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IMAGE CAPTURING LENS SYSTEM

Abstract

An image capturing lens system includes a first lens having negative refractive power, a second lens having positive refractive power while having a convex object-side surface, a third lens having positive refractive power, a fourth lens having positive refractive power, a fifth lens having negative refractive power with a concave object-side surface and a concave image-side surface, and a sixth lens having positive refractive power.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. patent application Ser. No. 18/317,337 filed on May 15, 2023, which is a continuation of U.S. patent application Ser. No. 16/433,081 filed on Jun. 6, 2019, now U.S. Pat. No. 11,686,920 issued on Jun. 27, 2023, which claims the benefit under 35 USC 119 (a) of Korean Patent Application No. 10-2019-0000279 filed on Jan. 2, 2019, in the Korean Intellectual Property Office, the entire disclosures of which are incorporated herein by reference for all purposes.

BACKGROUND
1. Field
[0002] The following description relates to an image capturing lens system which may implement constant optical performance irrespective of temperature variations in a surrounding environment.
2. Description of Background
[0003] Since a typical surveillance camera, mounted in a vehicle, captures only a shape of a peripheral object, such a surveillance camera does not need to have high resolution. However, as an autonomous driving function has been added to a vehicle, there is demand for a lens system appropriate for a camera which may capture a distant object or may clearly capture a nearby object.
SUMMARY
[0004] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.
[0005] In one general aspect, an image capturing lens system includes a first lens having negative refractive power, a second lens having positive refractive power while having a convex object-side surface, a third lens having positive refractive power, a fourth lens having positive refractive power, a fifth lens having negative refractive power while having a concave object-side surface and a concave image-side surface, and a sixth lens having positive refractive power. The first to sixth lenses are sequentially disposed from an object side of the image capturing lens system.
[0006] The image capturing lens system may include a stop disposed between the second lens and the third lens.
[0007] One of the third to sixth lenses may be formed of glass.
[0008] The one lens formed of glass may have positive refractive power.
[0009] Among the first to sixth lenses, four or more lenses may be formed of plastic.
[0010] The image capturing lens system may satisfy $Gf/f<2.0$, where Gf is a focal length of the one lens formed of glass, and f is a focal length of the image capturing lens system.
[0011] The first lens may include a convex object-side surface.
[0012] The image capturing lens system may satisfy $0.7<BFL/S8S13$, where BFL is a distance from an image-side surface of the sixth lens to an imaging plane, and S8S13 is a distance from an object-side surface of the fourth lens to an image-side surface of the sixth lens.
[0013] The image capturing lens system may satisfy $D34<D23$ and $D45<D34$, where D23 is a

distance from an image-side surface of the second lens to an object-side surface of the third lens, D34 is a distance from an image-side surface of the third lens to the object-side surface of the fourth lens, and D45 is a distance from an image-side surface of the fourth lens to an object-side surface of the fifth lens.

[0014] In another general aspect, an image capturing lens system includes a first lens, a second lens, a stop, a third lens, a fourth lens, a fifth lens, and a sixth lens sequentially disposed from an object side of the image capturing lens system. The third lens or the fourth lens is formed of glass and the image capturing lens system satisfies $0.7<BFL/S8S13$, where BFL is a distance from an image-side surface of the sixth lens to an imaging plane, and S8S13 is a distance from an object-side surface of the fourth lens to an image-side surface of the sixth lens.

[0015] The first lens may have negative refractive power.

[0016] The third lens and the fourth lens may have positive refractive power.

[0017] The image capturing lens system may satisfy $f3/f<2.0$ and $f4/f<2.0$, where f is a focal length of the image capturing lens system, f3 is a focal length of the third lens, and f4 is a focal length of the fourth lens.

[0018] The second lens may include a convex image-side surface.

[0019] The image capturing lens system may satisfy $D34<D23$, where D23 is a distance from an image-side surface of the second lens to an object-side surface of the third lens, and D34 is a distance from an image-side surface of the third lens to the object-side surface of the fourth lens. The image capturing lens system may satisfy $D45<D34$, where D34 is a distance from an image-side surface of the third lens to the object-side surface of the fourth lens, and D45 is a distance from an image-side surface of the fourth lens to an object-side surface of the fifth lens. The third lens may include a concave object-side surface.

[0020] Other features and aspects will be apparent from the following detailed description, the drawings, and the claims.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0021] FIG. **1** illustrates a configuration of an image capturing lens system according to a first example.

[0022] FIG. **2** illustrates aberration curves of the image capturing lens system illustrated in FIG. **1**.

[0023] FIG. **3** illustrates MTF curves depending on temperature variations of the image capturing lens system illustrated in FIG. **1**.

[0024] FIG. **4** illustrates a configuration of an image capturing lens system according to a second example.

[0025] FIG. **5** illustrates aberration curves of the image capturing lens system illustrated in FIG. **4**.

[0026] FIG. **6** illustrates MTF curves depending on temperature variations of the image capturing lens system illustrated in FIG. **4**.

[0027] FIG. **7** illustrates a configuration of an image capturing lens system according to a third example.

[0028] FIG. **8** illustrates aberration curves of the image capturing lens system illustrated in FIG. **7**.

[0029] FIG. **9** illustrates MTF curves depending on temperature variations of the image capturing lens system illustrated in FIG. **7**.

[0030] FIG. **10** illustrates a configuration of an image capturing lens system according to a fourth example.

[0031] FIG. **11** illustrates aberration curves of the image capturing lens system illustrated in FIG. **10**.

[0032] FIG. **12** illustrates MTF curves depending on temperature variations of the image capturing

lens system illustrated in FIG. **10**.
[0033] FIG. **13** illustrates a configuration of an image capturing lens system according to a fifth example.
[0034] FIG. **14** illustrates aberration curves of the image capturing lens system illustrated in FIG. **13**.
[0035] FIG. **15** illustrates MTF curves depending on temperature variations of the image capturing lens system illustrated in FIG. **13**.
[0036] FIG. **16** illustrates a configuration of an image capturing lens system according to a sixth example.
[0037] FIG. **17** illustrates aberration curves of the image capturing lens system illustrated in FIG. **16**.
[0038] FIG. **18** illustrates MTF curves depending on temperature variations of the image capturing lens system illustrated in FIG. **16**.
[0039] FIG. **19** is a cross-sectional view of a camera module according to an example.
[0040] Throughout the drawings and the detailed description, the same reference numerals refer to the same elements. The drawings may not be to scale, and the relative size, proportions, and depiction of elements in the drawings may be exaggerated for clarity, illustration, and convenience.

DETAILED DESCRIPTION

[0041] The following detailed description is provided to assist the reader in gaining a comprehensive understanding of the methods, apparatuses, and/or systems described herein. However, various changes, modifications, and equivalents of the methods, apparatuses, and/or systems described herein will be apparent after an understanding of the disclosure of this application. For example, the sequences of operations described herein are merely examples, and are not limited to those set forth herein, but may be changed as will be apparent after an understanding of the disclosure of this application, with the exception of operations necessarily occurring in a certain order. Also, descriptions of features that are known in the art may be omitted for increased clarity and conciseness.
[0042] The features described herein may be embodied in different forms, and are not to be construed as being limited to the examples described herein. Rather, the examples described herein have been provided merely to illustrate some of the many possible ways of implementing the methods, apparatuses, and/or systems described herein that will be apparent after an understanding of the disclosure of this application.
[0043] Herein, it is noted that use of the term “may” with respect to an example or embodiment, e.g., as to what an example or embodiment may include or implement, means that at least one example or embodiment exists in which such a feature is included or implemented while all examples and embodiments are not limited thereto.
[0044] Throughout the specification, when an element, such as a layer, region, or substrate, is described as being “on,” “connected to,” or “coupled to” another element, it may be directly “on,” “connected to,” or “coupled to” the other element, or there may be one or more other elements intervening therebetween. In contrast, when an element is described as being “directly on,” “directly connected to,” or “directly coupled to” another element, there can be no other elements intervening therebetween.
[0045] As used herein, the term “and/or” includes any one and any combination of any two or more of the associated listed items.
[0046] Although terms such as “first,” “second,” and “third” may be used herein to describe various members, components, regions, layers, or sections, these members, components, regions, layers, or sections are not to be limited by these terms. Rather, these terms are only used to distinguish one member, component, region, layer, or section from another member, component, region, layer, or section. Thus, a first member, component, region, layer, or section referred to in examples described herein may also be referred to as a second member, component, region, layer,

or section without departing from the teachings of the examples.
[0047] Spatially relative terms such as “above,” “upper,” “below,” and “lower” may be used herein for ease of description to describe one element's relationship to another element as shown in the figures. Such 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, an element described as being “above” or “upper” relative to another element will then be “below” or “lower” relative to the other element. Thus, the term “above” encompasses both the above and below orientations depending on the spatial orientation of the device. The device may also be oriented in other ways (for example, rotated 90 degrees or at other orientations), and the spatially relative terms used herein are to be interpreted accordingly.
[0048] The terminology used herein is for describing various examples only, and is not to be used to limit the disclosure. The articles “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms “comprises,” “includes,” and “has” specify the presence of stated features, numbers, operations, members, elements, and/or combinations thereof, but do not preclude the presence or addition of one or more other features, numbers, operations, members, elements, and/or combinations thereof.
[0049] Due to manufacturing techniques and/or tolerances, variations of the shapes shown in the drawings may occur. Thus, the examples described herein are not limited to the specific shapes shown in the drawings, but include changes in shape that occur during manufacturing.
[0050] The features of the examples described herein may be combined in various ways as will be apparent after an understanding of the disclosure of this application. Further, although the examples described herein have a variety of configurations, other configurations are possible as will be apparent after an understanding of the disclosure of this application.
[0051] Hereinafter, examples of the present disclosure will be described as follows with reference to the attached drawings.
[0052] In the examples, an entirety of a radius of curvature, a thickness, and a focal length of a lens are indicated in millimeters (mm). Further, a thickness of a lens, and a gap between lenses are distances measured based on an optical axis of the lens.
[0053] In a description of a form of a lens, a surface of a lens being convex indicates that an optical axis region of a corresponding surface is convex, while a surface of a lens being concave indicates that an optical axis region of a corresponding surface is concave. Therefore, in a configuration in which a surface of a lens is described as being convex, an edge portion of the lens may be concave. In a similar manner, in a configuration in which a surface of a lens is described as being concave, an edge portion of the lens may be convex.
[0054] An image capturing lens system may include a plurality of lenses and a stop. For example, the image capturing lens system may include a first lens, a second lens, a stop, a third lens, a fourth lens, a fifth lens, and a sixth lens, sequentially disposed from an object side. In the descriptions below, configurations of the lenses will be described.
[0055] The first lens may have refractive power. For example, the first lens may have negative refractive power.
[0056] The first lens may have a convex surface. For example, the first lens may have a convex object-side surface.
[0057] The first lens may be formed of a material having a constant refractive index in spite of temperature variations. For example, the first lens may be formed of glass, but a material of the first lens is not limited to glass.
[0058] The first lens may have a predetermined refractive index. For example, the first lens may have a refractive index of 1.7 or higher. When the first lens is formed of plastic, the first lens may have a refractive index lower than 1.7. The first lens may have an Abbe number greater than an Abbe number of the second lens. For example, the first lens may have an Abbe number of 45 or more.

[0059] The second lens may have refractive power. For example, the second lens may have positive or negative refractive power.
[0060] The second lens may have a convex surface. For example, the second lens may have a convex object-side surface or a convex image-side surface.
[0061] The second lens may include an aspherical surface. For example, both surfaces of the second lens may be aspherical. The second lens may be formed of a material having high light transmissivity and improved workability. For example, the second lens may be formed of plastic.
[0062] The second lens may have a predetermined refractive index. For example, the second lens may have a refractive index of 1.6 or more. The second lens may have a predetermined Abbe number. For example, the second lens may have an Abbe number lower than 23.
[0063] The stop is disposed between the second lens and the third lens. The stop may adjust an intensity of light, incident on an imaging plane, to clearly capture an image, even in a high-luminance environment. In addition, the stop may adjust an intensity of light, incident on the third to sixth lenses, to reduce thermal deformation of lenses caused by the incident light.
[0064] The third lens may have refractive power. For example, the third lens may have positive refractive power.
[0065] The third lens may have a convex surface. For example, the third lens may have a convex image-side surface. The third lens may have an Abbe number. As an example, the third lens may have an Abbe number of 50 or more.
[0066] The fourth lens may have refractive power. For example, the fourth lens may have positive refractive power.
[0067] The fourth lens may have at least one convex surface. For example, at least one of an image-side surface and an object-side surface of the fourth lens may be convex. The fourth lens may have an Abbe number of 45 or more.
[0068] One of the third and fourth lenses may be formed of a material having a constant refractive index in spite of temperature variations. For example, the third lens may be formed of glass or the fourth lens may be formed of glass.
[0069] The fifth lens may have refractive power. For example, the fifth lens may have negative refractive power.
[0070] The fifth lens may have at least one concave surface. For example, both an object-side surface and an image-side surface of the fifth lens may be concave.
[0071] The fifth lens may include at least one aspherical surface. For example, both the object-side surface and the image-side surface of the fifth lens may be aspherical. The fifth lens may be formed of a material having high light transmissivity and improved workability. For example, the fifth lens may be formed of plastic. The fifth lens may have a predetermined refractive index. For example, the fifth lens may have a refractive index of 1.6 or more. The fifth lens may have an Abbe number lower than an Abbe number of the fourth lens. For example, the fifth lens may have an Abbe number lower than 30.
[0072] The sixth lens may have refractive power. For example, the sixth lens may have a positive refractive index.
[0073] The sixth lens may have a convex surface. For example, the sixth lens may have a convex object-side surface.
[0074] The sixth lens may be formed of a material having high light transmissivity and improved workability. For example, the sixth lens may be formed of plastic, but a material of the sixth lens is not limited to the plastic. The sixth lens may include at least one aspherical surface. For example, both an object-side surface and an image-side surface of the sixth lens may be aspherical.
[0075] The sixth lens may have a predetermined refractive index. For example, the sixth lens may have a refractive index lower than 1.6.
[0076] The image capturing lens system may include one or more aspherical lenses. For example, among the first to sixth lenses, four or more lenses may include aspherical surfaces. For example,

one of the lenses, disposed on an object-side surface or an image-side surface of a stop, may be a spherical lens. The image capturing lens system, satisfying the above condition, may be advantageous to implement a high resolution and to improve aberration. The aspherical surface may be represented by Equation (1) below.

[00001] $$Z = \frac{cr^2}{1+\sqrt{1-(1+k)c^2r^2}} + Ar^4 + Br^6 + Cr^8 + Dr^{10} + Er^{12} + Fr^{14} + Gr^{16} + Hr^{18} \quad \text{Equation(1)}$$

[0077] In Equation (1), "c" is an inverse of a radius of a curvature of a respective lens, "k" is a conic constant, "r" is a distance from a certain point on an aspherical surface to an optical axis, "A" to "H" are aspheric constants, and "Z" (or SAG) is a height from a certain point on an aspherical surface to an apex of the aspherical surface in an optical axis direction.

[0078] An image capturing lens system includes an image sensor. The image sensor may be configured to implement high resolution. A surface of the image sensor may form an imaging plane on which an image is formed.

[0079] The image capturing lens system includes a filter and a cover glass. For example, the filter may be disposed between the sixth lens and the image sensor to filter components decreasing resolution, and the cover glass may block foreign objects.

[0080] The image capturing lens system is configured to significantly reduce a temperature-dependent variation in focal length. For example, among the first to sixth lenses, four or more lenses may be formed of plastic, and the other lenses may be formed of glass. One of the lenses, formed of glass, is disposed between the stop and the imaging plane and has positive refractive power. The image capturing lens system, satisfying the above condition, may have constant optical characteristics even at a high temperature or a low temperature, and reduction in manufacturing cost and weight lightening may be implemented.

[0081] The image capturing lens system is configured to satisfy at least one of the Conditional Expressions below.

[00002] $$\mathrm{Gf}/f < 2. \quad \text{ConditionalExpression1} \quad 0.7 < \mathrm{GFL}/S8S13 \quad \text{ConditionalExpression2}$$

$$D34 < D23 \quad \text{ConditionalExpression3} \quad D45 < D34 \quad \text{ConditionalExpression4}$$

$$f3/f < 2. \quad \text{ConditionalExpression5} \quad f4/f < 2. \quad \text{ConditionalExpression6}$$

$$\mathrm{TL}/f < 5. \quad \text{ConditionalExpression7}$$

[0082] In the Conditional Expressions, "f" is a focal length of the image capturing lens system, "Gf" is a focal length of a lens, among the third to sixth lenses, formed of glass and disposed closest to an object side, "BFL" is a distance from the image-side surface of the sixth lens to the imaging plane, "S8S13" is a distance from the object-side surface of the fourth lens to the image-side surface of the sixth lens, "f2" is a focal length of the third lens, "f4" is a focal length of the fourth lens, and "TL" is a distance from the object-side surface of the first lens to the imaging plane.

[0083] In the descriptions below, an image capturing lens system according to various examples will be described.

[0084] An image capturing lens system **100** according to a first example will be described with reference to FIG. **1**.

[0085] The image capturing lens system **100** includes a plurality of a plurality of lenses, each having refractive power. For example, the image capturing lens system **100** includes a first lens **110**, a second lens **120**, a third lens **130**, a fourth lens **140**, a fifth lens **150**, and a sixth lens **160**.

[0086] The first lens **110** has negative refractive power, with a convex object-side surface and a concave image-side surface. The second lens **120** has positive refractive power, with a convex object-side surface and a convex image-side surface. The third lens **130** has positive refractive power, with a concave object-side surface and a convex image-side surface. The fourth lens **140** has positive refractive power, with a convex object-side surface and a convex image-side surface. The fifth lens **150** has negative refractive power, with a concave object-side surface and a concave image-side surface. The sixth lens **160** has positive refractive power, with a convex object-side surface and a convex image-side surface.

[0087] The image capturing lens system **100** includes a plurality of aspherical lenses. For example, the second lens **120**, the third lens **130**, the fifth lens **150**, and the sixth lens **160** include aspherical surfaces.

[0088] The image capturing lens system **100** includes at least one lens, formed of glass, to perform constant optical performance in spite of temperature variations. In the example of FIG. **1**, the first lens **110** and the fourth lens **140** are formed of glass, and the other lenses are formed of plastic.

[0089] The image capturing lens system **100** includes a stop ST. The stop ST is disposed between the second lens **120** and the third lens **130**. The image capturing lens system **100** includes a filter **170** and a cover glass **180**. The filter **170** is disposed between the sixth lens **160** and an imaging plane **190** to block infrared light, and the cover glass **180** blocks foreign objects. In the image capturing lens system **100**, TL is 14.00 mm and f is 3.20 mm.

[0090] Table (1) lists lens characteristics of the image capturing lens system **100**, Table (2) lists aspherical constants, and Table (3) lists a focal length and a coefficient of linear thermal expansion (CTE) of each lens. FIG. **2** illustrates aberration curves of the image capturing lens system **100**, and FIG. **3** is a graph illustrating MTF characteristics of the image capturing lens system **100**.

TABLE-US-00001 TABLE 1 Surface Radius of Thickness/ Refractive Abbe No. Note Curvature Distance Index No. 1 First Lens 17.113 0.4 1.7725 49.62 2 2.167 0.908 3 Second Lens 14.248 0.851 1.6612 20.35 4 −17.422 0.962 5 Stop Infinity 0.225 6 Third Lens −4.909 1.431 1.5345 55.68 7 −3.273 0.1 8 Fourth Lens 6.025 1.574 1.7433 49.4 9 −7.126 0.238 10 Fifth Lens −7.873 0.625 1.6428 22.4 11 3.532 0.1 12 Sixth Lens 3.482 1.876 1.5345 55.68 13 −6.445 0.5 14 Filter Infinity 0.4 1.5168 64.17 15 Infinity 3.263 16 Cover Glass Infinity 0.4 1.5168 64.17 17 Infinity 0.15 18 Imaging Plane Infinity −0.006

TABLE-US-00002 TABLE 2 Surface No. K A B C D 3 −0.984959 −0.004207 0.000373 −0.000353 0 4 18.400288 0.002266 −0.00016 0 0 6 5.680808 0.015847 0.001601 −0.000682 0.000239 7 0.140001 0.006007 −0.000822 −0.000002 0 10 0.075623 0.001234 −0.001957 0.000277 −0.000013 11 −0.961879 −0.023497 0.006347 −0.000885 0.000048 12 −1.913323 −0.024659 0.007334 −0.000952 0.000044 13 −11.54384 −0.002763 0.000054 0.000084 −0.00001

TABLE-US-00003 TABLE 3 Note Material Focal Length CTE(ppm) First Lens Glass −3.23428 8 Second Lens Plastic 11.84906 66 Third Lens Plastic 14.007636 60 Fourth Lens Glass 4.606795 8 Fifth Lens Plastic −3.675012 71 Sixth Lens Plastic 4.50912 60

[0091] Hereinafter, an image capturing lens system **200** according to a second example will be described with reference to FIG. **4**.

[0092] The image capturing lens system **200** includes a plurality of lenses, each having refractive power. For example, the image capturing lens system **200** includes a first lens **210**, a second lens **220**, a third lens **230**, a fourth lens **240**, a fifth lens **250**, and a sixth lens **260**.

[0093] The first lens **210** has negative refractive power, with a convex object-side surface and a concave image-side surface. The second lens **220** has positive refractive power, with a convex object-side surface and a concave image-side surface. The third lens **230** has positive refractive power, with a convex object-side surface and a convex image-side surface. The fourth lens **240** has positive refractive power, with a convex object-side surface and a convex image-side surface. The fifth lens **250** has negative refractive power, with a concave object-side surface and a concave image-side surface. The sixth lens **260** has positive refractive power, with a convex object-side surface and a convex image-side surface.

[0094] The image capturing lens system **200** includes a plurality of aspherical lenses. For example, the second lens **220**, the third lens **230**, the fourth lens **240**, the fifth lens **250**, and the sixth lens **260** include aspherical surfaces.

[0095] The image capturing lens system **200** includes at least one lens, formed of glass, to perform

constant optical performance in spite of temperature variations. In the example of FIG. **4**, the first lens **210** and the third lens **230** are formed of glass, and the other lenses are formed of plastic.
[0096] The image capturing lens system **200** includes a stop ST. The stop ST is disposed between the second lens **220** and the third lens **230**. The image capturing lens system **200** includes a filter **270** and a cover glass **280**. The filter **270** is disposed between the sixth lens **260** and an imaging plane **290** to block infrared light, and the cover glass **280** blocks foreign objects. In the image capturing lens system **200**, TL is 14.00 mm and f is 3.20 mm.
[0097] Table (4) lists lens characteristics of the image capturing lens system **200**, Table (5) lists aspherical constants, and Table (6) lists a focal length and a coefficient of linear thermal expansion (CTE) of each lens. FIG. **5** illustrates aberration curves of the image capturing lens system **200**, and FIG. **6** is a graph illustrating MTF characteristics of the image capturing lens system **200**.
TABLE-US-00004 TABLE 4 Surface Radius of Thickness/ Refractive Abbe No. Note Curvature Distance Index No. 1 First Lens 56.928 0.44 1.7725 49.62 2 2.144 1.992 3 Second Lens 6.165 0.973 1.6612 20.35 4 6.799 0.357 5 Stop Infinity −0.107 6 Third Lens 8.707 1.559 1.755 52.3 7 −3.864 1.302 8 Fourth Lens 17.83 0.868 1.5348 55.72 9 −11.668 0.147 10 Fifth Lens −8.12 0.43 1.6612 20.35 11 5.421 0.368 12 Sixth Lens 3.671 1.547 1.5348 55.72 13 −10.687 0.5 14 Filter Infinity 0.4 1.5168 64.17 15 Infinity 2.675 16 Cover Glass Infinity 0.4 1.5168 64.17 17 Infinity 0.15 18 Imaging Plane Infinity 0
TABLE-US-00005 TABLE 5 Surface No. K A B C 3 −1.91777 −0.00201 −0.00067 0.000043 4 0.92986 0.000943 −0.00042 0.000042 8 −54.8172 −0.00195 0.000545 −1.90E−05 9 22.54924 −0.00936 0.00013 0.000039 10 6.951181 −0.00204 −0.00157 — 11 −25.8172 0.005009 −8.20E−05 −3.60E−05 12 −8.66933 −0.00372 0.000858 −3.10E−05 13 1.441256 −0.00211 −0.00037 0.000066
TABLE-US-00006 TABLE 6 Note Material Focal Length CTE(ppm) First Lens Glass −2.879873 8 Second Lens Plastic 61.251329 66 Third Lens Glass 3.727968 8 Fourth Lens Plastic 13.26758 60 Fifth Lens Plastic −4.800192 66 Sixth Lens Plastic 5.286187 60
[0098] An image capturing lens system **300** according to a third example will be described with reference to FIG. **7**.
[0099] The image capturing lens system **300** includes a plurality of lenses, each having refractive power. For example, the image capturing lens system **300** includes a first lens **310**, a second lens **320**, a third lens **330**, a fourth lens **340**, a fifth lens **350**, and a sixth lens **360**.
[0100] The first lens **310** has negative refractive power, with a convex object-side surface and a concave image-side surface. The second lens **320** has negative refractive power, with a concave object-side surface and a convex image-side surface. The third lens **330** has positive refractive power, with a convex object-side surface and a convex image-side surface. The fourth lens **340** has positive refractive power, with a convex object-side surface and a convex image-side surface. The fifth lens **350** has negative refractive power, with a concave object-side surface and a concave image-side surface. The sixth lens **360** has positive refractive power, with a convex object-side surface and a concave image-side surface.
[0101] The image capturing lens system **300** includes a plurality of aspherical lenses. For example, the first lens **310**, the second lens **320**, the fourth lens **340**, the fifth lens **350**, and the sixth lens **360** include aspherical surfaces.
[0102] The image capturing lens system **300** includes a lens, formed of glass, to perform constant optical performance in spite of temperature variations. In the example of FIG. **7**, the third lens **330** is formed of glass, and the other lenses are formed of plastic.
[0103] The image capturing lens system **300** includes a stop ST. The stop ST is disposed between the second lens **320** and the third lens **330**. The image capturing lens system **300** includes a filter **370** and a cover glass **380**. The filter **370** is disposed between the sixth lens **360** and an imaging plane **390** to block infrared light, and the cover glass **380** blocks foreign objects.
[0104] In the image capturing lens system **300**, TL is 14.00 mm and f is 3.244 mm.

[0105] Table (7) lists lens characteristics of the image capturing lens system **300**, Table (8) lists aspherical constants, and Table (9) lists a focal length and a coefficient of linear thermal expansion (CTE) of each lens. FIG. **8** illustrates aberration curves of the image capturing lens system **300**, and FIG. **9** is a graph illustrating MTF characteristics of the image capturing lens system **300**.
TABLE-US-00007 TABLE 7 Surface Radius of Thickness/ Refractive Abbe No. Note Curvature Distance Index No. 1 First Lens 7.045 0.4 1.5348 55.72 2 1.938 1.725 3 Second Lens −3.044 1.382 1.6612 20.35 4 −4.628 0.179 5 Stop Infinity −0.079 6 Third Lens 11.199 1.121 1.6968 55.41 7 −6.137 1.56 8 Fourth Lens 8.442 2.055 1.5348 55.72 9 −2.953 0.1 10 Fifth Lens −9.796 0.653 1.6612 20.35 11 4.95 0.1 12 Sixth Lens 4.897 1.568 1.5348 55.72 13 34.953 0.5 14 Filter Infinity 0.4 1.5168 64.17 15 Infinity 1.786 16 Cover Glass Infinity 0.4 1.5168 64.17 17 Infinity 0.15 18 Imaging Plane Infinity 0
TABLE-US-00008 TABLE 8 Surface No. K A B C D 1 −7.681703 0.002013 −0.000288 0.000025 — 2 0.061406 −0.000388 0.000518 −0.000389 — 3 0.5422 0.004976 0.000134 — — 4 −0.211763 0.002146 −0.000167 — — 8 −22.17865 0.007454 −0.000645 0.000011 — 9 −2.361881 0.001728 −0.000264 0.000014 — 10 3.825378 −0.00665 −0.000113 0.000164 −0.000011 11 −1.851574 −0.00174 −0.000081 0.000118 −0.000009 12 −1.778214 0.00078 −0.000226 0.000012 — 13 0.96103 −0.011395 0.001474 −0.00014 0.000005
TABLE-US-00009 TABLE 9 Note Material Focal Length CTE(ppm) First Lens Plastic −5.118755 60 Second Lens Plastic −20.45832 66 Third Lens Glass 5.820223 8 Fourth Lens Plastic 4.347073 60 Fifth Lens Plastic −4.83182 66 Sixth Lens Plastic 10.414383 60
[0106] An image capturing lens system **400** according to a fourth example will be described with reference to FIG. **10**.
[0107] The image capturing lens system **400** includes a plurality of lenses, each having refractive power. For example, the image capturing lens system **400** includes a first lens **410**, a second lens **420**, a third lens **430**, a fourth lens **440**, a fifth lens **450**, and a sixth lens **460**.
[0108] The first lens **410** has negative refractive power, with a convex object-side surface and a concave image-side surface. The second lens **420** has negative refractive power, with a concave object-side surface and a convex image-side surface. The third lens **430** has positive refractive power, with a convex object-side surface and a convex image-side surface. The fourth lens **440** has positive refractive power, with a convex object-side surface and a convex image-side surface. The fifth lens **450** has negative refractive power, with a concave object-side surface and a concave image-side surface. The sixth lens **460** has positive refractive power, with a convex object-side surface and a convex image-side surface.
[0109] The image capturing lens system **400** includes a plurality of aspherical lenses. For example, the first lens **410**, the second lens **420**, the fourth lens **440**, the fifth lens **450**, and the sixth lens **460** include aspherical surfaces.
[0110] The image capturing lens system **400** includes a lens, formed of glass, to perform constant optical performance in spite of temperature variations. In the example of FIG. **10**, the third lens **430** is formed of glass, and the other lenses are formed of plastic.
[0111] The image capturing lens system **400** includes a stop ST. The stop ST is disposed between the second lens **420** and the third lens **430**. The image capturing lens system **400** includes a filter **470** and a cover glass **480**. The filter **470** is disposed between the sixth lens **460** and an imaging plane **490** to block infrared light, and the cover glass **480** blocks foreign objects. In the image capturing lens system **400**, TL is 14.00 mm and f is 3.23 mm.
[0112] Table (10) lists lens characteristics of the image capturing lens system **400**, Table (11) lists aspherical constants, and Table (12) lists a focal length and a coefficient of linear thermal expansion (CTE) of each lens. FIG. **11** illustrates aberration curves of the image capturing lens system **400**, and FIG. **12** is a graph illustrating MTF characteristics of the image capturing lens system **400**.
TABLE-US-00010 TABLE 10 Surface Radius of Thickness/ Refractive Abbe No. Note Curvature

Distance Index No. 1 First Lens 6.604 0.4 1.5348 55.72 2 1.878 1.625 3 Second Lens −3.112 1.562 1.6612 20.35 4 −4.327 0.172 5 Stop Infinity −0.072 6 Third Lens 12.201 1.119 1.6968 55.41 7 −6.172 1.342 8 Fourth Lens 18.042 1.746 1.5348 55.72 9 −2.939 0.1 10 Fifth Lens −7.26 0.593 1.6612 20.35 11 6.556 0.1 12 Sixth Lens 5.226 1.649 1.5348 55.72 13 −38.415 0.5 14 Filter Infinity 0.4 1.5168 64.17 15 Infinity 0.1 16 Cover Glass Infinity 0.4 1.5168 64.17 17 Infinity 2.262 18 Imaging Plane Infinity 0.002

TABLE-US-00011 TABLE 11 Surface No. K A B C 1 −7.681703 0.001478 −0.000152 0.000011 2 0.061406 −0.000781 0.000079 −0.000256 3 0.5422 0.004871 0.000294 0 4 −0.211763 0.003197 −0.000192 0 8 −22.17865 0.006723 −0.000393 −0.000016 9 −2.361881 0.000913 −0.000116 −0.000004 10 3.825378 −0.003579 0.000122 0.000049 11 −1.851574 −0.000421 0.000531 −0.000031 12 −1.778214 0.000251 0.000062 −0.000009 13 0.96103 −0.007494 0.00069 −0.000033

TABLE-US-00012 TABLE 12 Note Material Focal Length CTE(ppm) First Lens Plastic −5.036333 60 Second lens Plastic −34.20897 66 Third Lens Glass 6.0078 8 Fourth Lens Plastic 4.846766 60 Fifth Lens Plastic −5.064417 66 Sixth Lens Plastic 8.679575 60

[0113] An image capturing lens system **500** according to a fifth example will be described with reference to FIG. **13**.

[0114] The image capturing lens system **500** includes a plurality of lenses, each having refractive power. For example, the image capturing lens system **500** includes a first lens **510**, a second lens **520**, a third lens **530**, a fourth lens **540**, a fifth lens **550**, and a sixth lens **560**.

[0115] The first lens **510** has negative refractive power, with a convex object-side surface and a concave image-side surface. The second lens **520** has positive refractive power, with a convex object-side surface and a concave image-side surface. The third lens **530** has positive refractive power, with a concave object-side surface and a convex image-side surface. The fourth lens **540** has positive refractive power, with a convex object-side surface and a convex image-side surface. The fifth lens **550** has negative refractive power, with a concave object-side surface and a concave image-side surface. The sixth lens **560** has positive refractive power, with a convex object-side surface and a convex image-side surface.

[0116] The image capturing lens system **500** includes a plurality of aspherical lenses. For example, the first lens **510**, the second lens **520**, the fourth lens **540**, the fifth lens **550**, and the sixth lens **560** include aspherical surfaces.

[0117] The image capturing lens system **500** includes a lens, formed of glass, to perform constant optical performance in spite of temperature variations. In the example of FIG. **13**, the third lens **530** is formed of glass, and the other lenses are formed of plastic.

[0118] The image capturing lens system **500** includes a stop ST. The stop ST is disposed between the second lens **520** and the third lens **530**. The image capturing lens system **500** includes a filter **570** and a cover glass **580**. The filter **570** is disposed between the sixth lens **560** and an imaging plane **590** to block infrared light, and the cover glass **580** blocks foreign objects. In the image capturing lens system **500**, TL is 14.00 mm and f is 3.20 mm.

[0119] Table (13) lists lens characteristics of the image capturing lens system **500**, Table (14) lists aspherical constants, and Table (15) lists a focal length and a coefficient of linear thermal expansion (CTE) of each lens. FIG. **14** illustrates aberration curves of the image capturing lens system **500**, and FIG. **15** is a graph illustrating MTF characteristics of the image capturing lens system **500**.

TABLE-US-00013 TABLE 13 Surface Radius of Thickness/ Refractive Abbe No. Note Curvature Distance Index No. 1 First Lens 15.895 0.469 1.5348 55.72 2 1.803 1.641 3 Second Lens 20 1 1.6612 20.35 4 100.599 0.16 5 Stop Infinity 0.1 6 Third Lens −13.344 2.05 1.755 52.3 7 −3.323 0.1 8 Fourth Lens 12.068 1.108 1.5348 55.72 9 −21.107 0.63 10 Fifth Lens −12.915 0.445 1.6612 20.35 11 5.266 0.1 12 Sixth Lens 3.565 1.623 1.5348 55.72 13 −7.933 0.5 14 Filter Infinity 0.4 1.5168 64.17 15 Infinity 0.1 16 Cover Glass Infinity 0.4 1.5168 64.17 17 Infinity 3.193 18 Imaging

Plane Infinity −0.016

TABLE-US-00014 TABLE 14 Surface No. K A B C 1 0 −0.002362 0.000071 0 2 −0.070237 −0.000027 −0.000937 0 3 −1.91777 0.000235 −0.000089 0.000274 4 0.92986 0.006087 0.001455 0.000122 8 −54.81723 −0.00522 0.000173 −0.000008 9 22.549235 −0.027239 0.002578 −0.000153 10 6.951181 −0.009539 0.000136 0 11 −25.81716 0.007946 −0.001059 0.000042 12 −8.669333 −0.001414 0.000379 −0.000014 13 −24.61728 −0.005844 0.00017 0.00002

TABLE-US-00015 TABLE 15 Note Material Focal Length CTE(ppm) First Lens Plastic −3.830711 60 Second Lens Plastic 37.146079 66 Third Lens Glass 5.361336 8 Fourth Lens Plastic 14.463942 60 Fifth Lens Plastic −5.540073 66 Sixth Lens Plastic 4.816803 60

[0120] An image capturing lens system **600** according to a sixth example will be described with reference to FIG. **16**.

[0121] The image capturing lens system **600** includes a plurality of lenses, each having refractive power. For example, the image capturing lens system **600** includes a first lens **610**, a second lens **620**, a third lens **630**, a fourth lens **640**, a fifth lens **650**, and a sixth lens **660**.

[0122] The first lens **610** has negative refractive power, with a concave object-side surface and a concave image-side surface. The second lens **620** has positive refractive power, with a convex object-side surface and a concave image-side surface. The third lens **630** has positive refractive power, with a concave object-side surface and a convex image-side surface. The fourth lens **640** has positive refractive power, with a convex object-side surface and a convex image-side surface. The fifth lens **650** has negative refractive power, with a concave object-side surface and a concave image-side surface. The sixth lens **660** has positive refractive power, with a convex object-side surface and a convex image-side surface.

[0123] The image capturing lens system **600** includes a plurality of aspherical lenses. For example, the first lens **610**, the second lens **620**, the fourth lens **640**, the fifth lens **650**, and the sixth lens **660** include aspherical surfaces.

[0124] The image capturing lens system **600** includes a lens, formed of glass, to perform constant optical performance in spite of temperature variations. In the example of FIG. **16**, the third lens **630** is formed of glass, and the other lenses are formed of plastic.

[0125] The image capturing lens system **600** includes a stop ST. The stop ST is disposed between the second lens **620** and the third lens **630**. The image capturing lens system **600** includes a filter **670** and a cover glass **680**. The filter **670** is disposed between the sixth lens **660** and an imaging plane **690** to block infrared light, and the cover glass **680** blocks foreign objects.

[0126] In the image capturing lens system **600**, TL is 14.00 mm and f is 3.20 mm.

[0127] Table (16) lists lens characteristics of the image capturing lens system **600**, Table (17) lists aspherical constants, and Table (18) lists a focal length and a coefficient of linear thermal expansion (CTE) of each lens. FIG. **17** illustrates aberration curves of the image capturing lens system **600**, and FIG. **18** is a graph illustrating MTF characteristics of the image capturing lens system **600**.

TABLE-US-00016 TABLE 16 Surface Radius of Thickness/ Refractive Abbe No. Note Curvature Distance Index No. 1 First Lens −89.277 0.553 1.5348 55.72 2 1.889 1.586 3 Second Lens 7.517 0.6 1.6612 20.35 4 17.903 0.43 5 Stop Infinity 0.129 6 Third Lens −50.109 2.013 1.755 52.3 7 −3.995 0.336 8 Fourth Lens 10.285 1.382 1.5348 55.72 9 −17.065 0.105 10 Fifth Lens −12.604 0.496 1.6612 20.35 11 4.469 0.2 12 Sixth Lens 2.968 1.519 1.5348 55.72 13 −9.847 0.5 14 Filter Infinity 0.4 1.5168 64.17 15 Infinity 3.2 16 Cover Glass Infinity 0.4 1.5168 64.17 17 Infinity 0.17 18 Imaging Plane Infinity −0.02

TABLE-US-00017 TABLE 17 Surface No. K A B C 1 0 0.000011 −0.000032 0 2 −0.070237 −0.001152 −0.00015 0 3 −1.91777 0.001147 −0.000301 0.000675 4 0.92986 0.004549 −0.00026 0.000653 8 −54.81723 0.002066 0.000217 −0.00002 9 22.549235 −0.027599 0.002957 −0.000119 10 6.951181 −0.01325 0.000595 0 11 −25.81716 −0.001702 0.001055 −0.000045 12 −8.669333 −0.007171 0.001496 −0.000066 13 −52.60729 −0.003063 0.000116 0.000002

TABLE-US-00018 TABLE 18

Note	Material	Focal Length	CTE(ppm)
First Lens	Plastic	−3.436194	60
Second Lens	Plastic	18.937894	66
Third Lens	Glass	5.617229	8
Fourth Lens	Plastic	12.163183	60
Fifth Lens	Plastic	−4.876618	66
Sixth Lens	Plastic	4.429409	60

[0128] In an image capturing lens system, focal lengths of first to sixth lengths may be determined to be within a predetermined range. For example, the focal length of the first lens may be determined in a range from −6.2 mm to −1.8 mm, the focal length of the second lens may be determined to be 10 mm or more or −20 mm or less, the focal length of the third lens may be determined in a range from 2.7 mm to 16.0 mm, the focal length of the fourth lens may be determined in a range from 3.6 mm to 14.0 mm, the focal length of the fifth lens may be determined in a range from −7.5 mm to −2.6 mm, and the focal length of the sixth lens may be determined in a range from 3.4 mm to 13.0 mm.

[0129] The image capturing lens system satisfies at least one of the above-described Conditional Expressions. Table (19) lists values of Conditional Expressions of image capturing lens systems according to the respective examples.

TABLE-US-00019 TABLE 19

	First Example	Second Example	Third Example	Fourth Example	Fifth Example	Sixth Example
Gf/f	1.4396	1.1650	1.7942	1.8600	1.6754	1.7554
BFL/S8S13	1.0666	1.2277	0.7230	0.8749	1.1718	1.2561
f3/f	4.3774	1.1650	1.7942	1.8600	1.6754	1.7554
f4/f	1.4396	4.1461	1.3400	1.5005	4.5200	3.8010
TL/f	4.3741	4.3753	4.3157	4.3344	4.3759	4.3747

[0130] A camera module **10** according to an example will be described with reference to FIG. **19**.

[0131] The camera module **10** includes one or more image capturing lens systems according to the above-described examples (for example, an image capturing lens system, illustrated in FIG. **19**, has the configuration as the image capturing lens system **100** according to the first example). The camera module **10** is configured such that optical performance of an image capturing lens system is constantly maintained irrespective of temperature variations. For example, the camera module **10** includes a lens barrel **20** and a housing **30** having different coefficients of linear thermal expansion. The coefficient of linear thermal expansion of the lens barrel **20** is 2×10.sup.−5 to 8×10.sup.−5, and the coefficient of linear thermal expansion of the housing **30** is 2×10.sup.−5 to 8×10.sup.−5. Although a range of the coefficient of linear thermal expansion of the lens barrel **20** is the same as a range of the coefficient of linear thermal expansion of the housing **30**, a camera module according to an example is selected to have different coefficients of linear thermal expansion.

[0132] The camera module **10** is configured to separately accommodate a lens portion and the imaging plane (an image sensor) **190** of the image capturing lens system **100**. For example, the lens portion of the image capturing lens system **100** is accommodated in the lens barrel **20**, and the imaging plane **190** thereof is accommodated in the housing **30**. The housing **30** may further include an additional substrate **40** to support the imaging plane **196**.

[0133] A length of the lens barrel **20** may be determined in consideration of a variation in back focal length (BFL) of the image capturing lens system **100** depending on temperature variations. For example, a distance h**1** from a bonding location B of the lens barrel **20** and the housing **30** to a lower end of the lens barrel **20** may be determined in consideration of the BFL of the image capturing lens system **100**, the coefficient of linear thermal expansion of the lens barrel **20**, and the like. Alternatively, the distance h**1** from the bonding location of the lens barrel **20** and the housing **30** to the lower end of the lens barrel **20** may be determined by a difference between the coefficients of linear thermal expansion of the lens barrel **20** and the housing **30**.

[0134] Similarly, the bonding location of the lens barrel **20** and the housing **30** may be determined in consideration of a variation in the BFL of the image capturing lens system **100** depending on temperature variations. For example, a distance h**2** from the bonding location B to the imaging plane **190** may be determined in consideration of the BFL of the image capturing lens system **100**, the coefficient of linear thermal expansion of the lens barrel **20**, and the like. Alternatively, the distance h**2** from the bonding location B to the imaging plane **190** may be determined by the difference between the coefficients of linear thermal expansion of the lens barrel **20** and the housing **30**.

[0135] As described above, an image capturing lens system according to the examples may perform constant optical performance irrespective of temperature variations of a surrounding environment.

[0136] While this disclosure includes specific examples, it will be apparent after an understanding of the disclosure of this application that various changes in form and details may be made in these examples without departing from the spirit and scope of the claims and their equivalents. The examples described herein are to be considered in a descriptive sense only, and not for purposes of limitation. Descriptions of features or aspects in each example are to be considered as being applicable to similar features or aspects in other examples. Suitable results may be achieved if the described techniques are performed in a different order, and/or if components in a described system, architecture, device, or circuit are combined in a different manner, and/or replaced or supplemented by other components or their equivalents. Therefore, the scope of the disclosure is defined not by the detailed description, but by the claims and their equivalents, and all variations within the scope of the claims and their equivalents are to be construed as being included in the disclosure.

Claims

1. An image capturing lens system comprising: a first lens having a refractive power; a second lens having a refractive power; a third lens having a refractive power; a fourth lens having positive refractive power; a fifth lens having a refractive power; and a sixth lens having a convex object-side surface, wherein the first to sixth lenses are sequentially disposed in ascending numerical order from an object side toward an imaging plane, wherein the image capturing lens system comprises no more than six lenses, wherein an absolute value of a radius of curvature of an image-side surface of the second lens is greater than an absolute value of a radius of curvature of an object-side surface of the second lens, wherein an absolute value of a radius of curvature of an image-side surface of the fourth lens is greater than an absolute value of a radius of curvature of an image-side surface of the fifth lens, wherein the first lens has a focal length within a range of −6.2 mm to −1.8 mm, and wherein the second lens has a refractive index of 1.6 or more.

2. The image capturing lens system of claim 1, wherein the first lens has a concave image-side surface.

3. The image capturing lens system of claim 1, wherein the second lens has a convex object-side surface.

4. The image capturing lens system of claim 1, wherein the third lens has a convex image-side surface.

5. The image capturing lens system of claim 1, wherein the fourth lens has a convex object-side surface.

6. The image capturing lens system of claim 1, wherein the fifth lens has a concave object-side surface.

7. An image capturing lens system comprising: a first lens having a refractive power; a second lens having a refractive power; a third lens having a refractive power; a fourth lens having positive refractive power; a fifth lens having a refractive power; and a sixth lens having a convex object-side surface, wherein the first to sixth lenses are sequentially disposed in ascending numerical order from an object side toward an imaging plane, wherein the image capturing lens system comprises no more than six lenses, wherein an absolute value of a radius of curvature of an image-side surface of the second lens is greater than an absolute value of a radius of curvature of an object-side surface of the second lens, wherein an absolute value of a radius of curvature of an image-side surface of the fourth lens is greater than an absolute value of a radius of curvature of an image-side surface of the fifth lens, wherein a thickness of the third lens is greater than a thickness of fourth lens, and wherein the first lens has a focal length within a range of −6.2 mm to −1.8 mm.

8. The image capturing lens system of claim 7, wherein the second lens has a convex object-side surface.
9. The image capturing lens system of claim 7, wherein the third lens has a convex image-side surface.
10. The image capturing lens system of claim 7, wherein the fourth lens has a convex object-side surface.
11. The image capturing lens system of claim 7, wherein the fourth lens has a convex image-side surface.
12. The image capturing lens system of claim 7, wherein the fifth lens has a concave object-side surface.
