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LENS MODULE

Abstract

A lens module may include a first lens having positive refractive power, a second lens having refractive power, a third lens having positive refractive power, a fourth lens having refractive power, a fifth lens having refractive power, a sixth lens having refractive power, and a seventh lens having negative refractive power. An inflection point may be formed on an image-side surface of the sixth lens. A turning point may be formed on an image-side surface of the seventh lens. The first lens, the second lens, the third lens, the fourth lens, the fifth lens, the sixth lens and the seventh lens are disposed in a sequential order from the first lens to the seventh lens.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. patent application Ser. No. 18/454,304 filed on Aug. 23, 2023, which is a continuation of U.S. patent application Ser. No. 17/022,658 filed on Sep. 16, 2020, now U.S. Pat. No. 11,774,719 issued on Oct. 3, 2023, which is a continuation of U.S. patent application Ser. No. 16/439,209 filed on Jun. 12, 2019, now U.S. Patent No. 11, 143,846 issued on Oct. 12, 2021, which is a continuation of U.S. patent application Ser. No. 15/211,429 filed on Jul. 15, 2016, now U.S. Pat. No. 10,365,456 issued on Jul. 30, 2019, which is a divisional of U.S. patent application Ser. No. 14/264,963 filed on Apr. 29, 2014, now U.S. Pat. No. 10,018,805 issued on Jul. 10, 2018, which claims the benefit under 35 USC 119(a) of Korean Patent Application Nos. 10-2013-0122193 filed on Oct. 14, 2013, and 10-2014-0008211 filed on Jan. 23, 2014, in the Korean Intellectual Property Office, the entire disclosures of which are incorporated herein by reference for all purposes.

BACKGROUND
[0002] The present technology generally relates to a lens module.
[0003] Recent mobile communications terminals have been provided with camera modules to capture images and to make video calls. In addition, as the functionality of camera modules provided in mobile communications terminals has been gradually increased, cameras for mobile communications terminals have gradually been required to have high degrees of resolution and high levels of performance.
[0004] However, since there is a trend for mobile communications terminals to be miniaturized and lightened, there are limitations on implementing camera modules having high degrees of resolution and high levels of performance.
[0005] Recently, lenses provided in camera modules have been formed of plastic, a material lighter than glass, and lens modules have been configured using five or more lenses in order to implement high resolution.
[0006] However, in the case of lenses formed of plastic, the improvement of chromatic aberrations and the implementation of relatively bright optical systems have been problematic, when compared to than lenses formed of glass.
SUMMARY
[0007] Some embodiments of the present disclosure may provide a lens module allowing for improvements in an aberration improvement effect and allowing for the implementation of high degrees of resolution.
[0008] According to some embodiments of the present disclosure, a lens module may include: a

first lens having positive refractive power; a second lens having refractive power; a third lens having positive refractive power; a fourth lens having refractive power; a fifth lens having refractive power; a sixth lens having refractive power; and a seventh lens having negative refractive power. At least one inflection point may be formed on the image-side surface of the sixth lens. At least one turning point may be formed on an image-side surface of the seventh lens. The first lens, the second lens, the third lens, the fourth lens, the fifth lens, the sixth lens and the seventh lens are disposed in a sequential order from the first lens to the seventh lens.

[0009] According to some embodiments of the present disclosure, a lens module may include: a first lens having positive refractive power; a second lens having positive refractive power; a third lens having positive refractive power; a fourth lens having refractive power; a fifth lens having refractive power; a sixth lens having refractive power; and a seventh lens having negative refractive power. At least one inflection point may be formed on the image-side surface of the sixth lens. At least one turning point may be formed on an image-side surface of the seventh lens.

[0010] According to some embodiments of the present disclosure, a lens module may include: a first lens having positive refractive power; a second lens having refractive power; a third lens having negative refractive power; a fourth lens having positive refractive power; a fifth lens having positive refractive power; a sixth lens having refractive power; and a seventh lens having negative refractive power. At least one inflection point may be formed on the image-side surface of the sixth lens. At least one turning point may be formed on an image-side surface of the seventh lens.

[0011] Some embodiments of the lens module may satisfy Conditional Expression 1:

[00001] $1. < f12 / f < 2.1$ [ConditionalExpression1]   [0012] where f12 is a synthetic focal length [mm] of the first and second lens, and f is an overall focal length [mm] of the optical system.

[0013] Some embodiments of the lens module may satisfy Conditional Expression 2:

[00002] $TTL / f < 1.4$ [ConditionalExpression2]   [0014] where TTL is a distance [mm] from an object-side surface of the first lens to an image surface, and f is an overall focal length [mm] of the optical system.

[0015] Some embodiments of the lens module may satisfy Conditional Expression 3:

[00003] $BFL / f > 2.$ [ConditionalExpression3]   [0016] where BFL is a distance [mm] from the image-side surface of the seventh lens to an image surface, and f is an overall focal length [mm] of the optical system.

[0017] Some embodiments of the lens module may satisfy Conditional Expression 4:

[00004] $R1 / f > 0.35$ [ConditionalExpression4]   [0018] where R1 is a radius of curvature [mm] of an object-side surface of the first lens, and f is an overall focal length [mm] of the optical system.

[0019] Some embodiments of the lens module may satisfy Conditional Expression 5:

[00005] $-0.6 < (R11 - R12) / (R11 + R12) < 8.$ [ConditionalExpression5]   [0020] where R11 is a radius of curvature [mm] of an object-side surface of the sixth lens, and R12 is a radius of curvature [mm] of an image-side surface of the sixth lens.

[0021] Some embodiments of the lens module may satisfy Conditional Expression 6:

[00006] $-2. < R13 / f < 1.$ [ConditionalExpression6]   [0022] where R13 is a radius of curvature [mm] of an object-side surface of the seventh lens.

[0023] Some embodiments of the lens module may satisfy Conditional Expression 7:

[00007] $-10. < (R5 - R6) / (R5 + R6) < 14.$ [ConditionalExpression7]   [0024] where R5 is a radius of curvature [mm] of an object-side surface of the third lens, and R6 is a radius of curvature [mm] of an image-side surface of the third lens.

[0025] Some embodiments of the lens module may satisfy Conditional Expression 8:

[00008] $ANG / f > 15.$ [ConditionalExpression8]   [0026] where ANG is an angle of view of the lens module, and f is an overall focal length [mm] of an optical system including the first to

seventh lenses.

[0027] The some embodiments of the lens module may satisfy Conditional Expression 9:

[00009] $.Math. f1 .Math. < .Math. f3 .Math.$ [ConditionalExpression9] [0028] where f1 is a focal length [mm] of the first lens, and f3 is a focal length [mm] of the third lens.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0029] Exemplary embodiments of the present disclosure will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

[0030] FIG. **1** is a configuration diagram of a lens module according to a first exemplary embodiment of the present disclosure;

[0031] FIG. **2** is a graph showing a modulation transfer function (MTF) of the lens module shown in FIG. **1**;

[0032] FIG. **3** is graphs showing aberration characteristics of the lens module shown in FIG. **1**;

[0033] FIG. **4** is a configuration diagram of a lens module according to a second exemplary embodiment of the present disclosure;

[0034] FIG. **5** is a graph showing a MTF of the lens module shown in FIG. **4**;

[0035] FIG. **6** is graphs showing aberration characteristics of the lens module shown in FIG. **4**;

[0036] FIG. **7** is a configuration diagram of a lens module according to a third exemplary embodiment of the present disclosure;

[0037] FIG. **8** is a graph showing a MTF of the lens module shown in FIG. **7**;

[0038] FIG. **9** is graphs showing aberration characteristics of the lens module shown in FIG. **7**;

[0039] FIG. **10** is a configuration diagram of a lens module according to a fourth exemplary embodiment of the present disclosure;

[0040] FIG. **11** is a graph showing a MTF of the lens module shown in FIG. **10**;

[0041] FIG. **12** is graphs showing aberration characteristics of the lens module shown in FIG. **10**;

[0042] FIG. **13** is a configuration diagram of a lens module according to a fifth exemplary embodiment of the present disclosure;

[0043] FIG. **14** is a graph showing a MTF of the lens module shown in FIG. **13**;

[0044] FIG. **15** is graphs showing aberration characteristics of the lens module shown in FIG. **13**;

[0045] FIG. **16** is a configuration diagram of a lens module according to a sixth exemplary embodiment of the present disclosure;

[0046] FIG. **17** is a graph showing a MTF of the lens module shown in FIG. **16**;

[0047] FIG. **18** is graphs showing aberration characteristics of the lens module shown in FIG. **16**;

[0048] FIG. **19** is a configuration diagram of a lens module according to a seventh exemplary embodiment of the present disclosure;

[0049] FIG. **20** is a graph showing a MTF of the lens module shown in FIG. **19**; and

[0050] FIG. **21** is graphs showing aberration characteristics of the lens module shown in FIG. **19**.

DETAILED DESCRIPTION

[0051] Exemplary embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. The invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein. Rather, these embodiments are provided to explain the principles of the invention and its practical applications, thereby enabling others skilled in the art to understand the invention for various embodiments and with various modifications as are suited to the particular use contemplated. In the drawings, the shapes and dimensions of elements may be exaggerated for clarity, and the same reference numerals will be used throughout to designate the same or like elements. It will also be understood that, although the terms first, second, etc. may be used herein to describe various elements, these

elements should not be limited by these terms. These terms are only used to distinguish one element from another. As used in this description and the appended claims, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0052] In the present exemplary embodiments, a first lens refers to a lens that is the closest to an object side and a seventh lens refers to a lens that is the closest to an image side. Further, the term 'front' refers to a direction from the lens module toward an object side, while the term 'rear' refers to a direction from the lens module toward an image sensor or the image side. In addition, a first surface of each lens refers to a surface close to the object side (or an object-side surface) and a second surface of each lens refers to a surface close to the image side (or an image-side surface). Further, unless particularly described, in the present exemplary embodiments, units of all of radii of curvature, thicknesses, TTLs, BFLs, and focal lengths (e.g., f, f1, f2, f3, f4, f5, f6, f7, and f12) of the lenses may be mm. In addition, the thickness of the lens, intervals between the lenses, the TTL (or OAL), SL, and BFL are distance measured on an optical axis of the lens. Further, in a description for a shape of the lens, the meaning that one surface of the lens is convex is that an optical axis portion of a corresponding surface is convex, and the meaning that one surface of the lens is concave is that an optical axis portion of a corresponding portion is concave. Therefore, although it is described that one surface of the lens is convex, an periphery portion of the lens may be concave. Likewise, although it is described that one surface of the lens is concave, an periphery portion of the lens may be convex. In addition, in the following detailed description, the term "inflection point" refers to a point at which a radius of curvature is changed in a portion that does not cross the optical axis. Further, in the following detailed description, the term "turning point" refers to a convex or concave point in a portion that does not cross the optical axis.

[0053] FIG. **1** is a configuration diagram of a lens module according to a first exemplary embodiment of the present disclosure, FIG. **2** is a graph showing a modulation transfer function (MTF) of the lens module shown in FIG. **1**, FIG. **3** is graphs showing aberration characteristics of the lens module shown in FIG. **1**, FIG. **4** is a configuration diagram of a lens module according to a second exemplary embodiment of the present disclosure, FIG. **5** is a graph showing a MTF of the lens module shown in FIG. **4**, FIG. **6** is graphs showing aberration characteristics of the lens module shown in FIG. **4**, FIG. **7** is a configuration diagram of a lens module according to a third exemplary embodiment of the present disclosure, FIG. **8** is a graph showing a MTF of the lens module shown in FIG. **7**, FIG. **9** is graphs showing aberration characteristics of the lens module shown in FIG. **7**, FIG. **10** is a configuration diagram of a lens module according to a fourth exemplary embodiment of the present disclosure, FIG. **11** is a graph showing a MTF of the lens module shown in FIG. **10**, FIG. **12** is graphs showing aberration characteristics of the lens module shown in FIG. **10**, FIG. **13** is a configuration diagram of a lens module according to a fifth exemplary embodiment of the present disclosure, FIG. **14** is a graph showing a MTF of the lens module shown in FIG. **13**, FIG. **15** is graphs showing aberration characteristics of the lens module shown in FIG. **13**, FIG. **16** is a configuration diagram of a lens module according to a sixth exemplary embodiment of the present disclosure, FIG. **17** is a graph showing a MTF of the lens module shown in FIG. **16**, FIG. **18** is graphs showing aberration characteristics of the lens module shown in FIG. **16**, FIG. **19** is a configuration diagram of a lens module according to a seventh exemplary embodiment of the present disclosure, FIG. **20** is a graph showing a MTF of the lens module shown in FIG. **19**, and FIG. **21** is graphs showing aberration characteristics of the lens module shown in FIG. **19**.

[0054] A lens module according to the present disclosure may include an optical system including seven lenses. The lens module may include a first lens, a second lens, a third lens, a fourth lens, a fifth lens, a sixth lens, and a seventh lens. The lens module may further include other components or additional one or more lenses if necessary. For example, the lens module may include a stop for controlling an amount of light. In addition, the lens module may further include an infrared cut-off

filter for cutting off an infrared ray. Further, the lens module may include an image sensor (that is, an imaging device) converting an image of a subject incident through the optical system into an electrical signal or data. The lens module may further include an interval maintaining member adjusting an interval between lenses. In addition to seven lenses, one or more lenses may be arranged in front of the first lens, behind the seventh lens, or between the first and seventh lenses.

[0055] At least one of the first to seventh lenses may be formed of plastic. For example, the first and seventh lenses may be formed of plastic, and the other lenses may be formed of a different material. However, materials of the first to seventh lenses are not limited to the above-mentioned materials. For example, all of the first to seventh lenses may be formed of plastic.

[0056] At least one of the object-side surface and image-side surface of at least one of the first to seventh lenses may be aspheric. For example, the object-side surfaces or image-side surfaces of the first to seventh lenses may be aspheric. As another example, the both of the surfaces (the object-side surfaces and image-side surfaces) of the first to seventh lenses may be aspheric. The aspheric surface of each of the lenses may be represented by Equation 1.

[00010]

$$Z = \frac{cY^2}{1 + \sqrt{1 - (1 + K)c^2 Y^2}} + AY^4 + BY^6 + CY^8 + DY^{10} + EY^{12} + FY^{14} + \ .\text{Math.} \quad [Equation1]$$

[0057] In Equation 1, Z indicates the height of a point on the aspheric surface at a distance Y from the optical axis relative to the tangential plane at the aspheric surface vertex, c indicates curvature (1/r), k indicates a conic constant, and Y indicates a distance from the point on the curve of the aspheric surface to the optical axis. Constants A to J sequentially indicate 4th-order to 20th-order aspheric coefficients.

[0058] In the lens module according to an exemplary embodiment of the present disclosure, the optical system including the first to seventh lenses may satisfy Conditional Expression 1:

[00011] $1. < f12 / f < 2.1$ [ConditionalExpression1]

[0059] Here, f12 is a synthetic focal length [mm] of the first and second lenses, and f is an overall focal length [mm] of the optical system.

[0060] Here, Conditional Expression 1 may be a numerical range for optimizing refractive power of the first and second lenses. For example, in the case in which the value of f12/f is below the lower limit value of Conditional Expression 1, refractive power may become large, such that it may be difficult to correct spherical aberration. On the contrary, in the case in which the value of f12/f is greater than the upper limit value of the Conditional Expression 1, the lens module may be advantageous for correcting aberration, but it may be difficult to miniaturize the optical system.

[0061] In the lens module according to an exemplary embodiment of the present disclosure, the optical system including the first to seventh lenses may satisfy Conditional Expression 2:

[00012] $TTL / f < 1.4$ [ConditionalExpression2]

[0062] Here, TTL is a distance [mm] from an object-side surface of the first lens to an image surface, and f is the overall focal length [mm] of the optical system.

[0063] Conditional Expression 2 may be a numerical range for miniaturizing the lens module. For example, in the case in which the value of TTL/f is greater than the upper limit value of Conditional Expression 2, it may be difficult to miniaturize the lens module.

[0064] In the lens module according to an exemplary embodiment of the present disclosure, the optical system including the first to seventh lenses may satisfy Conditional Expression 3:

[00013] $BFL / f > 2.$ [ConditionalExpression3]

[0065] Here, BFL is a distance [mm] from an image-side surface of the seventh lens to the image surface, and f is the overall focal length [mm] of the optical system.

[0066] Conditional Expression 3 may be a numerical range for optimizing the manufacturing convenience of the lens module. For example, in the case in which the value of BFL/f is below the lower limit value of Conditional Expression 3, a distance between the seventh lens and the image

surface may not be secured and it may be difficult to actually manufacture the lens module.

[0067] In the lens module according to an exemplary embodiment of the present disclosure, an optical system including the first to seventh lenses may satisfy Conditional Expression 4:

[00014] $R1/f > 0.35$ [ConditionalExpression4]

[0068] Here, R1 is a radius of curvature [mm] of the object-side surface of the first lens, and f is the overall focal length [mm] of the optical system.

[0069] Conditional Expression 4 may be a numerical range for optimizing a shape of the first lens. For example, in the case in which the value of R1/f is below the lower limit value of Conditional Expression 4, the radius of curvature may be excessively small, the first lens may be sensitive to a manufacturing tolerance, and it may be not easy to manufacture the first lens.

[0070] In the lens module according to an exemplary embodiment of the present disclosure, an optical system including the first to seventh lenses may satisfy Conditional Expression 5:

[00015] $-0.6 < (R11 - R12)/(R11 + R12) < 8.$ [ConditionalExpression5]

[0071] Here, R11 is a radius of curvature [mm] of the object-side surface of the sixth lens, and R12 is a radius of curvature [mm] of the image-side surface of the sixth lens.

[0072] Conditional Expression 5 may be a numerical range for optimizing a shape of the sixth lens. For example, in the case in which the value of (R11−R12)/(R11+R12) goes out of the numerical range of Conditional Expression 5, a deviation between the radii of curvature of the object-side surface and the image-side surface of the sixth lens may be large, and the sixth lens may be disadvantageous for correcting aberration.

[0073] In the lens module according to an exemplary embodiment of the present disclosure, the optical system including the first to seventh lenses may satisfy Conditional Expression 6:

[00016] $-2. < R13/f < 1.$ [ConditionalExpression6]

[0074] Here, R13 is a radius of curvature [mm] of the object-side surface of the seventh lens.

[0075] Conditional Expression 6 may be a numerical range for optimizing a shape of the seventh lens. For example, in the case in which the value of R13/f goes out of the numerical range of Conditional Expression 6, it may be difficult to manufacture the seventh lens, and an effect of correcting aberration may be reduced.

[0076] In the lens module according to an exemplary embodiment of the present disclosure, the optical system including the first to seventh lenses may satisfy Conditional Expression 7:

[00017] $-10. < (R5 - R6)/(R5 + R6) < 14.$ [ConditionalExpression7]

[0077] Here, R5 is a radius of curvature [mm] of the object-side surface of the third lens, and R6 is a radius of curvature [mm] of the image-side surface of the third lens.

[0078] For example, in the case in which the value of (R5−R6)/(R5+R6) goes out of the numerical range of Conditional Expression 7, a deviation between the radii of curvature of the object-side surface and the image-side surface of the third lens may be large, and the third lens may be disadvantageous for correcting aberration.

[0079] In the lens module according to an exemplary embodiment of the present disclosure, the optical system including the first to seventh lenses may satisfy Conditional Expression 8:

[00018] $ANG/f > 15.$ [ConditionalExpression8]

[0080] Here, ANG is an angle of view of the lens module, and f is the overall focal length [mm] of the optical system including the first to seventh lenses.

[0081] For example, in the case in which the value of ANG/f is below the lower limit value of Conditional Expression 8, the lens module may be disadvantageous for providing a wide angle of view.

[0082] In the lens module according to an exemplary embodiment of the present disclosure, an optical system including the first to seventh lenses may satisfy Conditional Expression 9:

[00019]   .Math. $f1$ .Math. $<$ .Math. $f3$ .Math.   [ConditionalExpression9]

[0083] Here, f1 is the focal length [mm] of the first lens, and f3 is the focal length [mm] of the third lens.

[0084] Hereinafter, the first to seventh lenses of the lens module according to an exemplary embodiment of the present disclosure will be described.

[0085] The first lens may have refractive power. For example, the refractive power of the first lens may be positive. The first lens may be formed of plastic. However, the material of the first lens is not limited to plastic. For example, different materials which may transmit light may be used to make the first lens. A first surface of the first lens may be convex, and a second surface thereof may be concave. For example, the first lens may have a meniscus shape in which it is convex toward the object side or a plano-convex shape in which one surface is convex. However, the shape of the first lens is not limited to the above-mentioned shape. For example, the second surface of the first lens may be convex if necessary. At least one of the first and second surfaces of the first lens may be aspheric. For example, the first or second surface of the first lens or both surfaces thereof may be aspheric.

[0086] The second lens may have refractive power. For example, the refractive power of the second lens may be positive or negative. The second lens may be formed of plastic. However, the material of the second lens is not limited to plastic. For example, different materials which may transmit light may be used to make the second lens. A first surface of the second lens may be convex, and a second surface thereof may be concave. For example, the second lens may have a meniscus shape in which it is convex toward the object side. However, the shape of the second lens is not limited to the above- mentioned shape. For example, the first surface of the second lens may be concave if necessary. At least one of the first and second surfaces of the second lens may be aspheric. For example, the first or second surface of the second lens or both surfaces thereof may be aspheric.

[0087] The third lens may have refractive power. For example, the refractive power of the third lens may be positive or negative. The third lens may be formed of plastic. However, the material of the third lens is not limited to plastic. For example, different materials which may transmit light may be used to make the third lens. Both surfaces of the third lens may be convex. However, the shape of the third lens is not limited to the above-mentioned shape. For example, the third lens may have a shape in which an optical axis portion of the object-side surface thereof is convex, and the peripheral portion of the object-side surface thereof is concave. In addition, a second surface of the third lens may be concave. At least one of the first and second surfaces of the third lens may be aspheric. For example, the first or second surface of the third lens or both surfaces thereof may be aspheric.

[0088] The fourth lens may have refractive power. For example, the refractive power of the fourth lens may be positive or negative. The fourth lens may be formed of plastic. However, the material of the fourth lens is not limited to the plastic. For example, different materials which may transmit light may be used to make the fourth lens. A first surface of the fourth lens may be concave, and a second surface thereof may be convex. For example, the fourth lens may have a meniscus shape in which it is convex toward the image side. However, the shape of the fourth lens is not limited to the above-mentioned shape. The fourth lens may have different shapes, for instance, that the first surface of the fourth lens is concave, and the second surface thereof is convex. At least one of the first and second surfaces of the fourth lens may be aspheric. For example, the first or second surface of the fourth lens or both surfaces thereof may be aspheric.

[0089] The fifth lens may have refractive power. For example, the refractive power of the fifth lens may be positive or negative. The fifth lens may be formed of plastic. However, the material of the fifth lens is not limited to plastic. For example, different materials which may transmit light may be used to make the fifth lens. A first surface of the fifth lens may be concave, and a second surface thereof may be convex. For example, the fifth lens may have a meniscus shape in which it is convex toward the image side. At least one of the first and second surfaces of the fifth lens may be aspheric. For example, the first or second surface of the fifth lens or both surfaces thereof may be

aspheric.

[0090] The sixth lens may have refractive power. For example, the refractive power of the sixth lens may be positive or negative. The sixth lens may be formed of plastic. However, the material of the sixth lens is not limited to plastic. For example, different materials which may transmit light may be used to make the sixth lens. A first surface of the sixth lens may be convex and a second surface thereof may be concave. However, the shape of the sixth lens is not limited to the above-mentioned shape. The sixth lens may have various shapes, for instance, that the first surface thereof is concave, and the second surface thereof is convex. In addition, the sixth lens may have a shape in which an inflection point is formed on at least one of the first and second surfaces thereof. For example, the second surface of the sixth lens may be concave at the center of an optical axis and become convex toward an edge thereof. At least one of the first and second surfaces of the sixth lens or both surfaces thereof may be aspheric.

[0091] The seventh lens may have refractive power. For example, the refractive power of the seventh lens may be negative. The seventh lens may be formed of plastic. However, the material of the seventh lens is not limited to plastic. For example, different materials which may transmit light may be used to make the seventh lens. A first surface of the seventh lens may be convex, and a second surface thereof may be concave. However, the shape of the seventh lens is not limited to the above-mentioned shape. The seventh lens may have various shapes, for instance, in which both surfaces thereof are concave. The seventh lens may have a shape in which an inflection point is formed on at least one of the first and second surfaces thereof. For example, the second surface of the seventh lens may be concave at the center of an optical axis and become convex toward an edge thereof. At least one of the first and second surfaces of the seventh lens or both surfaces thereof may be aspheric.

[0092] Some embodiments of the lens module configured as described above may decrease aberration which causes image quality deterioration. Further, some embodiments of the lens module configured as described above may improve lightness and reduce a manufacturing cost.

[0093] Hereinafter, lens modules according to the first to seventh exemplary embodiments of the present disclosure will be described.

[0094] Firstly, the lens module according to the first exemplary embodiment (Example 1) of the present disclosure will be described with reference to FIGS. **1** through **3**.

[0095] The lens module **100** according to this exemplary embodiment may include a first lens **10**, a second lens **20**, a third lens **30**, a fourth lens **40**, a fifth lens **50**, a sixth lens **60**, and a seventh lens **70**. The lens module **100** may further include an infrared cut-off filter **80** and an image sensor **90**. Additionally, the lens module **100** may include at least one aperture stop (not shown). The aperture stop (not shown) may be arranged in front of the first lens **10** or anywhere between the first lens **10** and the seventh lens **70**. For reference, an overall focal length f of the lens module **100** may be 4.543 [mm], a focal length of the first lens **10** may be 4.199, a focal length of the second lens **20** may be −9.17, a focal length of the third lens **30** may be 4.903, a focal length of the fourth lens **40** may be −6.400, a focal length of the fifth lens **50** may be −124.921, a focal length of the sixth lens **60** may be 27.141, and a focal length of the seventh lens **70** may be −14.863.

[0096] Table 1 below shows radii of curvature of the lenses, thicknesses of the lenses or distances between the lenses, refractive indices of the lenses, and abbe numbers of the lenses. More specifically, values in a horizontal row corresponding to S1 in a vertical column sequentially indicate a radius R1 of curvature of a first surface of the first lens **10**, a thickness of the first lens **10**, a refractive index of the first lens **10**, and an abbe number of first lens **10**. In addition, values in a horizontal row corresponding to S2 in a vertical column sequentially indicate a radius R2 of curvature of a second surface of the first lens **10** and a distance between the first lens **10** and the second lens **20**. Similarly, values in a horizontal row corresponding to S3 in a vertical column sequentially indicate a radius R3 of curvature of a first surface of the second lens **20**, a thickness of the second lens **20**, a refractive index of the second lens **20**, and an abbe number of second lens **20**.

In addition, values in a horizontal row corresponding to S4 in a vertical column sequentially indicate a radius R4 of curvature of a second surface of the second lens **20** and a distance between the second lens **20** and the third lens **30**. For reference, radii R5 to R14 of curvature of the third to seventh lenses, thickness of the third to seventh lenses or distances between the third to seventh lenses, refractive indices of the lenses, and abbe numbers of the third to seventh lenses are shown in the same scheme as described above.

[0097] Table 2 below indicates an aspheric constant of each of the lenses. In detail, the first horizontal axis in Table 2 indicates first and second surfaces of each of the lenses. For example, number 2 in the first horizontal row indicates the first surface of the first lens **10** and number 3 in the first horizontal axis indicates the second surface of the first lens **10**. In addition, number 4 in the first horizontal row indicates the first surface of the second lens **20** and number 5 in the first horizontal axis indicates the second surface of the second lens **20**. Similarly, numbers 6 to 15 in the first horizontal axis indicate first and second surfaces of the third to seventh lenses, respectively.

[0098] In this exemplary embodiment, the first lens **10** may have positive refractive power. The first surface of the first lens **10** may be convex, and the second surface thereof may be concave. The second lens **20** may have negative refractive power. The first surface of the second lens **20** may be convex, and the second surface thereof may be concave. The third lens **30** may have positive refractive power. Both surfaces of the third lens **30** may be convex. The fourth lens **40** may have negative refractive power. The first surface of the fourth lens **40** may be concave, and the second surface thereof may be convex. That is, the fourth lens **40** may have a meniscus shape in which it is convex toward an image side. The fifth lens **50** may have negative refractive power. The first surface of the fifth lens **50** may be concave, and the second surface thereof may be convex. That is, the fifth lens **50** may have a meniscus shape in which it is convex toward the image side. The sixth lens **60** may have positive refractive power. In addition, the first surface of the sixth lens **60** may be convex, and the second surface thereof may be concave. The sixth lens **60** may have inflection points formed on the first and second surfaces thereof, respectively. The seventh lens **70** may have negative refractive power. The first surface of the seventh lens **70** may be convex, and the second surface thereof may be concave. Further, the seventh lens **70** may have an inflection point formed on the second surface thereof.

[0099] The exemplary embodiment of the lens module configured as described above may have MTF characteristics and aberration characteristics as shown in FIGS. **2** and **3**, respectively.

TABLE 1

Example 1 number	Radius of Curvature	Tickness/ Distance	Refractive Index	Abbe number
Object	Infinity	Infinity		
ST	Infinity	0.050		
1	1.8598	0.518	1.544	56.1
2	9.0224	0.105		
3	3.9767	0.220	1.635	24.0
4	2.3118	0.327		
5	6.3324	0.470	1.544	56.1
6	−4.4884	0.341		
7	−1.2726	0.220	1.635	24.0
8	−1.9772	0.162		
9	−1.5843	0.220	1.544	56.1
10	−1.7015	0.100		
11	2.6609	0.519	1.635	24.0
12	2.9085	0.371		
13	2.34792	0.641	1.544	56.1
14	1.64465	0.438		
15	Infinity	0.300	1.517	64.2
16	Infinity	0.503	Image	

TABLE 2

Example 2	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Y Radius	1.860	9.022	3.977	2.312	6.332	−4.488	−1.273	−1.977	−1.584	−1.702	2.661	2.909	2.348	1.645
Conic Constant (K)	0.000	0.000	0.000	−8.131	0.000	0.000	−1.897	−0.498	0.055	−0.432	0.000	0.000	−14.574	−7.680
4th-order Coefficient (A)	−0.015	−0.140	−0.256	−0.120	−0.090	−0.055	−0.026	−0.026	0.058	0.038	−0.088	−0.098	−0.144	−0.086
6th-order Coefficient (B)	0.003	0.238	0.528	0.332	0.010	−0.012	0.023	0.030	0.011	0.016	−0.010	0.016	0.023	0.022
8th-order Coefficient (C)	−0.065	−0.381	−0.639	−0.347	−0.022	0.014	−0.017	−0.011	0.002	0.003	0.015	−0.004	0.007	−0.003
10th-order Coefficient (D)	0.073	0.289	0.477	0.222	0.022	−0.018	0.011	−0.002	0.002	−0.004	−0.009	0.000	−0.003	0.000
12th-order Coefficient (E)	−0.067	−0.116	−0.168	−0.047	−0.020	0.024	−0.001	0.003	0.001	0.001	0.002	0.000	0.000	0.000
14th-order Coefficient (F)	0.013	0.015	0.019	0.000	0.019	−0.010	−0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
16th-order Coefficient (G)														
18th-order Coefficient (H)														
20th-order Coefficient (J)														

[0100] The lens module according to the second exemplary embodiment (Example 2) of the present

disclosure will be described with reference to FIGS. **4** through **6**.

[0101] The lens module **100** according to this exemplary embodiment may include a first lens **10**, a second lens **20**, a third lens **30**, a fourth lens **40**, a fifth lens **50**, a sixth lens **60**, and a seventh lens **70**. The lens module **100** may further include an infrared cut-off filter **80** and an image sensor **90**. Further, the lens module **100** may include at least one aperture stop (not shown). The aperture stop (not shown) may be arranged in front of the first lens **10** or anywhere between the first lens **10** and the seventh lens **70**. For reference, an overall focal length f of the lens module **100** may be 4.462 [mm], a focal length of the first lens **10** may be 3.742, a focal length of the second lens **20** may be −7.998, a focal length of the third lens **30** may be 5.553, a focal length of the fourth lens **40** may be −8.276, a focal length of the fifth lens **50** may be 104.962, a focal length of the sixth lens **60** may be 517.567, and a focal length of the seventh lens **70** may be −12.343.

[0102] Table 3 below shows radii of curvature of the lenses, thicknesses of the lenses or distances between the lenses, refractive indices of the lenses, and abbe numbers of the lenses. Table 4 below indicates an aspheric constant of each surface of the lenses.

[0103] In this exemplary embodiment, the first lens **10** may have positive refractive power. A first surface of the first lens **10** may be convex, and a second surface thereof may be concave. The second lens **20** may have negative refractive power. A first surface of the second lens **20** may be convex, and a second surface thereof may be concave. The third lens **30** may have positive refractive power. Both surfaces of the third lens **30** may be convex. The fourth lens **40** may have negative refractive power. A first surface of the fourth lens **40** may be concave, and a second surface thereof may be convex. That is, the fourth lens **40** may have a meniscus shape in which it is convex toward an image side. The fifth lens **50** may have positive refractive power. A first surface of the fifth lens **50** may be concave, and a second surface thereof may be convex. That is, the fifth lens **50** may have a meniscus shape in which it is convex toward the image side. The sixth lens **60** may have positive refractive power. A first surface of the sixth lens **60** may be convex, and a second surface thereof may be concave. In addition, the sixth lens **60** may have inflection points formed on the first and second surfaces thereof, respectively. The seventh lens **70** may have negative refractive power. A first surface of the seventh lens **70** may be convex, and a second surface thereof may be concave. Further, the seventh lens **70** may have an inflection point formed on the second surface thereof.

[0104] The exemplary embodiment of the lens module configured as described above may have MTF characteristics and aberration characteristics as shown in FIGS. **5** and **6**, respectively.

TABLE-US-00003

TABLE 3

Example 2	Radius of Curvature	Tickness/ Distance	Refractive Index	Abbe number
Object	Infinity	Infinity		
ST	Infinity	0.050		
1	1.823	0.592	1.544	56.1
2	15.421	0.100		
3	4.172	0.220	1.635	24.0
4	2.244	0.375		
5	7.162	0.467	1.544	56.1
6	−5.106	0.336		
7	−1.312	0.240	1.635	24.0
8	−1.872	0.158		
9	−1.566	0.242	1.544	56.1
10	−1.607	0.100		
11	2.899	0.497	1.635	24.0
12	2.731	0.290		
13	3.143	0.724	1.544	56.1
14	1.967	0.265		
15	Infinity	0.300	1.517	64.2
16	Infinity	0.501		
Image				

TABLE-US-00004

TABLE 4

Example 2	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Y Radius	1.823	15.421	4.172	2.244	7.162	−5.106	−1.312	−1.872	−1.566	−1.607	2.899	2.731	3.143	1.967
Conic Constant (K)	0.000	0.000	0.000	−7.071	0.000	0.000	−1.313	−0.514	0.046	−0.462	0.000	0.000	−22.646	−8.489
4th-order Coefficient (A)	−0.010	−0.127	−0.256	−0.124	−0.099	−0.081	−0.031	−0.030	0.049	0.039	−0.076	−0.101	−0.135	−0.081
6th-order Coefficient (B)	0.007	0.240	0.525	0.329	0.007	−0.011	0.025	0.027	0.008	0.015	−0.012	0.015	0.024	0.023
8th-order Coefficient (C)	−0.062	−0.370	−0.640	−0.347	−0.024	0.013	−0.018	−0.010	0.000	0.002	0.014	−0.004	0.007	−0.004
10th-order Coefficient (D)	0.079	0.282	0.477	0.221	0.021	−0.019	0.011	−0.002	0.002	−0.004	−0.010	0.000	−0.003	0.000
12th-order Coefficient (E)	−0.066	−0.116	−0.170	−0.043	−0.020	0.024	−0.001	0.003	0.002	0.001	0.002	0.000	0.000	0.000
14th-order Coefficient (F)	0.014	0.017	0.021	0.000	0.021	−0.009	−0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
16th-order Coefficient (G)														
18th-order Coefficient (H)														
20th-order Coefficient (J)														

[0105] The lens module according to the third exemplary embodiment (Example 3) of the present disclosure will be described with reference to FIGS. **7** through **9**.

[0106] The lens module **100** according to this exemplary embodiment may include a first lens **10**, a second lens **20**, a third lens **30**, a fourth lens **40**, a fifth lens **50**, a sixth lens **60**, and a seventh lens **70**. The lens module **100** may further include an infrared cut-off filter **80** and an image sensor **90**. Further, the lens module **100** may include at least one aperture stop (not shown). The aperture stop (not shown) may be arranged in front of the first lens **10** or anywhere between the first lens **10** and the seventh lens **70**. For reference, an overall focal length f of the lens module **100** may be 4.271 [mm], a focal length of the first lens **10** may be 3.782, a focal length of the second lens **20** may be −7.960, a focal length of the third lens **30** may be 5.239, a focal length of the fourth lens **40** may be −6.790, a focal length of the fifth lens **50** may be 53.775, a focal length of the sixth lens **60** may be 72.888, and a focal length of the seventh lens **70** may be −15.543.

[0107] Table 5 below shows radii of curvature of the lenses, thicknesses of the lenses or distances between the lenses, refractive indices of the lenses, and abbe numbers of the lenses. Table 6 below indicates an aspheric constant of each surface of the lenses.

[0108] In this exemplary embodiment, the first lens **10** may have positive refractive power. A first surface of the first lens **10** may be convex, and a second surface thereof may be concave. The second lens **20** may have negative refractive power. A first surface of the second lens **20** may be convex, and a second surface thereof may be concave. The third lens **30** may have positive refractive power. Both surfaces of the third lens **30** may be convex. The fourth lens **40** may have negative refractive power. A first surface of the fourth lens **40** may be concave, and a second surface thereof may be convex. That is, the fourth lens **40** may have a meniscus shape in which it is convex toward an image side. The fifth lens **50** may have positive refractive power. A first surface of the fifth lens **50** may be concave, and a second surface thereof may be convex. That is, the fifth lens **50** may have a meniscus shape in which it is convex toward the image side. The sixth lens **60** may have positive refractive power. A first surface of the sixth lens **60** may be convex, and a second surface thereof may be concave. In addition, the sixth lens **60** may have inflection points formed on the first and second surfaces thereof, respectively. The seventh lens **70** may have negative refractive power. A first surface of the seventh lens **70** may be convex, and a second surface thereof may be concave. Further, the seventh lens **70** may have an inflection point formed on the second surface thereof.

[0109] The exemplary embodiment of the lens module configured as described above may have MTF characteristics and aberration characteristics as shown in FIGS. **8** and **9**, respectively.

TABLE-US-00005

TABLE 5

Example 3	Radius of Curvature	Tickness/ Distance	Refractive Index	Abbe number
Object	Infinity	Infinity		
ST	Infinity	0.050		
1	1.802	0.540	1.544	56.1
2	13.001	0.104		
3	4.169	0.242	1.635	24.0
4	2.233	0.301		
5	6.476	0.398	1.544	56.1
6	−4.982	0.347		
7	−1.252	0.240	1.635	24.0
8	−1.895	0.164		
9	−1.547	0.242	1.544	56.1
10	−1.551	0.100		
11	2.535	0.554	1.635	24.0
12	2.455	0.281		
13	2.075	0.537	1.544	56.1
14	1.514	0.252		
15	Infinity	0.300	1.517	64.2
16	Infinity	0.600		
image				

TABLE-US-00006

TABLE 6

Example	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Y Radius	1.802	13.001	4.169	2.233	6.476	−4.982	−1.252	−1.895	−1.547	−1.551	2.535	2.455	2.075	1.514
Conic Constant (K)	0.000	0.000	0.000	−7.719	0.000	0.000	−2.215	−0.619	0.052	−0.350	0.000	0.000	−15.289	−8.510
4th-order Coefficient (A)	−0.014	−0.145	−0.258	−0.120	−0.101	−0.047	−0.027	−0.023	0.051	0.048	−0.092	−0.107	−0.134	−0.089
6th-order Coefficient (B)	−0.001	0.239	0.524	0.331	0.012	−0.016	0.020	0.032	0.014	0.017	−0.008	0.017	0.022	0.023
8th-order Coefficient (C)	−0.064	−0.383	−0.639	−0.348	−0.023	0.012	−0.019	−0.011	0.004	0.003	0.015	−0.004	0.007	−0.003
10th-order Coefficient (D)	0.073	0.286	0.477	0.220	0.022	−0.019	0.010	−0.002	0.003	−0.004	−0.010	0.000	−0.003	0.000
12th-order Coefficient (E)	−0.069	−0.119	−0.170	−0.046	−0.020	0.024	−0.002	0.004	0.001	0.001	0.002	0.000	0.000	0.000
14th-order Coefficient (F)	0.009	0.015	0.021	0.000	0.022	−0.009	−0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
16th-order Coefficient (G)														
18th-order														

Coefficient (H) 20th-order Coefficient (J)

[0110] The lens module according to the fourth exemplary embodiment (Example 4) of the present disclosure will be described with reference to FIGS. **10** through **12**.

[0111] The lens module **100** according to this exemplary embodiment may include a first lens **10**, a second lens **20**, a third lens **30**, a fourth lens **40**, a fifth lens **50**, a sixth lens **60**, and a seventh lens **70**. The lens module **100** may further include an infrared cut-off filter **80** and an image sensor **90**. Further, the lens module **100** may further include at least one aperture stop (not shown). The aperture stop (not shown) may be arranged in front of the first lens **10** or anywhere between the first lens **10** and the seventh lens **70**. For reference, an overall focal length f of the lens module **100** may be 4.300 [mm], a focal length of the first lens **10** may be 5.204, a focal length of the second lens **20** may be 1000.000, a focal length of the third lens **30** may be 4.026, a focal length of the fourth lens **40** may be −4.520, a focal length of the fifth lens **50** may be 7.456, a focal length of the sixth lens **60** may be −31.268, and a focal length of the seventh lens **70** may be −5.024.

[0112] Table 7 below shows radii of curvature of the lenses, thicknesses of the lenses or distances between the lenses, refractive indices of the lenses, and abbe numbers of the lenses. Table 8 below indicates an aspheric constant of each of the lenses.

[0113] In this exemplary embodiment, the first lens **10** may have positive refractive power. A first surface of the first lens **10** may be convex, and a second surface thereof may be concave. The second lens **20** may have positive refractive power. A first surface of the second lens **20** may be convex, and a second surface thereof may be concave. The third lens **30** may have positive refractive power. Both surfaces of the third lens **30** may be convex. The fourth lens **40** may have negative refractive power. A first surface of the fourth lens **40** may be concave, and a second surface thereof may be convex. That is, the fourth lens **40** may have a meniscus shape in which it is convex toward an image side. The fifth lens **50** may have positive refractive power. A first surface of the fifth lens **50** may be concave, and a second surface thereof may be convex. That is, the fifth lens **50** may have a meniscus shape in which it is convex toward the image side. The sixth lens **60** may have negative refractive power. A first surface of the sixth lens **60** may be convex, and a second surface thereof may be concave. In addition, the sixth lens **60** may have inflection points formed on the first and second surfaces thereof, respectively. The seventh lens **70** may have negative refractive power. A first surface of the seventh lens **70** may be concave, and a second surface thereof may be concave. Further, the seventh lens **70** may have an inflection point formed on the second surface thereof.

[0114] The exemplary embodiment of the lens module configured as described above may have MTF characteristics and aberration characteristics as shown in FIGS. **11** and **12**, respectively.

TABLE-US-00007

TABLE 7

	Radius of Curvature	Tickness/ Distance	Refractive Index	Abbe number
Object	Infinity	Infinity		
ST	Infinity	0.050		
1	1.946	0.426	1.544	56.1
2	5.740	0.192		
3	5.025	0.250	1.635	24.0
4	4.968	0.222		
5	16.021	0.471	1.544	56.1
6	−2.512	0.188		
7	−1.396	0.570	1.635	24.0
8	−3.150	0.174		
9	−1.832	0.340	1.544	56.1
10	−1.344	0.100		
11	3.272	0.576	1.635	24.0
12	2.617	0.590		
13	−5.948	0.501	1.544	56.1
14	5.208	0.139		
15	Infinity	0.300	1.517	64.2
16	Infinity	0.489		
Image				

TABLE-US-00008

TABLE 8

Example	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Y Radius	1.946	5.740	5.025	4.968	16.021	−2.512	−1.396	−3.150	−1.832	−1.344	3.272	2.617	−5.948	5.208
Conic Constant	0.000	0.000	0.000	−45.000	0.000	0.000	−1.319	1.905	−0.184	−0.759	0.000	0.000	−50.000	−50.000
(K) 4th-order	−0.019	−0.190	−0.327	−0.210	−0.126	−0.069	−0.047	−0.022	0.071	0.100	−0.106	−0.137	−0.074	−0.045
Coefficient (A) 6th-order	0.040	0.287	0.485	0.269	0.002	−0.037	0.034	0.046	0.011	0.002	0.013	0.033	0.001	0.015
Coefficient (B) 8th-order	−0.098	−0.403	−0.617	−0.347	−0.070	0.004	−0.014	−0.010	−0.001	0.006	0.006	−0.005	0.007	−0.003
Coefficient (C) 10th-order	0.071	0.288	0.461	0.230	0.000	−0.022	0.010	−0.002	0.001	−0.003	−0.004	0.000	−0.002	0.000
Coefficient (D) 12th-order	−0.005	−0.118	−0.165	−0.058	−0.012	0.022	0.001	0.003	0.000	0.000	0.000	0.000	0.000	0.000
Coefficient (E) 14th-order	−0.040	0.004	0.015	0.000	0.023	−0.009	−0.004							

0.000 0.000 0.000 0.000 0.000 0.000 0.000 Coefficient (F) 16th-order Coefficient (G) 18th-order Coefficient (H) 20th-order Coefficient (J)

[0115] The lens module according to the fifth exemplary embodiment (Example 5) of the present disclosure will be described with reference to FIGS. **13** through **15**.

[0116] The lens module **100** according to this exemplary embodiment may include a first lens **10**, a second lens **20**, a third lens **30**, a fourth lens **40**, a fifth lens **50**, a sixth lens **60**, and a seventh lens **70**. The lens module **100** may further include an infrared cut-off filter **80** and an image sensor **90**. Further, the lens module **100** may further include at least one aperture stop (not shown). The aperture stop (not shown) may be arranged in front of the first lens **10** or anywhere between the first lens **10** and the seventh lens **70**.

[0117] For reference, an overall focal length f of the lens module **100** may be 4.522 [mm], a focal length of the first lens **10** may be 4.584, a focal length of the second lens **20** may be −8.221, a focal length of the third lens **30** may be 6.410, a focal length of the fourth lens **40** may be 73.896, a focal length of the fifth lens **50** may be 17.417, a focal length of the sixth lens **60** may be −12.539, and a focal length of the seventh lens **70** may be −6.829.

[0118] Table 9 below shows radii of curvature of the lenses, thicknesses of the lenses or distances between the lenses, refractive indices of the lenses, and abbe numbers of the lenses. Table 10 below indicates an aspheric constant of each surface of the lenses.

[0119] In this exemplary embodiment, the first lens **10** may have positive refractive power. A first surface of the first lens **10** may be convex, and a second surface thereof may be concave. The second lens **20** may have negative refractive power. A first surface of the second lens **20** may be convex, and a second surface thereof may be concave. The third lens **30** may have positive refractive power. Both surfaces of the third lens **30** may be convex. The fourth lens **40** may have positive refractive power. A first surface of the fourth lens **40** may be concave, and a second surface thereof may be convex.

[0120] That is, the fourth lens **40** may have a meniscus shape in which it is convex toward an image side. The fifth lens **50** may have positive refractive power. A first surface of the fifth lens **50** may be concave, and a second surface thereof may be convex. That is, the fifth lens **50** may have a meniscus shape in which it is convex toward the image side. The sixth lens **60** may have negative refractive power. A first surface of the sixth lens **60** may be convex, and a second surface thereof may be concave. In addition, the sixth lens **60** may have inflection points formed on the first and second surfaces thereof, respectively. The seventh lens **70** may have negative refractive power. A first surface of the seventh lens **70** may be convex, and a second surface thereof may be concave. Further, the seventh lens **70** may have an inflection point formed on the second surface thereof.

[0121] The exemplary embodiment of the lens module configured as described above may have MTF characteristics and aberration characteristics as shown in FIGS. **14** and **15**, respectively.

TABLE-US-00009 TABLE 9 Radius of Tickness/ Refractive Abbe Example 5 Curvature Distance Index number Object Infinity Infinity ST Infinity 0.050 1 2.004 0.440 1.544 56.1 2 9.413 0.102 3 5.035 0.220 1.635 24.0 4 2.520 0.305 5 4.272 0.481 1.544 56.1 2 −18.245 0.322 7 −2.964 0.262 1.635 24.0 8 −2.883 0.125 9 −2.348 0.329 1.544 56.1 10 −1.975 0.150 11 5.085 0.581 1.635 24.0 12 2.965 0.516 13 2.794 0.500 1.544 56.1 14 1.494 0.317 15 Infinity 0.300 1.517 64.2 16 Infinity 0.503 Image

TABLE-US-00010 TABLE 10 Example 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Y Radius 2.004 9.413 5.035 2.520 4.272 −18.245 −2.964 −2.883 −2.348 −1.975 5.085 2.965 2.794 1.494 Conic Constant 0.000 0.000 0.000 −10.034 0.000 0.000 −2.420 −0.992 0.398 −0.449 0.000 0.000 −21.513 −6.544 (K) 4th-order −0.016 −0.141 −0.255 −0.120 −0.103 −0.068 −0.021 −0.018 0.067 0.041 −0.103 −0.118 −0.141 −0.087 Coefficient (A) 6th-order 0.007 0.245 0.526 0.324 0.006 −0.026 0.032 0.029 0.007 0.024 0.004 0.028 0.025 0.026 Coefficient (B) 8th-order −0.063 −0.369 −0.643 −0.354 −0.028 0.011 −0.016 −0.011 −0.002 0.005 0.016 −0.003 0.004 −0.005 Coefficient (C) 10th-order 0.073 0.286 0.474 0.220 0.022 −0.018 0.011 −0.001 0.001 −0.005 −0.011 0.000 −0.001 0.000

Coefficient (D) 12th-order −0.063 −0.125 −0.171 −0.049 −0.020 0.023 0.001 0.002 −0.001 0.000 0.002 0.000 0.000 0.000 Coefficient (E) 14th-order 0.012 0.018 0.021 0.000 0.015 −0.009 −0.001 0.000 0.000 0.000 0.000 0.000 0.000 0.000 Coefficient (F) 16th-order Coefficient (G) 18th-order Coefficient (H) 20th-order Coefficient (J)

[0122] The lens module according to the sixth exemplary embodiment (Example 6) of the present disclosure will be described with reference to FIGS. **16** through **18**.

[0123] The lens module **100** according to this exemplary embodiment may include a first lens **10**, a second lens **20**, a third lens **30**, a fourth lens **40**, a fifth lens **50**, a sixth lens **60**, and a seventh lens **70**. The lens module **100** may further include an infrared cut-off filter **80** and an image sensor **90**. Further, the lens module **100** may further include at least one aperture stop (not shown). The aperture stop (not shown) may be arranged in front of the first lens **10** or anywhere between the first lens **10** and the seventh lens **70**. For reference, an overall focal length f of the lens module **100** may be 4.165 [mm], a focal length of the first lens **10** may be 3.794, a focal length of the second lens **20** may be −8.619, a focal length of the third lens **30** may be −341.847, a focal length of the fourth lens **40** may be 96.237, a focal length of the fifth lens **50** may be 3.198, a focal length of the sixth lens **60** may be −11.131, and a focal length of the seventh lens **70** may be −4.635.

[0124] Table 11 below shows radii of curvature of the lenses, thicknesses of the lenses or distances between the lenses, refractive indices of the lenses, and abbe numbers of the lenses. Table 12 below indicates an aspheric constant of each surface of the lenses.

[0125] In this exemplary embodiment, the first lens **10** may have positive refractive power. Both surfaces of the first lens **10** may be convex. The second lens **20** may have negative refractive power. Both surfaces of the second lens **20** may be concave. The third lens **30** may have negative refractive power. A first surface of the third lens **30** may be convex, and a second surface thereof may be concave. The fourth lens **40** may have positive refractive power. A first surface of the fourth lens **40** may be convex, and a second surface thereof may be concave. The fifth lens **50** may have positive refractive power. A first surface of the fifth lens **50** may be concave, and a second surface thereof may be convex. That is, the fifth lens **50** may have a meniscus shape in which it is convex toward the image side. The sixth lens **60** may have negative refractive power. A first surface of the sixth lens **60** may be concave, and a second surface thereof may be convex. The seventh lens **70** may have negative refractive power. A first surface of the seventh lens **70** may be convex, and a second surface thereof may be concave. Further, the seventh lens **70** may have an inflection point formed on the second surface thereof.

[0126] The exemplary embodiment of the lens module configured as described above may have MTF characteristics and aberration characteristics as shown in FIGS. **17** and **18**, respectively.

TABLE-US-00011 TABLE 11 Radius of Tickness/ Refractive: Abbe Example 6 Curvature Distance Index number Object Infinity Infinity ST Infinity 0.050 1 2.143 0.439 1.544 56.1 2 −51.915 0.111 3 −52.701 0.224 1.635 24.0 4 6.117 0.345 5 4.745 0.289 1.544 56.1 6 4.527 0.196 7 6.434 0.310 1.635 24.0 8 7.057 0.252 9 −4.163 0.578 1.544 56.1 10 −1.287 0.194 11 −1.732 0.300 1.635 24.0 12 −2.448 0.221 13 2.768 0.664 1.544 56.1 14 1.208 0.489 15 Infinity 0.300 1.517 64.2 16 Infinity 0.515 Image

TABLE-US-00012 TABLE 12 Example 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Y Radius 2.143 −51.915 −52.701 6.117 4.745 4.527 6.434 7.057 −4.163 −1.287 −1.732 −2.448 2.768 1.208 Conic Constant 0.000 0.000 0.000 −75.000 0.000 0.000 −50.000 25.000 7.020 −0.330 0.000 0.000 −24.215 −4.495 (K) 4th-order −0.020 −0.129 −0.233 −0.146 −0.123 −0.105 −0.141 −0.121 0.037 0.059 0.042 0.016 −0.074 −0.052 Coefficient (A) 6th-order 0.017 0.221 0.516 0.312 0.017 −0.004 0.014 0.000 −0.029 0.012 −0.002 0.006 0.004 0.013 Coefficient (B) 8th-order −0.078 −0.288 −0.621 −0.376 −0.031 −0.006 −0.027 −0.008 −0.002 −0.001 0.017 0.000 0.005 −0.002 Coefficient (C) 10th-order 0.085 0.250 0.417 0.197 0.007 −0.028 0.004 −0.001 0.002 0.000 −0.009 0.001 −0.001 0.000 Coefficient (D) 12th-order −0.043 −0.205 −0.200 −0.047 −0.019 0.017 0.000 0.002 0.003 0.003 0.002 0.000 0.000 0.000 Coefficient (E) 14th-order −0.019 0.064 0.049 0.000 0.009 −0.007 −0.002 0.000 0.000

0.000 0.000 0.000 0.000 0.000 Coefficient (F) 16th-order Coefficient (G) 18th-order Coefficient (H) 20th-order Coefficient (J)

[0127] The lens module according to the seventh exemplary embodiment (Example 7) of the present disclosure will be described with reference to FIGS. **19** through **21**.

[0128] The lens module **100** according to this exemplary embodiment may include a first lens **10**, a second lens **20**, a third lens **30**, a fourth lens **40**, a fifth lens **50**, a sixth lens **60**, and a seventh lens **70**. The lens module **100** may further include an infrared cut-off filter **80** and an image sensor **90**. Further, the lens module **100** may further include at least one aperture stop (not shown). The aperture stop (not shown) may be arranged in front of the first lens **10** or anywhere between the first lens **10** and the seventh lens **70**. For reference, an overall focal length f of the lens module **100** may be 4.000 [mm], a focal length of the first lens **10** may be 3.907, a focal length of the second lens **20** may be −9.478, a focal length of the third lens **30** may be −415.933, a focal length of the fourth lens **40** may be 986.711, a focal length of the fifth lens **50** may be 3.042, a focal length of the sixth lens **60** may be −10.825, and a focal length of the seventh lens **70** may be −4.979.

[0129] Table 13 below shows radii of curvature of the lenses, thicknesses of the lenses or distances between the lenses, refractive indices of the lenses, and abbe numbers of the lenses. Table 14 below indicates an aspheric constant of each surface of the lenses.

[0130] In this exemplary embodiment, the first lens **10** may have positive refractive power. Both surfaces of the first lens **10** may be convex. The second lens **20** may have negative refractive power. Both surfaces of the second lens **20** may be concave. The third lens **30** may have negative refractive power. A first surface of the third lens **30** may be convex, and a second surface thereof may be concave. The fourth lens **40** may have positive refractive power. A first surface of the fourth lens **40** may be convex, and a second surface thereof may be concave. The fifth lens **50** may have positive refractive power. A first surface of the fifth lens **50** may be concave, and a second surface thereof may be convex. That is, the fifth lens **50** may have a meniscus shape in which it is convex toward the image side. The sixth lens **60** may have negative refractive power. A first surface of the sixth lens **60** may be concave, and a second surface thereof may be convex. The seventh lens **70** may have negative refractive power. A first surface of the seventh lens **70** may be convex, and a second surface thereof may be concave. Further, the seventh lens **70** may have an inflection point formed on the second surface thereof.

[0131] The exemplary embodiment of the lens module configured as described above may have MTF characteristics and aberration characteristics as shown in FIGS. **20** and **21**, respectively.

TABLE-US-00013 TABLE 13 Radius of Tickness/ Refractive Abbe Example 7 Curvature Distance Index number Object Infinity Infinity ST Infinity 0.05 1 2.158 0.415 1.544 56.1 2 −135.165 0.100 3 −252.549 0.220 1.635 24.0 4 6.167 0.372 5 5.119 0.298 1.544 56.1 6 4.903 0.165 7 7.230 0.313 1.635 24.0 8 7.191 0.238 9 −4.289 0.634 1.544 56.1 10 −1.256 0.100 11 −1.725 0.221 1.635 24.0 12 −2.419 0.221 13 2.586 0.744 1.544 56.1 14 1.189 0.527 15 Infinity 0.300 1.517 64.2 16 Infinity 0.515 Image

TABLE-US-00014 TABLE 14 Example 2 3 4 5 6 7 8 Y Radius 2.158 −135.165 −252.549 6.167 5.119 4.903 7.230 Conic Constant 0.000 0.000 0.000 −75.000 0.000 0.000 −50.000 (K) 4th-order −0.019 −0.129 −0.226 −0.138 −0.130 −0.118 −0.150 Coefficient (A) 6th-order 0.015 0.224 0.511 0.303 0.024 0.007 0.017 Coefficient (B) 8th-order −0.079 −0.295 −0.628 −0.377 −0.037 −0.008 −0.024 Coefficient (C) 10th-order 0.089 0.233 0.415 0.199 0.003 −0.031 0.005 Coefficient (D) 12th-order −0.050 −0.206 −0.204 −0.046 −0.023 0.016 −0.001 Coefficient (E) 14th-order −0.023 0.073 0.062 0.000 0.009 −0.008 −0.003 Coefficient (F) 16th-order Coefficient (G) 18th-order Coefficient (H) 20th-order Coefficient (J) Example 9 10 11 12 13 14 15 Y Radius 7.191 −4.289 −1.256 −1.725 −2.419 2.586 1.189 Conic Constant 25.000 7.250 −0.377 0.000 0.000 −18.411 −4.222 (K) 4th-order −0.119 0.040 0.055 0.049 0.017 −0.074 −0.050 Coefficient (A) 6th-order 0.002 −0.032 0.014 −0.005 0.007 0.005 0.012 Coefficient (B) 8th-order −0.008 −0.001 −0.003 0.017 0.000 0.004 −0.002 Coefficient (C) 10th-order 0.000 0.001 −0.001 −0.009 0.001 −0.001

0.000 Coefficient (D) 12th-order 0.002 0.002 0.003 0.002 0.000 0.000 0.000 Coefficient (E) 14th-order 0.000 0.000 0.000 0.000 0.000 0.000 0.000 Coefficient (F) 16th-order Coefficient (G) 18th-order Coefficient (H) 20th-order Coefficient (J)

[0132] The lens modules according to first to seventh exemplary embodiments of the present disclosure configured as described above may satisfy Conditional Expression 1 to 8 as shown in Table 15 below and improve optical performance of the lenses.

TABLE-US-00015 TABLE 15 Example Example Example Example Example Example Example Remark Conditional Expression 1 2 3 4 5 6 7 1 $1.0 < f12/f < 2.0$ 1.455 1.318 1.405 1.181 1.906 1.472 1.526 2 $TTL/f < 1.40$ 1.211 1.223 1.229 1.279 1.216 1.318 1.362 3 $BFL/f > 0.2$ 0.272 0.239 0.270 0.218 0.247 0.317 0.339 4 $R1/f > 0.35$ 0.409 0.409 0.422 0.452 0.443 0.515 0.539 5 $-0.6 < (R11 - R12)/(R11 + R12) < 8.0$ −0.044 0.030 0.016 0.112 0.263 −0.171 −1.173 6 $-2.0 < R13/f < 1.0$ 0.517 0.704 0.486 −1.383 0.618 0.665 0.647 7 $-10.0 < (R5 - R6)/(R5 + R6) < 14.0$ 5.868 5.966 7.673 1.372 −1.611 0.023 0.022 8 $ANG/f > 15.0$ 16.101 15.258 16.438 17.715 16.264 18.647 20.350

[0133] As set forth above, according to exemplary embodiments of the present disclosure, aberration may be easily corrected and high resolution may be implemented.

[0134] While exemplary embodiments have been shown and described above, it will be apparent to those skilled in the art that modifications and variations could be made without departing from the spirit and scope of the present disclosure as defined by the appended claims. The illustrative discussions above are not intended to be exhaustive or to limit the invention to the precise forms disclosed.

Claims

1. A lens module comprising: a first lens having a refractive power; a second lens having negative refractive power; a third lens having a convex object-side surface; a fourth lens having a refractive power; a fifth lens having a refractive power; a sixth lens having positive refractive power and a concave image-side surface; and a seventh lens having a refractive power, wherein the first to seventh lenses are sequentially disposed from an object side toward an image plane, wherein the lens module has a total of seven lenses having refractive power, and wherein $-2.0 < R13/f < 1.0$, where R13 is a radius of curvature of an object-side surface of the seventh lens and f is a focal length of the lens module.

2. The lens module of claim 1, wherein the first lens has a convex object-side surface.

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

4. The lens module of claim 1, wherein the fourth lens has a convex image-side surface.

5. The lens module of claim 1, wherein the sixth lens has a convex object-side surface.

6. The lens module of claim 1, wherein the seventh lens has a concave image-side surface.

7. A lens module comprising: a first lens having a refractive power; a second lens having negative refractive power; a third lens having a convex object-side surface and a concave image-side surface; a fourth lens having a refractive power; a fifth lens having a refractive power; a sixth lens having a refractive power; and a seventh lens having a refractive power, wherein the first to seventh lenses are sequentially disposed from an object side toward an image plane, wherein the lens module has a total of seven lenses having refractive power, wherein an absolute value of a radius of curvature of an object-side surface of the second lens is greater than an absolute value of a radius of curvature of an object-side surface of the sixth lens, and wherein $-2.0 < R13/f < 1.0$, where R13 is a radius of curvature of an object-side surface of the seventh lens and f is a focal length of the lens module.

8. The lens module of claim 7, wherein the first lens has a convex object-side surface.

9. The lens module of claim 7, wherein the second lens has a concave image-side surface.

10. The lens module of claim 7, wherein the fourth lens has a convex object-side surface.

11. The lens module of claim 7, wherein the seventh lens has a convex object-side surface.

12. The lens module of claim 7, wherein the seventh lens has a concave image-side surface.