DESCRIPTION

TITLE OF INVENTION: IMAGING DEVICE AND WINDOW GLASS EQUIPPED WITH IMAGING DEVICE

TECHNICAL FIELD

[0001]

The present invention relates to an imaging device and a window glass equipped with an imaging device.

BACKGROUND ART

[0002]

A window camera is conventionally known, including: an image capturing unit configured to capture an image of outdoors from an indoor-side surface of a window glass; a housing having an rectangular attachment surface to face in parallel with the indoor-side surface so that the image capturing unit is attached to the attachment surface in a recessed manner with an optical axis of the image capturing unit being aligned with an intersection of a pair of diagonal lines of the attachment surface; and a light shielding member made of an elastic material and having a rectangular frame shape according to the outer shape of the attachment surface to protrude from the attachment surface toward the indoor-side surface and close a gap between the indoor-side surface and the attachment surface by elastic deformation under pressure from the housing. This window camera is fixed to the indoor-side surface of the window glass by a suction cup piece of a suction cup mechanism of the housing. The suction cup piece is formed of an elastic material (see, for example, Patent Document 1).

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0003]

Patent Document 1: JP-A-2021-111812

DISCLOSURE OF INVENTION

TECHNICAL PROBLEM

[0004]

When an image of outdoors is captured from the indoor side of the window glass at night, a reflected image formed by reflections of indoors from the window glass may overlap the image of outdoors and thereby make the image of outdoors difficult to see. This phenomenon is pronounced particularly in the case where indoor lighting is on or in the case where the window glass is provided with a heat reflective film such as Low-E (low emissivity) film.

[0005]

One possible way for reducing such reflections is to attach a lens hood to the window camera. However, the lens hood protrudes toward the window glass and expands in the direction of increasing opening diameter, making it difficult to install the window camera close to a structural part such as a sash (window frame) or a pillar. Furthermore, the attachment of the lens hood results in a larger size of the window camera so that the window camera is made more conspicuous when viewed from the outdoor side and is not suitable for e.g. security surveillance applications.

[0006]

It is accordingly an object of the present disclosure to provide an imaging device capable of capturing an image of outdoor scene without the use of a lens hood even under a situation that indoor lighting is on at night, and to provide a window glass equipped with such an imaging device.

SOLUTION TO PROBLEM

[0007]

According to an aspect of the present disclosure, there is provided an imaging device comprising: a housing having a surface to face an indoor-side main surface of a window glass of a building structure; a lens disposed in an opening on the surface of the housing so as to face the main surface; and an imaging unit disposed within the housing and configured to capture an image of outdoor scene outside the window glass through the lens, wherein: the imaging device has an angle of view of 40 degrees or more; and a distance between the lens and a structural part in contact with the window glass in a direction parallel to the main surface is greater than or equal to 0 mm and less than or equal to 180 mm.

ADVANTAGEOUS EFFECTS OF INVENTION

[0008]

According to the present disclosure, it is possible to provide an imaging device capable of capturing an image of outdoors without the use of a lens hood even under a situation that indoor lighting is on at night, and to provide a window glass equipped with such an imaging device.

BRIEF DESCRIPTION OF DRAWINGS

[0009]

Fig. 1A is a schematic view illustrating an arrangement example of an imaging device.

Fig. 1B is an enlarged view illustrating a configuration example of the imaging device of Fig. 1A and its surroundings.

Fig. 2A is a schematic view illustrating the configuration example of the imaging device.

Fig. 2B is a schematic view illustrating the configuration example of the imaging device.

Fig. 2C is a cross-sectional view, as taken along line IIC-IIC of Fig. 2B, illustrating the configuration example of the imaging device.

Fig. 3A is a schematic view illustrating an example of why reflections are included in an image captured by a comparative imaging device.

Fig. 3B is a schematic view illustrating an example of why reflections are included in an image captured by the comparative imaging device.

Fig. 4A is a schematic view illustrating an example of why the imaging device according to one embodiment can reduce reflections.

Fig. 4B is a schematic diagram illustrating an example of why the imaging device according to one embodiment can reduce reflections.

Figs. 5AA to 5AF are examples of images captured by fixed-point imaging using a camera with horizontal angles of view θx set to 40 degrees, 50 degrees, 70 degrees, 80 degrees, 105 degrees and 120 degrees, respectively.

Fig. 5B is a diagram illustrating examples of simulation results of the reflection

reduction rate Rx (%) relative to the distance Dx with a horizontal angle of view θx set in 10-degree increments from 40 degrees to 100 degrees.

Fig. 5C is a diagram illustrating examples of simulation results with a horizontal angle of view θx set to 40 degrees.

Fig. 6 is a schematic view illustrating an example of the reflection reduction rate Rx relative to the distance Dx in the imaging device according to one embodiment.

DESCRIPTION OF EMBODIMENTS

[0010]

Hereinafter, embodiments of an imaging device and an imaging device-equipped window glass according to the present disclosure will be described below. In the following, the same elements are designated by the same reference numerals, and duplicate descriptions thereof may be omitted.

[0011]

In the respective drawings, the scales of components may sometimes be different from the actual scales for ease of understanding. In the present embodiments, a three-dimensional orthogonal coordinate system constituted by three axes (X axis, Y axis and Z axis) is employed where the width direction (lateral direction) of the window glass is taken as the X direction; the height direction of the window glass is taken as the Y direction; and the thickness direction of the window glass is taken as the Z direction. As an example, a direction toward the position of attachment of the imaging device to the window glass along the width direction of the window glass is defined as a +X direction; and a direction opposite to the +X direction is defined as a −X direction. As an example, a direction from the bottom to the top of the window glass is defined as a +Y direction; and a direction opposite to the +Y direction is defined as a −Y direction. Furthermore, as an example, a direction toward the indoor side of the window glass is defined as a +Z direction; and a direction toward the outdoor side of the window glass is defined as a −Z direction. In the following description, the +Y direction may be referred to as the top side; the −Y direction may be referred to as the bottom side. The term “plan view” means XY plane view. As an example, the X direction and the Z direction are substantially in parallel with a direction (horizontal direction) parallel to the horizontal plane; and the Y direction is substantially in parallel with a direction vertical to the

horizontal plane.

[0012]

The X direction, the Y direction and the Z direction represent a direction parallel to the X axis, a direction parallel to the Y axis and a direction parallel to the Z axis, respectively. The X direction, the Y direction and the Z direction are orthogonal to one another. The XY plane, the YZ plane and the ZX plane represent an imaginary plane parallel to the X and Y directions, an imaginary plane parallel to the Y and Z directions and an imaginary plane parallel to the Z and X directions, respectively.

[0013]

<Embodiments>

Fig. 1A is a schematic view illustrating an arrangement example of an imaging device 100 of the present disclosure as viewed from outside a building 1. Fig. 1B is an enlarged view illustrating a configuration example of the imaging device 100 of Fig. 1A and its surroundings. In Figs. 1A and 1B, a window 10 attached to a wall 1W of the building 1 is also shown. The building 1 is an example of a building structure.

[0014]

The window 10 has a window glass 11 and a window frame 12. The window frame 12 is an example of a structural part in contact with the window glass 11. The window frame 12 may be in direct contact with the window glass 11 or may be in indirect contact with the window glass 11 via any member etc. The window glass 11 is, for example, a so-called FIX window, but may be a horizontal sliding window or the like. In Fig. 1B, only parts of the window glass 11 and the window frame 12 are shown. In the following, the window frame 12 is illustrated as being made of a magnetic metal as an example.

[0015]

The imaging device 100 is used in a state of being installed to face an indoor-side main surface 11B2 (see Fig. 1B) of the window glass 11 of the window 10 of the building 1. The imaging device 100 is, for example, triangular box-shaped in plan view and is positioned at the +X+Y direction-side corners of the window glass 11 and the window frame 12.

[0016]

Here, the window glass 11, the window frame 12 and the imaging device 100

constitute an imaging device-equipped window glass 200. The imaging device-equipped window glass 200 may however be provided with the window glass 11 and the imaging device 100 but not with the window frame 12.

[0017]

The imaging device 100 is a device that captures an image of outdoors through the window glass 11 and, as an example, is connected via a cable 101 (see Fig. 1B) to a processing device for image processing etc. The imaging device 100 transmits image data to the processing device through the cable 101. Further, the imaging device 100 receives a control signal for e.g. ON/OFF switching of an imaging unit 140, as well as a power supply, from the processing device through the cable 101.

[0018]

The processing device is arranged inside the building 1, but is omitted from illustration in Figs. 1A and 1B. As an example, the processing device may be connected to an outdoor information processing device such as server via a wireless communication device inside the building 1 or via a cable. The processing device may be, as an example, connected to a PC (personal computer) or an information processing device such as server inside the building 1 via a cable or a wireless communication device, and the PC or the server etc. may be connected to an outdoor upper server or the like via a cable or a wireless communication device.

[0019]

Although the window glass 11 is attached to the building 1 in the present embodiment, the window glass 11 may be attached to any building structure other than the building 1. Examples of the building structure other than the building 1 include: civil engineering structures such as a bridge pier, a bridge and a dam; historical structures; and artistic structures.

[0020]

The window glass 11 is a pane of glass used for windows of building structures such as the building 1. The window glass 11 may be a glass facade e.g. at the entrance of the building 1. The window glass 11 is, for example, rectangular-shaped in plan view, having a surface facing the outside of the building 1 and a surface facing the inside of the building 1. The inside of the building 1 refers to an indoor side of the building 1. The thickness of the window glass 11 is set according to the specifications

of the building 1. Here, the term “rectangular shape” is meant to include not only the shape of a rectangle or square but also the shape of a rounded rectangle or rounded square. The shape of the window glass in plan view is not limited to a rectangular shape, and may be any other shape such as a circular shape.

[0021]

The window glass 11 is, for example, a single glazing having an outdoor-side main surface 11A1 and an indoor-side main surface 11B2. The window glass 11 is not limited to a single glazing, and may be a laminated glass or a multiple glazing. Further, the window glass 11 may be a Low-E (low emissivity) glass or a light control glass.

[0022]

Examples of the material of the window glass 11 include soda-lime silica glass, borosilicate glass, aluminosilicate glass and alkali-free glass.

[0023]

The thickness of the window glass 11 is preferably from 1.0 to 20 mm. When the thickness of the window glass 11 is 1.0 mm or larger, the window 10 shows sufficient strength for attachment of the imaging device 100. When the thickness of the window glass is 20 mm or smaller, the window shows sufficient electromagnetic wave transmission performance for stable wireless communication connection between a wireless communication device and an outdoor information processing device such as server. The thickness of the window glass is more preferably from 3.0 to 15 mm, still more preferably from 9.0 to 13 mm.

[0024]

The window glass 11 has a visible light reflectance of e.g. 6% or higher as specified in JIS R3106: 2019. Further, the window glass 11 has a visible light transmittance (TV) of e.g. from 30% to 96% as specified in JIS R3106: 2019. When the TV of the window glass 11 is 30% or higher, the imaging device 100 can capture an image of outdoors with sufficient image quality through the window glass 11. When the TV of the window glass 11 is 98% or lower, the window glass can achieve excellent solar shading performance. The TV of the window glass 11 is preferably 50% or higher, more preferably 70% or higher, still more preferably 75% or higher, particularly preferably 80% or higher. The TV of the window glass 11 is preferably 95% or lower, more preferably 92% or lower, still more preferably 90% or lower, particularly preferably

85% or lower.

[0025]

The imaging device 100 is used as attached to the indoor side of the window glass 11 of the building 1, and is capable of capturing video images and still images. Here, the general configuration and functions of the imaging device 100 will be described below with reference to Figs. 1A and 1B, and the detailed configuration of the imaging device 100 will be described later with reference to Figs. 2A to 2C in addition to Figs. 1A and 1B.

[0026]

The imaging device 100 has a lens 130 arranged to face the indoor-side main surface 11B2 of the window glass 11, and captures an image of outdoor subject through the lens 130 and the window glass 11. The subject is a scene viewed through the window glass 11 (everything visible through the window glass 11). The scene may, for example, be a road, a sidewalk, a walkway, an intersection, an entrance/exit of the building 1, a station ticket gate, a station entrance/exit or the like, and may include people, vehicles and the like. The imaging device 100, when having an infrared imaging function, may capture an infrared image. The information captured by the imaging device 100 may be used for digital twin computing.

[0027]

This imaging device 100 can be used for various applications and is not limited to any particular use. Images of the subject outside the window glass 11 of the building 1, captured by the imaging device 100, can be used for various purposes. As an example, the use of the imaging device 100 as a surveillance camera for security will be hereinafter described below. The imaging device 100 is arranged facing the indoor-side main surface 11B2 of the window glass 11 and thus is difficult to see from outside the window glass 11 due to reflection. Accordingly, the use of the imaging device 100 as a surveillance camera is an example of suitable application.

[0028]

It is preferable that the height of attachment of the imaging device 100 to the window glass 11 is higher than the average human height from the viewpoint of ensuring a clear view of monitoring area. The height of attachment of the imaging device 100 to the window glass 11 is, for example, preferably 2 m or more. The

imaging device 100 may be attached to the window glass 11 on the second or higher floor of the building 1. When the height of attachment of the imaging device 100 to the window glass 11 is 2 m or more, it is less likely that the imaging device will be visibly recognized by a person being monitored.

[0029]

The height of attachment of the imaging device 100 to the window glass 11 may be set such that appropriate images can be captured in consideration of, for example, the range where image capture is possible within the angle of view of the imaging device 100, the distance from the imaging device 100 to the subject and the like. The upper limit of the attachment height of the imaging device 100 to the window glass 11 is the height of the top edge of the window glass 11 located at the highest position among window glasses 11 of the building 1. The height of the imaging device 100 is defined as the height from a standard surface in parallel with the horizontal plane (for example, the ground, the floor level or imaginary plane). The height of the imaging device 100 may be the height of the lens 130.

[0030]

<Detailed Configuration of Imaging Device 100>

The detailed configuration of the imaging device 100 will be described below with reference to Figs. 2A to 2C in addition to Figs. 1A and 1B. Figs. 2A and 2B are schematic views illustrating the configuration example of the imaging device 100. Fig. 2C is a cross-sectional view, as taken along line IIC-IIC of Fig. 2B, illustrating the configuration example of the imaging device.

[0031]

The imaging device 100 includes a case 110, a magnet part 120, a lens 130 and an imaging unit 140.

[0032]

<Case 110>

The case 110 is a housing of the imaging device 100 and has a box shape which is triangular in plan view. In other words, the case 110 is a triangular prism-shaped housing which is triangular in plan view and has a low height in the Z direction.

[0033]

The case 110 can be made of, for example, a resin material or a metal material.

Examples of the resin material include thermoplastic resins such as PC (polycarbonate)/ASA (acrylate styrene acrylonitrile), ASA, AES (acrylonitrile ethylene styrene) and the like. Examples of the metal material include aluminum, iron, stainless steel and the like.

[0034]

The case 110 has, as surfaces exposed outside, a first surface 111, a second surface 112 (see, in particular, Fig. 2C) and a side surface 113. As shown in Fig. 2C, the case 110 includes an outer case 110A, inner cases 110B and 110C, and a holder 110D.

[0035]

In the following description of the positional relationship between the first surface 111, the second surface 112 and the side surface 113 (113A, 113B and 113C), the expression “the first surface 111 and the side surface 113A are connected to each other” and similar expressions may be used. For example, the expression “the first surface 111 and the side surface 113A are connected to each other” is meant to include the case where the first surface 111 and the side surface 113A are in a positional relationship that appears to be connected as a part of the appearance of the case 110, even without physical connection of the first surface 111 and the side surface 113A due to the presence of a boundary of the outer case 110A and the inner case 110C between the first surface 111 and the side surface 113A. The same applies to the combination of any two of the first surface 111, the second surface 112 and the side surface 113 (113A, 113B and 113C) other than the combination of the first surface 111 and the side surface 113A.

[0036]

<First Surface 111>

The first surface 111 is a surface situated on the −Z direction side and oriented in parallel with the XY plane. The first surface 111 is, among the outer surfaces of the case 110, a surface to face the indoor-side main surface 11B2 of the window glass 11. As an example, the case 110 is placed such that the first surface 111 is in contact with the indoor-side main surface 11B2 of the window glass 11. This is to, when the imaging unit 140 captures an image through the lens 130, prevent the window glass 11 from being reflected in the captured image. The first surface 111 may however be

spaced away from the main surface 11B2.

[0037]

As an example, the first surface 111 is in the shape of an isosceles right triangle in plan view and has, in a center portion thereof, a recess 111A that is recessed in the +Z direction. A surface of the recess 111A is conically concave and is annular in plan view. Although the first surface 111 is herein illustrated as having an isosceles right triangle shape in plan view as an example, the first surface 111 may have a right triangle shape in which the lengths of two sides other than the hypotenuse are different in plan view or may have a shape other than the right triangle shape. Further, the recess 111A may be provided at a position offset from the center portion of the first surface 111 in plan view.

[0038]

The recess 111A has an opening 111A1 in e.g. a center region thereof in plan view. Portions of the lens 130 and the holder 110D are exposed through the opening 111A1. As an example, the recess 111A has a depth recessed relative to the first surface 111 such that the lens 130 and the holder 110D do not protrude from the first surface 111 in the Z direction toward the −Z direction side. In other words, the recess 111A has a depth recessed relative to the first surface 111 such that the lens 130 and the holder 110D are set back from the first surface 111 in the Z direction toward the +Z direction side (the second surface 112 side). This is to, when the imaging device 100 is arranged facing the main surface 11B2 of the window glass 11 with the first surface 111 brought into contact with the main surface 11B2 of the window glass 11, keep the lens 130 and the holder 110D from contact with the main surface 11B2 of the window glass 11.

[0039]

Furthermore, the recess 111A is tapered, such that the recess diameter in plan view increases with distance from the opening 111A1, to remain outside the field of view defined by the lens 130 and the imaging unit 140. This is to, when the imaging device 100 captures an image, prevent the recess 111A from being reflected in the captured image. The orientation of the lens 130 relative to the case 110 is variable. The recess 111A has a widely tapered shape so as to, even when the orientation of the lens 130 is varied such that the angle of the lens 130 relative to the Z axis becomes

maximum, be prevented from being reflected in the captured image.

[0040]

As an example, the recess 111A may have a depth such that the lens 130 and the holder 110D are in flush with the first surface 111 in the Z direction, or may have a depth such that the lens 130 and the holder 110D protrude from the first surface 111 in the Z direction toward the −Z direction side. Such a configuration is applicable, for example, in the case where the imaging device 100 is arranged facing the main surface 11B2 of the window glass 11 with the first surface 111 spaced apart from the main surface 11B2 of the window glass 11.

[0041]

The opening 111A1 may be provided at a position offset from the center of the recess 111A in plan view.

[0042]

<Second Surface 112>

As specifically shown in Fig. 2C, the second surface 112 is a surface opposite the first surface 111 and, as an example, has the same isosceles right triangle shape and size as the first surface 111. The second surface 112 is parallel to the XY plane. The second surface 112 is aligned with the first surface 111 such that the hypotenuse and two sides adjacent to the right angle of the second surface 112 respectively overlap the hypotenuse and two sides adjacent to the right angle of the first surface 111 in plan view. The expression “two adjacent sides” of a right triangle is used to mean two sides that form the right angle of the right triangle, that is, two sides of the right triangle other than the hypotenuse. Thus, two adjacent sides of a right triangle shape will hereinafter refer to two sides of the right triangle shape other than the hypotenuse. Although the second surface 112 is not shown in Figs. 1B, 2A and 2B, the position of the second surface is indicated by the reference symbol.

[0043]

<Side Surface 113>

The side surface 113 is composed of three side surfaces 113A, 113B and 113C. These three side surfaces 113A, 113B and 113C are hereinafter simply referred to as the side surface 113 when not specifically distinguished. The side surfaces 113A, 113B and 113C connect the first surface 111 and the second surface 112 among the

outer surfaces of the case 110.

[0044]

<Side Surface 113A>

The side surface 113A is a surface oriented in parallel with the XZ plane and connecting one of the two adjacent sides of the first surface 111 extending in the X direction to one of the two adjacent sides of the second surface 112 extending in the X direction. The side surface 113B is connected to a +X direction side of the side surface 113A, whereas the side surface 113C is connected to a −X direction side of the side surface 113A.

[0045]

The side surface 113A has, as an example, an opening 113A1 in a center region thereof in XZ plane view. One of two magnet parts 120 is embedded in the side surface 113A with a portion of the magnet part 120 exposed through the opening 113A1. The side surface 113A is, as an example, in flush with the portion of the magnet part 120 exposed through the opening 113A1.

[0046]

Here, the expression “the magnet part 120 is embedded in the side surface 113A” means that the magnet part 120 may be partially exposed through the opening 113A1 of the side surface 113A as shown in Fig. 2B, or may be located inside the case 110 by being covered by the side surface 113A with no opening 113A1 formed in the side surface 113A.

[0047]

Although the magnet part 120 is as an example embedded in the center region of the side surface 113A in XZ plane view, the position of the magnet part 120 may be offset from the center region of the side surface 113A in either direction along the XZ plane.

[0048]

Furthermore, as an example, a cutout 113A2 is formed in a −X−Z direction-side end region of the side surface 113A so as to feed therethrough the cable 101 (see Fig. 1A). The position of the cutout 113A2 is not limited to that shown in Fig. 2B. No cutout 113A2 may be formed in the side surface 113A.

[0049]

<Side Surface 113B>

The side surface 113B is a surface oriented at an angle of 90 degrees to the side surface 113A and in parallel with the YZ plane. The side surface 113B connects one of the two adjacent sides of the first surface 111 extending in the Y direction to one of the two adjacent sides of the second surface 112 extending in the Y direction. The side surface 113A is connected to a +Y direction side of the side surface 113B, whereas the side surface 113C is connected to a −Y direction side of the side surface 113B.

[0050]

The side surface 113B has, as an example, an opening 113B1 in a center region thereof in YZ plane view. The other of the two magnet parts 120 is embedded in the side surface 113B with a portion of the magnet part 120 exposed through the opening 113B1. The side surface 113B is, as an example, in flush with the portion of the magnet part 120 exposed through the opening 113B1.

[0051]

Here, the expression “the magnet part 120 is embedded in the side surface 113B” means that the magnet part 120 may be partially exposed through the opening 113B1 of the side surface 113B as shown in Fig. 2B, or may be located inside the case 110 by being covered by the side surface 113B with no opening 113B1 formed in the side surface 113B.

[0052]

Although the magnet part 120 is as an example embedded in the center region of the side surface 113B in YZ plane view, the position of the magnet part 120 may be offset from the center region of the side surface 113B in either direction along the YZ plane.

[0053]

Furthermore, as an example, a cutout 113B2 is formed in a −Y−Z direction-side end region of the side surface 113B so as to feed therethrough the cable 101 (see Fig. 1A). The position of the cutout 113B2 is not limited to that shown in Fig. 2B. No cutout 113B2 may be formed in the side surface 113B.

[0054]

In the case where the imaging device 100 is connected to the processing device via the cable 101, the case 110 may be provided with either one of cutouts 113A2 and

113B2. However, the case 110 with both cutouts 113A2 and 113B2 facilitates selection of the direction of routing of the cable 101 at the attached position of the imaging device 100.

[0055]

<Side Surface 113C>

The side surface 113C is a surface connecting the hypotenuse of the first surface 111 to the hypotenuse of the second surface 112. The side surface 113C is oriented at an angle of 45 degrees to the XZ and YZ planes. The side surfaces 113A and 113B are connected to the side surface 113C. The cutouts 113A2 and 113B2 are also positioned in end regions of the side surface 113C abutting the side surfaces 113A and 113B, respectively.

[0056]

<Outer Case 110A>

The outer case 110A is provided with the second surface 112, the side surfaces 113A, 113B and 113C as well as an opening 110A1. The outer case 110A is, among constituent members of the triangular prism-shaped case 110 with a low height in the Z direction, a case composed of thin walls extending along the second surface 112 and the side surfaces 113A, 113B and 113C. In other words, the outer case 110A is a triangular prism-shaped case having a hollow space therein and an opening 110A1 in a −Z direction side thereof where the first surface 111 is located. The inner case 110B, the inner case 110C and the holder 110D are placed in the outer case 110A.

[0057]

<Inner Case 110B>

The inner case 110B is a case located at the farthest back position within the outer case 100A when viewed from the opening 110A1. In plan view, the inner case 110B is triangular-shaped and has a through hole 110B1 formed through a center portion thereof in the Z direction. For example, an inner side surface 110B2 of this inner case surrounding the through hole 110B1 has a shape that corresponds to the inner surface of a hemispherical shell excluding its vertex portion.

[0058]

<Inner Case 110C>

The inner case 110C is a case located, at a position in front of the inner case

110B when viewed from the opening 110A1, within the outer case 110A. The inner case 110C is placed inside the outer case 110A in a state of being stacked on the inner case 110B. A surface of the inner case 110C on the −Z direction side is the first surface 111.

[0059]

In plan view, the inner case 110C is triangular-shaped and has a through hole 110C1 formed through a center portion thereof in the Z direction. The opening 111A1 is defined midway of the through hole 110C1 in the Z direction. The opening 111A1 is a region located between both end regions of the through hole 110C1 in the Z direction and having the smallest opening diameter in plan view. In other words, the opening 111A1 is defined as the most inwardly narrowed region between both end regions of the through hole 110C1 in the Z direction. The opening 111A1 is an opening through which the holder 110D is exposed when the imaging device 100 is viewed from the −Z direction side (front side).

[0060]

A region of the through hole 110C1 on the −Z direction side relative to the opening 111A1 corresponds to an inner space of the recess 111A. An inner side surface 110C2 of the inner case, surrounding a region of the through hole 110C1 on the +Z direction side relative to the opening 111A1, has a shape that corresponds to the inner surface of a hemispherical shell excluding its vertex portion. The opening 111A1 is located at a position corresponding to the vertex portion of this hemispherical shell. The inner side surface 110C2 communicates with the inner side surface 110B2 of the inner case 110B, forming a shape that corresponds to the inner surface of a spherical shell excluding its two vertex portions on the Z axis.

[0061]

The magnet parts 120 are embedded in the side surfaces 113A and 113B of the case 110, respectively. In Fig. 2C, the magnet part 120 embedded in the opening 113B1 of the side surface 113B of the outer case 110A is shown. In actual, the magnet part 120 is embedded as an example across the outer case 110A and the inner cases 110B and 110C. Hence, openings are formed in the inner cases 110B and 110C to be in communication with the opening 113B1 of the outer case 110A. The magnet part 120 is embedded in the opening 113B1 of the outer case 110A and the

openings of the inner cases 110B and 110C. The same configuration applies to the opening 113A1 of the side surface 113A of the outer case 110A, and openings are formed in the inner cases 110B and 110C to be in communication with the opening 113A1.

[0062]

<Holder 110D>

The holder 110D is a semi-spherical member and is disposed in a space defined by the inner side surface 110C2 of the inner case 110C and the inner side surface 110B2 of the inner case 110B. A recess 110D1 is formed in a −Z direction side of the holder 110D to install therein the lens 130. An opening is formed in a region of the recess 110D1 overlapping the lens 130. The recess 110D1 is tapered, such that the recess diameter in plan view increases with distance from the lens 130, so as to remain outside the field of view defined by the lens 130 and the imaging unit 140. This is to, when the imaging device 100 captures an image, prevent the recess 110D1 from being reflected in the captured image.

[0063]

A portion of the holder 110D surrounding the recess 110D1 is exposed inside the recess 111A through the opening 111A1. Further, the holder 110D has a recessed installation portion 110D2 to install therein the imaging unit 140 in back (on the +Z side in Fig. 2C) of the lens 130. The installation portion 110D2 is in communication with the recess 110D1 through the opening of the recess 110D1.

[0064]

This holder 110D is rotatable relative to the inner cases 110B and 110C along the inner side surfaces 110B2 and 110C2, and thus is capable of varying the orientation of the lens 130. Here, the case 110 is not necessarily configured to allow variable orientation of the lens 130, and the orientation of the lens 130 may be fixed.

[0065]

<Magnet Part 120>

The magnet part 120 is, for example, a member having a permanent magnet covered by a magnetic metal, a resin material or the like. Preferred examples of the permanent magnet are those having strong magnetic attraction, such as neodymium magnet. Examples of the magnetic metal to cover the permanent magnet are iron,

nickel and the like. Examples of the resin material to cover the permanent magnet are thermoplastic resins such as PC (polycarbonate)/ASA (acrylate styrene acrylonitrile), ASA and AES (acrylonitrile ethylene styrene).

[0066]

As an example, the imaging device 100 has two magnet parts 120. As shown in Fig. 2B, one of the magnet parts 120 is embedded in the center region of the side surface 113A; and the other of the magnet parts 120 is embedded in the side surface 113B. By these magnet parts 120 (see Fig. 2B), the imaging device 100 is magnetically attracted to and fixed to the window frame 12 as shown in Fig. 1B. In the case where the window frame 12 is not made of a magnetic metal, the imaging device 100 may be fixed to the window frame 12 by, for example, applying a magnetic metal sheet to the window frame 12 and causing magnetic attraction of the magnet parts 120 to the magnetic metal sheet on the window frame.

[0067]

Herein, the imaging device 100 is as an example illustrated as being provided with the magnet parts 120 and attached by magnetic attraction to the window frame 12 of magnetic metal. However, the imaging device 100 may alternatively be fixed to the window frame 12 by forming the case 110 of a magnetic metal, applying a sheet-shaped magnet part 120 onto the window frame 12 and causing magnetic attraction of the case 110 to the sheet-shaped magnet part 120 on the window frame 12.

[0068]

The imaging device 100 may be adhered to the window frame 12 using an adhesive such as a double-sided tape instead of the magnet part 120. In this case, the adhesive such as double-sided tape may be applied to a portion of the case 110 of the imaging device 100 located between the side surface 113A or 113B and the window frame 12 and not directly exposed to ultraviolet radiation. Even in the case where the imaging device 100 is adhered to the window frame 12 using the adhesive such as double-sided tape, the adhesive can be suppressed from degradation by ultraviolet radiation unless directly exposed to ultraviolet radiation so that it is possible to stably fix the imaging device 100 to the window frame 12.

[0069]

Although the imaging device 100 is herein illustrated as being fixed to the window

frame 12 as an example, the imaging device 100 may be fixed to any structural part around the window glass 11 other than the window frame 12, such as a ceiling or wall around the window glass 11. In the case where the ceiling or wall etc. is not made of a magnetic metal, the imaging device 100 may be fixed to the ceiling or wall etc. by applying a magnetic metal sheet to the ceiling or wall etc. The imaging device 100 may be fixed to the ceiling or wall etc. by forming the case 110 of a magnetic metal and applying a sheet-shaped magnet part 120 to the ceiling or wall etc. The imaging device 100 may be fixed to the ceiling or wall etc. by applying an adhesive such as a double-sided tape to the area located between the case 110 and the ceiling or wall etc. and not directly exposed to ultraviolet radiation.

[0070]

The imaging device 100 may be fixed apart from the window frame 12. For example, the imaging device may be fixed relative to the window frame 12 with a box-shaped member of resin transparent to visible light being disposed between the imaging device and the window frame 12. Here, “transparent” to visible light means having a luminous transmittance of at least 40% or higher, preferably 60% or higher, still more preferably 70% or higher, further more preferably 80% or higher. The imaging device may be fixed apart from the window frame 12 with a rod stay or another member disposed therebetween.

[0071]

Furthermore, the imaging device 100 may be suspended from the ceiling by means of a stay or another member. The imaging device 100 may be adhered to the indoor-side main surface 11B2 of the window glass 11 by an adhesive or a double-sided tape. In such a case, the imaging device 100 may be fixed with a space left between the imaging device and the window frame 12.

[0072]

<Lens 130>

The lens 130 is disposed in the opening of the recess 110D1 of the holder 110D of the case 110. Since the opening of the recess 110D1 is in communication with the installation portion 110D2 in back of the recess 110D1, the imaging unit 140 installed in the installation portion 110D2 captures an image of scene outside the window glass 11 through the opening of the recess 110D1 and the lens 130. A lens 130 may also be

provided on the second surface 112 to image both of the outdoor side and the indoor side. The lens 130 may only be provided on the second surface 112 to image only the indoor side.

[0073]

<Imaging Unit 140>

The imaging unit 140 is a camera body capable of capturing digital images such as video images and still images, and may have, for example, an image sensor using an imaging element such as CMOS (complementary metal oxide semiconductor) or CCD (charge coupled device). The camera body refers to any part of a camera other than lens 130. In other words, the imaging unit 140 and the lens 130 constitute a digital camera.

[0074]

The imaging unit 140 is fixed inside the installation portion 110D2 of the holder 110D. This is to capture an image of the subject outside the window glass 11 through the lens 130. The imaging unit 140 may have, or may not have, a telephoto function. The imaging unit 140 without a telephoto function is low in cost, which leads to low-cost production of the imaging device 100. The imaging unit 140 is connected to the processing device via the cable 101 (see Fig. 1B).

[0075]

<Attachment of Imaging Device 100 to Window Frame 12>

Next, the attachment of the imaging device 100 to the window frame 12 will be described below with reference to mainly Fig. 1B. As an example, it is assumed that a frame part 12X of the window frame 12 extending in the X direction along the top edge of the window glass 11 and a frame part 12Y of the window frame 12 extending in the Y direction along the +X direction-side edge of the window glass 11 meet at an angle of 90 degrees at the +X+Y direction-side corner of the window frame 12.

[0076]

The imaging device 100 is positioned, as an example, at the top corner portions of the window glass 11 and the window frame 12 as shown in Fig. 1B. It is because: the top corner portion of the window frame 12 is difficult to see and less conspicuous when viewed from outside by a large number of unspecified people; and the attachment of the imaging device 100 at a certain height enables image capture over a wider area. The

attachment position of the imaging device 100 is however not limited to the top corner portion of the window frame 12.

[0077]

The main surface 11B2 of the window glass 11 has a side 11AX extending in the X direction on the top edge and a side 11AY extending in the Y direction on the +X direction-side edge. The sides 11AX and 11AY are connected to each other at the +X+Y direction-side corner of the main surface 11B2 to form an angle of 90 degrees therebetween. In other words, the sides 11AX and 11AY are adjacent sides. Since the sides 11AX and 11AY are connected perpendicularly to each other, the angle formed between the frame parts 12X and 12Y of the window frame 12, which hold the window glass 11, is 90 degrees.

[0078]

The imaging device 100 is fixed to the top corner portion of the window frame 12 by bringing the side surfaces 113A and 113B (see Fig. 2B) of the case 110 into contact with the top corner portion of the window frame 12 and magnetically attaching the magnet parts 120 to the window frame 12. The side surfaces 113A and 113B extend along the sides 11AX and 11AY, respectively. More specifically, the side surface 113A extends along the side 11AX in the X direction; and the side surface 113B extends along the side 11AY in the Y direction.

[0079]

Since the case 110 of the imaging device 100 has a corner angle of 90 degrees between the side surfaces 113A and 113B, the side surfaces 113A and 113B can be brought into contact with the inner corner portion between the frame parts 12X and 12Y of the window frame 12. Thus, the two magnet parts 120 on the side surfaces 113A and 113B of the imaging device 100 are magnetically attracted to the frame parts 12X and 12Y of the window frame 12 just by pressing the side surfaces 113A and 113B against the inner corner portion between the frame parts 12X and 12Y. In this way, it is possible to easily attach the imaging device 100 to the window frame 12.

[0080]

Furthermore, the imaging device 100 has a triangular shape in plan view and fits right into the inner corner portion between the frame parts 12X and 12Y of the window frame 12. The imaging device 100 thus appears to be integrated with the window

frame 12, which leads to good design property.

[0081]

<Surface Color of Recesses 110D1 and 111A of Case 110>

It is preferable that the surfaces of the recesses 110D1 and 111A, which are positioned around the lens 130, are lower in light reflectance. The color of the surfaces of the recesses 110D1 and 111A is preferably black, which absorbs light most effectively, but may be any color other than black. The surfaces of the recesses 110D1 and 111A can be colored in any appropriate color by, for example, applying a paint. Preferred examples of the paint are those less susceptible to degradation by ultraviolet radiation, such as a radical-controlled paint.

[0082]

As an example, the color of the surfaces of the recesses 110D1 and 111A may be a color with a lightness of 5 or lower. The lightness refers to e.g. a lightness value as specified in JIS Z8721: 1993.

[0083]

There is a correlation between the reflectance and the lightness, and a lightness of 5 or lower corresponds to a visible light reflectance of 20% or lower. When the surfaces of the recesses 110D1 and 111A have a visible light reflectance of 20% or lower, it is possible to prevent quality deterioration of captured images caused by strong incident light such as sunlight unnecessarily reflecting off the recesses 110D1 and 111A to the lens 130.

[0084]

Therefore, one example of suitable application of the imaging device 100 is as a surveillance camera. The imaging device 100, when used as a surveillance camera to image the outdoor side, may be in such a position as to be backlit by the sun depending on the time of day or the location of installation. Even in such a case, it is possible for the imaging device to easily capture a high-quality image of the outdoor monitoring area including the target subject.

[0085]

The hue and chroma of the surface color of the recesses 110D1 and 111A are not particularly limited so far as the surface color has a lightness of 5 or lower. As the color with a lightness of 5 or lower, not only black but also dark gray and the like may be

mentioned.

[0086]

When the surfaces of the recesses 110D1 and 111A are sufficiently low in reflectance as described above, the imaging device 100 can capture sufficiently clear images even without the use of a reflection suppression member such as a so-called lens hood. Since the lens hood is often made of a material susceptible to degradation by ultraviolet radiation, such as silicone rubber, the imaging device 100 with no lens hood is advantageous in terms of degradation by ultraviolet radiation.

[0087]

<Color of Case 110>

Parts of the surfaces of the case 110, other than the recesses 110D1 and 111A of the first surface 111, are visible from outside through the window glass 11 and thus may preferably be in a less conspicuous color as in the case of the recesses 110D1 and 111A. It is because, when the imaging device 100 is used as a surveillance camera as an example, the monitoring target is less wary of the imaging device in the case where the first surface 111 in front of the imaging device 100 is not visible from outside the window glass 11.

[0088]

In a state that the imaging device 100 is fixed to the window frame 12, the side surface 113C of the case 110 is exposed outside. When the side surface 113C is in the same color as or a similar color to the window frame 12, the case 110 becomes less conspicuous, making the imaging device particularly effective for use as a surveillance camera. The side surfaces 113A and 113B are not visible in a state that the imaging device 100 is fixed to the window frame 12. Thus, the color of the side surfaces 113A and 113B is not particularly limited. When the side surfaces 113A and 113B are painted in the same color as the side surface 113C, however, the imaging device 100 itself can achieve good design property and the painting process of the side surfaces 113A to 113C can be simplified.

[0089]

<Reduction of Reflections by Utilizing Window Frame 12>

The imaging device 100 reduces reflections by the utilization of the window frame 12 so as to capture an image of outdoors without the use of a lens hood even under a

situation that indoor lighting is on at night. This feature will be described below with reference to Figs. 3A, 3B, 4A and 4B.

[0090]

Figs. 3A and 3B are schematic views illustrating an example of why reflections are included in an image captured by a comparative imaging device 50, not by the imaging device of the present embodiment. The comparative imaging device 50 has the same camera configuration as that of the imaging device 100 of the present embodiment shown in Figs. 2A to 2C, but differs in that there are no dimensional specifications between the window frame 12 and a heat reflective film 11C as will be described later for the imaging device 100 of the present embodiment. Here, the comparative imaging device 50 is illustrated as having a lens 130 and an imaging device 140 as in the case of the imaging device 100 of the present embodiment.

[0091]

In Fig. 3A, a part of the window glass 11 in the X direction is shown in XZ cross section as viewed from the +Y direction side in the case where the window glass is as an example in double glazed form. In Fig. 3A, the imaging device 50 is also shown in a simplified manner. The optical axis of the lens 130 is denoted by C; and the horizontal angle of view of the imaging device 50 is denoted by θx. In Fig. 3A, the position of the XZ cross section in the Y direction is a position passing through the optical axis C of the lens 130. For simplicity of description, the imaging device 50 is assumed to be rectangular as in XZ plane view and symmetrical in shape with respect to the optical axis C of the lens 130.

[0092]

Here, the configuration of the window glass 11 in double glazed form, which is more difficult to reduce reflections than single glazed form, will be described below with reference to Fig. 3A, after which the reason why reflections are included in an image captured by the imaging device 50 will be described.

[0093]

<Configuration of Window Glass 11 in Double Glazed Form>

The window glass 11, when in double glazed form, has a glass plate 11A, a glass plate 11B and a heat reflective film 11C. The glass plate 11A is an example of a first glass plate to be located on the outdoor side; and the glass plate 11B is an example of

a second glass plate to be located on the indoor side.

[0094]

The heat reflective film 11C is a metal film transparent to visible light. Here, "transparent" to visible light means having a luminous transmittance of at least 40% or higher, preferably 60% or higher, still more preferably 70% or higher, further more preferably 80% or higher.

[0095]

The glass plate 11A has an outdoor-side main surface 11A1 and an indoor-side main surface 11A2. The glass plate 11B has an outdoor-side main surface 11B1 and an indoor-side main surface 11B2. The main surface 11A1 is an example of a first main surface. The main surface 11A2 is an example of a second main surface. The main surface 11B1 is an example of a third main surface. The main surface 11B2 is an example of a fourth main surface.

[0096]

The main surface 11A1 is located on the outdoor side relative to the main surface 11A2. The main surface 11A2 is located on the indoor side relative to the main surface 11A1. Thus, the outdoor-side main surface 11A1 means that the main surface 11A1 is located on the outdoor side relative to the main surface 11A2; and the indoor-side main surface 11A2 means that the main surface 11A2 is located on the indoor side relative to the main surface 11A1. The same applies to the main surfaces 11B1 and 11B2.

[0097]

The glass plates 11A and 11B are held at a constant interval in the Z direction with a spacer (not shown) disposed therebetween. The glass plates 11A and 11B are uniform in thickness and are parallel to the XY plane. The heat reflective film 11C is, for example, formed on the main surface 11A2. In Figs. 3A, 3B, 4A and 4B, the Z-direction thickness of the heat reflective film 11C is shown exaggeratedly relative to the Z-direction thickness of the glass plates 11A and 11B. Although the heat reflective film 11C is herein illustrated as being formed on the indoor-side main surface 11A2 of the outdoor-side glass plate 11A as an example, the heat reflective film 11C may be formed on the outdoor-side main surface 11B1 of the indoor-side glass plate 11B. The spacer is made of, for example, a metal material or a resin material. Examples of the metal material usable for the spacer include aluminum and stainless steel.

[0098]

The heat reflective film performs its heat reflecting function by incorporating a conductive film layer. The heat reflective film may include any layer other than the conductive film layer as long as the effects of the present disclosure are achieved. Hereinafter, the layer other than the conductive film layer in the heat reflective film may be referred to as the “other layer”.

[0099]

In the present specification, the term “conductive film layer” refers to a film layer having an electrical resistivity of 100 Ω·cm or lower at 20°C. The component of the conductive film layer is not particularly limited. For example, the conductive film layer preferably contains a main component selected from: highly heat reflective metals such as silver, aluminum and stainless steel; indium tin oxide (ITO); tin oxide doped with at least one of fluorine and antimony (SnO_2: F, Sb); titanium nitride; niobium nitride; chromium nitride; zirconium nitride; hafnium nitride; and the like (hereinafter, these are also referred to as “conductive film layer component group A”). In the present specification, the term “main component” refers to a component whose content is 50 at% or more to all the constituent components. In other words, it is preferable that: the conductive film layer of the present embodiment contains at least one type selected from the conductive film layer component group A; and the total content of the conductive film layer component group A in the conductive film layer of the present embodiment is 50 at% or more.

[0100]

In order for the heat reflective film to exhibit excellent heat reflecting properties, the conductive film layer preferably contains at least one of silver and aluminum as the main component. The conductive film layer more preferably contains silver as the main component (that is, 50 at% or more), and still more preferably contains 95 at% or more of silver.

[0101]

The conductive film layer, when containing silver as the main component as described above, may further contain one or more additive elements such as gold, palladium, copper, bismuth, neodymium, platinum and the like. When the conductive film layer contains silver as the main component together with such an additive element,

it is possible to suppress silver diffusion and obtain improved moisture resistance. The additive element is not limited to the above-exemplified types. Any element can be added as long as the effects of the present disclosure are achieved.

[0102]

From the viewpoint of durability, the heat reflective film preferably has a layer configuration in which the conductive film layer is sandwiched between the above-described other layers such as metal oxide layers or metal nitride layers. Example of the metal oxide layer are layers of metal oxides, such as those predominantly containing aluminum oxide, zinc oxide, indium oxide, titanium oxide, niobium oxide, tin oxide, bismuth oxide, tantalum oxide, tungsten oxide, zirconium oxide, silicon oxide and the like. Among these, zinc oxide is preferred as the main component of the metal oxide layer because it has good compatibility with silver as the preferred component of the conductive film layer and contributes to improved durability of the conductive film layer. Examples of the metal nitride layers are layers of metal nitrides, such as those predominantly containing silicon nitride (Si_3N_4), aluminum nitride (AlN), titanium nitride and the like.

[0103]

<Reason Why Double glazing Is More Difficult to Reduce Reflections than Single Glazing>

When the window glass 11 is in double glazed form, the distance between the main surface 11A1 or 11A2 of the outdoor-side glass plate 11A and the lens 130 increases by the sum of the thickness of the spacer and the thickness of the glass plate 11B so that reflections are more likely to be captured. Furthermore, the heat reflective film 11C of high reflectance is provided on the indoor-side main surface 11A2 of the outdoor-side glass plate 11A or the outdoor-side main surface 11B1 of the indoor-side glass plate 11B of the double glazing, which leads to more pronounced reflections. Consequently, the double glazing is more difficult to reduce reflections than the single glazing.

[0104]

<Reason Why Imaging Device 50 Captures Reflections>

Unless otherwise specified, the following description will be given of the situation that the imaging device 50 captures an image of outdoors through the window glass 11

from the indoor side where lighting is on at night. Night means, as an example, a period of time from sunset to sunrise. When lighting is turned on at night, the indoor environment becomes bright while the outdoor environment remains dark.

[0105]

In the case where the heat reflective film 11C has a higher reflectance than those of the glass plates 11A and 11B, reflections from the heat reflective film 11C are more easily visible to the human eye than reflections from the glass plates 11A and 11B when the window glass 11 is viewed from the indoor side. Hence, reflections included in the image captured by the imaging device 50 are more dominantly occupied by reflections from the heat reflective film 11C than by reflections from the glass plates 11A and 11B. For such a reason, reflections from the heat reflective film 11C will now be described below.

[0106]

In Fig. 3A, the path of light traveling from the +Z direction side to the −Z direction side of the imaging device 50 and reflecting off the heat reflective film 11C toward the +Z direction side is indicated by thick arrows. Further, the horizontal angle of view θx is divided into regions (1) and (2) in Fig. 3A. The region (1) is a region where light from the indoor side toward the window glass 11 does not reach the heat reflective film 11C. The region (2) is a region where light from the indoor side toward the window glass 11 reaches the heat reflective film 11C.

[0107]

In Fig. 3A, the range of the horizontal angle of view θx and the boundaries between the regions (1) and (2) are indicated by four dash-dotted lines. The four dash-dotted lines are folded at the +Z direction-side surface of the heat reflective film 11C toward the lens 130 because these lines indicate the boundaries of the regions where light travels from the +Z direction side to the −Z direction side of the imaging device 50 and reflects off the heat reflective film 11C toward the +Z direction side.

[0108]

Fig. 3B is used for ease of view of the horizontal angle of view θx and the regions (1) and (2). Light incident from the indoor side to the heat reflective film 11C in Fig. 3A is shown in mirror in the −Z direction side of Fig. 3B with respect to the heat reflective film 11C as if traveling toward the heat reflective film 11C from the −Z direction side.

Thus, in Fig. 3B, the four dash-dotted lines indicating the horizontal angle of view θx and the regions (1) and (2) are drawn straight; and the path of reflected light indicated by thick arrows is shown as a straight light path directed from the −Z direction side to the window glass 11, passing through the heat reflective film 11C and reaching the lens 130.

[0109]

In Fig. 3B, an imaging device mirror image 50R and a lens mirror image 130R are also shown as mirror images of the imaging device 50 and the lens 130 relative to the heat reflective film 11C, respectively. Assuming the heat reflective film 11C as a plane, the imaging device mirror image 50R and the lens mirror image 130R are symmetrical in shape to the imaging device 50 and the lens 130, respectively, with respect to the heat reflective film 11C.

[0110]

Here, the XYZ coordinates shown in Fig. 3B are used for the actually existing objects such as the window glass 11 and the imaging device 50, and are not used for the imaging device mirror image 50R, the lens mirror image 130R and the light path.

[0111]

The central region (1) within the horizontal angle of view θx is a region in which the heat reflective film 11C is located behind the imaging device 50 and does not cause light reflection. The region (1) is defined between the center of the lens 130 and two of the dash-dotted lines passing through two window glass 11-side corners of the housing of the imaging device 50. The path of light in the region (1) is as described below with reference to Figs. 3A and 3B.

[0112]

In Fig. 3A, light (arrows 1A) traveling from the indoor side toward the heat reflective film 11C through the region (1) is obstructed by the imaging device 50 from reaching and reflecting off the heat reflective film 11C. Thus, light in the region (1) is not incident on the lens 130 and is not captured by the imaging unit 140. This light path is as described below with reference to Fig. 3B. In Fig. 3B, light (arrows 1A) traveling through the region (1) toward the heat reflective film 11C is obstructed by the imaging device mirror image 50R from reaching the heat reflective film 11C. Thus, light (arrows 1A) in the region (1) is not incident on the lens 130 and is not captured by

the imaging unit 140.

[0113]

The region (2) within the horizontal angle of view θx is a region in which light reaches and reflects off the heat reflective film 11C without being obscured by the imaging device 50. There are two regions (2) on both sides (−X direction side and +X direction side) of the region (1). These two regions (2) are defined by excluding the central region (1) from the range of the horizontal angle of view θx in XZ plane view. The path of light in the regions (2) is as described below with reference to Figs. 3A and 3B.

[0114]

In Fig. 3A, light (arrows 2A) traveling from the indoor side toward the heat reflective film 11C through the region (2) is not obstructed by the imaging device 50 and thus reaches and reflects off the heat reflective film 11C. Light reflecting off the heat reflective film 11C is transmitted through the lens 130 and captured by the imaging unit 140. In Fig. 3B, light (arrows 2A) traveling through the region (2) toward the heat reflective film 11C is not obstructed by the imaging device mirror image 50R and reaches and reflects off the heat reflective film 11C. In Fig. 3B, light reflecting off the heat reflective film 11C is illustrated as light passing straight through the heat reflective film 11C. Light reflecting off the heat reflective film 11C is transmitted through the lens 130 and captured by the imaging unit 140. Therefore, reflections due to light (arrows 2A) traveling through the region (2) are included in the image captured by the imaging device 50.

[0115]

<Reason Why Imaging Device 100 Reduces Reflections>

Figs. 4A and 4B are schematic diagrams illustrating an example of why the imaging device 100 of the present embodiment can reduce reflections. This reason will first be described below with reference to Fig. 4A.

[0116]

As in Fig. 3B, in Fig. 4A, a part of the window glass 11 in the X direction is shown in XZ cross section as viewed from the +Y direction side in the case where the window glass is in double glazed form as an example. In Fig. 4A, the position of the XZ cross section in the Y direction is a position passing through the optical axis C of the lens 130.

In Fig. 4A, the imaging device 100 is also shown in a simplified manner. The optical axis of the lens 130 is denoted by C. For simplicity of description, the imaging device 100 is assumed to be rectangular in XZ plane view and symmetrical in shape with respect to the optical axis C of the lens 130. The horizontal angle of view of the imaging device 100 is denoted by θx.

[0117]

In Fig. 4A, an imaging device mirror image 100R and a lens mirror image 130R are shown as mirror images of the imaging device 100 and the lens 130, respectively, as in Fig. 3B. Further, the window frame 12 and an window frame mirror image 12R as a mirror image of the window frame 12 are also shown in Fig. 4A. More specifically, the window frame 12 shown in Fig. 4A is the frame part 12Y of the window frame 12 extending in the Y direction on the +X direction side of the window glass 11 and thus is denoted by reference symbol 12Y in parentheses. Unless otherwise specified, this frame part will be regarded as the window frame 12 in the following description.

[0118]

Assuming the heat reflective film 11C as a plane, the imaging device mirror image 100R, the lens mirror image 130R and the window frame mirror image 12R are symmetrical in shape to the imaging device 100, the lens 130 and the window frame 12, respectively, with respect to the heat reflective film 11C.

[0119]

Here, the XYZ coordinates shown in Fig. 4A are used for the actually existing objects such as the window glass 11 and the imaging device 100 and are not used for the imaging device mirror image 100R, the lens mirror image 130R, the window frame mirror image 12R and the light path unless otherwise specified.

[0120]

In Fig. 4A, the horizontal angle of view θx is divided into a region (1), two regions (2) and a region (3) as indicated by five dash-dotted lines.

[0121]

The central region (1) within the horizontal angle of view θx is the same as the region (1) shown in Fig. 3B. Light traveling from the indoor side toward the heat reflective film 11C through the region (1) is obstructed by the imaging device 100 from reflecting off the heat reflective film 11C. Thus, light in this region is not incident on the

lens 130 and is not captured by the imaging unit 140.

[0122]

The region (3) is a region corresponding to an outer part of the +X direction-side region (2) of Fig. 3B within the horizontal angle of view θx, in which light is obstructed by the window frame mirror image 12R. The region (3) is defined between two dash-dotted lines, one connecting the +X direction-side end of the horizontal angle of view θx to the center of the lens 130 and the other connecting the −X−Z direction-side corner of the window frame mirror image 12R to the center of the lens 130.

[0123]

Light traveling from the indoor side toward the heat reflective film 11C through the region (3) is obstructed by the window frame mirror image 12R from reflecting off the heat reflective film 11C. Thus, light in this region is not incident on the lens 130 and is not captured by the imaging unit 140. Therefore, the imaging device 100 can eliminate reflections due to light traveling through the outer part of the +X direction-side region (2) shown in Fig. 3B within the horizontal angle of view θx and reflecting off the heat reflective film.

[0124]

Since the −X direction-side region (2) is the same as that shown in Fig. 3B, reflections due to light (arrows 2A) traveling through the −X direction-side region (2) are included in the image captured by the imaging device 100.

[0125]

In Fig. 4A, the region (2) is present between the region (1) and the region (3) but is significantly decreased as compared to the +X direction-side region (2) of Fig. 3B. As described above, the imaging device 100 utilizes the window frame 12 to reduce reflections due to light traveling from the window frame 12 side relative to the optical axis C of the lens 130 and reflecting off the heat reflective film 11C. For the region on the +X direction side relative to the optical axis C of the lens 130, the window frame 12 is utilized in place of a lens hood.

[0126]

In Fig. 4B, the imaging device 100 is illustrated as being in contact with the indoor-side main surface 11B2 of the window glass 11. By positioning the imaging device 100 closer to the window glass 11 than that shown in Fig. 4A, the region (2) between the

region (1) and the region (3) can be reduced or eliminated as compared to the +X direction-side region (2) shown in Fig. 4A. The imaging device 100, when positioned as shown in Fig. 4B, can eliminate reflections due to light incident from the window frame 12 side relative to the optical axis C and reflecting off the heat reflective film and thereby reduce reflections from the heat reflective film 11C as compared to that shown in Fig. 4A.

[0127]

In order to reduce reflections from the heat reflective film 11C by utilizing the structural part such as window frame 12 in contact with the window glass 11 as described above, the position of the imaging device 100 relative to the window frame 12 (structural part) and the window glass 11 may be set as follows as an example in terms of the horizontal angle of view θx, the distance Dx and the distance Dz.

[0128]

<Horizontal Angle of View θx, Distance Dx and Distance Dz>

In the imaging device 100, the horizontal angle of view θx, the X-direction distance Dx between the lens 130 and the window frame 12 and the distance Dz between the lens 130 and the heat reflective film 11C as shown in Fig. 4A are specified to reduce reflections due to light reflecting off the heat reflective film 11C. Here, the horizontal angle of view θx and the distance Dx are specified in relation to the frame part 12Y of the window frame 12. In relation to the frame part 12X of the window frame 12, the vertical angle of view θy of the lens 130 and the Y-direction distance Dy between the lens 130 and the frame part 12X may be specified. The distance Dz is common in both of these cases. The horizontal angle of view θx and the vertical angle of view θy are examples of the angle of view of the imaging device 100.

[0129]

<Horizontal Angle of View θx >

The imaging device 100 has, for example, a horizontal angle of view θx of 40 degrees or more, preferably from 70 degrees to 100 degrees. The imaging device 100 is intended for use as e.g. a surveillance camera for security and thus requires a certain width of field of view.

[0130]

The horizontal angle of view θx will now be described below with reference to

Figs. 5AA to 5AF. Figs. 5AA to 5AF are examples of images captured by fixed-point imaging using a camera with horizontal angles of view θx set to 40 degrees, 50 degrees, 70 degrees, 80 degrees, 105 degrees and 120 degrees, respectively.

[0131]

Referring to Figs. 5AA to 5AF, the image with a horizontal angle of view θx of 40 degrees (see Fig. 5AA, top left) includes a building, but not the entire building, on its left side. Here, the building is a 10-story building as an example. The image with a horizontal angle of view θx of 50 degrees (see Fig. 5AB, top center) includes the entire building on its left side, but the imaging range is not so wide. The image with a horizontal angle of view θx of 70 degrees (see Fig. 5AC, top right) includes the entire building and its surroundings. The image with a horizontal field of view θx of 80 degrees (see Fig. 5AD, bottom left) includes the entire building and its surroundings, covering a wider imaging range than the image with a horizontal field of view θx of 70 degrees. The image with a horizontal field of view θx of 105 degrees (see Fig. 5AE, bottom center) includes the entire building and its surroundings, but there is seen distortion in this image. In the image with a horizontal field of view θx of 120 degrees (see Fig. 5AF, bottom right), there is seen more pronounced distortion than in the image with a horizontal field of view θx of 105 degrees.

[0132]

By capturing images with horizontal angles of view θx set to a value less than 40 degrees and to a value more than 120 degrees, it is found that the field of view is too narrow when the horizontal angle of view θx is e.g. about 30 degrees. The camera with a horizontal angle of view θx of less than 40 degrees is difficult to use. For this reason, the horizontal angle of view θx is preferably 40 degrees or more.

[0133]

As is seen from the six images shown in Figs. 5AA to 5AF, the horizontal angle of view θx is more preferably from 70 degrees to 100 degrees. It is because: when the horizontal angle of view θx is 70 degrees or more, the entire 10-story building and its surroundings can be included in the image; and when the horizontal angle of view θx is 100 degrees or less, there occurs almost no distortion in the image.

[0134]

As described above, the horizontal angle of view θx is preferably 40 degrees or

more, preferably from 70 degrees to 100 degrees. The same applies to the vertical angle of view θy.

[0135]

<Distance Dx between Lens 130 and Window Frame 12>

The X-direction distance Dx between the lens 130 and the window frame 12 is a distance from the center of the lens 130 to a −X direction-side wall of the window frame 12 in the X direction as shown in Fig. 4A. Here, the X direction is a direction parallel to the main surface 11B2 of the window glass 11.

[0136]

The distance Dx is preferably from 0 mm to 180 mm. The reason for this will be described below with reference to Figs. 5B and 5C. Fig. 5B is a diagram illustrating examples of simulation results of the reflection reduction rate Rx (%) relative to the distance Dx with the horizontal angle of view θx set in 10-degree increments from 40 degrees to 100 degrees. Fig. 5C is a diagram illustrating examples of simulation results with the horizontal angle of view θx set to 40 degrees.

[0137]

The reflection reduction rate Rx (%) is calculated, from an X-direction length Xt (see Fig. 4A) of a portion of the +Z direction-side surface of the heat reflective film 11C within the horizontal angle of view θx and an X-direction length X3 (see Fig. 4A) of a portion of the +Z direction-side surface of the heat reflective film 11C within the region (3), as a value (X3/Xt) of division of the length X3 by the length Xt. The reflection reduction rate Rx (%) represents a rate of reduction of reflected light at the part of the +Z direction-side surface of the heat reflective film 11C within the horizontal angle of view θx.

[0138]

Here, simulations were conducted with the distance Dz set to 1 mm and with the Z-direction length of the window frame 12 set to 500 mm under the assumption that the outdoor-side main surface 11A1 of the window glass 11 was aligned in position with the outer surface of the window frame 12 extending on the −Z direction side in parallel to the XY plane. It is generally considered that: a window frame 12 of a building structure such as a building has a sufficient length in the Z direction toward the indoor side with respect to an outdoor-side surface 11A1 of a window glass 11; and even when the

length of the window frame 12 itself in the Z direction is shorter than 500 mm, there exists any structural part such as an inner wall extending in the +Z direction continuously to the window frame 12. Thus, the Z-direction length of the window frame 12 was set to 500 mm for the simulations.

[0139]

As shown in Fig. 5B, the reflection reduction rate R showed nearly equal peak values at a distance Dx of about 5 mm for all the horizontal angles of view θx. Further, the reflection reduction rate showed a tendency to decrease nearly linearly with increase in distance Dx for all the horizontal angles of view θx. Among the seven horizontal angles of view θx from 40 degrees to 100 degrees, the reflection reduction rate R was the lowest at the narrowest horizontal angle of view of 40 degrees and tended to increase with the horizontal angle of view θx. The reason for this is assumed to be that the greater the horizontal angle of view θx, the larger the area occupied by the window frame 12 within the horizontal angle of view θx, the larger the amount of light obstructed by the window frame 12, the more reduced the reflections due to reflected light.

[0140]

The reflection reduction rate R at the narrowest horizontal angle of view θx of 40 degrees was 1% when the distance Dx was 180 mm, but became 0% when the distance Dx exceeded 180 mm and reached 190 mm.

[0141]

It has been apparent from the above results that, to reduce reflections due to light reflecting off the heat reflective film 11C by utilizing the structural part such as window frame 12 in contact with the window glass 11, the position of the imaging device 100 relative to the window frame 12 (structural part) and the window glass 11 can be set such that, as an example, the horizontal angle of view θx is 40 degrees or more and the distance Dx is from 0 mm to 180 mm.

The reflection reduction rate Rx (%) is preferably higher than 0% and lower than or equal to 50%. When Rx is higher than 0% and lower than or equal to 50%, it is easy to capture an image of outdoors without the use of a lens hood even under a situation that indoor lighting is on at night. Rx is more preferably 10% or higher, still more preferably 20% or higher, particularly preferably 30% or higher. Rx may be 45% or

lower, may be 40% or lower, or may be 35% or lower.

[0142]

The reflection reduction rate Rx (%), which represents a rate of reduction of reflected light at the part of the +Z direction-side surface of the heat reflective film 11C within the horizontal angle of view θx, has been described above. Since the frame part 12X of the window frame 12 is located on the +Y direction side of the imaging device 100, the reflection reduction rate Ry (%) for the vertical angle of view θy can be calculated in the same manner as above. The reflection reduction rate Ry (%) represents a rate with which reflections due to reflected light are reduced by the frame part 12X at the part of the +Z direction-side surface of the heat reflective film 11C within the vertical angle of view θy. The rate with which the imaging device 100 can reduce reflections by utilizing the window frame 12 is determined by subtracting the duplicate of the reflection reduction rates Rx and Ry from the sum of the reflection reduction rates Rx and Ry.

The reflection reduction rate Ry (%) is preferably higher than 0% and lower than or equal to 50%. When Ry is higher than 0% and lower than or equal to 50%, it is easy to capture an image of outdoors without the use of a lens hood even under a situation that indoor lighting is on at night. Ry is more preferably 10% or higher, still more preferably 20% or higher, particularly preferably 30% or higher. Ry may be 45% or lower, may be 40% or lower, or may be 35% or lower.

[0143]

<Distance Dz between Lens 130 and Heat Reflective Film 11C>

The distance Dz between the lens 130 and the heat reflective film 11C is defined as a Z-direction distance from the vertex of the lens 130, which is a convex lens projecting in the −Z direction, to the +Z direction-side surface (reflection surface) of the heat reflective film 11C. In the case where the window glass 11 is in double glazed form, the distance Dz varies depending on the thickness of the spacer between the glass plate 11A and the glass plate 11B.

[0144]

The lens 130 is disposed in the opening of the recess 110D1 of the holder 110D of the case 110. The vertex of the lens 130 on the −Z direction side is preferably set back from the first surface 111 of the case 110 in the +Z direction, but may be in flush

with the first surface 111. Further, the heat reflective film 11C is provided on the indoor-side main surface 11A2 of the outdoor-side glass plate 11A in Figs. 4A and 4B, but may be provided on the outdoor-side main surface 11B1 of the indoor-side glass plate 11B.

[0145]

In the case where the imaging device 100 is arranged part from the window glass 11 in the +Z direction, the Z-direction space between the window glass 11 and the lens 130 increases to widen the region (2) between the regions (1) and (3) in Fig. 4A (the angle of the region (2) in XZ plane view), resulting in increased occurrence of reflections due to light incident from the window frame 12 side relative to the optical axis C and reflecting off the heat reflective film. In view of this, it has been derived from simulations that the distance Dz is preferably 100 mm or less.

[0146]

As is seen from the above, the distance Dz between the lens 130 and the heat reflective film 11C is preferably from 0 mm to 100 mm when the reflectance of the heat reflective film 11C is higher than the reflectance of the glass plate of the window glass 11. This makes it possible to effectively reduce reflections from the heat reflective film 11C.

[0147]

Even in the case where the window glass 11 is in double glazing form with the heat reflective film 11C, reflections from the window glass 11 are dominant when the reflectance of the heat reflective film 11C is lower than the reflectance of the glass plates 11A and 11B of the window glass 11. In such a case, the Z-direction distance between the focal point of the lens 130 and the outdoor-side main surface 11A1 of the outdoor-side glass plate 11A of the double-glazed window glass 11 is regarded as the above distance Dz, and it is possible to effectively reduce reflections from the window glass 11 by setting the distance Dz between the focal point of the lens 130 and the outdoor-side main surface 11A1 of the outdoor-side glass plate 11A of the double-glazed window glass 11.

[0148]

Although the window glass 11 has been illustrated as being in double glazed form with reference to the Figs. 3A to 4B, the window glass 11 may be in single glazed form

as described above. In the case where the window glass 11 is in single glazed form with a heat reflective film provided on the outdoor-side main surface 11A1 (see Fig. 1B) or on the indoor-side main surface 11B2 (see Fig. 1B) and having a reflectance higher than that of the window glass 11, the Z-direction distance between the focal point of the lens 130 and the heat reflective film is regarded as the distance Dz as in the case where the window glass 11 is in double glazed form.

[0149]

In the case where the window glass 11 is in single glazed form with no heat reflective film 11C, there occur reflections from the window glass 11. Thus, in the case where the window glass is single glazed form with no heat reflective film 11C, the Z-direction distance between the focal point of the lens 130 and the outdoor-side main surface 11A1 (see Fig. 1B) of the single-glazed window glass 11 is regarded as the distance Dz, and it is possible to effectively reduce reflections from the window glass 11 by setting the distance Dz between the focal point of the lens 130 and the outdoor-side main surface 11A1 of the single-glazed window glass 11

[0150]

Even in the case where the window glass 11 is in single glazed form with the heat reflective film 11C, reflections from the window glass 11 are dominant when the reflectance of the heat reflective film 11C is lower than the reflectance of the glass plate of the window glass 11. In such a case, the Z-direction distance between the focal point of the lens 130 and the outdoor-side main surface 11A1 (see Fig. 1B) of the single-glazed window glass 11 is regarded as the distance Dz. It is possible to effectively reduce reflections from the window glass 11 by setting the distance Dz between the focal point of the lens 130 and the outdoor-side main surface 11A1 of the single-glazed window glass 11.

[0151]

In the case where the window glass 11 is in single glazed form with no heat reflective film 11C, light from the indoor side reflects off the indoor-side main surface 11B2 (see Fig. 1B) and the outdoor-side main surface A1 (see Fig. 1B) toward the indoor side. The reflection of light at the outdoor-side main surface 11A1 occurs by light passing through the indoor-side surface 11B2 and reflecting off the inner side of the outdoor-side main surface 11A1 within the window glass 11. Since each of the

main surface 11B2 and 11A1 has a visible light reflectance of about 4%, the window glass 11 has a total visible light reflectance of about 8%.

[0152]

As described above, it is also possible in the case where the window glass 11 is in single glazed form with no heat reflective film 11C to reduce reflections by setting the position of the imaging device 100 such that the horizontal angle of view θx, the distance Dx and the distance Dx satisfy the above-described conditions, as in the case where the window glass 11 is double glazed with the heat reflective film 11C.

[0153]

<Reflection Reduction Rate Rx (%) Relative to Distance Dx>

Fig. 6 is a schematic view illustrating an example of the reflection reduction rate Rx (%) relative to the distance Dx in the imaging device 100 according to one embodiment.

[0154]

In Fig. 6, a part of the double-glazed window glass 11 in the X direction is shown in XZ cross section as viewed from the +Y direction side, as in Fig. 4A. The position of the XZ cross section in the Y direction in Fig. 6 is a position passing through the optical axis C of the lens 130. Further, the imaging device 100 is shown in a simplified manner in Fig. 6. The optical axis of the lens 130 is denoted by C. For simplicity of description, the imaging device 100 is assumed to be rectangular in XZ plane view and symmetrical in shape with respect to the optical axis C of the lens 130. Here, the horizontal angle of view θx of the imaging device 100 is greater than the horizontal angle of view θx shown in Fig. 4A.

[0155]

In Fig. 6, an imaging device mirror image 100R and a lens mirror image 130R are shown as mirror images of the imaging device 100 and the lens 130, respectively, as in Fig. 4A. The window frame 12 and a window frame mirror image 12R as a mirror image of the window glass 12 are also shown in Fig. 6. More specifically, the window frame 12 shown in Fig. 6 is the flame part 12Y of the window frame 12 extending in the Y direction on the +X direction side of the window glass 11 and is thus denoted by reference symbol 12Y in parentheses. Unless otherwise specified, this frame part will be regarded as the window frame 12 in the following description.

[0156]

Furthermore, an outdoor-side window frame 12A is also provided in addition to the window frame 12 in Fig. 6. The window frame 12A protrudes toward the outdoor side (−Z directions side) from the outdoor-side main surface 11A1 of the glass plate 11A. The X-direction width of the window frame 12A is, as an example, equal to the X-direction width of the window frame 12. The Z-direction length of the window frame 12A is shorter than the Z-direction length of the window frame 12, and a −Z direction-side end of the window frame 12A is located on the +Z direction side relative to a −Z direction-side end of the window frame mirror image 12R. Accordingly, the position of the −Z direction-side end of the window frame mirror image 12R corresponds to the position of the −Z direction-side end of the window frame mirror image 12R shown in Fig. 4A.

[0157]

Assuming the heat reflective film 11C as a plane, the imaging device mirror image 100R, the lens mirror image 130R and the window frame mirror image 12R are symmetrical in shape to the imaging device 100, the lens 130 and the window frame 12, respectively, with respect to the heat reflective film 11C.

[0158]

Here, the XYZ coordinates shown in Fig. 6 are used for the actually existing objects such as the window glass 11 and the imaging device 100 and, unless otherwise specified, are not used for the imaging device mirror image 100R, the lens mirror image 130R, the window frame mirror image 12R and the light path.

[0159]

Fig. 6 mainly illustrates the +X direction side with respect to the optical axis C, omitting a part of the −X direction side with respect to the optical axis C. In Fig. 6, shown are not only the regions (1) to (3) but also regions (4) and (5) on the +X direction side with respect to the optical axis C. All of the regions (1) to (5) are situated within the horizontal angle of view θx in Fig. 6. The regions (1) and (2) are the same as the regions (1) and (2) shown in Fig. 4A.

[0160]

In Fig. 6, the region (3) is a region, located outward of the +X direction-side region (2) within the horizontal angle of view θx, where light is obstructed by the window frame

mirror image 12R but is not obstructed by the window frame 12A as the real image. The region (3) is defined between two dash-dotted lines: one connecting the −X−Z direction-side corner of the window frame mirror image 12R to the center of the lens 130, and the other connecting the −X−Z direction-side corner of the window frame 12A to the center of the lens 130.

[0161]

The region (4) is a region located outward of the region (3) within the horizontal angle of view θx, and is defined between two dash-dotted lines: one connecting the −X−Z direction-side corner of the window frame 12A to the center of the lens 130 and the other connecting the +X direction-side end of the +Z direction-side surface of the heat reflective film 11C to the center of the lens 130. The region (4) is a region where light is obstructed by the window frame 12A as the real image.

[0162]

The region (5) is a region located outward of the region (4) within the horizontal angle of view θx, and is defined between two dash-dotted lines: one connecting the +X direction-side end of the +Z direction-side surface of the heat reflective film 11C to the center of the lens 130 and the other connecting the +X direction-side end of the horizontal angle of view θx to the center of the lens 130.

[0163]

Light 3A traveling from the indoor side toward the heat reflective film 11C through the region (3) is obstructed by the window frame mirror image 12R from reflecting off the heat reflective film 11C and is not incident on the lens 130 and not captured by the imaging unit 140. It is thus possible to eliminate reflections due to light 3A traveling through the region (3) of Fig. 6 and reflecting off the heat reflective film.

[0164]

As in the case of light 3A in the region (3), lights 4A and 5A in the regions (4) and (5) do not reflect off the heat reflective film 11C and thus is not incident on the lens 130. Since the window frame 12A as the real image exists in the regions (4) and (5), these lights 4A and 5A do not contribute to a reduction of reflections.

[0165]

Even in the case where the window frame 12A is provided, the imaging device 100 can utilize the window frame 12 to reduce reflections due to light incident from the

window frame 12 side relative to the optical axis C of the lens 130 and reflecting off the heat reflective film 11C. On the +X direction side with respect to the optical axis C of the lens 130, the window frame 12 is utilized in place of a lens hood.

[0166]

In the imaging device 100, not only the horizontal angle of view θx, the X-direction distance Dx between the lens 130 and the window frame 12 and the distance Dz between the lens 130 and the heat reflective film 11C as shown in Fig. 6, but also the distances d, e, f and g as shown in Fig. 6 are specified to reduce reflections due to light reflecting off the heat reflective film 11C.

[0167]

The distance d is a Z-direction distance between the +Z direction-side end of the window frame 12 and the heat reflective film 11C and is equal to a Z-direction distance between the −Z direction-side end of the window frame mirror image 12R and the heat reflective film 11C. The distance e is a distance between the heat reflective film 11C and the −Z direction-side end of the window frame 12A. The distance f is a distance between the lens 130 and the −Z direction-side end of the window frame 12A and is expressed as f = Dz + e. The distance g is a distance between the lens 130 and the −Z direction-side end of the window frame mirror image 12R and is expressed as g = Dz + d.

[0168]

Here, the horizontal angle of view θx, the distance Dx and the distances d, e, f and g in XZ plane view are specified in relation to the frame part 12Y of the window frame 12. In relation to the frame part 12X of the window frame 12, the vertical angle of view θy, the distance Dy between the lens 130 and the frame part 12X in the Y direction and the distances d, e, f and g in XZ plane view may be specified. The distance Dz is common in both of these cases. The horizontal angle of view θx and the vertical angle of view θy are examples of the angle of view of the imaging device 100.

[0169]

Although the optical axis C of the lens 130 is parallel to the Z direction in Fig. 6, the angle between the optical axis C and the Z direction is herein referred to as θc to describe a more general case. It is assumed that, when viewed from the +Y direction side, θc takes positive values for angles tilting clockwise from the −Z direction side

toward the +X direction side and take negative values for angles tilting counterclockwise from the −Z direction side toward the −X direction side.

[0170]

Whether the −X−Z direction-side corner of the window frame 12A is reflected as an actual image on the lens 130 depends on whether the condition $f \times \tan(\theta x/2+\theta c) > Dx$ is satisfied. When $f \times \tan(\theta x/2+\theta c) > Dx$, the window frame 12A is reflected on the lens 130. When $f \times \tan(\theta x/2+\theta c) \leq Dx$, the window frame 12A is not reflected on the lens 130. The expression “the window frame 12A is not reflected on the lens 130” means that the window frame 12A is out of the horizontal angle of view θx. The expression “the window frame 12A is reflected on the lens 130” means that the window frame 12 is located within the horizontal angle of view θx.

[0171]

<When Window frame 12A Is Reflected onto Lens 130>

When the window frame 12A is reflected on the lens 130, the length X12 of the reflection surface of the heat reflective film 11C is expressed by the following formula (1) using the ratio between the length Dz and the distance g. Here, the length X12 is a total length of a portion of the reflective surface of the heat reflective film 11C on the +X direction side within the region (1), with respect to a straight line passing through the center of the lens 130 and extending parallel to the normal of the window glass 11, and a portion of the reflective surface of the heat reflective film 11C within the +X direction-side region (2).

$$X12 = Dx \times Dz/g = Dx \times Dz/(Dz+d) \quad (1)$$

[0172]

When the window frame 12A is reflected on the lens 130, the X-direction length X4 of the region (4) on the reflection surface of the heat reflective film 11C is expressed by the following formula (2) using the ratio between the distance f and the distance e.

$$X4 = Dx \times e/f = Dx \times e/(Dz+e) \quad (2)$$

[0173]

When the window frame 12A is reflected on the lens 130, the X-direction length X5 of the region (5) on the reflection surface of the heat reflective film 11C is expressed by the following formula (3).

$$X5 = Dz \times \tan(\theta x/2+\theta c) - Dx \quad (3)$$

[0174]

Taking the X-direction length of the reflection surface of the heat reflective film 11C within the horizontal angle of view θx as Xt, the length Xt is expressed by the following formula (4).

$$Xt = Dz \times \{\tan(\theta x/2-\theta c) + \tan(\theta x/2+\theta c)\} \quad (4)$$

[0175]

When the window frame 12A is reflected on the lens 130, the X-direction length X3 of the region (3) on the reflection surface of the heat reflective film 11C is determined by subtracting the length Dz × tan(θx/2+θc) from the lengths X12, X4 and X5 and thus is expressed by the following formula (5). The length Dz × tan(θx/2+θc) is a length determined from the length Xt/2, which is half the length Xt, in consideration of the angle θc between the optical axis C of the lens 130 and the Z direction.

$$X3 = Dz \times \tan(\theta x/2+\theta c) - X12 - X4 - X5$$
$$= Dz \times \tan(\theta x/2+\theta c) - Dx \times Dz/(Dz+d) - Dx \times e/(Dz+e) - (Dz \times \tan(\theta x/2+\theta c)-Dx)$$
$$= Dz \times Dx \times \{1/(Dz+e)-1/(Dz+d)\} \quad (5)$$

[0176]

From the above, the reduction reflection rate Rx (%) relative to the distance Dx can be expressed by the following formula (6) using the lengths X3 and Xt when the window frame 12A is reflected on the lens 130.

$$Rx\ (\%) = X3/Xt \times 100$$
$$= [Dz \times Dx \times \{1/(Dz+e)-1/(Dz+d)\}]/[Dz\times\{\tan(\theta x/2-\theta c)+\tan(\theta x/2+\theta c)\}] \times 100$$
$$= Dx \times \{1/(Dz+e)-1/(Dz+d)\}/\{\tan(\theta x/2-\theta c)+\tan(\theta x/2+\theta c)\} \times 100 \quad (6)$$

[0177]

Although the horizontal angle of view θx, the distance Dx and the distances d, e, f and g in XZ plane view are herein specified in relation to the frame part 12Y of the window frame 12, the vertical angle of view θy of the lens 130, the Y-direction distance Dy between the lens 130 and the window frame 12X and the distances d, e, f and g in XZ plane view may be specified in relation to the frame part 12X of the window frame 12.

[0178]

The reflection reduction rate Rx (%) relative to the distance Dx as expressed by the formula (6) is preferably higher than 0% and lower than or equal to 50%. When Rx

is higher than 0% and lower than or equal to 50%, it is easy to capture an image of outdoors without the use of a lens hood even under a situation that indoor lighting is turned on at night. Rx is more preferably 10% or higher, still more preferably 20% or higher, particularly preferably 30% or higher. Rx may be 45% or lower, may be 40% or lower, or may be 35% or lower.

[0179]

The reflection reduction rate Ry (%) relative to the distance Dy can be expressed by the following formula (7) using the lengths X3 and Xt when the window frame 12A is reflected on the lens 130.

$$Ry\ (\%) = X3/Xt \times 100$$
$$= [Dz \times Dy \times \{1/(Dz+e)-1/(Dz+d)\}]/[Dz \times \{\tan(\theta y/2-\theta c) +\tan(\theta y/2+\theta c)\}] \times 100$$
$$= Dy \times \{1/(Dz+e)-1/(Dz+d)\}/\{\tan(\theta y/2-\theta c)+\tan(\theta y/2+\theta c)\} \times 100 \quad (7)$$

[0180]

The reflection reduction rate Ry (%) relative to the distance Dy as expressed by the formula (7) is preferably higher than 0% and lower than or equal to 50%. When Ry is higher than 0% and lower than or equal to 50%, it is easy to capture an image of outdoors without the use of a lens hood even under a situation that indoor lighting is turned on at night. Ry is more preferably 10% or higher, still more preferably 20% or higher, particularly preferably 30% or higher. Ry may be 45% or lower, may be 40% or lower, or may be 35% or lower.

[0181]

<When Window Frame 12A Is Not Reflected onto Lens 130>

When the window frame 12A is not reflected on the lens 130, there are no regions (4) and (5) in Fig. 6. There are no regions (4) and (5), for example, in the case where the horizontal angle of view θx is so narrow that the window frame 12A is not reflected or in the case where no window frame 12A exists as shown in Fig. 4A.

[0182]

In such a case, within the XZ plane view, the terms with the lengths X4 and X5 are removed from the formula (5). The length X3 is thus expressed by the following formula (8).

$$X3 = Dz \times \tan(\theta x/2+\theta c) - X12 = Dz \times \tan(\theta x/2+\theta c)-Dx\times Dz/(Dz+d) \quad (8)$$

[0183]

From the above, the reflection reduction rate Rx (%) relative to the distance Dx can be expressed by the following formula (9) using the length X3 expressed by the formula (8) and the length Xt when the window frame 12A is not reflected on the lens 130.

$$Rx\ (\%) = X3/Xt \times 100$$
$$= Dz \times \tan(\theta x/2+\theta c) - Dx \times Dz/(Dz+d)/[Dz \times \{\tan(\theta x/2-\theta c)+\tan(\theta x/2+\theta c)\}] \times 100$$
$$= \{\tan(\theta x/2+\theta c)-Dx/(Dz+d)\}/\{\tan(\theta x/2-\theta c)+\tan(\theta x/2+\theta c)\} \times 100 \quad (9)$$

[0184]

In relation to the frame part 12X of the window frame 12, the reflection reduction rate Ry (%) relative to the distance Dy can be obtained using the vertical angle of view θy of the lens 130, the Y direction distance Dy between the lens 130 and the frame part 12X and the distances d, e, f and g in XZ plane view when the window frame 12A is reflected on the lens 130.

[0185]

The reflection reduction rate Rx (%) relative to the distance Dx as expressed by the formula (9) is preferably higher than 0% and lower than or equal to 50%. When Rx is higher than 0% and lower than or equal to 50%, it is easy to capture an image of outdoors without the use of a lens hood even under a situation that indoor lighting is turned on at night. Rx is more preferably 10% or higher, still more preferably 20% or higher, particularly preferably 30% or higher. Rx may be 45% or lower, may be 40% or lower, or may be 35% or lower.

[0186]

The reflection reduction rate Ry (%) can be expressed by the following formula (10) using the lengths X3 and Xt.

$$Ry\ (\%) = X3/Xt \times 100$$
$$= Dz \times \tan(\theta y/2+\theta c) - Dy \times Dz/(Dz+d)/[Dz \times \{\tan(\theta y/2-\theta c)+\tan(\theta y/2+\theta c)\}] \times 100$$
$$= \{\tan(\theta y/2+\theta c)-Dy/(Dz+d)\}/\{\tan(\theta y/2-\theta c)+\tan(\theta y/2+\theta c)\} \times 100 \quad (10)$$

[0187]

The reflection reduction rate Ry (%) relative to the distance Dy as expressed by the formula (10) is preferably higher than 0% and lower than or equal to 50%. When Ry is higher than 0% and lower than or equal to 50%, it is easy to capture an image of outdoors without the use of a lens hood even under a situation that indoor lighting is

turned on at night. Ry is more preferably 10% or higher, still more preferably 20% or higher, particularly preferably 30% or higher. Ry may be 45% or lower, may be 40% or lower, or may be 35% or lower.

[0188]

<Effects>

The imaging device 100 includes: the case 110 (housing) having the surface (first surface 111) to face the indoor-side main surface 11B2 of the window glass 11 of the building structure; the lens 130 disposed in the opening of the surface (first surface 111) of the case 110 so as to face the main surface 11B2; and the imaging unit 140 disposed within the case 110 and configured to capture an image of outdoor scene outside the window glass 11 through the lens 130, wherein: the imaging device has an angle of view of 40 degrees or more; and the distance Dx between the lens 130 and the window frame 12 (structural part) in contact with the window glass 11 in the direction parallel to the main surface 11B2 is greater than or equal to 0 mm and less than or equal to 180 mm. By arranging the imaging device 100 in such a manner that the distance Dx falls within the above-described appropriate range, the window frame 12 (structural part) can be utilized to suppress the entry of light onto the window glass 11 from the window frame 12 (structural part) side relative to the optical axis C of the lens 130 and thereby reduce reflections due to reflected light. The reflections are pronounced when indoor lighting is on at night. From the viewpoint of ease of positioning of the imaging device 100 closer to the structural part such as window frame 12 and inconspicuousness of the imaging device 100, it is desirable to reduce reflections without the use of a lens hood.

[0189]

The imaging device 100 is provided, capable of capturing an image of outdoors with the use of no lens hood even under a situation that indoor lighting is on at night. With the use of no lens hood, the imaging device can be easily positioned closer to the lens 130 to the window glass 11 and be made inconspicuous when viewed from outside the window glass 11.

[0190]

The distance Dz between the lens 130 and the outdoor-side main surface 11A1 may preferably be greater than or equal to 0 mm and less than or equal to 100 mm. It is possible to effectively reduce reflections by arranging the imaging device 100 in such

a manner that the distance Dz falls within the appropriate range. The imaging device 100 is preferably arranged such that the distance Dz falls within this range particularly in the case where the window glass 11 has no heat reflective film 11C or in the case where the window glass 11C has a heat reflective film 11C lower in reflectance than the glass plate of the window glass 11.

[0191]

The window glass 11 may have the heat reflective film 11C with the distance Dz between the lens 130 and the heat reflective film 11C ranging from 0 mm to 100 mm. It is possible to effectively reduce reflections by arranging the imaging device 100 such that the distance Dz falls within the appropriate range. In the case where the heat reflective film 11C is provided to the window glass 11 and has a higher reflectance than that of the glass plate of the window glass 11, reflections from the heat reflective film 11C become dominant. In such a case, the imaging device 100 is preferably arranged such that the distance Dz falls within this range.

[0192]

The window glass 11 may be a double glazing having the outdoor-side glass plate 11A (first glass plate), the indoor-side glass plate 11B (second glass plate) and the heat reflective film 11C on the indoor-side main surface 11A2 of the glass plate 11A or the outdoor-side main surface 11B1 of the glass plate 11B. In the case where the heat reflective film 11C is provided on the main surface 11A1 or 11A2, the distance Dz becomes longer so that reflections are more likely to occur. By arranging the imaging device 100 such that the distance Dz ranges from 0 mm to 100 mm, it is possible to effectively reduce reflections.

[0193]

The lens 130 may be positioned farther apart from the window glass 11 than the surface (first surface 111) of the case 110. When the lens 130 is recessed in the +Z direction relative to the first surface 111, it is possible to reduce light incident on the lens 130 and effectively reduce reflections.

[0194]

The angle of view may preferably be greater than or equal to 70 degrees and less than or equal to 100 degrees. By setting the more appropriate angle of view, the window frame 12 (structural part) can be more effectively utilized to suppress the entry

of light onto the window glass 11 from the window frame 12 (structural part) side relative to the optical axis C of the lens 130 and further reduce reflections.

[0195]

In the case where the structural part in contact with the window glass 11 is reflected on the lens 130, the reflection reduction rate Rx (%) relative to Dx as expressed by the following formula (11) may preferably be higher than 0% and lower than or equal to 50%

$$Rx\ (\%) = Dx \times \{1/(Dz+e)-1/(Dz+d)\}/\{\tan(\theta x/2-\theta c)+\tan(\theta x/2+\theta c)\} \times 100 \quad (11)$$

where Dx is the horizontal distance between the lens 130 and the structural part in contact with the window glass 11; Dz is the distance between the lens 130 and the heat reflective film 11C; θx is the horizontal angle of view; θc is the angle between the optical axis C of the lens 130 and the normal direction of the window glass 11 in the horizontal plane passing through the center of the lens 130; d is the distance between the indoor-side end of the structural part in contact with the window glass 11 and the heat reflective film 11C in the normal direction; and e is the distance between the heat reflective film 11C and the outdoor-side end of the structural part in contact with the window glass 11.

[0196]

In the case where the structural part in contact with the window glass 11 is reflected on the lens 130 as viewed in the horizontal direction, the reflection reduction rate Rx (%) relative to the distance Dx can be calculated according to the formula (11). When Rx is higher than 0% and lower than or equal to 50%, it is easy to capture an image of outdoors without the use of a lens hood even under a situation that indoor lighting is on at night.

[0197]

In the case where the structural part in contact with the window glass 11 is reflected on the lens 130, the reflection reduction rate Ry (%) relative to Dy as expressed by the following formula (12) may preferably be higher than 0% and lower than or equal to 50%

$$Ry\ (\%) = Dy \times \{1/(Dz+e)-1/(Dz+d)\}/\{\tan(\theta y/2-\theta c)+\tan(\theta y/2+\theta c)\} \times 100 \quad (12)$$

where Dy is the vertical distance between the lens 130 and the structural part in contact with the window glass 11; Dz is the distance between the lens 130 and the heat reflective film 11C; θy is the vertical angle of view; θc is the angle between the optical

axis C of the lens 130, which passes through the center of the lens 130 in the vertical plane, and the normal direction of the window glass 11; d is the distance between the indoor-side end of the structural part in contact with the window glass 11 and the heat reflective film 11C in the normal direction; and e is the distance between the heat reflective film 11C and the outdoor-side end of the structural part in contact with the window glass 11.

[0198]

In the case where the structural part in contact with the window glass 11 is reflected on the lens 130 as viewed in the vertical direction, the reflection reduction rate Ry (%) relative to the distance Dy can be calculated according to the formula (12). When Ry is higher than 0% and lower than or equal to 50%, it is easy to capture an image of outdoors without the use of a lens hood even under a situation that indoor lighting is on at night.

[0199]

In the case where the structural part in contact with the window glass 11 is not reflected on the lens 130, the reflection reduction rate Rx (%) relative to Dx as expressed by the following formula (13) may preferably be higher than 0% and lower than or equal to 50%

$$Rx\ (\%) = \{\tan(\theta x/2+\theta c)-Dx/(Dz+d)\}/\{\tan(\theta x/2-\theta c)+\tan(\theta x/2+\theta c)\} \times 100 \quad (13)$$

where Dx is the horizontal distance between the lens 130 and the structural part in contact with the window glass 11; Dz is the distance between the lens 130 and the heat reflective film 11C; θx is the horizontal angle of view; θc is the angle between the optical axis C of the lens 130, which passes through the center of the lens 130 in the horizontal plane, and the normal direction of the window glass 11; and d is the distance between the indoor-side end of the structural part in contact with the window glass 11 and the heat reflective film 11C.

[0200]

In the case where the structural part in contact with the window glass 11 is not reflected on the lens 130 as viewed in the horizontal direction, the reflection reduction rate Rx (%) relative to the distance Dx can be calculated according to the formula (13). When Rx is higher than 0% and lower than or equal to 50%, it is easy to capture an image of outdoors without the use of a lens hood even under a situation that indoor

lighting is on at night.

[0201]

In the case where the structural part in contact with the window glass 11 is not reflected on the lens 130, the reflection reduction rate Ry (%) relative to the distance Dy as expressed by the following formula (14) may preferably be higher than 0% and lower than or equal to 50%

$$Ry\ (\%) = \{\tan(\theta y/2+\theta c)-Dy/(Dz+d)\}/\{\tan(\theta y/2-\theta c)+\tan(\theta y/2+\theta c)\} \times 100 \quad (14)$$

where Dy is the vertical distance between the lens 130 and the structural part in contact with the window glass 11; Dz is the distance between the lens 130 and the heat reflective film 11C; θy is the vertical angle of view; θc is the angle between the optical axis C of the lens 130 and the normal direction of the window glass 11 in the vertical plane passing through the center of the lens 130; and d is the distance between the indoor-side end of the structural part in contact with the window glass 11 and the heat reflective film 11C in the normal direction.

[0202]

In the case where the structural part in contact with the window glass 11 is not reflected on the lens 130 as viewed in the vertical direction, the reflection reduction rate Ry (%) relative to the distance Dy can be calculated according to the formula (14). When Ry is higher than 0% and lower than or equal to 50%, it is easy to capture an image of outdoors without the use of a lens hood even under a situation that indoor lighting is on at night.

[0203]

The imaging device-equipped window glass 200 includes the above-described imaging device 100 and the window glass 11. By arranging the imaging device 100 in such a manner that the distance Dx falls within the above-described appropriate range, the window frame 12 (structural part) can be utilized to suppress the entry of light onto the window glass 11 from the window frame 12 (structural part) side relative to the optical axis C of the lens 130 and thereby reduce reflections due to reflected light. The reflections are pronounced when indoor lighting is on at night. From the viewpoint of ease of positioning of the imaging device 100 closer to the structural part such as window frame 12 and inconspicuousness of the imaging device 100, it is desirable to reduce reflections without the use of a lens hood.

[0204]

The imaging device-equipped window glass 200 is provided, in which the imaging device is capable of capturing an image of outdoors without the use of a lens hood even under a situation that indoor lighting is on at night.

[0205]

Although the embodiments of the imaging device and the image device-equipped window glass according to the present disclosure have been described above, the present disclosure is not limited to the above-described embodiments; and various changes and modifications are possible within the range that does not depart from the claimed scope.

REFERENCE SYMBOLS

[0206]

11: Window glass

11A: Glass plate (Example of first glass plate)

11B: Glass plate (Example of second glass plate)

11A1: Main surface (Example of outdoor-side main surface of first glass plate)

11A2: Main surface (Example of indoor-side main surface of first glass plate)

11B1: Main surface

11B2: Main surface (Example of indoor-side main surface)

11C: Heat reflective film

12: Window frame (Example of structural part in contact with window glass)

100: Imaging device

100R: Imaging device mirror image

110: Case (Example of housing)

111: First surface (Example of surface of housing)

130: Lens

130R: Lens mirror image

140: Imaging unit

The entire disclosure of Japanese Patent Application No. 2023-182227 filed on October 24, 2023, including specification, claims, drawings and summary, is

incorporated herein by reference in its entirety.

CLAIMS

[Claim 1]

An imaging device, comprising:

a housing having a surface to face an indoor-side main surface of a window glass of a building structure;

a lens disposed in an opening in the surface of the housing so as to face the main surface; and

an imaging unit disposed within the housing and configured to capture an image of outdoor scene outside the window glass through the lens, wherein:

the imaging device has an angle of view of 40 degrees or more; and

a distance between the lens and a structural part in contact with the window glass in a direction parallel to the main surface is greater than or equal to 0 mm and less than or equal to 180 mm.

[Claim 2]

The imaging device according to Claim 1, wherein a distance between the lens and an outdoor-side main surface of the window glass is greater than or equal to 0 mm and less than or equal to 100 mm.

[Claim 3]

The imaging device according to Claim 1, wherein:

the window glass comprises a heat reflective film; and

a distance between the lens and the heat reflective film is greater than or equal to 0 mm and less than or equal to 100 mm.

[Claim 4]

The imaging device according to Claim 3, wherein:

the window glass is a double glazing comprising a first glass plate on an outdoor side and a second glass plate on an indoor side; and

the heat reflective film is provided on an indoor-side main surface of the first glass plate or an outdoor-side main surface of the second glass plate.

[Claim 5]

The imaging device according to any one of Claims 1 to 4, wherein the lens is positioned farther away from the window glass than the surface of the housing.

[Claim 6]

The imaging device according to any one of Claims 1 to 5, wherein the angle of view is greater than or equal to 70 degrees and less than or equal to 100 degrees.

[Claim 7]

The imaging device according to any one of Claims 1 to 6, wherein, when the structural part in contact with the window glass is reflected on the lens, a reflection reduction rate Rx (%) relative to a distance Dx, as expressed by the following formula (1), is higher than 0% and lower than or equal to 50%

$$Rx\ (\%) = Dx \times \{1/(Dz+e)-1/(Dz+d)\}/\{\tan(\theta x/2-\theta c)+\tan(\theta x/2+\theta c)\} \times 100 \quad (1)$$

where Dx is a distance between the lens and the structural part in contact with the window glass in the horizontal direction; Dz is a distance between the lens and the heat reflective film; θx is a horizontal angle of view; θc is an angle between an optical axis of the lens and a normal direction of the window glass in a horizontal plane passing through the center of the lens; d is a distance between an indoor-side end of the structural part in contact with the window glass 11 and the heat reflective film in the normal direction; and e is a distance between the heat reflective film and the outdoor-side end of the structural part in contact with the window glass.

[Claim 8]

The imaging device according to any one of Claim 1 to 6, wherein, when the structural part in contact with the window glass is reflected on the lens, a reflection reduction rate Ry (%) relative to a distance Dy, as expressed by the following formula (2), is higher than 0% and lower than or equal to 50%

$$Ry\ (\%) = Dy \times \{1/(Dz+e)-1/(Dz+d)\}/\{\tan(\theta y/2-\theta c)+\tan(\theta y/2+\theta c)\} \times 100 \quad (2)$$

where Dy is a distance between the lens and the structural part in contact with the window glass in the vertical direction; Dz is a distance between the lens and the heat reflective film; θy is a vertical angle of view; θc is an angle between an optical axis of the lens and a normal direction of the window glass in a vertical plane passing through the center of the lens; d is a distance between an indoor-side end of the structural part in contact with the window glass and the heat reflective film in the normal direction; and e is a distance between the heat reflective film and an outdoor-side end of the structural part in contact with the window glass.

[Claim 9]

The imaging device according to any one of Claims 1 to 6, wherein, when the

structure in contact with the window glass is not reflected on the lens, a reflection reduction rate Rx (%) relative to a distance Dx, as expressed by the following formula (3), is higher than 0% and lower than or equal to 50%

$$Rx\ (\%) = \{\tan(\theta x/2+\theta c)-Dx/(Dz+d)\}/\{\tan(\theta x/2-\theta c)+\tan(\theta x/2+\theta c)\} \times 100 \quad (3)$$

where Dx is a distance between the lens and the structural part in contact with the window glass in the horizontal direction; Dz is a distance between the lens and the heat reflective film; θx is a horizontal angle of view; θc is an angle between an optical axis of the lens and a normal direction of the window glass in a horizontal plane passing through the center of the lens; and d is a distance between an indoor-side end of the structural part in contact with the window glass and the heat reflective film in the normal direction.

[Claim 10]

The imaging device according to any one of Claims 1 to 6, wherein, when the structural part in contact with the window glass is not reflected on the lens, a reflection reduction rate Ry (%) relative to a distance Dy, as expressed by the following formula (4), is higher than 0% and lower than or equal to 50%

$$Ry\ (\%) = \{\tan(\theta y/2+\theta c)-Dy/(Dz+d)\}/\{\tan(\theta y/2-\theta c)+\tan(\theta y/2+\theta c)\} \times 100 \quad (4)$$

where Dy is a distance between the lens and the structural part in contact with the window glass in the vertical direction; Dz is a distance between the lens and the heat reflective film; θy is a vertical angle of view; θc is an angle between an optical axis of the lens and a normal direction of the window glass in a vertical plane passing through the center of the lens; and d is a distance between an indoor-side end of the structural part in contact with the window glass and the heat reflective film in the normal direction.

[Claim 11]

An imaging device-equipped window glass, comprising:

the imaging device according to any one of Claims 1 to 10; and

the window glass.