

(19)



(11)

EP 4 538 589 A1

(12)

EUROPEAN PATENT APPLICATION published in accordance with Art. 153(4) EPC

(43) Date of publication:

16.04.2025 Bulletin 2025/16(21) Application number: **23819939.2**(22) Date of filing: **12.06.2023**

(51) International Patent Classification (IPC):

F21S 2/00 ^(2016.01) **F21V 3/00** ^(2015.01)
F21V 3/06 ^(2018.01) **F21V 3/10** ^(2018.01)
F21V 7/00 ^(2006.01) **F21V 7/24** ^(2018.01)
F21V 33/00 ^(2006.01) **G08G 1/09** ^(2006.01)
G09F 13/04 ^(2006.01) **F21W 111/02** ^(2006.01)
F21Y 113/10 ^(2016.01) **F21Y 115/10** ^(2016.01)

(52) Cooperative Patent Classification (CPC):

F21S 2/00; F21V 3/00; F21V 3/06; F21V 3/10;
F21V 7/00; F21V 7/24; F21V 33/00; G08G 1/09;
G09F 13/04; F21W 211/02; F21Y 2113/10;
F21Y 2115/10

(86) International application number:

PCT/JP2023/021801

(87) International publication number:

WO 2023/238959 (14.12.2023 Gazette 2023/50)

(84) Designated Contracting States:

AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR

Designated Extension States:

BA

Designated Validation States:

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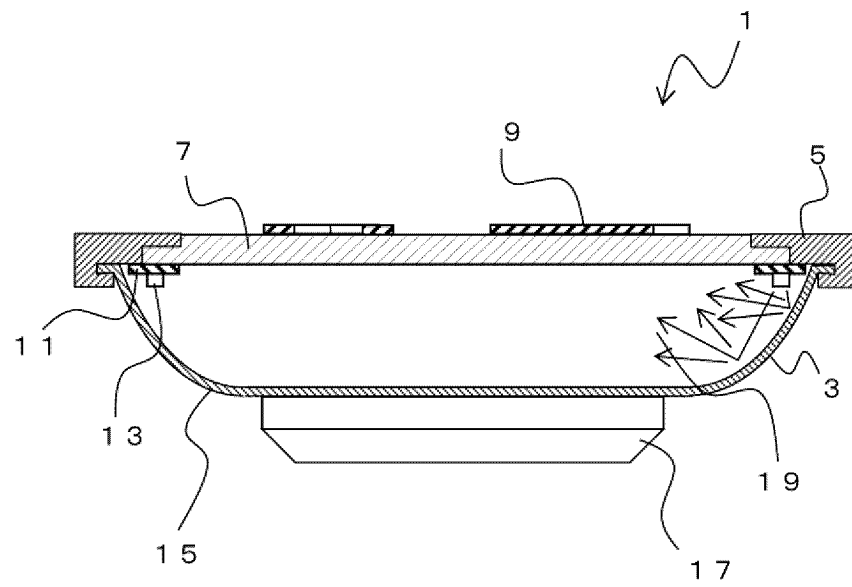
(54) **COMPOSITE STRUCTURE OF ILLUMINATION DEVICE AND WIRELESS COMMUNICATION DEVICE, PLACEMENT METHOD FOR ILLUMINATION DEVICE AND WIRELESS COMMUNICATION DEVICE, AND ILLUMINATION DEVICE-EQUIPPED WIRELESS COMMUNICATION DEVICE PLACED BY SAID PLACEMENT METHOD**

(57) This composite structure (1) is a structure in which an illumination device (3) and a wireless communication device (17) have been integrated and composited. A light transmitting member (7) is placed on the opening side of a micro-foamed resin sheet (15) having a depression-like recessed shape. A light guiding space (19) is formed between the molded micro-foamed resin sheet (15) and the light transmitting member (7). An LED light source (13) is placed on a substrate (11). A wireless communication device (17) is placed on the back surface side of the micro-foamed resin sheet (15), which is the

side opposite to the light guiding space (19). In the composite structure (1), the micro-foamed resin sheet (15) placed in front of the wireless communication device (17) functions as a portion of a housing of the illumination device (3), and is placed so as to contact a radio wave-emitting surface of the wireless communication device (17). As a result, it is possible to obtain a composite structure of an illumination device and a wireless communication device that not only excels in light diffuse reflectance properties and low radio wave transmission loss, but also excels in radio wave scattering loss.

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Fig.2A



Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a composite structure in which an LED illumination device and a wireless communication device are integrated, a placement method for the illumination device and the wireless communication device, and an illumination device-equipped wireless communication device placed by the placement method.

BACKGROUND OF THE INVENTION

10 **[0002]** Due to expansion of 5G services and higher demands in information communication, multiple numbers of Small Cell base stations are to be installed at various places including not only outdoor places but also indoor places, for example. Thus, small and low-cost wireless communication devices have been in demand.

15 **[0003]** Conventional wireless communication devices are often installed on rooftops or on walls of buildings, for example. However, to install multiple wireless communication devices, there are concerns arising such as securing installation sites or cost increase due to installation operations. For this reason, to install multiple wireless communication devices outdoors and indoors for diversification, composition with an illumination device, for example, has been considered.

20 **[0004]** For example, Patent Document 1 has disclosed a base station device in which a housing accommodates and integrates together a base station unit, a guide light unit, and a common power source unit. The base station device in Patent Document 1 includes the base station unit that connects wirelessly to a mobile terminal and relays communication to a device on the other end of the mobile terminal, the guide light unit that receives power supply and executes predetermined operations, the common power source unit that supplies electric power to the base station unit and the guide light unit, and the housing that is disposed being fixed indoors or outdoors.

25 **[0005]** On the housing of the base station device of Patent Document 1, a luminescence panel portion as an illumination device and a display panel portion made of resin are disposed in front of an electrical facility unit. In the luminescence panel, a light guiding plate on which an LED light source is disposed or a surface-like EL element is disposed, and the illumination device is disposed in front of the wireless communication device inside the same housing. Patent Document 1 can provide the base station device that is small in size and that can be manufactured at low cost, can avoid radio wave interference, and can operate even at a time of a disaster.

30 **[0006]** Also, Patent Document 2 has proposed a bus-stop signboard safety system that provides a bus-stop signboard equipped with multi-purpose functions as an interactive communication device for familiar information. In the bus-stop signboard safety system of Patent Document 2, the interactive communication functions added with a sign device of familiar information and advertisement by texts and images is installed on the bus stop. Also, the bus-stop signboard safety system of Patent Document 2 includes solar cells or batteries so that a variety of information including an urgent disaster information announcement can be provided through wireless LAN at the time of power cut during the disaster.

35 **[0007]** As above, the bus-stop signboard safety system of Patent Document 2 can display signs and send various announcements and warnings such as disaster information, local government public information, emergency earthquake warning, news, weather information, heavy rain information, pollen information, and high wave warning, or various types of latest information and advertisement such as bullet-in information of public race facilities including cycling race, horse race, and boat race, events and guides in neighboring areas, and other information such as gourmet food information for house wives. Also, the bus-stop signboard safety system of Patent Document 2 may also include notification means such as an emergency rotary red lamp, sirens, and speakers, and it is possible to build a network information system utilizing the bus-stop signboard.

45 **[0008]** Also, Patent Document 3 has disclosed a self-contained system including an illumination device and a wireless communication device, in which all the electric power consumed by the system is generated independently by using renewable energy, and the generated electricity is supplied to drive and light the equipment with no CO₂ emission.

50 **[0009]** In the independent power generation system of Patent Document 3, electricity generated by solar power generation device, which is disposed at a back surface of a liquid-crystal display device, is charged to an accumulative layer of a power storage device or a secondary battery. The charged electric power can be further utilized to amplify and transmit 5G radio waves that are sent from a 5G base station and received by the said small base station.

55 **[0010]** Conventionally, internally illuminated signboards and externally illuminated signboards, or various types of illumination equipment that brightly lights up and illuminates interior spaces of shops have received supply of commercial electric power, emitting light energy that can be even considered as glare light pollution, and emitting a lot of carbon dioxide (CO₂), thereby accelerating global warming. The illumination device and the wireless communication device of Patent Document 3, however, can prevent such issues.

[0011] Also, Patent Document 4 has proposed a device built-in antenna attached with an illumination, in which the device built-in antenna is disposed on an antenna substrate. For example, Patent Document 4 has proposed signboards with the

device built-in antenna that are applicable as signboards that can be installed on walls, projected signboards, field standing signboards, standing signboards, and pole signboards that can be used at buildings, convenience stores, drugstores, pay parking lot, railway stations, and post offices.

[0012] The signboard of Patent Document 4 includes an oblong rectangular substrate, and two rows, each of which is at a predetermined distance from a center line, of a plurality of light emitting elements provided on a surface of the substrate being substantially parallel to a long side of the substrate. The device built-in antenna for communication is disposed at a substantial center of the substrate. Thus, the LED light emitting elements as an illumination device and the device built-in antenna are disposed at different positions on the same substrate so as not to interfere with each other.

[0013] In Patent Document 4, switching means can switch between a direct connection and a connection via a delay line. The switching of the switching means determines a phase of power feeding signals supplied to the first to the fourth elements, and thus a sheet determines a direction of antenna beams of the device built-in antenna. That is, pasting a predetermined sheet to the antenna substrate can set the direction of the antenna beams.

[0014] Also, Patent Document 5 has proposed a position measurement system using visual light communication system, which can be implemented easily. The position measurement system of Patent Document 5 uses a visual light communication beacon, which sends position information by visual light signals, and image information taken by a camera so as to measure the current position of a vehicle.

[0015] The visual light communication beacon of Patent Document 5 includes a road-lighting lamp provided on a road-lighting pole and a visual light communication device. The vehicle has a camera being installed and has a vehicle position measurement device that demodulates visual light signals into position information of the visual light communication beacon to calculate the current position. In Patent Document 5, although an outdoor lamp includes both an illumination device and a communication device, the illumination device and the communication device are provided at different positions.

RELATED ART

PATENT DOCUMENT

[0016]

[Patent Document 1] Japanese Unexamined Patent Application Publication No. 2015-226201 (JP-A-2015-226201)
 [Patent Document 2] Japanese Unexamined Patent Application Publication No. 2010-102279 (JP-A-2010-102279)
 [Patent Document 3] Japanese Unexamined Patent Application Publication No. 2021-35318 (JP-A-2021-35318)
 [Patent Document 4] Japanese Unexamined Patent Application Publication No. 2021-158492 (JP-A-2021-158492)
 [Patent Document 5] Japanese Unexamined Patent Application Publication No. 2009-36571 (JP-A-2009-36571)

SUMMARY OF THE INVENTION

(PROBLEMS TO BE SOLVED BY THE INVENTION)

[0017] Unfortunately, in the conventional structures, the illumination device may hinder radio waves for wireless communications. For example, absorption when radio waves transmit through a substance tends to increase as a dielectric constant of the substance increases. However, a substrate used for an illumination device often has a high dielectric constant and radio waves may be absorbed when transmitting through the substrate, which may increase transmission loss.

[0018] Also, a reflecting plate is often used to even out the light taken out from the illumination device. However, a metal reflecting plate, for example, has the high dielectric constant as mentioned above, and the transmission loss of radio waves may increase. However, if the reflecting plate is not appropriately disposed, this may cause uneven brightness due to direct light from the light source.

[0019] In contrast, if the illumination device and the wireless communication device are disposed at different positions as in Patent Document 5, it is possible to have a layout in which the radio waves from the wireless communication device are not influenced by the illumination device. However, in this way, the illumination device and the wireless communication device are to be disposed individually, which makes downsizing difficult.

[0020] The present invention was made in view of such problem. It is an object of the present invention to provide a composite structure of an illumination device and a wireless communication device, a placement method for the illumination device and the wireless communication device, and an illumination device-equipped wireless communication device placed by the placement method. In the composite structure, loss in radio waves from the wireless communication device is small, and light with uniform brightness can be taken out from the composite structure.

(MEANS FOR SOLVING PROBLEMS)

[0021] To achieve the above object, a first aspect of the present invention is a composite structure of an illumination device and a wireless communication device using a micro-foamed resin sheet, in which the illumination device being disposed in front of the wireless communication device. The illumination device includes an LED light source, a substrate that supports the LED light source, a light transmitting member, a frame member that supports an outer periphery part of the light transmitting member, and a light diffusion reflective micro-foamed resin sheet. The micro-foamed resin sheet of which a cross section is shaped in a depression-like recessed shape is disposed at a rear of the light transmitting member supported by the frame member such that a light guiding space is formed between the light transmitting member and the micro-foamed resin sheet. An emission surface of the LED light source is disposed facing the micro-foamed resin sheet in an opposite direction to the light transmitting member such that light emitted from the emission surface of the LED light source is reflected by the micro-foamed resin sheet. The wireless communication device is disposed on a back surface side of a light reflective surface of the micro-foamed resin sheet. The micro-foamed resin sheet disposed in front of the wireless communication device is disposed to be in contact with a radio wave-emitting surface of the wireless communication device as a part of a housing of the illumination device, or disposed to be a predetermined distance away from the radio wave-emitting surface of the wireless communication device. The micro-foamed resin sheet excels in light diffuse reflectance properties as well as in radio wave transmission performance with a low dielectric constant compared to the substrate or the light transmitting member. Here, the substrate is preferably formed at a requisite position of a frame member on a side of the light guiding space or on an outer periphery of the light transmitting member on the side of the light guiding space, or formed over both the frame member and the light transmitting member on the side of the light guiding space.

[0022] The composite structure of the illumination device and the wireless communication device can be characterized in that a center part of the illumination device that corresponds to the radio wave-emitting surface in front of the wireless communication device is provided with only the light emission member and the micro-foamed resin sheet, without the substrate, the frame member, and the housing being disposed, so as not to hinder transmission of radio waves from the wireless communication device, and the LED light source and the substrate of the illumination device, the frame member, and the housing are disposed on the outer periphery part of the illumination device. Here, such the members are not disposed at the positions corresponding to the radio wave-emitting surface of the wireless communication device because, if such the members are disposed in front of the radio wave-emitting surface, such the members may absorb, reflect, or scatter radio waves emitted from the wireless communication device, which may cause transmission loss. Thus, it is preferable that the LED light source, the substrate, the frame member, and the housing are disposed on the outer periphery part as necessary to an extent that the such members do not hinder emission of radio waves of the wireless communication device.

[0023] The micro-foamed resin sheet disposed in front of the wireless communication device is a micro-foamed resin sheet having an average bubble diameter of 0.2 - 10 μm . The micro-foamed resin sheet is a light reflecting plate, which can also serve as a housing of the illumination device, having a diffuse reflectance to a barium sulfate standard plate of 95% or more when a diffuse reflectance to the barium sulfate standard plate in a visual light band of wavelength 450 - 650 nm is 100%. A dielectric constant of the micro-foamed resin sheet measured by a method specified in ASTM D2520 and JIS C2565 at a measurement frequency of 2 GHz may be 1.8 or less, both in a case in which the micro-foamed resin sheet is disposed to be in contact with the radio wave-emitting surface of the wireless communication device and in a case in which the micro-foamed resin sheet is disposed at a predetermined distance away from the radio wave-emitting surface of the wireless communication device. If the micro-foamed resin sheet and the radio wave-emitting surface of the wireless communication device are a predetermined distance apart, the distance is preferably 5 mm or less.

[0024] Since the micro-foamed resin sheet has the average bubble diameter of 0.2 - 10 μm , the micro-foamed resin sheet disposed in front of the wireless communication device excels in diffuse reflectance properties and dielectric properties. Thus, in the composite structure of the illumination device and the wireless communication device, not only radio wave transmission loss is small but also radio wave scattering loss is small.

[0025] By arranging the illumination device and the wireless communication device in this way, an indirect-light illumination device is achieved with the micro-foamed resin sheet as a light reflecting plate of the illumination device and, at the same time, the micro-foamed resin sheet has a protection effect for a surface of the wireless communication device without hindering transmission of radio waves emitted from the wireless communication device. Downsizing of the composite structure of the indirect-light illumination device and the wireless communication device can be achieved by further disposing the illumination device in front of the wireless communication device.

[0026] The light transmitting member may be any one of light transmissive transparent resin of any one of PC resin, ABS resin, PET resin, polyvinyl chloride resin, acrylic resin, polystyrene resin, COP resin, and COC resin, transparent glass, translucent resin made by adding pigment to the transparent resin, translucent resin made translucent by roughening or forming a micro-uneven structure on a surface on a light taking-out side of transparent resin, translucent laminate made by attaching a translucent resin film onto a surface of the transparent resin or the transparent glass, and translucent colored

glass. Here, examples of resin forming the light transmitting member include COP resin and COC resin. COP resin is known as a general-purpose engineering plastic that excels in high transparency, heat resistance, and water absorption properties and is used in optical, biotechnological, medical, and automobile fields. COP resin further excels in low dielectric properties and low dielectric loss tangent and is used for high frequency connectors and high frequency antenna substrate materials. COC resin is a copolymer of COP resin with ethylene resin or rubber resin and is used to adjust mechanical properties such as heat resistance and impact properties in the case of COP resin.

[0027] Furthermore, when selecting the light transmitting member in consideration of transmittivity of radio waves from the wireless communication device, COP resin and COC resin having the low dielectric constant and low relative dielectric loss tangent are especially preferable among the above-mentioned resin forming the light guiding plate, compared to PC resin, ABS resin, PET resin, polyvinyl chloride resin, acrylic resin, and polystyrene resin.

[0028] A part of a front surface or a back surface of the light transmitting member may be coated with a thin film-like covering member of colored paint, metal deposition, or metal plating. Alternatively, non light-transmissive colored resin having a predetermined thickness may be disposed on the front surface or the back surface of the light transmitting member, at a position that is on a substantially same plane as the light transmitting member, or inside the light transmitting member. Further alternatively, colored resin having a thickness that is same as or different from the thickness of the light transmitting member may be disposed in place of a part of the light transmitting member. In the present invention, the covering member is to be used as a light shielding member for shielding light and is synonymous with a light shielding member.

[0029] If the covering member is provided at a predetermined position of the light transmitting member and the covering member is exposed to the back surface of the light transmitting member, the micro-foamed resin sheet having the same size as the covering member may be attached directly to the back surface of the covering member. If the covering member is not exposed to the back surface of the light transmitting member, the micro-foamed resin sheet having the similar shape as and a slightly smaller size than the covering member may be attached to an inner periphery position of the light transmitting member corresponding to the covering member. In this way, the composite structure can include the illumination device, in which all positions except for the light transmission portions on a side of the light guiding space of the light transmitting member are mostly coated with the micro-foamed resin sheet, and the wireless communication device. In such the case, it is preferable that the covering member is provided on an inner surface of the light transmitting member and the micro-foamed resin sheet directly coats the covering member.

[0030] When the part of the light transmitting member is coated by the covering member of any one of colored paint, metal deposition, metal plating, and the non light-transmissive colored resin having the predetermined thickness, or the non light-transmissive colored resin having the predetermined thickness is disposed at the part of the light transmitting member in place of the light transmitting member, light may be taken out from a light transmission portion where the light transmitting member is not coated by the covering member or from the light transmission portion where the colored resin is not disposed.

[0031] With the non light-transmissive colored resin having the predetermined thickness used as the covering member in this way, it is possible to have a design in which changing an arrangement, shape, and thickness of the covering member can change the shape and thickness of the coated light transmitting member in any way. Also, here, continuously changing the thickness of the covering member or of a light transmission portion side of the light transmitting member can provide a three-dimensional effect to a shape of a light taking-out portion side of the illumination device, thereby improving design features. To achieve such a coating structure of the light transmitting member and the covering member, composite molding such as injection molding may be used. Also, if the covering member is formed in a thin film by colored paint, metal deposition, or metal plating, the light transmitting member having a thin film-like texture can be obtained.

[0032] If the covering member is provided at a predetermined position of the light transmitting member and the covering member is formed being exposed to the back surface of the light transmitting member, the micro-foamed resin sheet having the same size as the covering member may be attached directly to the back surface of the covering member. If the covering member is not exposed to the back surface of the light transmitting member, the micro-foamed resin sheet having the similar shape as and a slightly smaller size than the covering member, or the micro-foamed resin sheet having the same size as the covering member, may be attached to the position corresponding to the covering member on the back surface of the light transmitting member.

[0033] The LED light source disposed on the substrate may be any one of RGB light source, a single-chip LED light source in which emission color can be switched to RGB, a white LED light source, a day-light color LED light source, a white LED light source using phosphors, and a white or daylight-color LED array light source, or a combination of the above.

[0034] The covering member provided on the light transmitting member may divide the light transmission portion into an outer-periphery side and an inner-periphery side, and indirect light having substantially the same brightness can be taken out from the light transmission portion on each of the outer-periphery side and the inner-periphery side.

[0035] By having an arrangement such that a range of an orientation angle of the LED light source does not include the light transmission portion transmitting light from the light transmitting member, even if the light transmitting member is formed in a plate-like shape or in a curved shape with an uneven structure and the shape of the light transmission portion

side in the light guiding space is formed in a plate-like shape or in a curved shape with an uneven structure, reflected light is diffused and reflected multiple times inside the light guiding space and thus the light taken out from the illumination device can only be the substantially uniform indirect light. In this way, even if the shape of the light transmission portion side of the light guiding space is formed in the curved shape with the uneven structure, the indirect-light illumination device that can take out indirect light with substantially the same brightness from the light transmission portions, regardless of light taking-out positions from the light transmitting member, can be achieved.

[0036] The illumination device may be an outdoor illumination device, and the wireless communication device may be a wireless communicator that is installed in a park, on a street, on a building wall, or on a rooftop to communicate with pedestrians and vehicles traveling on the road.

[0037] The wireless communication device may be a wireless transmitter used in 5G communications, and the illumination device may be an electronic advertisement signboard illumination device or an electronic guidance signboard device.

[0038] The illumination device may be an illumination device attached to a mobile body and the wireless communication device may be a millimeter wave radar transmitter. Also, the mobile body refers to artificial means of transportation with self-propelling ability. For example, the illumination device may be used as a peripheral or forward monitoring radar for obstacle detection for a train, a drone, or a robot.

[0039] The micro-foamed resin sheet may be a PET resin sheet or a PC resin sheet, in which the micro-foamed resin sheet has a diffuse reflectance to a barium sulfate standard plate of 95% or more when a diffuse reflectance to the barium sulfate standard plate in a visual light band of wavelength 450 - 650 nm is 100%, and a radio wave attenuation rate of the micro-foamed resin sheet with respect to the radio wave attenuation rate due to air radio wave absorption in the wavelength band corresponding to 70 - 100 GHz is within the range between 0 and -0.15 dB.

[0040] A second aspect of the present invention is a placement method for an illumination device and a wireless communication device in a composite structure of the illumination device and the wireless communication device using a micro-foamed resin sheet, in which the illumination device is disposed in front of the wireless communication device. The illumination device includes an LED light source, a substrate that supports the LED light source, a light transmitting member, a frame member that supports an outer periphery part of the light transmitting member, and a light diffusion reflective micro-foamed resin sheet. An emission surface of the LED light source is disposed facing the micro-foamed resin sheet in an opposite direction to the light transmitting member with the micro-foamed resin sheet being formed to have a cross section shaped in a depression-like recessed shape thereby forming a light guiding space between the light transmitting member and the micro-foamed resin sheet, such that light emitted from the emission surface of the LED light source is reflected by the micro-foamed resin sheet. The wireless communication device is disposed on a back surface side of a light reflective surface of the micro-foamed resin sheet. The micro-foamed resin sheet disposed in front of the wireless communication device is disposed to be in contact with a radio wave-emitting surface of the wireless communication device as a part of a housing of the illumination device, or disposed to be a predetermined distance away from the radio wave-emitting surface of the wireless communication device. In front of the radio wave-emitting surface at a front of the wireless communication device, either only the light transmitting member or the light transmitting member and the micro-foamed resin sheet are to be disposed. The micro-foamed resin sheet excels in light diffuse reflectance properties as well as in radio wave transmission performance with a low dielectric constant of 1.8 or less, compared to the substrate or the light transmitting member, and a material formed of the micro-foamed resin sheet is used as a light reflecting plate.

[0041] Also, in the placement method for the illumination device and the wireless communication device of the second aspect of the present invention, the micro-foamed resin sheet may be formed in a depression-like recessed shape by thermoforming and may be a molded body with a cross-sectional-view shape of a substantially U shape, a reversed trapezoid, or a bowl shape, having a flat portion at a center of the depression-like recessed shape. Also, as the shape of the molded body of the micro-foamed resin sheet, a part thereof may include a protruding portion as long as an overall shape is in a depression-like recessed shape. By having such the shape, the micro-foamed resin sheet, as the reflection plate, provides diffusion reflective properties to the illumination device, and thus an indirect-light illumination can be achieved. At the same time, the micro-foamed resin sheet also serves as the housing, which makes it unnecessary to provide a separate housing.

[0042] Also, according to a third aspect of the present invention, which is a placement method of an illumination device and a wireless communication device in a composite structure of the illumination device and the wireless communication device, by disposing members in the composite structure of the illumination device and the wireless communication device, it is possible to obtain the wireless communication device equipped with the illumination device that excels in properties as well as radio wave transmission loss and radio wave scattering loss.

[0043] Also, as the wireless communication device, even if the illumination device is disposed in front of the wireless communication device, no housing that absorbs radio waves exists in front of the wireless communication device and only the micro-foamed resin sheet exists in front of the wireless communication device, and thus the wireless communication device that absorbs little radio waves can be obtained. Also, the micro-foamed resin sheet can provide a protection effect that protects a surface of the wireless communication device. At this time, the LED light sources may be disposed on an

inner periphery surface of an outer periphery side surface of the molded body of the micro-foamed resin sheet, and an arrangement in which the emission surfaces thereof face the opposite outer periphery side surface of the molded body is also possible. Here, it is preferable that the micro-foamed resin sheet is molded into a cylindrical shape and the LED light sources are attached to an inner periphery surface of a circumference surface of the cylinder so as to face each other.

[0044] According to the present invention, with the light guiding space formed by the light reflective micro-foamed resin sheet and multiple diffusion reflection of light from the LED light source by the micro-foamed resin sheet inside the light guiding space, brightness of the light taken out from the light emission member of the illumination device can be made uniform. At this time, since the substrate and the LED light source with high radio wave absorbing properties are disposed on the outer periphery of the light guiding space, light from the LED light source and radio waves of the wireless communication device are not shielded by the substrate or the like, and thus there are no disturbance for light reflection or for radio waves emitted from the wireless communication device.

[0045] Also, since the illumination device and the wireless communication device are composited, radio waves emitted from the wireless communication device are to transmit through the light reflective micro-foamed resin sheet. However, the micro-foamed resin sheet has a low dielectric constant and thus transmission loss of radio waves when transmitting through the micro-foamed resin sheet is small. Also, since the illumination device is disposed in front of the wireless communication device, downsizing of the composite structure of the illumination device and the wireless communication device is possible.

[0046] Also, the micro-foamed resin sheet forming the light guiding space serves as a part of the housing of the illumination device, and thus there is no need to separately provide a housing for the illumination device even if the illumination device is disposed in front of the wireless communication device. Also, with no separate housing provided for the illumination device disposed in front of the wireless communication device, it is possible to prevent absorption reflection loss of radio waves due to the housing of the illumination device.

[0047] Furthermore, when the micro-foamed resin sheet is disposed so as to be in contact with or 5 mm or less away from the surface of the wireless communication device, the micro-foamed resin sheet, which is a foamed body, can protect the surface of the wireless communication device even if stress is applied from outside, and thus the micro-foamed resin sheet has a surface protection effect for the wireless communication device.

[0048] Also, if the dielectric constant of the micro-foamed resin sheet is 1.8 or less, transmission loss of radio waves when transmitted through the micro-foamed resin sheet can be suppressed with certainty. For example, the dielectric constant of the micro-foamed resin sheet is lower than a dielectric constant of common transparent resin that exceeds 2.0, and thus loss at the time of radio wave transmission due to reflection, absorption, scattering, and the like is small. Preferably, the dielectric constant of the micro-foamed resin sheet is 1.50 or less.

[0049] Also, as the light emission member, not only a transparent light transmitting member but also a translucent light transmitting member, or a translucent laminate in which a translucent resin film is attached to a surface of transparent resin or transparent glass may be used. In this way, more complicated and luxurious color expression is possible. Although both glass and resin may be used as the light transmitting member, resin is preferable to glass in general in terms of lowering the dielectric constant.

[0050] Also, providing a 1 or colored resin to coat the light transmitting member can provide design features to the illumination device, and thus the illumination device with excellent design properties can be obtained. Although the surface of the light transmitting member has been described as a planar surface, the surface of the light transmitting member may be formed, though not specifically illustrated, in a three-dimensional shape having an uneven structure by injection molding or the like.

[0051] Also, attaching the micro-foamed resin sheet at a position corresponding to the covering member coating a part of a light taking-out member can improve diffusion reflection properties in the light guiding space. This can improve brightness of light taken out from a light taking-out portion. At this time, if the micro-foamed resin sheet is attached to a position where the covering member is not formed, the micro-foamed resin sheet is seen and recognized directly from outside of the light transmitting member, thereby degrading design features. However, by being placed to cover the covering member, the micro-foamed resin sheet is not seen and recognized from the outside of the light transmitting member, thereby improving the design features.

[0052] As above, providing the non light-transmissive covering member or colored resin that coats the light transmitting member enables to take out light only from the light transmission portions other than the covering member and the colored resin, thereby providing design features to the illumination device.

[0053] Also, by using a plurality of types of the LED light sources, it is possible to switch between different colored lights or to turn on different colors of light at the same time. Thus, color controlling by switching colors of light or color controlling by adding and mixing different colors can be performed. Also, disposing a plurality of rows of the LED light sources, such as the LED array light source, can increase the size of the illumination device.

[0054] Also, by making the light transmission portion of the light transmitting member not to be included within the range of the orientation angle of the LED light source, even if the light transmitting member is formed in a plate-like shape or in a curved shape with an uneven structure and the shape of the light transmission portion side in the light guiding space is

formed in a plate-like shape or in a curved shape with an uneven structure, reflected light is diffused and reflected multiple times inside the light guiding space, and thus the light taken out from the illumination device can only be the substantially uniform indirect light. Thus, glare sensation due to direct light can be reduced.

[0055] Also, the covering member provided on the light transmitting member divides the light transmission portions into the outer periphery side and the inner periphery side. This enables to take out indirect light from the light transmission portions of the outer periphery side and the inner periphery side of the covering member with substantially the same brightness. For example, when a logo mark that can divide the light transmission portions into the outer periphery side and the inner periphery side is provided on a large electronic signboard, light with uniform brightness can be taken out from both the outer periphery side and the inner periphery side of the logo mark. When applying the present invention to a large illumination device, it is preferable to use a collective light source in which the LED light sources are arranged on the substrate in a grid, in a staggered lattice, or in arrays, and a plurality of the wireless communication devices adjoined to each other may be disposed.

[0056] Also, wireless transmitters may be provided beside the outdoor illumination device and installed in a park, on a street, on a building wall, or on a rooftop to be the wireless communication device that is suitable for communication with pedestrians and vehicles traveling on the road. For example, if a wireless transmitter is attached to the outdoor illumination device and the wireless transmitter performs communications with pedestrians and vehicles, there are no obstacles between the pedestrians or the vehicles and the outdoor illumination device, which makes it suitable for communications with people outside such as pedestrians and vehicles travelling on the road.

[0057] Also, for the wireless communication device used in 5G communications, it is inevitable to build small cells for stabilization of communications and thus the wireless communication devices are usually installed on rooftops or wall surfaces. However, applying the wireless communication devices to advertisement electronic signboard illumination device and the like facilitates to obtain installation locations, with fewer restrictions on the installation locations.

[0058] Also, if the wireless communication device is provided beside a mobile body, the composite structure of the wireless communication device and the illumination device may be for obstacle detection for securing safety for the mobile body such as a train, a drone, or a robot. Here, the wireless communication device of the mobile body may be in the composite structure with a peripheral or forward monitoring radar and the illumination device.

[0059] Also, the rate of change in radio wave attenuation rate of the micro-foamed resin sheet with respect to the radio wave attenuation rate due to air radio wave absorption in the wavelength band corresponding to 70 to 100 GHz is within the range of 0 to -0.15 dB. Thus, as mentioned above, absorption of radio waves by the micro-foamed resin sheet disposed in front of the wireless communication device can be suppressed with more certainty.

(EFFECTS OF THE INVENTION)

[0060] The present invention can provide a composite structure of an illumination device and a wireless communication device, a placement method for the illumination device and the wireless communication device, and an illumination device-equipped wireless communication device placed by the placement method. In the composite structure, loss in radio waves from the wireless communication device is small, and light with uniform brightness can be taken out from the composite structure.

BRIEF DESCRIPTION OF DRAWINGS

[0061]

FIG. 1 is a plan view showing a composite structure 1.

FIG. 2A is a cross-sectional view taken along A-A line in FIG. 1.

FIG. 2B is a cross-sectional view taken along B-B line in FIG. 1.

FIG. 3 is an enlarged view of proximity of an LED light source 13.

FIG. 4 is a cross-sectional view showing a composite structure 1a.

FIG. 5A is a cross-sectional view showing a composite structure 1b.

FIG. 5B is a partially enlarged view of FIG. 5A.

FIG. 6A is a cross-sectional view showing a composite structure 1c.

FIG. 6B is a cross-sectional view showing a composite structure 1d.

FIG. 7A is a cross-sectional view showing a composite structure 1e.

FIG. 7B is a cross-sectional view showing a composite structure 1f.

FIG. 8 is a cross-sectional view showing a composite structure 1g.

DETAILED DESCRIPTION

(First Embodiment)

[0062] Hereinafter, an embodiment of the present invention will be described with reference to the accompanying drawings. FIG. 1 is a plan view showing a composite structure 1 of an illumination device and a wireless communication device. FIG. 2A is a cross-sectional view taken along A-A line in FIG. 1 and FIG. 2B is a cross-sectional view taken along B-B line in FIG. 1. In descriptions hereafter, illustrations of wirings etc. will be omitted.

[0063] As shown in FIG. 2A and FIG. 2B, the composite structure 1 is a structure in which an illumination device 3 and a wireless communication device 17 are integrated and composited. The illumination device 3 mainly includes an LED light source 13, a substrate 11 that supports the LED light source 13, a light transmitting member 7, a frame member 5 that supports an outer periphery part of the light transmitting member, a light diffusion reflective micro-foamed resin sheet 15, and so on.

[0064] Here, although the illumination device 3 and the wireless communication device 17 are integrated and composited in FIG. 2B, the illumination device 3 and the wireless communication device 17 may not be integrated but may be disposed being in contact with each other or may be disposed separately from one another within a predetermined distance range.

[0065] An outline shape of a plan view of the composite structure (the illumination device 3) may be in any shapes, such as a substantially circular shape, a substantially oval shape, a substantially elliptical shape, a substantially triangular shape, a substantially rectangular shape, a substantially polygonal shape, or a substantially H shape in which diffuse reflectance in a light guiding space below is not to be impaired. In a case of the substantially polygonal shape in particular, the polygonal shape with even number of sides having major and minor axes is preferable in terms of design.

[0066] Here, in a case of the composite structure 1 (the illumination device 3) of the present invention, in terms of brightness of the illumination device, it is preferable to dispose the LED light source 13 over an entire periphery of the substrate 11 that is disposed over an entire periphery. However, in any of the embodiments, the LED light source 13 may be disposed at a part of or over the entire periphery of the substrate 11 that is disposed over an entire periphery, or the LED light source 13 may be disposed over the entire substrate that is disposed at a part of the entire periphery. Such the positional relations between the substrate 11 and the LED light source 13 may be decided suitably according to the design of the illumination device.

[0067] The micro-foamed resin sheet 15 is formed by thermoforming or a forming process without heating such as a bending process such that a cross sectional shape thereof is formed into a depression-like recessed shape. The thermoforming may be any one of press molding, vacuum molding, pressure forming, vacuum pressure forming, and match mold forming using upper and lower metal molds. Here, a plan-view shape of the micro-foamed resin sheet may be any shape that does not impair diffuse reflectance. However, when considering a protection effect of the micro-foamed resin sheet, a cross-sectional-view shape of the micro-foamed resin sheet is preferably a substantially U shape, a reversed trapezoid, or a bowl shape, having a flat portion at a center of the depression-like recessed shape. As above, since the micro-foamed resin sheet 15 has a micro foam structure, even if the sheet is molded using various molding methods, the micro-foamed resin sheet 15 has a characteristic that radio wave transmission loss and radio wave scattering loss based on diffuse reflectance and dielectric constant before and after molding are almost the same as long as the foam structure does not change significantly in general.

[0068] The micro-foamed resin sheet 15 is a PET resin sheet or a PC resin sheet, for example. The micro-foamed resin sheet 15 is a micro-foamed resin sheet having a diffuse reflectance to a barium sulfate standard plate of 95% or more, more preferably 96% or more, or even more preferably 98% or more, when a diffuse reflectance to the barium sulfate standard plate in a visual light band of wavelength of 450 - 650 nm is 100%, and a dielectric constant is 1.8 or less. Higher the diffuse reflectance is, higher the brightness can be obtained even after multiple reflections. That is, the micro-foamed resin sheet 15 is a material that excels in the light diffuse reflectance and, at the same time, compared to substrates or light transmitting members, also excels in low radio wave transmission performance with the dielectric constant of 1.8 or less, and thus can be used as a light reflecting plate.

[0069] In the present invention, the dielectric constant of the micro-foamed resin sheet is measured by a method specified in ASTM D2520 and JIS C2565, using a sample of 78 mm long x 2.4 mm wide x 1 mm thick (expansion ratio 4 times) at a measurement frequency of 2 GHz.

[0070] Although dielectric constants of common non-foamed material of PET resin or PC resin are 2.9 - 3.0, the dielectric constants of PET resin foam, PC resin foam, and, especially, micro-foamed resin foam of PET resin foam and PC resin foam can be 1.8 or less, or even 1.5 or less. As above, while the dielectric constant of ordinary transparent resin exceeds 2.0, the dielectric constant of a foam is low and thus it is possible to reduce losses in reflection, absorption, and scattering when radio waves are transmitted. For example, to show the actual measured values, the measurement result of the dielectric constant of the micro-foamed resin sheet of PET resin is 1.31 with $\tan \delta$ (Tangent Delta) of 0.0020, the dielectric constant of the micro-foamed resin sheet of PC resin is 1.39 with $\tan \delta$ of 0.0022, and the dielectric constant of both PET

resin and PC resin is 1.50 or less with $\tan \delta$ also satisfying 0.0022 or less, and it can be found that there is a little heat loss of radio waves. Also, as will be described separately, compared to common foam bodies, with the micro foam structure, the micro-foamed resin sheet has a characteristic that scattering loss during transmission of radio waves is small.

[0071] In addition to the above, radio wave absorption loss is evaluated by using an S parameter method. That is, a pair of horn antennas are disposed facing each other with a predetermined distance of 400 mm apart from each other with a micro-foamed resin sheet having a dimension of 210 mm x 297 mm and 1 mm of plate thickness being disposed at a predetermined position in a space between the horn antennas, and reception levels between the antennas are evaluated as the transmission loss. The transmission loss between both the antennas without the micro-foamed resin sheet being disposed is 0 dB. For evaluation of radio wave absorption loss, absorption loss in a frequency band of 70 - 100 GHz is obtained from S21 of the S parameter using a network analyzer (model number N5291A, manufactured by KEY SIGHT).

[0072] Here, it is preferable that a rate of change in radio wave attenuation rate of the micro-foamed resin sheet of PET resin and PC resin with respect to the radio wave attenuation rate due to air radio wave absorption in the wavelength band corresponding to 70 - 100 GHz is within the range between 0 and -0.15 dB. By suppressing the radio wave attenuation rate to a maximum of 3.5% greater than that of air, it is possible to reduce the loss when the radio waves emitted from the wireless communication device 17 disposed on the back surface of the micro-foamed resin sheet 15 are transmitted.

[0073] Note that an average bubble diameter of the micro-foamed resin sheet 15 is in a range between 0.2 μm and 10 μm , for example. If the average bubble diameter is smaller than 0.2 μm , light transmittance increases and reflectance decreases. Also, if the average bubble diameter is too large, diffuse reflectance decreases. Thus, the average diameter is preferably 0.2 μm or more and 10 μm or less. Since the average bubble diameter of the micro-foamed resin sheet 15 that is disposed in front of the wireless communication device is 0.2 - 10 μm , the micro-foamed resin sheet 15 excels in diffuse reflectance properties and dielectric properties, with little wave radio transmission loss as well as low radio wave scattering loss.

[0074] Now, the scattering loss due to the micro-foamed resin sheet 15 is considered. In the present invention, since the micro-foamed resin sheet 15 is disposed in front of the wireless communication device 17, not only the transmission loss is to be considered but also an influence of the scattering loss of radio waves emitted from the wireless communication device 17 is to be considered.

[0075] Here, if a wavelength of radio waves used is 100 GHz, for example, then the wavelength is 3 mm. Here, the foam of the present invention has a bubble diameter of 0.2 - 10 μm , which is approximately one-hundredth of the wavelength of the above radio waves and sufficiently small, and thus scattering due to bubbles hardly occurs at the time of transmission through the micro-foamed resin sheet. However, when a common foam is used, a bubble diameter is 100 μm - 300 μm and the wavelength is relatively large, ranging from one-tenth to several tenths of the wavelength of a millimeter wave band of radio waves, which is approximately 3 mm, and thus bubbles themselves may cause scattering of radio waves. As above, the micro-foamed resin sheet 15 has effects of reducing not only transmission loss but also scattering loss of the radio waves.

[0076] A light transmitting member 7 is disposed on a side of an opening of the micro-foamed resin sheet 15 molded to have the depression-like recessed shape. A frame member 5 fixes the light transmitting member 7 to an edge of the opening of the micro-foamed resin sheet 15. Although the light transmitting member 7 is in a flat plate shape, a front surface of the light transmitting member 7 may not be in a flat-surface shape. For example, the front surface of the light transmitting member 7 may have some evenness, such as a shape in which a center part of the light transmitting member 7 protrudes forward.

[0077] For the light transmitting member 7, light transmissive transparent resin of any one of PC resin, ABS resin, PET resin, polyvinyl chloride resin, acrylic resin such as PMMA resin, polystyrene resin, COP resin, and COC resin, for example, or transparent glass are applicable. Also, the light transmitting member 7 may be translucent resin, which is made by adding pigment to the transparent resin. Also, the light transmitting member 7 may be translucent resin that is made translucent by roughening or forming a micro uneven structure on a surface on a light taking-out side of transparent resin. Also, the light transmitting member 7 may be translucent laminate made by attaching a translucent resin film onto a surface of transparent resin or transparent glass, or may be translucent colored glass.

[0078] As the translucent light transmitting member 7, titanium oxide, zinc oxide, talc, mica, kaolin, etc. may be added as white pigment to transparent resin, for example. In such the case, an amount of the pigment to be added is to be in a range such that transparency can be maintained, and thus the addition amount is to be controlled. Also, in the case of the laminate made by attaching a translucent resin film to a surface of transparent resin or glass, a resin film made by coating a polyester film with polyvinyl chloride resin can be used, for example.

[0079] A light guiding space 19 is formed between the molded micro-foamed resin sheet 15 and the light transmitting member 7. More specifically, disposing the micro-foamed resin sheet 15, which is molded to have a depression-like recessed cross-sectional shape, at a rear of the light transmitting member 7, which is supported by the frame member, forms the light guiding space 19 between the molded micro-foamed resin sheet 15 and the light transmitting member 7. The substrate 11 is disposed inside the light guiding space 19 on the outer periphery part of the frame member 5 or the light transmitting member 7. That is, the substrate 11 is formed on the outer periphery of the light transmitting member 7 and

disposed on the outer periphery part of the light guiding space 19. The composite structure of the illumination device and the wireless communication device of the present invention is obtained.

[0080] FIG. 3 is an enlarged view of proximity of the substrate 11. As mentioned above, the LED light source 13 is disposed on the substrate 11. For the LED light source 13, any one of RGB light source, a single-chip LED light source in which emission color can be switched to RGB, a white LED light source, a day-light color LED light source, a white LED light source using phosphors, and a white or daylight-color LED array light source, or a combination of the above is applicable.

[0081] The LED light source 13 is disposed facing toward the micro-foamed resin sheet 15 such that light emitted from the LED light source 13 is reflected by the micro-foamed resin sheet 15. That is, a light emission surface of the LED light source 13 is disposed facing the micro-foamed resin sheet 15 in an opposite direction to the light transmitting member such that the light emitted from the LED light source 13 is reflected by the micro-foamed resin sheet 15. Also, since the micro-foamed resin sheet 15 has the high diffuse reflectance, the light emitted from the LED light source 13 is diffused and reflected by the micro-foamed resin sheet 15, and a part of the light is directed toward the light transmitting member 7 while other light is repeatedly diffused and reflected inside the light guiding space 19. This evens out the light so that uniform indirect light can be taken out.

[0082] The shape of the light guiding space 19 may be any shape with a depression-like recessed cross-sectional shape that facilitates receiving irradiation of the LED light source 13 and reflecting the reflected light toward the light transmitting member 7. For example, the cross-sectional shape of the micro-foamed resin sheet 15 may be a U shape, a reversed trapezoid, a bowl shape, or a gentle depression-like recessed shape. On the other hand, if a purpose is to provide the protective effect on the surface of the wireless communication device 17, a substantial U shape or a reversed trapezoid having a flat portion at a center of the depression-like recessed shape is preferable.

[0083] A covering member 9 is disposed on the front surface of the light transmitting member 7, thereby coating a part of the light transmitting member 7. As the covering member 9, for example, the covering member 9 may be a thin film of colored paint, metal deposition, or metal plating. In such the case, for example, In, Ge, Sn, etc. may be deposited as a thin-film plating, or Al may be deposited through a mask of a multiple-dotted pattern. Alternatively, as the covering member 9, non light-transmissive colored resin having a predetermined thickness may be provided on the front surface of the light transmitting member 7.

[0084] If the part of the light transmitting member 7 is coated by the covering member 9 of any one of colored paint, metal deposition, metal plating, and non light-transmissive colored resin with a predetermined thickness, light is taken out from a light transmission portion where the light transmitting member 7 is not coated by the covering member 9 of colored paint, metal deposition or metal plating, or from the light transmission portion where the colored resin is not disposed.

[0085] Here, as shown in FIG. 1, the covering member 9 that is disposed on the light transmitting member 7 divides the light transmission portion into an outer-periphery side 8 and an inner-periphery side 10. That is, the inner-periphery side 10 is a part that is surrounded by the covering member 9, and the outer-periphery side 8 is a part formed between the covering member 9 and the frame member 5.

[0086] Here, the LED light source 13 is disposed facing toward a side of the micro-foamed resin sheet 15. At this time, as mentioned above, since the light is made uniform by the inner light guiding space 19, substantially uniform light can be taken out from the light transmission portion of the light transmitting member 7 at which the covering member 9 is not disposed. Thus, it is possible to take out the indirect light from the light guiding space 19 with substantially the same brightness from each of the light transmission portions of the outer-periphery side 8 and the inner-periphery side 10.

[0087] An emission direction of the LED light source 13 may not always be in an opposite direction to the light taking-out direction. However, by having an arrangement such that a range of an orientation angle of the LED light source 13 does not include the light transmission portion transmitting light from the light transmitting member 7, it is possible to take out only the substantially uniform indirect light from the illumination device 3. For example, even if the light transmitting member 7 is formed in a plate-like shape or in a curved shape with an uneven structure and the shape of the light transmission portion side in the light guiding space 19 is formed in a plate-like shape or in a curved shape with an uneven structure, reflected light is diffused and reflected multiple times inside the light guiding space 19 and thus the light taken out from the illumination device 3 can only be the substantially uniform indirect light.

[0088] The wireless communication device 17 is disposed on a back surface side of a reflective surface of the micro-foamed resin sheet 15 on an opposite side of the light guiding space 19. That is, the wireless communication device 17 is disposed on a back surface side of the illumination device 3. The wireless communication device 17 is fixed to a part of the illumination device 3 (e.g., the frame member 5) by, for example, a supporting member or the like, of which illustration is omitted.

[0089] The wireless communication device 17 is a device that can emit radio waves and can be used for millimeter wave radars or 5G communications, for example. The millimeter wave radars are characterized in that the radars are not easily affected by weather conditions, such as rain, snow, and fogs, or by optical environment conditions such as brightness. For this reason, although millimeter waves in a frequency band from 24 GHz to approximately 80 GHz is used for obstacle detection, the millimeter waves are not limited to the above range but also can be applied to the frequency band applied to the current 5G communications.

[0090] Here, in the composite structure 1, the micro-foamed resin sheet 15 disposed in front of the wireless communication device 17 is a light reflecting plate that can also serve as a housing of the illumination device. The micro-foamed resin sheet 15 is disposed such that the micro-foamed resin sheet 15 functions as a part of the housing of the illumination device 3 and is in contact with a radio wave-emitting surface of the wireless communication device 17. Also, the substrate 11 is formed on the outer periphery of the light transmitting member 7, and the substrate 11 is not disposed at a center of the illumination device 3. For this reason, the substrate 11 is not disposed in an irradiation range of radio waves in front of the wireless communication device 17, and radio waves emitted from the wireless communication device 17 passes through the micro-foamed resin sheet 15 and the light transmitting member 7 to be irradiated forward. At this time, since the micro-foamed resin sheet 15 has the dielectric constant that is lower than that of the substrate 11 and is a material that excels in radio wave transmission performance with low radio wave absorption performance, radio wave loss can be reduced compared to the case in which the substrate 11 is disposed on the back surface of the illumination device 3. For example, the dielectric constant of a glass epoxy substrate is 4.5 - 5.2.

[0091] As above, according to the present embodiment, because of the molded micro-foamed resin sheet 15, the light guiding space 19 is formed between the micro-foamed resin sheet 15 and the light transmitting member 7 and this enables to take out only indirect light, instead of direct light, from the LED light source 13, which can even out the brightness of light at different parts.

[0092] Also, although the micro-foamed resin sheet 15 is disposed so as to cover an emission range of radio waves emitted from the wireless communication device 17, the micro-foamed resin sheet 15 is formed of a material with a low dielectric constant with little reflection and absorption of the radio waves and thus an effect of loss in radio waves when being transmitted through the micro-foamed resin sheet 15 can be reduced. Since the micro-foamed resin sheet 15 has the micro foam structure, even if the sheet is molded by thermoforming, the foam structure does not change significantly and light diffuse reflectance, dielectric constant, radio wave transmission loss, and radio wave scattering loss are almost the same before and after the molding.

[0093] On the other hand, the substrate 11 has a higher dielectric constant and a higher radio wave absorption rate compared to the micro-foamed resin sheet 15. However, the substrate 11 is disposed on the outer periphery of the light transmitting member 7, radio waves emitted from the wireless communication device 17, which is disposed at the back surface side of the micro-foamed resin sheet 15, are emitted toward the front of the composite structure 1 without being transmitted through the substrate 11. Thus, loss at the time of being transmitted through the substrate 11 can be suppressed.

[0094] As above, the center of the illumination device that corresponds to the radio wave-emitting surface in front of the wireless communication device is provided with only the light transmitting member 7, or only the light transmitting member 7 and the micro-foamed resin sheet 15, without the LED light source 13 and substrate 11 of the illumination device, the frame member 5, and the housing being disposed, so as not to hinder transmission of radio waves from the wireless communication device, and the LED light source and substrate of the illumination device, the frame member, and the housing are disposed on the outer periphery part of the illumination device, thereby reducing the effect of radio wave loss. Also, a distance between the micro-foamed resin sheet 15 and the wireless communication device is 5 mm or less both in a case in which the micro-foamed resin sheet 15 is disposed to be in contact with the radio wave-emitting surface of the wireless communication device and in a case in which the micro-foamed resin sheet 15 is disposed at a predetermined distance away from the radio wave-emitting surface of the wireless communication device. The effect can be obtained with more certainty since the micro-foamed resin sheet 15 has a micro-foamed bubble structure that makes the dielectric constant of the micro-foamed resin sheet 1.8 or less. That is, the micro-foamed resin sheet is formed of a material that excels in light diffuse reflectance performance, and, at the same time, excels in radio wave transmission performance because of the dielectric constant thereof that is lower than that of the substrate or the light transmitting member.

[0095] Such the composite structure 1 is applicable, for example, in a case where the illumination device 3 is an outdoor illumination device and the wireless communication device 17 is a wireless transmitter that communicates with a pedestrian outside or a vehicle travelling on the road. According to such the composite structure in which the outdoor illumination device is provided with the wireless transmitter, there are no obstacles between the pedestrian or the vehicle and the outdoor illumination device, which makes it suitable for outdoor communications through the wireless transmitter.

[0096] The composite structure 1 can also be utilized when the wireless communication device 17 is a wireless transmitter used in 5G communications and the illumination device 3 is an illumination device for an electronic advertisement signboard or an electronic guidance signboard device. Applying the wireless transmitter to the illumination device for the electronic advertisement signboard or the like facilitates to obtain installation locations, with fewer restrictions on the installation locations. The current 5G communications include frequencies of 30 GHz or less, such as a 28 GHz band, and cover a band range with an upper limit of around 100 GHz.

[0097] Here, in the composite structure of the illumination device and the wireless communication device of the present invention, when being used as a large illumination device in an outdoor illumination device, an illumination device for an electronic advertisement signboard or an electronic guidance signboard device, the LED light sources disposed on the outer periphery part of the illumination device on the substrate with a predetermined width provided at the frame member

are used as a plurality of collective light sources arranged in a grid, in a staggered lattice, or in arrays such that the illumination device can be made larger and brightness of the illumination device can be enhanced. Also, a plurality of the wireless communication devices can be provided side by side. Also, even if enlargement of the illumination device is not intended, arranging a plurality of the LED light sources can improve the brightness alone.

[0098] Also, in a case where the illumination device 3 is an illumination device attached to a mobile body such as a train, a drone, a robot, or the like and the wireless communication device 17 is a millimeter wave radar transmitter, the composite structure 1 can be used as a radar for peripheral monitoring or forward monitoring to detect obstacles for the mobile body. In this way, it is possible to enhance the design of the composite structure 1 of the wireless communication device 17 that can emit millimeter radar etc., for example, and the illumination device 3 for decoration through functions of light emission display of color emission, letters, logos, advertisement, and the like.

[0099] For a wavelength band range to be used by the wireless transmitter for the mobile body communications, millimeter wave radars with radar wavelengths in band ranges such as a 24 - 26 GHz band, a 77 GHz band, and a 79 GHz band can be used. At this time, comparing the typical 79 GHz band and the 24 GHz band, transmission loss, which depends on materials such as glass, resin materials, or concrete, is larger in the 79 GHz band as an attenuation characteristic of the millimeter waves.

(Second Embodiment)

[0100] Next, a second embodiment will be described. FIG. 4 is a cross-sectional view showing a composite structure 1a according to the second embodiment. In the descriptions hereafter, the same notations as in FIG. 1 - FIG. 3 will be used for structures having the similar functions etc. as the composite structure 1 and redundant descriptions will be omitted.

[0101] The composite structure 1a has a substantially similar structure as the composite structure 1 except that an arrangement of the wireless communication device 17 is different. In the composite structure 1a, a housing 21 is used, and the outer periphery parts of the illumination device 3 and the wireless communication device 17 are fixed respectively to the common housing 21. At this time the micro-foamed resin sheet 15 disposed in front of the wireless communication device 17 is disposed a predetermined distance away from the radio wave-emitting surface of the wireless communication device 17. Here, although not specifically illustrated, the illumination device 3 and the wireless communication device 17 are not to be always fixed as being integrated but may be disposed the predetermined distance away from each other, being mutually separated and fixed to another member with the predetermined distance therebetween. Alternatively, the illumination device 3 may be disposed in front of the wireless communication device 17 being in contact with each other, or the illumination device 3 and the wireless communication device 17 may be separated from each other and fixed to other members, respectively.

[0102] In such the composite structure 1a, the similar effects as in the above-mentioned composite structure 1 can be obtained. As above, the illumination device 3 and the wireless communication device 17 may be in contact with each other, or may be the predetermined distance away from each other without being in contact with each other.

(Third Embodiment)

[0103] FIG. 5A is a cross-sectional view showing a composite structure 1b according to a third embodiment. In the descriptions hereafter, an embodiment in which the wireless communication device 17 is disposed to be in contact with the micro-foamed resin sheet 15 that forms the light guiding space will be described. However, the wireless communication device 17 may be disposed the predetermined distance away from the micro-foamed resin sheet 15 as in the composite structure 1a.

[0104] The composite structure 1b has substantially the same structure as the composite structure 1 except for an arrangement of the covering member 9. FIG. 5B is an enlarged view of C portion in FIG. 5A. While the covering member 9 is disposed on the front surface of the light transmitting member 7 in the composite structure 1, the covering member 9 is disposed on a back surface of the light transmitting member 7 in the composite structure 1b. That is, a part of the back surface of the light transmitting member 7 is coated by the thin-film covering member 9 of colored paint, metal deposition, or metal plating, or a non light-transmissive covering member of colored resin having a predetermined thickness is disposed on the back surface of the light transmitting member 7.

[0105] Also, on a further back surface of the covering member 9, a micro-foamed resin sheet 15a is directly attached to an inner periphery surface of a position corresponding to the covering member 9. That is, all positions on a side of the light guiding space 19 of the light transmitting member 7 except for the light transmission portions are coated with the light reflective micro-foamed resin sheet 15a. The same member as the micro-foamed resin sheet 15 can be applied to the micro-foamed resin sheet 15a.

[0106] According to the composite structure 1b, the micro-foamed resin sheet 15a can prevent light inside the light guiding space 19 from being absorbed and reflected by the covering member, which results in more efficient diffusion and reflection of the light. Thus, diffusion reflection light with further improved uniform brightness level can be taken out.

[0107] Here, when the micro-foamed resin sheet 15a is directly attached to the back surface of the light transmitting member 7 without disposing the covering member 9, since the micro-foamed resin sheet 15a is a white sheet-like member with no design features given, the design feature is degraded if the micro-foamed resin sheet 15a is directly seen and recognized through the front surface of the light transmitting member 7. In contrast, by disposing the micro-foamed resin sheet 15a only on the back surface of the covering member 9, the micro-foamed resin sheet 15a cannot be directly seen and recognized through the front surface of the light transmitting member 7, thereby improving the design feature.

[0108] A composite structure using the covering member 9 and the micro-foamed resin sheet 15a is not limited to the composite structure 1b. FIG. 6A is a cross-sectional view showing a composite structure 1c.

[0109] Although the covering member 9 is disposed on the front surface of the light transmitting member 7 in the composite structure 1c, the micro-foamed resin sheet 15a is disposed on a back surface side of the light transmitting member 7 at a position corresponding to the covering member 9. Even in the composite structure 1c, it is possible to take out light with uniform brightness because of diffusion and reflection by the micro-foamed resin sheet 15a, and, at the same time, the covering member 9 can prevent the micro-foamed resin sheet 15a from being seen and recognized through the front surface of the light transmitting member 7.

[0110] In such the case, the micro-foamed resin sheet 15a is disposed at a predetermined distance away from the colored resin as the covering member 9 on the back surface side of the light transmitting member 7 at the position corresponding to the colored resin. Thus, it is preferable that the micro-foamed resin sheet 15a is formed in a similar shape as that of the colored resin and slightly smaller than the colored resin so that the micro-foamed resin sheet 15a cannot be seen and recognized from outside when the light transmission portion of the light transmitting member 7 is viewed from an oblique direction. On the other hand, if a part of the outer periphery part of the micro-foamed resin sheet 15a may be allowed to be seen and recognized from the outside, the micro-foamed resin sheet 15a may be formed in the same size as the colored resin.

[0111] Also, FIG. 6B is a cross-sectional view showing a composite structure 1d. The composite structure 1d is substantially similar to the composite structure 1c except that non light-transmissive colored resin 9a is disposed on the front surface of the light transmitting member 7 so as to be on substantially the same plane as the front surface of the light transmitting member 7. That is, the non light-transmissive colored resin 9a having a predetermined thickness is disposed at a portion that is substantially the same plane as the light transmitting member 7, which is a part of the front surface of the light transmitting member 7. The micro-foamed resin sheet 15a is disposed at the back surface side of the light transmitting member 7 at a position corresponding to the colored resin 9a. The same effects as in the composite structure 1c and the like can be obtained also in the composite structure 1d.

[0112] In such the case, since the micro-foamed resin sheet 15a is disposed a predetermined distance away from the colored resin 9a as the covering member 9 at the position corresponding to the colored resin 9a on the back surface side of the light transmitting member 7, similarly to FIG. 6A, the micro-foamed resin sheet 15a is preferably formed in a similar shape as and slightly smaller than the colored resin 9a. However, the micro-foamed resin sheet 15a may also be formed in the same size as the colored resin 9a.

[0113] Also, FIG. 7A is a cross-sectional view showing a composite structure 1e. The composite structure 1e is substantially similar to the composite structure 1b except that the colored resin 9a is disposed on the back surface of the light transmitting member 7 so as to be on substantially the same plane as the back surface of the light transmitting member 7. That is, the non light-transmissive colored resin 9a having a predetermined thickness is disposed at a portion that is substantially the same plane as the light transmitting member 7, which is a part of the back surface of the light transmitting member 7. The micro-foamed resin sheet 15a having the same shape as the colored resin 9a is disposed at the back surface side of the light transmitting member 7 at a position corresponding to the colored resin 9a. The same effects as in the composite structure 1c and the like can be obtained also in the composite structure 1e.

[0114] Also, FIG. 7B is a cross-sectional view showing a composite structure 1f. The composite structure 1f is substantially similar to the composite structure 1e except that the colored resin 9a is disposed inside the light transmitting member 7. That is, the non light-transmissive colored resin 9a having a predetermined thickness is disposed inside the light transmitting member 7, and the micro-foamed resin sheet 15a is disposed at the back surface side of the light transmitting member 7 at a position corresponding to the colored resin 9a. The same effects as in the composite structure 1c and the like can be obtained also in the composite structure 1f.

[0115] In such the case, since the micro-foamed resin sheet 15a is disposed a predetermined distance away from the colored resin 9a as the covering member 9 at the position corresponding to the colored resin 9a on the back surface side of the light transmitting member 7, similarly to FIG. 6B, the micro-foamed resin sheet 15a is preferably formed in a similar shape as and slightly smaller than the colored resin 9a. However, the micro-foamed resin sheet 15a may also be formed in the same size as the colored resin 9a.

[0116] Also, FIG. 8 is a cross-sectional view showing a composite structure 1g. The composite structure 1g is substantially similar to the composite structure 1f except that the colored resin 9a is disposed to have substantially the same thickness as the light transmitting member 7. In any of the drawings of FIG. 5 to FIG. 8, the micro-foamed resin sheet 15a can be disposed at the predetermined distance away from the colored resin 9a on the back surface of the light

transmitting member 7 at the position corresponding to the colored resin 9a as the covering member 9, or the micro-foamed resin sheet 15a can be disposed directly on the back surface of the covering member 9 that is disposed on the back surface side of the light transmitting member 7. However, if improvement of the brightness level of the light taken out from the light transmission portion is to be suppressed at a predetermined level, the micro-foamed resin sheet 15a may not be disposed on the back surface side of the covering member 9 or the colored resin 9a.

[0117] Even in the composite structure 1g, the micro-foamed resin sheet 15a is disposed on the back surface side of the colored resin 9a. Thus, it is possible to take out light with uniform brightness because of diffusion and reflection by the micro-foamed resin sheet 15a, and, at the same time, the colored resin 9a can prevent the micro-foamed resin sheet 15a from being seen and recognized through the front surface of the light transmitting member 7.

[0118] As above, a part of the front surface, or the back surface, of the light transmitting member 7 may be coated with the thin-film covering member 9 by colored paint, metal deposition, or metal plating; the non light-transmissive colored resin 9a having the predetermined thickness may be disposed on the front surface or the back surface of the light transmitting member 7, at the portion that is substantially the same plane as the light transmitting member 7, or inside the light transmitting member 7; or the colored resin having the same thickness as the light transmitting member 7 may be disposed in place of a part of the light transmitting member 7. If the part of the light transmitting member 7 is coated by the covering member 9 of any of colored paint, metal deposition, metal plating, and the non light-transmissive colored resin having the predetermined thickness, or the non light-transmissive colored resin 9a having the predetermined thickness is disposed in place of the light transmitting member 7 at a part of the light transmitting member 7 in this way, light can be taken out from the light transmission portion where the light transmitting member 7 is not coated by the covering member 9 or from the light transmission portion where the colored resin 9a is not disposed.

[0119] Also, by disposing the micro-foamed resin sheet 15a on the back surface side of the light transmitting member 7 at the position corresponding to the covering member 9 or the colored resin 9a, it is possible to take out light with uniform brightness because of diffusion and reflection by the micro-foamed resin sheet 15a, and, at the same time, the covering member 9 or the colored resin 9a can prevent the micro-foamed resin sheet 15a from being seen and recognized through the front surface of the light transmitting member 7.

[0120] At this time, if the covering member 9 is provided at a predetermined position of the light transmitting member 7 and the covering member 9 is formed being exposed to the back surface of the light transmitting member 7, the micro-foamed resin sheet 15a having the same size as the covering member 9 may be attached directly to the back surface of the covering member 9. Also, if the covering member 9 is not exposed to the back surface of the light transmitting member 7, the micro-foamed resin sheet 15a having the similar shape as and a slightly smaller size than the covering member 9, or the micro-foamed resin sheet 15a having the same size as the covering member 9, may be attached to the position corresponding to the covering member 9 on the back surface of the light transmitting member 7.

[0121] As above, according to the composite structure of the illumination device using the light diffusion reflective micro-foamed resin sheet of the present invention and the wireless communication device and the invention of the placement method of the illumination device and the wireless communication device, even if the illumination device is disposed in front of the wireless communication device, it is possible to obtain the indirect-light illumination device with excellent design where absorption loss of radio waves transmitted from the wireless communication device due to forming members of the illumination device is small and brightness of the light taken out from the illumination device is kept substantially constant regardless of forming positions of the light transmission portions from which the light is taken out from the light transmitting member of the illumination device. In such the inventions, except for the micro-foamed resin sheet that excels in transmissivity of radio waves, only the light transmitting member at least a part of which is coated by the covering member, which is a member having a dielectric constant of 2.0 or more in general, is disposed in front of the wireless communication device. Thus, even if the illumination device is disposed in front of the wireless communication device, a structure and a placement method of the wireless communication device and the illumination device that excels in radio wave transmissivity can be obtained. Also, the composite structure of the illumination device and the wireless communication device that not only has the low radio wave transmission loss but also excels in radio wave scattering loss can be obtained. Also, by arranging the composite structure of the illumination device and the wireless communication device by using such the placement method of the illumination device and the wireless communication device, the wireless communication device equipped with the illumination device that excels not only in diffuse reflectance properties but also excels in radio wave transmission loss and radio wave scattering loss.

[0122] Although the embodiments of the present invention have been described referring to the attached drawings, the technical scope of the present invention is not limited to the embodiments described above. It is obvious that persons skilled in the art can think out various examples of changes or modifications within the scope of the technical idea disclosed in the claims, and it will be understood that they naturally belong to the technical scope of the present invention.

(DESCRIPTION OF NOTATIONS)

[0123]

1, 1a, 1b, 1c, 1d, 1e, 1f, 1g	composite structure
3	illumination device
5	frame member
7	light transmitting member
5 8	outer-periphery side
9	covering member
9a	colored resin
10	inner-periphery side
11	substrate
10 13	LED light source
15, 15a	micro-foamed resin sheet
17	wireless communication device
19	light guiding space
21	housing

Claims

1. A composite structure of an illumination device and a wireless communication device using a micro-foamed resin sheet, the illumination device being disposed in front of the wireless communication device, wherein

the illumination device comprising:

- an LED light source;
- a substrate that supports the LED light source;
- a light transmitting member;
- a frame member that supports an outer periphery part of the light transmitting member; and
- a light diffusion reflective micro-foamed resin sheet;

the micro-foamed resin sheet of which a cross section is shaped in a depression-like recessed shape is disposed at a rear of the light transmitting member supported by the frame member such that a light guiding space is formed between the light transmitting member and the micro-foamed resin sheet;

an emission surface of the LED light source is disposed facing the micro-foamed resin sheet in an opposite direction to the light transmitting member such that light emitted from the emission surface of the LED light source is reflected by the micro-foamed resin sheet;

the wireless communication device is disposed on a back surface side of a light reflective surface of the micro-foamed resin sheet;

the micro-foamed resin sheet disposed in front of the wireless communication device is disposed to be in contact with a radio wave-emitting surface of the wireless communication device as a part of a housing of the illumination device, or disposed to be a predetermined distance away from the radio wave-emitting surface of the wireless communication device; and

the micro-foamed resin sheet is a material that excels in light diffuse reflectance properties as well as in radio wave transmission performance with a low dielectric constant compared to the substrate or the light transmitting member.

2. The composite structure of the illumination device and the wireless communication device according to claim 1, wherein

a center part of the illumination device that corresponds to the radio wave-emitting surface in front of the wireless communication device is provided with only the light emission member and the micro-foamed resin sheet, without the LED light source, the substrate, the frame member, and the housing of the illumination device being disposed, so as not to hinder transmission of radio waves from the wireless communication device, and the LED light source, the substrate, the frame member, and the housing of the illumination device are disposed on an outer periphery part of the illumination device.

3. The composite structure of the illumination device and the wireless communication device according to claim 2, wherein

the micro-foamed resin sheet disposed in front of the wireless communication device is a micro-foamed resin sheet having an average bubble diameter of 0.2 μm - 10 μm ;

the micro-foamed resin sheet is a light reflecting plate, which can also serve as a housing of the illumination device, having a diffuse reflectance to a barium sulfate standard plate of 95% or more when a diffuse reflectance to the barium sulfate standard plate in a visual light band of wavelength of 450 - 650 nm is 100%; and a dielectric constant of the micro-foamed resin sheet measured by a method specified in ASTM D2520 and JIS C2565 at a measurement frequency of 2 GHz is 1.8 or less, both in a case in which the micro-foamed resin sheet is disposed to be in contact with the radio wave-emitting surface of the wireless communication device and in a case in which the micro-foamed resin sheet is disposed at a predetermined distance away from the radio wave-emitting surface of the wireless communication device.

4. The composite structure of the illumination device and the wireless communication device according to claim 3, wherein since the average bubble diameter is 0.2 - 10 μm , the micro-foamed resin sheet disposed in front of the wireless communication device excels in diffuse reflectance properties and dielectric properties with small radio wave transmission loss as well as small radio wave scattering loss.

5. The composite structure of the illumination device and the wireless communication device according to claim 1, wherein the light transmitting member is any one of light transmissive transparent resin of any one of PC resin, ABS resin, PET resin, polyvinyl chloride resin, acrylic resin, polystyrene resin, COP resin, and COC resin, transparent glass, translucent resin made by adding pigment to the transparent resin, translucent resin made translucent by roughening or forming a micro uneven structure on a surface on a light taking-out side of the transparent resin, translucent laminate made by attaching a translucent resin film onto a surface of the transparent resin or the transparent glass, and translucent colored glass.

6. The composite structure of the illumination device and the wireless communication device according to claim 5, wherein

a part of a front surface or a back surface of the light transmitting member is coated with a thin film-like covering member of colored paint, metal deposition, or metal plating;
non light-transmissive colored resin having a predetermined thickness is disposed on the front surface or the back surface of the light transmitting member, at a position that is on a substantially same plane as the or inside the light transmitting member; or light transmitting member, colored resin having a thickness that is same as the thickness of the light transmitting member is disposed in place of a part of the light transmitting member.

7. The composite structure of the illumination device and the wireless communication device according to claim 6, wherein

if the covering member is provided at a predetermined position of the light transmitting member and the covering member is formed to be exposed to the back surface of the light transmitting member, the micro-foamed resin sheet having the same size as the covering member is attached directly to the back surface of the covering member; and
if the covering member is not exposed to the back surface of the light transmitting member, the micro-foamed resin sheet having the similar shape as and a slightly smaller size than or same size as the covering member is attached to a position of the back surface of the light transmitting member corresponding to the covering member.

8. The composite structure of the illumination device and the wireless communication device according to claim 6, wherein

if the part of the light transmitting member is coated by the covering member of any one of colored paint, metal deposition, metal plating, and the non light-transmissive colored resin having the predetermined thickness, or the non light-transmissive colored resin having the predetermined thickness is disposed at the part of the light transmitting member in place of the light transmitting member, light is taken out from a light transmission portion where the light transmitting member is not coated by the covering member or from the light transmission portion where the colored resin is not disposed.

9. The composite structure of the illumination device and the wireless communication device according to claim 1, wherein the LED light source disposed on the substrate is any one of RGB light source, a single-chip LED light source in which

emission color can be switched to RGB, a white LED light source, a day-light color LED light source, a white LED light source using phosphors, and a white or daylight-color LED array light source, or a combination of the above.

10. The composite structure of the illumination device and the wireless communication device according to claim 1, wherein

by having an arrangement such that a range of an orientation angle of the LED light source does not include the light transmission portion transmitting light from the light transmitting member, even if the light transmitting member is formed in a plate-like shape or in a curved shape with an uneven structure and the shape of the light transmission portion side in the light guiding space is formed in a plate-like shape or in a curved shape with an uneven structure, reflected light is diffused and reflected multiple times inside the light guiding space and thus the light taken out from the illumination device is only the substantially uniform indirect light.

11. The composite structure of the illumination device and the wireless communication device according to claim 8, wherein

the covering member provided on the light transmitting member divides the light transmission portion into an outer-periphery side and an inner-periphery side, and indirect light having substantially the same brightness is taken out from the light transmission portion on each of the outer-periphery side and the inner-periphery side.

12. The composite structure of the illumination device and the wireless communication device according to any one of claims 1 to 11, wherein

the illumination device is an outdoor illumination device, and the wireless communication device is a wireless communicator that is installed in a park, on a street, on a building wall, or on a rooftop to communicate with pedestrians and vehicles traveling on the road.

13. The composite structure of the illumination device and the wireless communication device according to any one of claims 1 to 11, wherein

the wireless communication device is a wireless transmitter used in 5G communications, and the illumination device is an electronic advertisement signboard illumination device or an electronic guidance signboard device.

14. The composite structure of the illumination device and the wireless communication device according to any one of claims 1 to 11, wherein

the illumination device is an illumination device attached to a mobile body and the wireless communication device is a millimeter wave radar transmitter.

15. The composite structure of the illumination device and the wireless communication device according to claim 1, wherein

a change rate in a radio wave attenuation rate of the micro-foamed resin sheet with respect to the radio wave attenuation rate due to air radio wave absorption in the wavelength band corresponding to 70 - 100 GHz is within a range between 0 and -0.15 dB.

16. A placement method for an illumination device and a wireless communication device in a composite structure of the illumination device and the wireless communication device using a micro-foamed resin sheet, the illumination device being disposed in front of the wireless communication device, wherein

the illumination device comprising:

- an LED light source;
- a substrate that supports the LED light source;
- a light transmitting member;
- a frame member that supports an outer periphery part of the light transmitting member; and
- a light diffusion reflective micro-foamed resin sheet.

an emission surface of the LED light source is disposed facing the micro-foamed resin sheet in an opposite direction to the light transmitting member with the micro-foamed resin sheet being formed to have a cross section shaped in a depression-like recessed shape thereby forming a light guiding space between the light transmitting member and the micro-foamed resin sheet, such that light emitted from the emission surface of the LED light source is reflected by the micro-foamed resin sheet;

the wireless communication device is disposed on a back surface side of a light reflective surface of the micro-

foamed resin sheet;

the micro-foamed resin sheet disposed in front of the wireless communication device is disposed to be in contact with a radio wave-emitting surface of the wireless communication device as a part of a housing of the illumination device, or disposed to be a predetermined distance away from the radio wave-emitting surface of the wireless communication device;

in front of the radio wave-emitting surface at a front of the wireless communication device, either only the light transmitting member or the light transmitting member and the micro-foamed resin sheet are to be disposed; and the micro-foamed resin sheet is a material that excels in light diffuse reflectance as well as in radio wave transmission performance with a low dielectric constant of 1.8 or less, compared to the substrate or the light transmitting member, and the micro-foamed resin sheet is used as a light reflecting plate.

17. The placement method for the illumination device and the wireless communication device according to claim 16, wherein

the micro-foamed resin sheet is formed in a depression-like recessed shape by molding with or without heat and is a molded body with a cross-sectional-view shape of a substantially U shape, a reversed trapezoid, or a bowl shape, having a flat portion at a center of the depression-like recessed shape; and diffuse reflectance and dielectric constant of the micro-foamed resin sheet before and after molding are the same.

18. An illumination device-equipped wireless communication device that excels in diffuse reflectance properties as well as in radio wave transmission loss and radio wave scattering loss, wherein the illumination device-equipped wireless communication device is obtained by disposing a composite structure of the illumination device and the wireless communication device using the placement method of the illumination device and the wireless communication device according to claim 16 or claim 17.

Fig.1

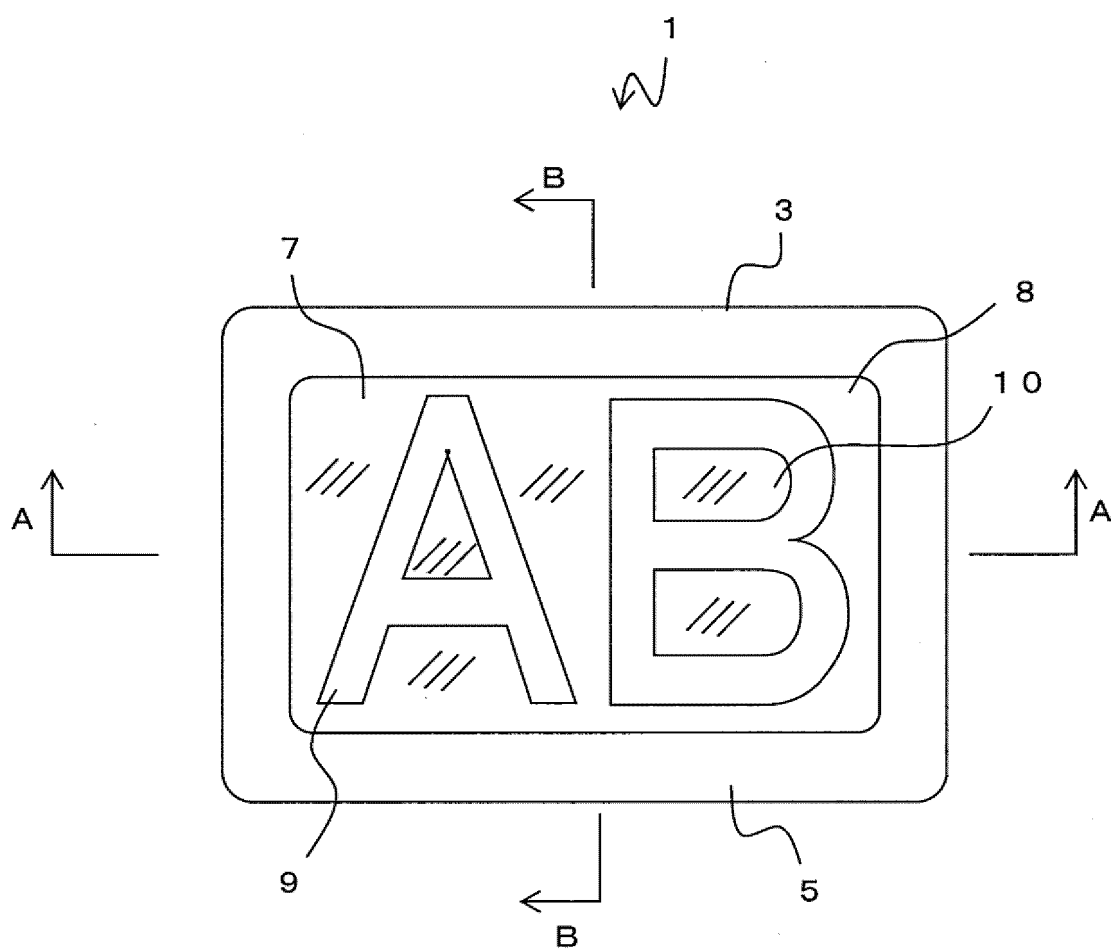


Fig.2A

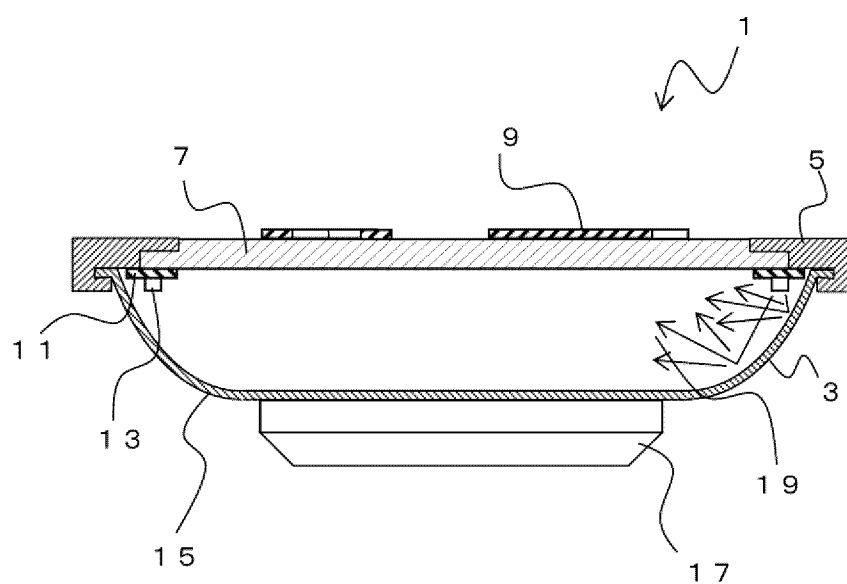


Fig.2B

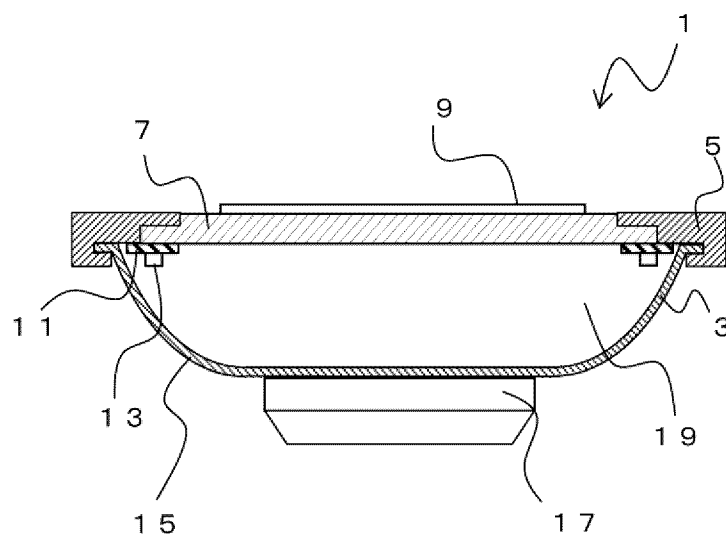


Fig.3

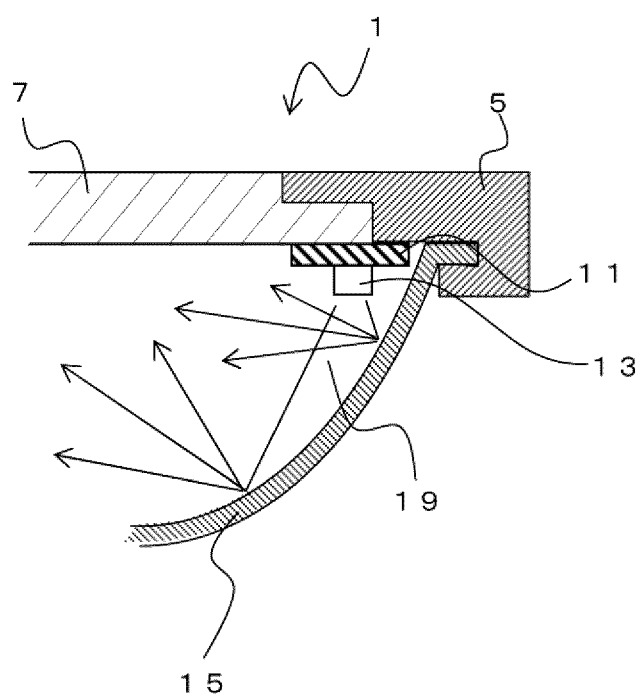


Fig.4

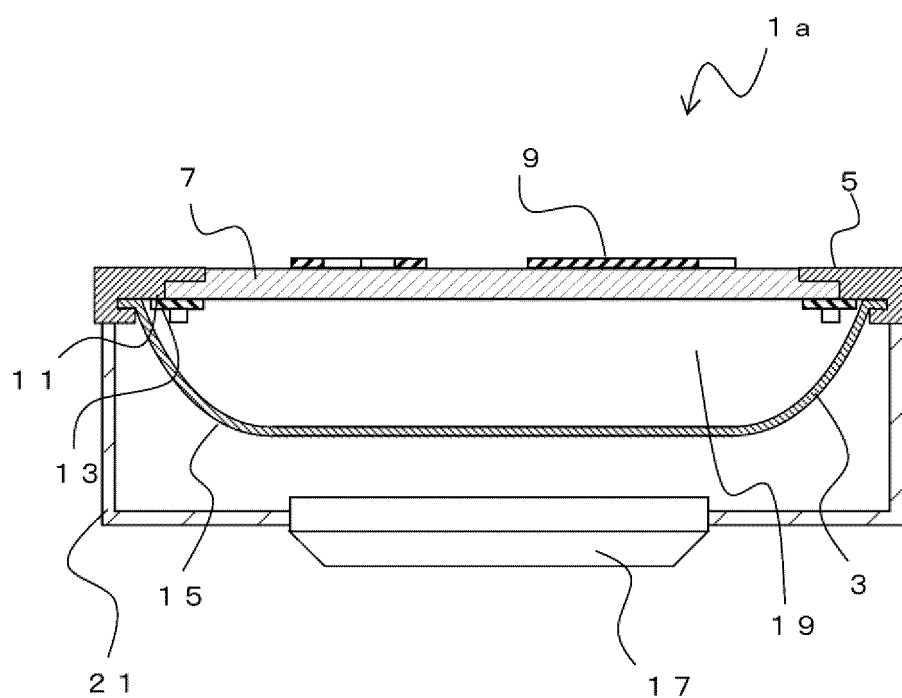


Fig.5A

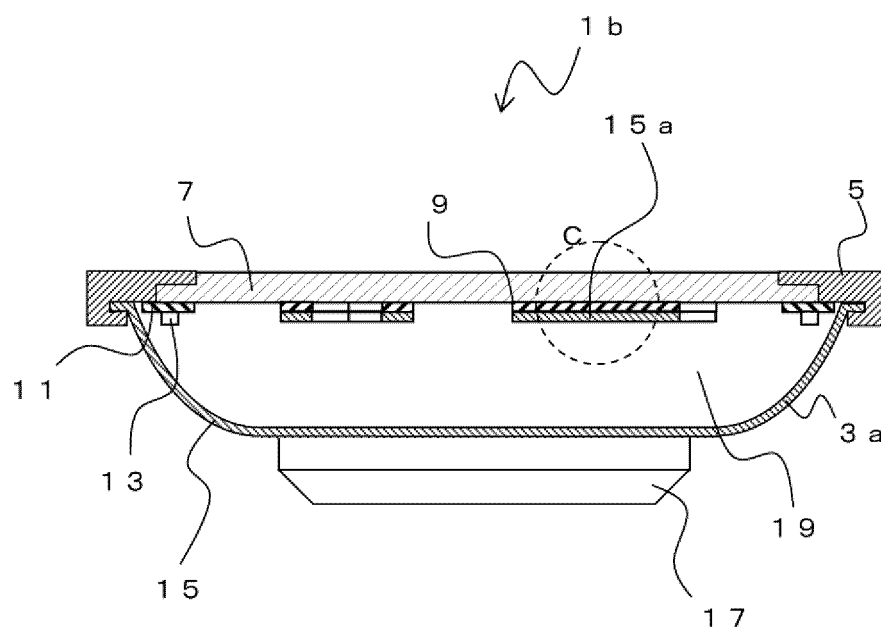


Fig.5B

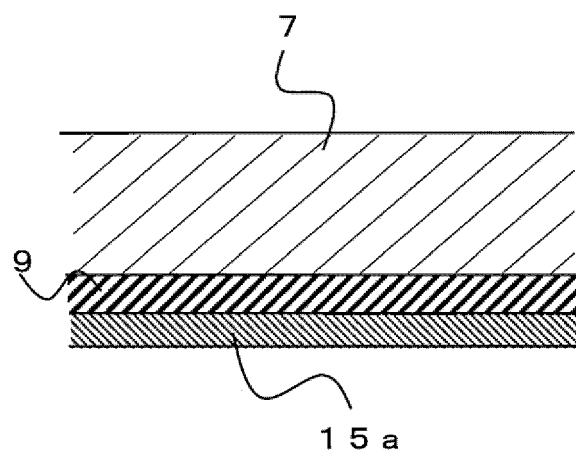


Fig.6A

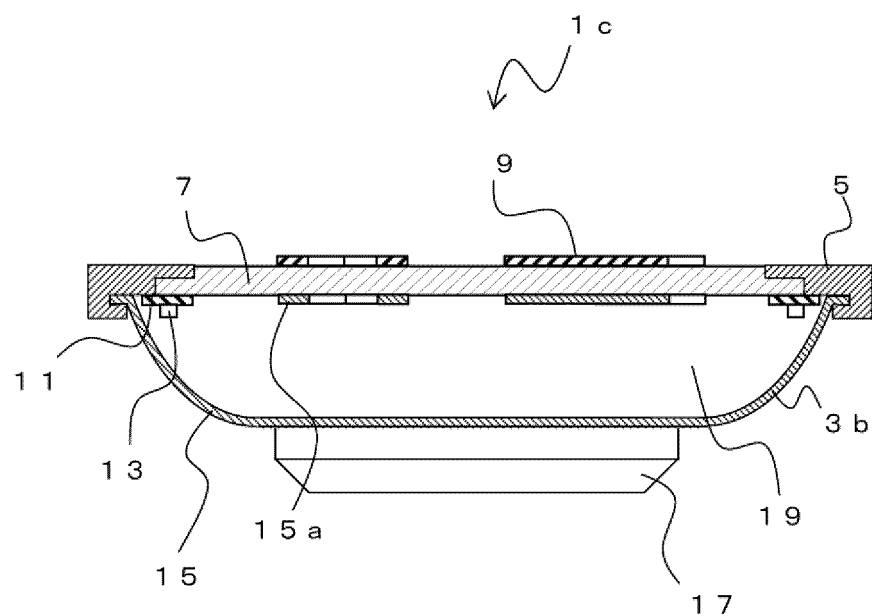


Fig.6B

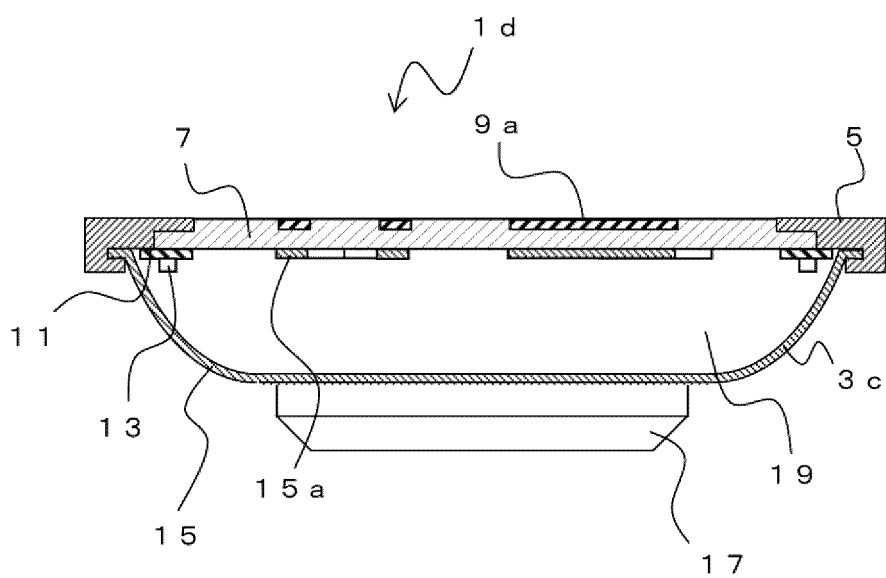


Fig.7A

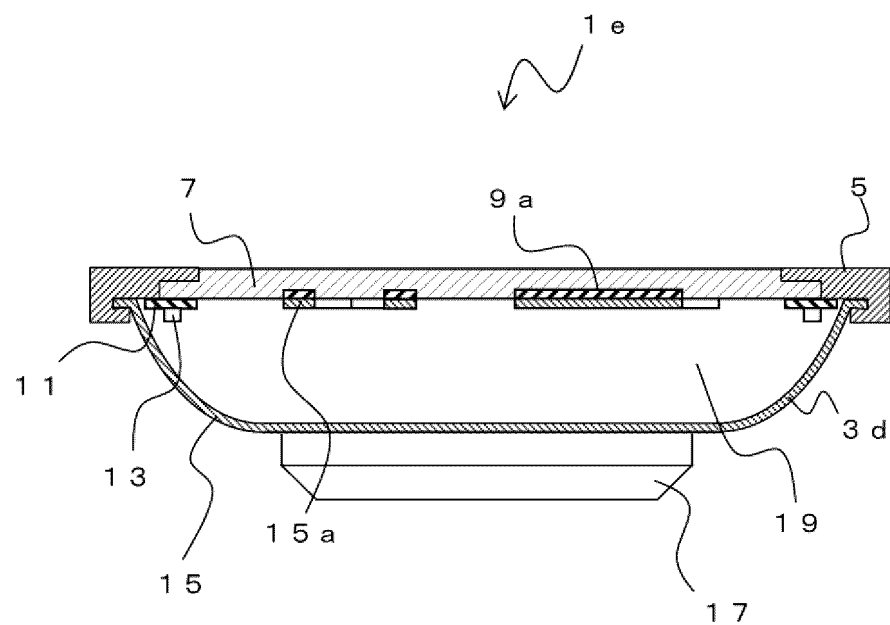


Fig.7B

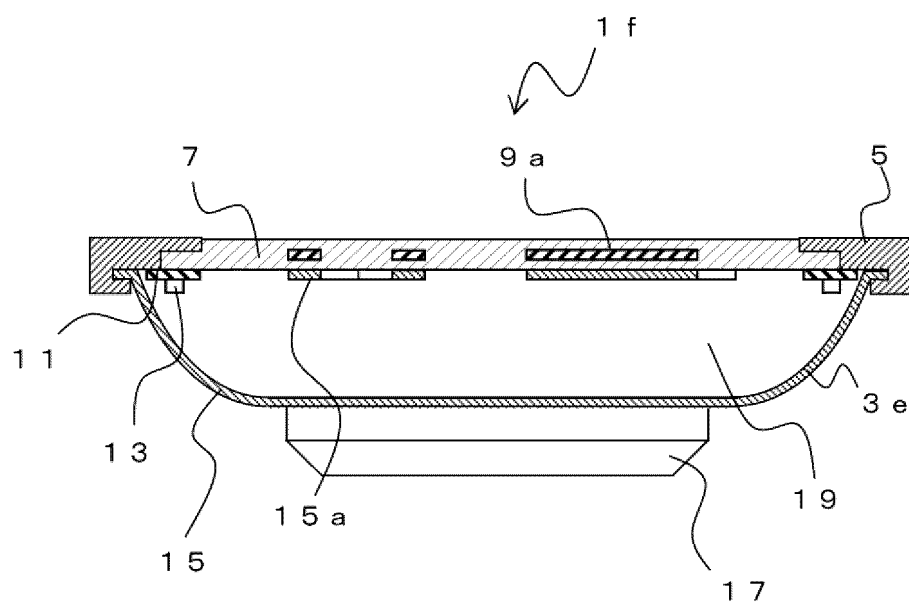
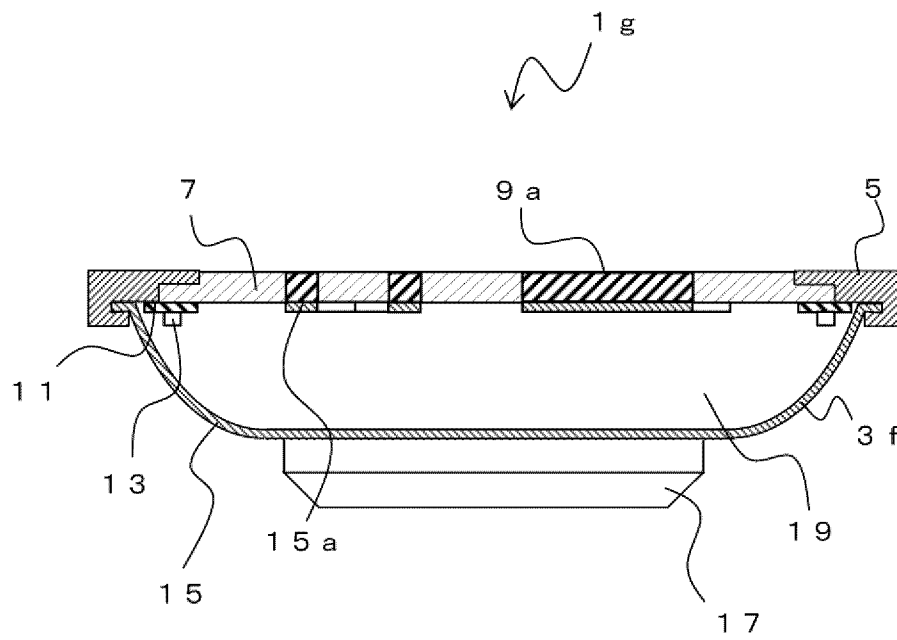


Fig.8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2023/021801

A. CLASSIFICATION OF SUBJECT MATTER

F21S 2/00(2016.01)i; **F21V 3/00**(2015.01)i; **F21V 3/06**(2018.01)i; **F21V 3/10**(2018.01)i; **F21V 7/00**(2006.01)i;
F21V 7/24(2018.01)i; **F21V 33/00**(2006.01)i; **G08G 1/09**(2006.01)i; **G09F 13/04**(2006.01)i; **F21W 111/02**(2006.01)n;
F21Y 113/10(2016.01)n; **F21Y 115/10**(2016.01)n
 FI: F21S2/00 495; F21V3/10 370; F21V7/24; F21V7/00 320; F21V3/06 110; F21V3/10 310; F21V3/00 320; F21V3/10 330;
 F21V33/00 400; F21V7/00 530; F21S2/00 498; G08G1/09 F; G09F13/04 D; F21W111:02; F21Y113:10; F21Y115:10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F21S2/00; F21V3/00; F21V3/06; F21V3/10; F21V7/00; F21V7/24; F21V33/00; G08G1/09; G09F13/04; F21W111/02;
 F21Y113/10; F21Y115/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2023
 Registered utility model specifications of Japan 1996-2023
 Published registered utility model applications of Japan 1994-2023

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2021-99984 A (STANLEY ELECTRIC CO., LTD.) 01 July 2021 (2021-07-01) entire text, all drawings	1-18
A	JP 2018-082352 A (THE FURUKAWA ELECTRIC CO., LTD.) 24 May 2018 (2018-05-24) entire text, all drawings	1-18
A	JP 2018-137037 A (THE FURUKAWA ELECTRIC CO., LTD.) 30 August 2018 (2018-08-30) entire text, all drawings	1-18

☐ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

* Special categories of cited documents:

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“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

06 July 2023

Date of mailing of the international search report

18 July 2023

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)
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 Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/021801

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2021-99984 A	01 July 2021	US 2023/0018354 A1 entire text, all drawings	
		WO 2021/125047 A1	
		EP 4063722 A1	
		CN 114829835 A	
JP 2018-082352 A	24 May 2018	(Family: none)	
JP 2018-137037 A	30 August 2018	WO 2017/082332 A1 entire text, all drawings	

REFERENCES CITED IN THE DESCRIPTION

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- JP 2009036571 A [0016]