

# US Patent & Trademark Office

## Patent Public Search | Text View

---

United States Patent	12392982
Kind Code	B2
Date of Patent	August 19, 2025
Inventor(s)	Tachibana; Minoru et al.

---

### Infrared lens unit and infrared detection device

---

#### Abstract

An infrared lens unit includes a lens barrel and an infrared lens supported on the lens barrel. The lens barrel includes a tubular part extending along a central axis extending in upward and downward directions and having an inner circumferential surface surrounding the central axis and a through-hole therein demarcated by the inner circumferential surface, and a protruding part disposed on the inner circumferential surface of the tubular part. The infrared lens is supported by the tubular part via the protruding part. The infrared lens is made of chalcogenide glass. The protruding part includes, in a cross section of the protruding part on a plane on which the central axis extends a linear portion extending in an upward direction from its lower end to its upper end and a sloping portion including an upper end and a lower end located at the upper end of the linear portion. The first sloping portion is inclined with respect to the linear portion such that the first sloping portion is away from the central axis as extending from the lower end to the upper end of the first sloping portion. The infrared lens contacts the linear portion and the sloping portion of the protruding part.

---

<b>Inventors:</b>	<b>Tachibana; Minoru (Osaka, JP), Haseyama; Ryo (Osaka, JP), Murata; Jun (Osaka, JP)</b>
<b>Applicant:</b>	<b>Panasonic Intellectual Property Management Co., Ltd. (Osaka, JP)</b>
<b>Family ID:</b>	<b>1000008765279</b>
<b>Assignee:</b>	<b>PANASONIC INTELLECTUAL PROPERTY MANAGEMENT CO., LTD. (Osaka, JP)</b>
<b>Appl. No.:</b>	<b>18/249410</b>
<b>Filed (or PCT Filed):</b>	<b>November 19, 2021</b>
<b>PCT No.:</b>	<b>PCT/JP2021/042680</b>
<b>PCT Pub. No.:</b>	<b>WO2022/185628</b>
<b>PCT Pub. Date:</b>	<b>September 09, 2022</b>

## Prior Publication Data

### Document Identifier

US 20230393363 A1

### Publication Date

Dec. 07, 2023

## Foreign Application Priority Data

JP 2021-034056 Mar. 04, 2021

---

## Publication Classification

**Int. Cl.:** G02B7/02 (20210101); G01J5/08 (20220101); G02B3/04 (20060101)

**U.S. Cl.:**

CPC G02B7/02 (20130101); G01J5/08 (20130101); G02B3/04 (20130101);

## Field of Classification Search

**CPC:** G02B (7/02); G02B (3/04); G01J (5/08)

---

## References Cited

### U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2006/0166407	12/2005	Kaushal	438/115	G01J 5/0806
2012/0019905	12/2011	Teraoka	359/356	G02B 7/021
2013/0308212	12/2012	Kubala	359/819	G02B 7/021
2014/0285671	12/2013	Ishii	348/164	H10F 39/806
2015/0070754	12/2014	Kawai	N/A	N/A
2018/0321457	12/2017	Symmons	N/A	G02B 7/021
2020/0209549	12/2019	Endo et al.	N/A	N/A
2021/0041911	12/2020	Furukawa et al.	N/A	N/A
2022/0057596	12/2021	Symmons	N/A	B29D 11/00

### FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
2010-156905	12/2009	JP	N/A
2013-195795	12/2012	JP	N/A
2013-202894	12/2012	JP	N/A
2020-106735	12/2019	JP	N/A
2021-026951	12/2020	JP	N/A

### OTHER PUBLICATIONS

International Search Report of PCT application No. PCT/JP2021/042680 dated Jan. 11, 2022. cited by applicant

---

Primary Examiner: Maupin; Hugh

## Background/Summary

### CROSS-REFERENCE TO RELATED APPLICATIONS

(1) This application is a U.S. national stage application of the PCT International Application No. PCT/JP2021/042680 filed on Nov. 19, 2021, which claims the benefit of foreign priority of Japanese patent application No. 2021-034056 filed on Mar. 4, 2021, the contents all of which are incorporated herein by reference.

### TECHNICAL FIELD

(2) The present disclosure relates to an infrared lens unit including a lens barrel and an infrared lens supported inside the lens barrel, and to an infrared detection device.

### BACKGROUND ART

(3) Generally, a lens unit in which a lens barrel and a glass lens are integrated with each other has a structure where the glass lens is supported by a pressure contact stress from the lens barrel. The lens unit includes a sensor chip, such as a light receiving element, mounted inside the lens barrel so as to be enclosed therein, and undergoes an optical process for the sensor chip and hermetic sealing.

(4) The pressure contact stress from the lens barrel that supports the glass lens is a stress that arises from the difference in the coefficients of linear thermal expansion between the lens barrel and the glass lens when a glass material is press-formed inside the lens barrel.

(5) An infrared lens unit includes an infrared lens corresponding to infrared rays. The glass of the infrared lens is made of chalcogenide glass that transmits infrared rays.

(6) PTL 1 discloses a conventional lens unit.

### CITATION LIST

#### Patent Literature

(7) PTL 1: Japanese Patent Lid-Open Publication No. 2010-156905

### SUMMARY

(8) An infrared lens unit includes a lens barrel and an infrared lens supported on the lens barrel. The lens barrel includes a tubular part extending along a central axis extending in upward and downward directions and having an inner circumferential surface surrounding the central axis and a through-hole therein demarcated by the inner circumferential surface, and a protruding part disposed on the inner circumferential surface of the tubular part. The infrared lens is supported by the tubular part via the protruding part. The infrared lens is made of chalcogenide glass. The protruding part includes, in a cross section of the protruding part on a plane on which the central axis extends a linear portion extending in an upward direction from its lower end to its upper end and a sloping portion including an upper end and a lower end located at the upper end of the linear portion. The first sloping portion is inclined with respect to the linear portion such that the first sloping portion is away from the central axis as extending from the lower end to the upper end of the first sloping portion. The infrared lens contacts the linear portion and the sloping portion of the protruding part.

(9) This lens unit allows the infrared lens made of chalcogenide glass to be formed by press-molding.

---

## Description

## BRIEF DESCRIPTION OF THE DRAWINGS

- (1) FIG. 1A is a schematic cross-sectional view of an infrared detection device according to an exemplary embodiment of the present disclosure.
- (2) FIG. 1B is a schematic top plan view of the infrared detection device according to the embodiment.
- (3) FIG. 2A is a schematic view of a press forming apparatus illustrating a method of forming an infrared lens unit according to the embodiment.
- (4) FIG. 2B is another schematic view of the press forming apparatus illustrating the method of forming the infrared lens unit according to an exemplary embodiment.
- (5) FIG. 2C is another schematic view of the press forming apparatus illustrating the method of forming the infrared lens unit according to the embodiment.
- (6) FIG. 3 is an enlarged cross-sectional view of the infrared lens unit according to the embodiment.
- (7) FIG. 4 is an enlarged cross-sectional view of another infrared lens unit according to the embodiment.

## DESCRIPTION OF EMBODIMENTS

(8) An infrared lens unit according to exemplary embodiments of the present disclosure will be described below with reference to the drawings. Note that each of the exemplary embodiments described hereinbelow illustrates a specific example of the present disclosure. Accordingly, the shapes, arrangements, and connections of constituent elements, etc. shown in the following exemplary embodiments are merely examples, and are not intended to limit the present disclosure. Therefore, among the constituent elements in the following exemplary embodiments, those not recited in any one of the independent claims which indicate the broadest concepts of the present disclosure are described as optional elements.

(9) In addition, the drawings are schematic and do not necessarily depict the elements exactly. In the drawings, substantially the same parts are designated by the same reference numerals, and the repetitive description thereof may be omitted or simplified.

- (10) FIGS. 1A and 1B are a cross-sectional view and a top plan view schematically illustrating infrared detection device **100** according to an exemplary embodiment of the present disclosure, respectively. FIG. 1A shows a cross section of infrared detection device **100** taken along line IA-IA shown in FIG. 1B. Infrared detection device **100** includes infrared lens unit **10** and infrared sensor **20**. Infrared lens unit **10** includes lens barrel **11** and infrared lens **12**. Infrared rays **30** entering infrared lens **12** are focused on light receiving surface **20A** of infrared sensor **20**. For example, infrared ray **31** entering a central portion of infrared lens **12** focuses at a central portion of light receiving surface **20A**. Infrared ray **32** entering a peripheral portion of infrared lens **12** that is on the right of the figure focuses on a left side portion of light receiving surface **20A**. Infrared ray **33** entering a peripheral portion of infrared lens **12** that is on the left of the figure focuses on a right side portion of light receiving surface **20A**. Note that the dash-dotted line in the figure indicates central axis **11B** of through-hole **11A** in lens barrel **11**. Central axis **11B** substantially agrees with the normal line of light receiving surface **20A** passing through the center of light receiving surface **20A**. In according to this embodiment, upward and downward directions along central axis **11B** shown in FIG. 1A are defined as extension direction D. Infrared detection device **100** is configured to detect, for example, the status of a human, the temperature distribution in a room, or the like.
- (11) Infrared sensor **20** includes semiconductor chip **21** for detecting infrared rays and base **22**. Light receiving surface **20A** is disposed on upper surface **21A** of semiconductor chip **21**. Semiconductor chip **21** is mounted on upper surface **22A** of base **22**.
- (12) Infrared lens unit **10** is mounted on upper surface **22A** of base **22**. Semiconductor chip **21** is disposed in space **40**, which is a closed space surrounded by base **22** and infrared lens unit **10**.
- (13) Infrared lens unit **10** includes lens barrel **11** that is in a tubular shape and made of metal, and

infrared lens **12** that has a light focusing function. Infrared lens **12** is made of chalcogenide glass. Infrared lens **12** is configured to cause infrared rays **30** entering infrared lens **12** from the outside of infrared detection device **100** to focus on light receiving surface **20A** of semiconductor chip **21**. Infrared lens unit **12** is supported on an inside of lens barrel **11**. As illustrated in FIG. **1A**, space **40** is formed that is surrounded by infrared lens unit **10** and base **22**. Semiconductor chip **21** is disposed inside space **40**. An inert gas, such as nitrogen gas, fills space **40**, which is a closed space, in order to prevent oxidation of semiconductor chip **21**.

(14) Lens barrel **11** includes tubular part **111** having inner circumferential surface **111A** and through-hole **11A** demarcated by inner circumferential surface **111A**, protruding part **112** disposed on inner circumferential surface **111A** of tubular part **111** and arranged along circumferential direction **111D** (see FIG. **1B**) centering about central axis **11B** of inner circumferential surface **111A**, and flange part **113** disposed at lower end **2111**, which is one of the opposite ends (i.e., upper end **1111** and lower end **2111**) along extension direction **D** of tubular part **111**. Inner circumferential surface **111A** is a cylindrical tubular surface centering about central axis **11B**. Inner circumferential surface **111A** surrounds central axis **11B** and is opposed to central axis **11B**. Protruding part **112** has a ring shape extended along inner circumferential surface **111A** of tubular part **111**. Protruding part **112** will be detailed later. Lower surface **113A** of flange part **113** is connected to upper surface **22A** of base **22**. A protrusion for welding may be provided on lower surface **113A** of flange part **113**.

(15) A method of manufacturing infrared lens unit **10** will be described below. FIGS. **2A**, **2B**, and **2C** are schematic views of press forming apparatus **50** for illustrating the method of manufacturing infrared lens unit **10**. Infrared lens **12** of infrared lens unit **10** is press-formed with press forming apparatus **50**.

(16) Press forming apparatus **50** includes stationary mold **51**, slidable mold **52**, and barrel mold **53**. Stationary mold **51** has a circular columnar shape including larger diameter portion **51A**, middle diameter portion **51B**, and smaller diameter portion **51C**, which have different diameters. Respective diameters of larger diameter portion **51A**, middle diameter portion **51B**, smaller diameter portion **51C** decrease in this order. Upper surface **151C** of smaller diameter portion **51C** constitutes a molding surface configured to transfer one of lens surfaces of infrared lens **12** (for example, lower surface **12B** of infrared lens **12** shown in FIGS. **2A** to **2C**). Slidable mold **52** has a circular columnar shaped including larger diameter portion **52A**, middle diameter portion **52B**, and smaller diameter portion **52C**, which have different diameters. Respective diameters of larger diameter portion **52A**, middle diameter portion **52B**, smaller diameter portion **52C** decrease in this order. A molding surface configured to transfer the other one of the lens surfaces of infrared lens **12** (for example, upper surface **12A** of infrared lens **12** shown in FIGS. **2A** to **2C**) is disposed in lower surface **252C** of smaller diameter portion **52C**. Barrel mold **53** has a cylindrical shape including thick-wall portion **53A** and thin-wall portion **53B** which have different thicknesses. Thick-wall portion **53A** is thicker than thin-wall portion **53B**. Lower end **253A** of thick-wall portion **53A** is connected to upper end **153B** of thin-wall portion **53B**. Stationary mold **51** is inserted into an opening provided in one end of barrel mold **53**. Stationary mold **51** is fixed to barrel mold **53**. Lower surface **253B** of thin-wall portion **53B** contacts upper surface **151A** of larger diameter portion **51A**. Inner circumferential surface **253C** of thin-wall portion **53B** contacts outer circumferential surface **451B** of middle diameter portion **51B**. Slidable mold **52** is inserted into an opening provided in the other end of barrel mold **53**. Slidable mold **52** is slidable on barrel mold **53**. Inner circumferential surface **353A** of thick-wall portion **53A** contacts outer circumferential surface **452B** of middle diameter portion **52B**, thereby allowing barrel mold **53** to function as a sliding guide that restricts a sliding direction of slidable mold **52**. Each of stationary mold **51** and slidable mold **52** is provided with temperature controller **54** configured to control the mold temperature in press forming. Temperature controller **54** may be composed of, for example, a known heater block.

(17) The method of manufacturing infrared lens unit **10** will be described below. First, lens barrel

**11** and glass material **15** are prepared. Lens barrel **11** may be processed to have a shape including tubular part **111**, protruding part **112**, and flange part **113** by, for example, cutting a metal. Glass material **15** may be a block glass material formed by molding chalcogenide glass to have a rectangular columnar shape or a spherical glass material formed by molding chalcogenide glass to have a spherical shape. Next, lens barrel **11** and glass material **15** that have been prepared are placed in a mold space that is formed by stationary mold **51**, slidable mold **52**, and barrel mold **53**. Next, the temperature of glass material **15** placed inside press forming apparatus **50** is raised to a temperature equal to or higher than the softening point temperature. After the temperature of glass material **15** reaches a temperature that is able to be press-formed, slidable mold **52** is moved to slide to press glass material **15**, thereby deforming glass material **15** to reach a tip end portion of protruding part **112** by presswork and providing press-formed product **15A**. After that, press-formed product **15A** is cooled until the temperature of press-formed product **15A** decreases to a temperature at which press-formed product **15A** is removable. After the cooling, slidable mold **52** is removed from barrel mold **53** to remove, from the mold space, infrared lens unit **10** including lens barrel **11** and infrared lens **12** which integrated together.

(18) At the above-mentioned cooling, infrared lens **12** is supported on protruding part **112** of lens barrel **11** due to a stress caused by the difference between linear thermal expansion coefficients of lens barrel **11** and glass material **15**. More specifically, infrared lens **12** is supported on lens barrel **11** such that infrared lens **12** is supported on tubular part **111** via protruding part **112**. This stress is produced due to the fact that the coefficient of linear thermal expansion of glass material **15** is smaller than the coefficient of linear thermal expansion of lens barrel **11**. More specifically, since the amount of shrinkage of glass material **15** is less than the amount of shrinkage of lens barrel **11** during the cooling, lens barrel **11** applies pressure contact stress to press-formed product **15A** after the cooling.

(19) Protruding part **112** disposed on lens barrel **11** will be described below. FIG. 3 is a cross-sectional view of infrared lens unit **10** for showing a portion of infrared lens unit **10** around protruding part **112**. FIG. 3 shows a cross section of infrared lens unit **10** taken along extension direction D, more specifically, a cross section of protruding part **112** taken along plane **100S** on which central axis **11B** extends as shown in FIG. 1B. In the just-mentioned cross section, protruding part **112** protrudes from inner circumferential surface **111A** of lens barrel **11** toward central axis **11B**. In the just-mentioned cross section, protruding part **112** includes upper portion **112A**, lower portion **112B**, linear portion **112C**, and sloping portion **112D**. Lower portion **112B** faces infrared sensor **20** and is perpendicular to extension direction D. Upper portion **112A** faces an opposite side to lower portion **112B** and is perpendicular to extension direction D. Linear portion **112C** is on an inner circumferential surface of protruding part **112** and extends along extension direction D. Sloping portion **112D** is inclined with respect to extension direction D, that is, linear portion **112C**. Lower end **2112D** which is the inner circumferential end of sloping portion **112D** continues to upper end **1112C** of linear portion **112C**. Upper end **1112D** which is the outer circumferential end of the sloping portion **112D** continues to inner circumferential end **1112A** of upper portion **112A**. Linear portion **112C** and sloping portion **112D** of protruding part **112** contact infrared lens **12**. In other words, upper portion **112A** and lower portion **112B** of protruding part **112** do not contact infrared lens **12**.

(20) Specifically, linear portion **112C** includes upper end **1112C** and lower end **2112C**, and extends linearly upward from lower end **2112C** to upper end **1112C**. Sloping portion **112D** includes upper end **1112D** and lower end **2112D** located at upper end **1112C** of linear portion **112C**. Sloping portion **112D** is inclined with respect to linear portion **112C** such that sloping portion **112D** becomes away from central axis **11B** as extending linearly from lower end **2112D** to upper end **1112D**. Upper portion **112A** includes inner circumferential end **1112A** located at upper end **1112D** of sloping portion **112D** and outer circumferential end **2112A** located at inner circumferential surface **111A**. Upper portion **112A** becomes away from central axis **11B** as extending linearly from

inner circumferential end **1112A** to outer circumferential end **2112A**. In accordance with the embodiment, upper portion **112A** extends from inner circumferential end **1112A** to outer circumferential end **2112A** in a direction perpendicular to central axis **11B**. Lower portion **112B** includes inner circumferential end **1112B** located at lower end **2112C** of linear portion **112C** and outer circumferential end **2112B** located at inner circumferential surface **111A**. Lower portion **112B** becomes away from central axis **11B** as extending linearly from inner circumferential end **1112B** to outer circumferential end **2112B**. In accordance with the embodiment, lower portion **112B** extends from inner circumferential end **1112B** to outer circumferential end **2112B** in a direction perpendicular to central axis **11B**. Upper portion **112A** and lower portion **112B** may not necessarily extend in the direction perpendicular to central axis **11B** from inner circumferential ends **1112A** and **1112B** to outer circumferential ends **2112A** and or **2112B**, respectively, and they may not necessarily extend linearly. Infrared lens **12** contacts upper end **1112C** of linear portion **112C** and lower end **2112D** of sloping portion **112D** of protruding part **112**. In accordance with the embodiment, infrared lens **12** do not contact lower end **2112C** of linear portion **112C** or upper end **1112D** of sloping portion **112D** of protruding part **112**, but infrared lens **12** may contact at least one of lower end **2112C** and upper end **1112D**.

(21) As shown in FIG. 3, when an the angle formed by direction **D11** from lower end **2112C** toward upper end **1112C** of linear portion **112C** and direction **D21** from lower end **2112D** toward upper end **1112D** of sloping portion **112D** is defined as  $\theta 1$ , the width of the contact surface of sloping portion **112D** contacting infrared lens **12** is defined as **L1**, and the width extending along extension direction **D** from lower end **2112D** of sloping portion **112D** to the upper surface of infrared lens **12** is defined as **L2**, width **L1** is expressed as:  $L1=L2/\cos \theta 1$ . That is, sloping portion **112D** has the contact surface contacting infrared lens **12**. This configuration increases the contact surface area in comparison with a lens unit in which the contact surface is formed only by linear portion **112C**. In addition, since the increase of the contact surface area reduces the pressure contact stress per unit area applied from lens barrel **11**, accordingly reducing a chipping resulting from press forming. As a result, infrared lens **12** of infrared lens unit **10** made of chalcogenide glass can be formed by press forming.

(22) Chalcogenide glass is more brittle than oxide glass, which is a glass material of a glass lens that is commonly used in press forming. A verification test concerning scratch hardness of glass shows that chalcogenide glass is more brittle than common oxide glass, and the cause is considered to be, for example, that chalcogenide glass has a relatively small binding energy. Due to the brittleness of chalcogenide glass, press forming of an infrared lens unit made of chalcogenide glass has not been developed.

(23) Infrared lens unit **10** according to the exemplary embodiment allows infrared lens **12** made of chalcogenide glass to be formed by press forming, as described above.

(24) The above-mentioned contact surface area can be increased by increasing the angle  $\theta 1$  formed by sloping portion **112D** and extension direction **D**, i.e., central axis **11B**. However, the increase in the contact surface area leads to a decrease in the pressure contact stress between infrared lens **12** and protruding part **112** accordingly. For infrared lens unit **10**, a pressure test between the inside of infrared lens **12** in lens barrel **11**, i.e., the side toward infrared sensor **20**, and the outside of infrared lens **12**, i.e., the outside of infrared detection device **100**, was conducted to check hermeticity. As a result, it was confirmed that angle  $\theta 1$  within the range of  $20^{\circ} \leq \theta 1 \leq 35^{\circ}$  ensured hermeticity.

(25) As shown in FIG. 3, assuming that the pressure contact stress per unit area of linear portion **112C** is **F1** and the pressure contact stress per unit area of sloping portion **112D** is **F2**, **F2** is expressed as:  $F1 \cdot \cos \theta 1$ . This means that pressure contact stress **F1** per unit area of linear portion **112C** is constant irrespective of a change of  $\theta 1$ , the pressure contact stress per unit area of sloping portion **112D** changes according to a change of  $\theta 1$ . Therefore, in order to proactively ensure hermeticity in association with a reduction in pressure contact stress of sloping portion **112D**, the surface roughness of sloping portion **112D** may be preferably greater than the surface

roughness of linear portion **112C**.

(26) As for the types of chalcogenide glass, sulfide-based chalcogenide glass and selenide-based chalcogenide glass are suitable for the above-described press forming. When sulfide-based chalcogenide glass is used for infrared lens **12**, the metal used for lens barrel **11** may be preferably stainless steel, which has a coefficient of linear thermal expansion of  $17.3 \times 10^{-6}$ , because the linear thermal expansion coefficient of sulfide-based chalcogenide glass is  $14 \times 10^{-6}$ . For the sulfide-based chalcogenide glass, it is possible to use, for example, ILR-SF2 made by Isuzu Glass Ltd. This sulfide-based chalcogenide glass has a softening point temperature of  $276^\circ \text{C}$ ., a glass transition temperature of  $245^\circ \text{C}$ ., and a molding temperature of  $300^\circ \text{C}$ . The pressing force may preferably range from 5 KgF to 50 KgF in this case. The temperature at which the press-formed product can be taken out (press release temperature) may be set to  $240^\circ \text{C}$ .

(27) When selenide-based chalcogenide glass is used for infrared lens **12**, the metal used for lens barrel **11** may be preferably aluminum, which has a linear thermal expansion coefficient of  $23.8 \times 10^{-6}$ , or brass, which has a linear thermal expansion coefficient of  $19.6 \times 10^{-6}$  since the linear thermal expansion coefficient of selenide-based chalcogenide glass is  $16.2 \times 10^{-6}$ . For the selenide-based chalcogenide glass, it is possible to use, for example, IRG203 made by Hubei New Huaguang Information Materials Co., Ltd. This selenide-based chalcogenide glass has a softening point temperature of  $301^\circ \text{C}$ ., a glass transition temperature of  $266^\circ \text{C}$ ., and a molding temperature of  $330^\circ \text{C}$ . The pressing force may preferably range from 5 KgF to 50 KgF in this case. The temperature at which the press-formed product can be taken out (press release temperature) may be set to  $260^\circ \text{C}$ .

#### Modified Example

(28) FIG. **4** is a cross-sectional view of infrared lens unit **101** of a modified example. In FIG. **4**, items in infrared lens unit **10** shown in FIGS. **1A**, **1B**, and **3** are denoted by the same reference numerals. In place of protruding part **112** of infrared lens unit **10**, infrared lens unit **101** includes protruding part **114** disposed on inner circumferential surface **111A** of tubular part **111**. FIG. **4** is an enlarged view of a portion around the protruding part.

(29) In a cross section of protruding part **114** along extension direction D, protruding part **114** includes upper portion **112A**, linear portion **112C**, sloping portion **112D**, and lower portion **112B**, which are like those of protruding part **112**, and further includes sloping portion **114E** provided between lower portion **112B** and linear portion **112C**. In other words, protruding part **114** of the modified example includes sloping portion **114D** that continues to upper portion **114A** and linear portion **114C** between upper portion **114A** and linear portion **114C**, and sloping portion **114E** that continues to lower portion **114B** and linear portion **114C** between lower portion **114B** and linear portion **114C**. Linear portion **114C**, sloping portion **114D**, and sloping portion **114E** of protruding part **114** contact infrared lens **12**. In other words, upper portion **114A** and lower portion **114B** of protruding part **114** do not contact infrared lens **12**. This structure causes infrared lens **12** to sandwich protruding part **112** from above and below so that infrared lens **12** can be prevented from removing off from lens barrel **11**. Upper portion **114A** and lower portion **114B** of protruding part **114** do not contact infrared lens **12**.

(30) Specifically, linear portion **114C** includes upper end **1114C** and lower end **2114C**, and extends linearly upward from lower end **2114C** to upper end **1114C**. Sloping portion **114D** includes upper end **1114D** and lower end **2114D** located at upper end **1114C** of linear portion **114C**. Sloping portion **114D** is inclined with respect to linear portion **114C** such that sloping portion **114D** becomes away from central axis **11B** as extending linearly from lower end **2114D** to upper end **1114D**. Sloping portion **114E** includes lower end **2114E** and upper end **1114E** located at lower end **2114C** of linear portion **114C**. Sloping portion **114E** is inclined with respect to linear portion **114C** such that sloping portion **114E** becomes away from central axis **11B** as extending linearly from upper end **1114D** to lower end **2114D**. Upper portion **114A** includes inner circumferential end **1114A** located at upper end **1114D** of sloping portion **114D** and outer circumferential end **2114A**



located at inner circumferential surface **111A**. Upper portion **114A** becomes away from central axis **11B** as extending linearly from inner circumferential end **1114A** to outer circumferential end **2114A**. In accordance with the embodiment, upper portion **114A** extends from inner circumferential end **1114A** to outer circumferential end **2114A** in a direction perpendicular to central axis **11B**. Lower portion **114B** includes inner circumferential end **1114B** located at lower end **2114E** of sloping portion **114E** and outer circumferential end **2114B** located at inner circumferential surface **111A**. Lower portion **114B** becomes away from central axis **11B** as extending linearly from inner circumferential end **1114B** to outer circumferential end **2114B**. In accordance with the embodiment, lower portion **114B** extends from inner circumferential end **1114B** to outer circumferential end **2114B** in a direction orthogonal to central axis **11B**. Upper portion **114A** and lower portion **114B** may not necessarily extend in a direction perpendicular to central axis **11B** from inner circumferential ends **1114A** and **1114B** to outer circumferential ends **2114A** and **2114B**, respectively, and may not extend linearly. Infrared lens **14** contacts upper end **1114C** of linear portion **114C**, lower end **2114D** of sloping portion **114D**, and upper end **1114E** of sloping portion **114E** of protruding part **114**. In accordance with the embodiment, infrared lens **14** does not contact lower end **2114E** of sloping portion **114E** or upper end **1114D** of sloping portion **114D** of protruding part **114**, but infrared lens **12** may contact at least one of lower end **2114E** and upper end **1114D**.

(31) Angle  $\theta_2$  formed by direction **D12** from upper end **1114C** toward lower end **2114C** of the linear portion **114C** and direction **D22** from upper end **114E** toward lower end **2114E** may preferably be equal to angle  $\theta_1$  formed by direction **D11** from lower end **2114C** toward upper end **1114C** of linear portion **114C** and direction **D21** from lower end **2114D** toward upper end **1114D** of sloping portion **114D**. Angle  $\theta_1$  and angle  $\theta_2$  within the range  $20^\circ \leq \theta_1 \leq 35^\circ$  and the range  $20^\circ \leq \theta_2 \leq 35^\circ$  ensure hermeticity. In order to proactively ensure hermeticity in association with a reduction in pressure contact stress of sloping portions **114D** and **114E**, the surface roughness of sloping portions **114D** and **114E** may be preferably greater than the surface roughness of linear portion **114C**.

(32) The other configurations may provide the same or similar advantageous effects of the infrared detection device in accordance with the embodiment.

(33) In the exemplary embodiments, terms indicating directions, such as “upward and downward directions”, “upper end”, “lower end”, “upper portion”, and “lower portion”, merely indicate relative directions that depend only on relative positional relationships of structural components, such as a lens barrel and an infrared lens, of the infrared lens unit, and do not indicate absolute directions, such as a vertical direction.

## INDUSTRIAL APPLICABILITY

(34) An infrared lens unit according to the present disclosure enables press forming to be used for manufacture and is particularly useful in an infrared detection device that is used in monitoring systems for building air conditioning or the like, in which lower cost is demanded.

## REFERENCE MARKS IN THE DRAWINGS

(35) **10** infrared lens unit **11** lens barrel **11A** through-hole **11B** central axis **12** infrared lens **22** base **20** infrared sensor **40** space **100** infrared detection device **112**, **114** protruding part **112C**, **114C** linear portion **112D** sloping portion (first sloping portion) **114D** sloping portion (first sloping portion) **114E** sloping portion (second sloping portion) **D** extension direction

## Claims

1. An infrared lens unit comprising: a lens barrel including a tubular part extending along a central axis extending in upward and downward directions, the tubular part having an inner circumferential surface surrounding the central axis, the tubular part having a through-hole therein demarcated by the inner circumferential surface, and a protruding part disposed on the inner circumferential

surface of the tubular part, the protruding part having an annular shape extending in a circumferential direction about the central axis; and an infrared lens supported on the lens barrel such that the infrared lens is supported by the tubular part via the protruding part, wherein the infrared lens is made of chalcogenide glass, the protruding part includes, in a cross section of the protruding part on a plane on which the central axis extends: a linear portion including an upper end and a lower end extending in an upward direction from the lower end to the upper end; and a first sloping portion including an upper end and a lower end located at the upper end of the linear portion, the first sloping portion being inclined with respect to the linear portion such that the first sloping portion is away from the central axis as extending from the lower end of the first sloping portion to the upper end of the first sloping portion, and the infrared lens contacts the linear portion and the sloping portion of the protruding part.

2. The infrared lens unit according to claim 1, wherein an angle formed by a direction from the lower end of the linear portion toward the upper end of the linear portion and a direction from the lower end of the first sloping portion toward the upper end of the first sloping portion is greater than or equal to  $20^{\circ}$  and less than or equal to  $35^{\circ}$ .

3. The infrared lens unit according to claim 1, wherein a surface roughness of the first sloping portion is greater than a surface roughness of the linear portion.

4. The infrared lens unit according to claim 1, wherein: the infrared lens is made of sulfide-based chalcogenide glass; and the lens barrel is made of stainless steel.

5. The infrared lens unit according to claim 1, wherein: the infrared lens is made of selenide-based chalcogenide glass; and the lens barrel is made of aluminum or brass.

6. The infrared lens unit according to claim 1, wherein the protruding part further includes, in the cross section, a second sloping portion including a lower end and an upper end located at the lower end of the linear portion, the second sloping portion being inclined with respect to the linear portion such that the second sloping portion is away from the central axis as extending from the upper end of the second sloping portion to the lower end of the second sloping portion.

7. The infrared lens unit according to claim 6, wherein an angle formed by a direction from the lower end of the linear portion toward the upper end of the linear portion and a direction from the lower end of the first sloping portion toward the upper end of the first sloping portion is equal to an angle formed by a direction from the upper end of the linear portion toward the lower end of the linear portion and a direction from the upper end of the second sloping portion toward the lower end of the second sloping portion.

8. The infrared lens unit according to claim 7, wherein the infrared lens contacts the linear portion, the first sloping portion, and the second sloping portion of the protruding part.

9. An infrared detection device comprising: a base; an infrared sensor disposed on the base; and the infrared lens unit according to claim 1, the infrared lens unit being disposed on the base, wherein the infrared sensor is disposed in a space surrounded by the base and the infrared lens unit.

10. The infrared detection device according to claim 9, wherein the space in which the infrared sensor is disposed is surrounded by the base, the infrared lens of the infrared lens unit, and the tubular part of the lens barrel of the infrared lens unit.

---