, including a flat transparent material at a bottom surface of the housing; and an optical sensing system of claim **1** disposed in the housing; wherein the optical sensor senses an object around the electronic device through the flat transparent material.

In some embodiments of the present disclosure, the flat transparent material is a flat glass.

In some embodiments of the present disclosure, the flat transparent material is a flat sapphire glass.

In some embodiments of the present disclosure, the electronic device is an electronic wrist watch or a heart rate monitor.

Some embodiments of the present disclosure provide an electronic device, including: a housing, including a flat transparent material at a bottom surface of the housing; and an optical sensing system of claim **11** disposed in the housing; wherein the optical sensor senses an object around the electronic device through the flat transparent material.

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

What is claimed is:

1. An optical sensing system, comprising:

a printed circuit board (PCB) comprising a top surface and a bottom surface;

a supporter having a first surface and a second surface opposite to the first surface;

an optic structure extending downwardly from the top surface through the bottom surface of the PCB; and

a sensor bonded and electrically coupled to the first surface of the supporter, the sensor including a light source, an optical detector, a first lens element and a second lens element, the light source being between the first lens element and the supporter, and the optical detector being between the second lens element and the supporter, wherein a width of the optic structure is greater than a width of the sensor;

wherein the supporter is bonded to the PCB with the first surface of the supporter facing the optic structure, so that the sensor and the PCB are at the same side of the supporter, the sensor is electrically coupled to the PCB through the supporter, and the sensor at least partially extends to the optic structure.

2. The optical sensing system of claim **1**, wherein the optic structure at least covering the first lens element and the second lens element of the sensor.

3. The optical sensing system of claim **2**, wherein the optic structure comprises a convex structure covering the first lens element, and the first lens element is between the convex structure and the light source.

4. The optical sensing system of claim **3**, wherein the optic structure further comprises a concave structure covering the second lens element, and the second lens element is between the concave structure and the optical detector.

5. The optical sensing system of claim **2**, wherein the optic structure further fills and encompasses spaces between the substrate and the optical sensor.

6. The optical sensing system of claim **1**, wherein the optical sensor is a heart rate sensor.

7. The optical sensing system of claim **1**, further comprising a motion sensor bonded and coupled to the first surface of the supporter, and the motion sensor is at least partially extends to the optic structure.

8. The optical sensing system of claim **1**, further comprising a die bonded and coupled to the supporter, wherein the die comprises a power management integrated circuits (PMICs) or a microcontroller unit (MCU).

9. The optical sensing system of claim **8**, wherein the die is bonded and coupled to the second surface of the supporter.

10. The optical sensing system of claim **1**, wherein a sidewall of the optic structure is tilted toward the bottom surface of the PCB.

11. An electronic device, comprising:

a housing, comprising a flat transparent material at a bottom surface of the housing; and

an optical sensing system disposed in the housing, the optical sensing system comprising:

a printed circuit board (PCB) comprising a top surface and a bottom surface;

a supporter having a first surface and a second surface opposite to the first surface;

an optic structure extending downwardly from the top surface through the bottom surface of the PCB; and

a sensor bonded and electrically coupled to the first surface of the supporter, the sensor including a light source, an optical detector, wherein a width of the optic structure is greater than a width of the sensor;

wherein the supporter is bonded to the PCB with the first surface of the supporter facing the optic structure, so that the sensor and the PCB are at the same side of the supporter, the sensor is electrically coupled to the PCB through the supporter, and the sensor at least partially extends to the optic structure;

wherein the sensor senses an object around the electronic device through the flat transparent material.

12. The electronic device of claim **11**, wherein the flat transparent material is a flat glass.

13. The electronic device of claim **11**, wherein the flat transparent material is a flat sapphire glass.

14. The electronic device of claim **11**, wherein the electronic device is an electronic wrist watch or a heart rate monitor.

15. An optical sensing system, comprising:

a substrate comprising a top surface and a bottom surface;

a chip package including a die, a redistribution layer (RDL) and a plurality of electrical connectors, the RDL being between the die and the electrical connectors;

an optical sensor bonded and electrically coupled to the electrical connectors, wherein the optical sensor comprises a primary optic structure; and

a secondary optic structure extending downwardly from the top surface through the bottom surface of the PCB, wherein a width of the secondary optic structure is greater than a width of the optical sensor;

wherein the chip package is bonded to the substrate through the electrical connectors, so that the optical sensor is electrically coupled to the substrate and the die and at least partially in the secondary optic structure.

16. The optical sensing system of claim **15**, wherein the secondary optic structure at least covering the primary optic structure of the optical sensor.

17. The optical sensing system of claim **16**, wherein the secondary optic structure comprises a convex structure.

18. The optical sensing system of claim **17**, wherein the secondary optic structure further comprises a concave structure.

19. The optical sensing system of claim **16**, wherein the secondary optic structure further fills and encompasses spaces between the substrate and the optical sensor.

20. The optical sensing system of claim **15**, wherein the optical sensor is a heart rate sensor.

* * * * *

patsnap

专利名称(译)	光学传感系统和相关的电子设备		
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摘要(译)

公开了一种光学传感系统。光学传感系统包括印刷电路板（PCB），支架和光学传感器。PCB包括顶表面，底表面和通腔，其中通腔从顶表面向下延伸到底表面。支架具有顶面和底面。光学传感器被结合并耦合到支撑件的顶表面，其中光学传感器包括主光学结构。其中支撑件翻转并粘合到PCB上，其顶表面面向通腔，使得光学传感器耦合到PCB并且至少部分延伸到通腔。还公开了相关的电子设备。