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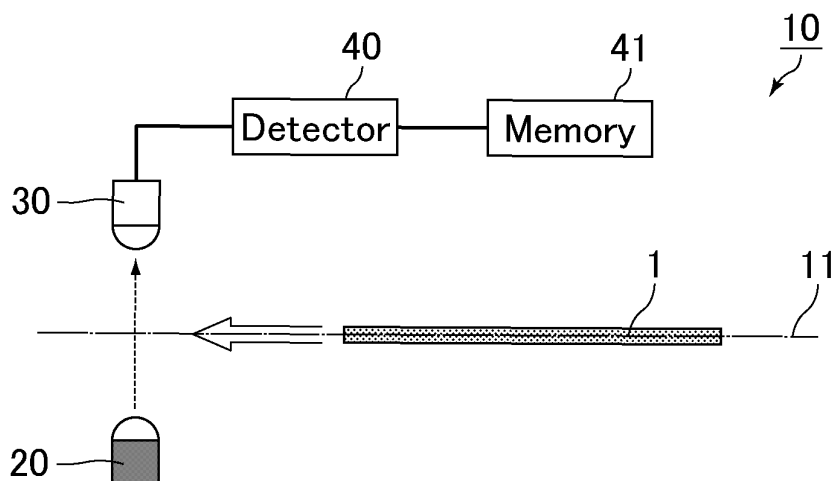
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(54) **PAPER SHEET SENSING DEVICE**

(57) The present invention provides a sheet detection device (10) capable of detecting a variety of sheets including a variety of transparent portions. The sheet detection device (10) is configured to detect a sheet including a transparent portion (2) transmitting light in a visible range and being transported along a transport path (11), the device (10) including: at least one ultraviolet light

source (20) configured to apply ultraviolet light to the transport path (11); at least one photodetector (30) configured to detect the ultraviolet light applied by the at least one ultraviolet light source (20); and a detector (40) configured to detect the sheet based on an output signal from the photodetector (30).

FIG.2



Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to sheet detection devices. The present invention more specifically relates to a sheet detection device suitable for detection of a sheet transported.

BACKGROUND ART

10 **[0002]** Typical sheet detection devices configured to detect a sheet transported in a device such as a sheet handling machine utilize a transmissive optical sensor (for example, Patent Literatures 1 to 3).

[0003] Paper used for sheets such as banknotes is commonly made from vegetable fibers. Yet, paper made from synthetic fibers or a polymer sheet, which is a sheet made from a synthetic resin, may be used in order to improve the properties such as durability, water resistance, and security. Banknotes made from polymer sheets are called polymer banknotes. Sheets may have a variety of security characteristics. For example, some polymer banknotes have a clear window (transparent window) for anti-counterfeiting.

15 **[0004]** There are techniques to detect such sheets comprising a clear window. For example, Patent Literature 4 discloses a banknote detection device that reflects light emitted by an emitter element of an emission sensor on a side face of a case so as to obliquely transmit the light through the transport path for banknotes, and detects the transmitted light using a photodetector element. In this device, light emitted by the emitter element reaches the transparent portion of a banknote obliquely, so that part of the light is reflected by the transparent portion. This causes attenuation of light transmitted through the transparent portion, reducing the amount of light detected by the photodetector element. The device recognizes the transparent portion based on this amount of light.

20 **[0005]** Patent Literature 5 discloses a banknote detection device comprising a passage determination portion that comprises a through rate limiter, a sample hold circuit, a low-pass filter, and a comparator. The comparator compares a value of a processing signal generated by the through rate limiter with a second threshold based on a threshold reference value output from the low-pass filter so as to detect the presence or absence of a polymer banknote or a card.

CITATION LIST

30 - Patent Literature

[0006]

35 Patent Literature 1: JP 4723003 B
 Patent Literature 2: JP 3649879 B
 Patent Literature 3: JP 2576054 U
 Patent Literature 4: JP 2015-95023 A
 Patent Literature 5: JP 2015-138437 A

SUMMARY OF INVENTION

- Technical Problem

45 **[0007]** A transmissive optical sensor used as a sheet detection device typically comprises an emitter element configured to emit infrared light and a photodetector element configured to detect the infrared light emitted by the emitter element, from the viewpoints of availability and cost, for example. Such an optical sensor shows a transmissive state when no sheet is present, and shows a light-shielding state when a sheet blocks infrared light emitted by the emitter element. This mechanism is utilized to detect a sheet transported. However, in the case of a sheet comprising a transparent portion such as a clear window, infrared light passes through the transparent portion, and thus the optical sensor does not show a light-shielding state in response to the transparent portion. For example, polymer banknotes are typically made from a polypropylene sheet, and the polymer banknotes have an infrared light transmittance of approximately 90% in their clear windows. The polymer banknotes are therefore difficult to detect by the conventional regulation method for the optical sensor and the detection method utilizing transmission or blocking of infrared light. This is because conditions need to be considered, including output variation due to dust adhering to the optical sensor, regulation variation in regulating the optical sensor, and changes in environment such as the temperature. Hence, the optical sensor utilizing infrared light may falsely recognize one sheet as two sheets. This may cause defects such as a fake jam. The fake jam is a phenomenon caused by a factor such as abnormality of the optical sensor itself, where the sheet handling machine

determines that a jam occurred and stops even when a sheet is not actually jammed.

[0008] One measure to prevent such defects is, for example, to increase the number of the optical sensors. Meanwhile, more countries issue polymer banknotes. The polymer banknotes comprise a clear window at various positions, and some comprise a larger clear window than before. Also, some polymer banknotes comprise two or more clear windows. It has therefore been difficult to handle such various polymer banknotes of the individual countries by increasing the number of the optical sensors or improving the method of controlling the optical sensors. The same applies to cases of using the technique disclosed in Patent Literature 4 or 5.

[0009] In response to the above issues, an object of the present invention is to provide a sheet detection device capable of detecting a variety of sheets comprising a variety of transparent portions.

- Solution to Problem

[0010] One aspect of the present invention is a sheet detection device configured to detect a sheet transported along a transport path, the device comprising: at least one ultraviolet light source configured to apply ultraviolet light to the transport path; at least one photodetector configured to detect the ultraviolet light applied by the at least one ultraviolet light source; and a detector configured to detect the sheet based on an output signal from the photodetector.

[0011] In the above aspect of the present invention, the detector detects the sheet based on an attenuation rate of the output signal from the photodetector.

[0012] In the above aspect of the present invention, the detector detects the sheet based on an attenuation rate of the ultraviolet light applied by the at least one ultraviolet light source.

[0013] In the above aspect of the present invention, the at least one ultraviolet light source applies light having a peak wavelength in an ultraviolet range.

[0014] In the above aspect of the present invention, the at least one ultraviolet light source applies only ultraviolet light having a peak wavelength in an ultraviolet range.

[0015] In the above aspect of the present invention, the peak wavelength is 350 nm or shorter.

[0016] In the above aspect of the present invention, the peak wavelength is 280 nm or shorter.

[0017] In the above aspect of the present invention, the at least one ultraviolet light source comprises an ultraviolet LED as an emitter element.

[0018] In the above aspect of the present invention, the sheet to be detected is a sheet comprising a transparent portion that transmits light in a visible range.

[0019] In the above aspect of the present invention, the sheet detection device functions as a timing sensor of a sheet recognition device.

[0020] In the above aspect of the present invention, the sheet detection device is configured to detect a sheet transported inside a sheet handling machine.

[0021] In the above aspect of the present invention, the at least one ultraviolet light source comprises a plurality of ultraviolet light sources, the at least one photodetector comprises a plurality of photodetectors paired with the plurality of ultraviolet light sources, and the detector is configured to detect the sheet based on output signals from the plurality of photodetectors.

[0022] In the above aspect of the present invention, the at least one photodetector faces the at least one ultraviolet light source, and the sheet is transported between the at least one ultraviolet light source and the at least one photodetector.

[0023] In the above aspect of the present invention, the sheet detection device further comprises a reflector facing the at least one ultraviolet light source and the at least one photodetector, wherein the reflector is configured to reflect the ultraviolet light applied by the at least one ultraviolet light source to the at least one photodetector, and the sheet is transported between the at least one ultraviolet light source and the reflector and between the at least one photodetector and the reflector.

[0024] In the above aspect of the present invention, the reflector comprises at least one of fluorite or quartz glass.

[0025] In the above aspect of the present invention, the at least one ultraviolet light source comprises an emitter element configured to emit the ultraviolet light, and a protector containing at least one of fluorite or quartz glass and facing an emission surface of the emitter element.

[0026] In the above aspect of the present invention, the at least one photodetector contains a phosphor to be excited by the ultraviolet light applied by the ultraviolet light source and thereby emit visible light, and a photodetector element configured to detect the visible light emitted by the phosphor.

- Advantageous Effects of Invention

[0027] The sheet detection device of the present invention can detect a variety of sheets comprising a variety of transparent portions.

BRIEF DESCRIPTION OF DRAWINGS

[0028]

Fig. 1 is a schematic plan view of a preferred exemplary sheet that includes a transparent portion and is to be detected by a sheet detection device of Embodiment 1.

Fig. 2 is a schematic view showing the configuration of the sheet detection device of Embodiment 1.

Fig. 3 includes schematic views of an ultraviolet light source in Embodiment 1; Fig. 3(a) is a front view and Fig. 3(b) is a perspective view.

Fig. 4 is a graph of an exemplary emission spectrum of the ultraviolet light source in Embodiment 1.

Fig. 5 includes schematic views of a photodetector in Embodiment 1; Fig. 5(a) is a front view and Fig. 5(b) is a perspective view.

Fig. 6-1 is a graph of spectral transmittances of a variety of polymer banknotes detectable by the sheet detection device of Embodiment 1.

Fig. 6-2 is a graph of spectral transmittances of a variety of polymer banknotes detectable by the sheet detection device of Embodiment 1, which are different from the polymer banknotes in Fig. 6-1.

Fig. 7 is an enlarged superimposed graph of the spectral transmittances in Figs. 6-1 and 6-2 in a wavelength range of 220 to 500 nm.

Fig. 8 is a schematic perspective view showing the appearance of the sheet handling machine in Embodiment 1.

Fig. 9 is a view showing the outline of the internal configuration of the sheet handling machine in Embodiment 1.

Fig. 10 is a schematic view showing the configuration of a sheet detection device of Embodiment 2.

Fig. 11 is a schematic view showing the configuration of a sheet detection device of Embodiment 3.

Fig. 12 is a schematic view showing the configuration of a modified device of the sheet detection device of Embodiment 3.

DESCRIPTION OF EMBODIMENTS

(Embodiment 1)

Preferred embodiments of the sheet detection device of the present invention are described in detail with reference to the drawings. The sheet detection device of the present embodiment is used to detect sheets long-edge fed along a transport path.

[0030] Non-limiting examples of sheets to be detected by the sheet detection device of the present embodiment comprise banknotes, vouchers, checks, documents of value, and card-like media. The paper used for banknotes is mainly paper made from vegetable fibers. Still, in order to improve characteristics such as durability, water resistance, and security performance, paper made from synthetic fibers or a sheet of a synthetic resin, i.e., a polymer sheet, may be used. Banknotes made from a polymer sheet are called polymer banknotes.

[0031] The sheets to be detected may each comprise an opaque portion blocking light. Yet, the sheet preferably at least partially comprises a transparent portion transmitting at least light in the visible range (visible light). Such a transparent portion is preferably made from a synthetic resin such as polypropylene. Thus, the sheet to be detected is preferably formed from a polymer sheet. The sheet to be detected may also be a sheet (hybrid sheet) whose transparent portion is a polymer sheet and whose opaque portion is paper made from vegetable fibers or synthetic fibers.

[0032] An exemplary sheet preferred as a sheet to be detected by the sheet detection device of the present embodiment is described using Fig. 1. Fig. 1 shows that a sheet 1 has clear windows 2a and 2b as transparent portions 2 transmitting visible light at its lower left portion and right portion, respectively. The clear window 2a has an island shape and is surrounded by an opaque portion 3 blocking light. The clear window 2b has a belt shape and extends from one edge to the other edge of the sheet 1 in the short edge direction (corresponding to the transport direction in the present embodiment).

[0033] Each transparent portion 2 has a lower transmittance in the ultraviolet range (wavelength range of ultraviolet light) than in the visible range (wavelength range of visible light) and the infrared range (wavelength range of ultraviolet light). The spectral transmittance of the transparent portion 2 usually gradually decreases in the visible range and longer wavelength ranges than the visible range as the wavelength becomes shorter, but significantly decreases in a range from a wavelength of about 400 nm to a shorter wavelength (e.g., wavelength of substantially 250 nm) as the wavelength becomes shorter. The transmittance of the transparent portion 2 at a wavelength of 280 nm is usually 0% or higher and about 70% or lower. The transmittance of the transparent portion 2 transmitting visible light is usually 60% or higher and 95% or lower in the visible range. The transparent portion 2 may be coated with a material blocking infrared light. In this case, the spectral transmittance of the transparent portion 2 may have a negative peak (valley) with a depth of about 10 to 20% in the infrared range. The transparent portion 2 may partially include an optically variable element such as a

rainbow hologram. Yet, the transmittance characteristics described above are preferably of a region without such an optically variable element.

[0034] The ultraviolet light as used herein means light having a wavelength in the ultraviolet range. The ultraviolet range is preferably a wavelength range of about 200 nm or longer and about 400 nm or shorter.

[0035] The sheet detection device 10 of the present embodiment detects the sheet 1 comprising the transparent portion 2 based on the characteristic that, as described above, the sheet 1 has a significantly low ultraviolet light transmittance in the transparent portion 2. As shown in Fig. 2, the sheet detection device 10 comprises an ultraviolet light source 20 configured to apply ultraviolet light to a transparent path 11 along which the sheet 1 is transported; a photodetector 30 configured to detect the ultraviolet light applied by the ultraviolet light source 20; a detector 40 configured to detect the sheet based on an output signal from the photodetector 30; and a memory 41 configured to store data such as a variety of thresholds.

[0036] The ultraviolet light source 20 applies ultraviolet light to the transport path 11, and usually emits ultraviolet light within a predetermined angle range. As shown in Fig. 3, the ultraviolet light source 20 configured to emit ultraviolet light comprises an emitter element 21, a substrate (not illustrated) on which the emitter element 21 is mounted, a case 22 housing these members and protecting them, and a terminal 23 provided at an edge of the case 22.

[0037] Specific examples of the emitter element 21 comprise, but are not particularly limited to, light emitting diodes (LEDs), black light, mercury lamps, deuterium lamps, and plasma discharge tubes. Preferred are light emitting diodes, with ultraviolet light emitting diodes (ultraviolet LEDs), which have a peak wavelength λ_p in the ultraviolet range, being particularly preferred. Also, in the case where a laser diode (semiconductor laser) having a peak wavelength λ_p in the ultraviolet range is developed in the future, such a laser diode is also preferred as the emitter element 21. The peak wavelength λ_p as used herein means a wavelength at which the emission intensity is the maximum in the emission spectrum.

[0038] The case 22 comprises a substantially quadrilateral member 22a having a circular opening in its front part, a cylindrical member 22b coupled to the opening, and a protector 22c covering an opening in the cylindrical member 22b. The emission surface of the emitter element 21 faces the center of the protector 22c. Ultraviolet light emitted by the emitter element 21 travels to the outside through the protector 22c.

[0039] The substantially quadrilateral member 22a may be made of any material such as a resin, a metal, or a composite of these materials. The cylindrical member 22b and the protector 22c, which are to be irradiated with ultraviolet light, are preferably made of a material less likely to deteriorate under ultraviolet light. Specifically, the cylindrical member 22b is preferably made of a metal, and the protector 22c is preferably made of fluorite mainly containing CaF_2 (calcium fluoride) or quartz glass containing substantially only SiO_2 (glass with approximately 100% SiO_2 content).

[0040] Applying or emitting ultraviolet light herein means applying or emitting light comprising at least ultraviolet light. Hence, the ultraviolet light source 20 and the emitter element 21 may or may not apply or emit light other than ultraviolet light, such as visible light or infrared light, together with ultraviolet light. Yet, in order to increase the sheet detection accuracy, the ultraviolet light source 20 preferably applies light having a peak wavelength λ_p in the ultraviolet range, more preferably only ultraviolet light having a peak wavelength λ_p in the ultraviolet range. Applying only ultraviolet light having a peak wavelength λ_p in the ultraviolet range means applying substantially only the ultraviolet light (ultraviolet light having a peak wavelength λ_p in the ultraviolet range). Specifically, applying only ultraviolet light having a peak wavelength λ_p in the ultraviolet range means, as shown in Fig. 4, applying light having a peak wavelength λ_p in the ultraviolet range and having no emission peak in wavelength ranges other than the ultraviolet range, wherein the emission intensity of ultraviolet light at a wavelength of 400 nm is 20% or less (preferably 10% or less, more preferably 5% or less) of the emission intensity of the ultraviolet light at the peak wavelength λ_p . The light having a peak wavelength λ_p in the ultraviolet range may include light other than ultraviolet light, such as visible light or infrared light, but preferably has no emission peak in wavelength ranges other than the ultraviolet range.

[0041] The peak wavelength λ_p is preferably 350 nm or shorter, more preferably 280 nm or shorter. With a peak wavelength λ_p of 350 nm or shorter, polymer banknotes of some countries can be detected with a higher degree of accuracy. With a peak wavelength λ_p of 280 nm or shorter, all the polymer banknotes available as of the filing date of the present application can be detected with a higher degree of accuracy. The ultraviolet light source 20 therefore preferably applies ultraviolet light having a wavelength of 350 nm or shorter, more preferably ultraviolet light having a wavelength of 280 nm or shorter. The lower limit of the peak wavelength λ_p may be, but is not particularly limited to, 200 nm or longer.

[0042] In order to embody these preferred configurations easily, the emitter element 21 is preferably the above-described ultraviolet LED.

[0043] The photodetector 30 detects ultraviolet light emitted by the ultraviolet light source 20. As shown in Fig. 5, the photodetector 30 comprises a photodetector element 31, a substrate on which the photodetector element 31 is mounted (not shown), a case 32 housing these members and protecting them, and a terminal 33 provided at an edge of the case 32.

[0044] The photodetector element 31 detects ultraviolet light and output a signal corresponding to the detected amount of ultraviolet light. Specific examples of the photodetector element 31 comprise, but are not particularly limited to,

photodiodes (PDs), phototransistors (PTs), and solar cells. Preferred are photodiodes. Output signals (output current) from a photodiode detecting the applied ultraviolet light have high linearity, enabling detection of the sheet 1 comprising the transparent portion 2 with a higher degree of accuracy.

[0045] The case 32 has substantially the same shape and size as the case 22 of the ultraviolet light source 20, and comprises a substantially quadrilateral member 32a having a circular opening in its front part, a cylindrical member 32b coupled to the opening, and a protector 32c covering an opening in the cylindrical member 32b. The detection surface of the photodetector element 31 faces the center of the protector 32c. Ultraviolet light emitted by the emitter element 21 reaches the photodetector element 31 through the protector 32c.

[0046] The substantially quadrilateral member 32a may be made of any material such as a resin, a metal, or a mixture of these materials. The cylindrical member 32b and the protector 32c, which are to be irradiated with ultraviolet light, are preferably made of a material less likely to deteriorate under ultraviolet light. Specifically, the cylindrical member 32b is preferably made of a metal, and the protector 32c is preferably made of fluorite mainly containing CaF_2 (calcium fluoride) or quartz glass containing substantially only SiO_2 (glass with approximately 100% SiO_2 content).

[0047] The photodetector 30 faces the ultraviolet light source 20 with a predetermined space (e.g., 1 mm or more) in between. Each sheet 1 is transported between the ultraviolet light source 20 and the photodetector 30. The photodetector element 31 is preferably positioned on the optical axis of ultraviolet light emitted by the ultraviolet light source 20, but may not be positioned on the optical axis as long as the sheet 1 can be detected.

[0048] The detector 40 detects the sheet 1 based on the output signal from the photodetector 30. Specifically, when no sheet 1 is present in the direction in which ultraviolet light emitted by the ultraviolet light source 20 travels, the ultraviolet light is transmitted through the transport path 11 and detected by the photodetector 30 without being attenuated. When the transparent portion 2 or the opaque portion 3 of the sheet 1 is present in the direction in which ultraviolet light emitted by the ultraviolet light source 20 travels, at least part of the ultraviolet light is absorbed (blocked) by the transparent portion 2 or the opaque portion 3 of the sheet 1. The ultraviolet light transmitted through the transparent portion 2 or the opaque portion 3 is attenuated, and the attenuated ultraviolet light is detected by the photodetector 30. The amount of light detected by the photodetector 30 is smaller in the case where the transparent portion 2 or the opaque portion 3 of the sheet 1 is present in the direction in which ultraviolet light travels than in the case where no sheet 1 is present in the direction in which ultraviolet light travels. The output value, e.g., output current, from the photodetector 30 is lower in the former case than in the latter case. The detector 40 therefore can detect the sheet 1 based on the amount of light detected by the photodetector 30, i.e., the output signal from the photodetector 30.

[0049] The sheet detection device 10, utilizing ultraviolet light, can detect the sheet 1 comprising the transparent portion 2, regardless of the position, size, shape, or other conditions of the transparent portion 2. In other words, the sheet detection device 10 can detect a variety of sheets 1 comprising a variety of transparent portions 2.

[0050] The present embodiment enables detection of the sheet 1 as described above while eliminating the need to dispose a plurality of pairs of the ultraviolet light sources 20 and the photodetectors 30 at positions other than the positions where the transparent portion 2 of the sheet 1 passes. This can minimize the number of sensors used to detect the sheet 1.

[0051] The detector 40 preferably detects the sheet 1 based on the attenuation rate of the output signal from the photodetector 30. Specifically, in this case, the detector 40 obtains an output value from the photodetector 30 and stores the value as the initial value in the memory 41 before the sheet 1 is transported. The detector 40 then sequentially obtains output values from the photodetector 30 at predetermined intervals while the sheet 1 is transported. The detector 40 calculates the attenuation rate of each obtained output value relative to the initial value from the following formula.

$$\text{Attenuation rate (\%)} = (\text{initial value} - \text{output value}) / \text{initial value} \times 100$$

[0052] The detector 40 detects the sheet 1 by determining that the sheet 1 is present when the attenuation rate is equal to or higher than the threshold stored in the memory 41, and determining that no sheet 1 is present when the attenuation rate is lower than the threshold.

[0053] Likewise, the detector 40 may detect the sheet 1 based on the attenuation rate of ultraviolet light applied by the ultraviolet light source 20. In this case, the attenuation rate of ultraviolet light can be calculated using the transmittance of ultraviolet light as with the attenuation rate of the output signal from the photodetector 30.

[0054] The sheet detection device 10 comprises, as well as the members described above, members such as a known light source controller (not illustrated) configured to control emission from the ultraviolet light source 20, and a known output controller (not illustrated) configured to control the output from the photodetector 30.

[0055] Preferred examples of the application of the sheet detection device 10 comprise, but are not particularly limited to, timing sensors for a sheet recognition device, i.e., sensors used to determine when the sheet recognition device performs the recognition process. This can prevent the sheet recognition device from performing the recognition process for the sheet comprising a transparent portion at a wrong time. The preferred examples also comprise sensors configured

to detect sheets transported in the sheet handling machine. With such a sensor, defects such as a fake jam in the sheet handling machine can be prevented. The sheet detection device 10 is also preferably configured to detect at least one of passage, arrival, or presence of the sheet.

[0056] The recognition process performed by the sheet recognition device may be any process such as recognition of the type of a sheet (denomination in the case of a banknote), authentication of the sheet, determination of the fitness of the sheet, or reading of symbols, comprising numbers and characters printed on the sheet.

[0057] The spectral transmittances of the clear windows of polymer banknotes available as of the filing date of the present application were measured using a spectrophotometer (U-4000 from Hitachi, Ltd.), and the results are described using Figs. 6-1, 6-2, and 7. The measurement revealed that the transmittance decreases in the ultraviolet range as described above. The transmittances of polymer banknotes A and B from Country A and polymer banknotes C and D from Country B are each approximately 90% from the infrared range to around 400 nm in the ultraviolet range and attenuated significantly at a wavelength of 400 nm or shorter. The spectral transmittance of the clear window of each of the polymer banknotes A to D is similar to the spectral transmittance of polypropylene, which is a common material of polymer banknotes. In contrast, the transmittances of a polymer banknote E from Country C and polymer banknotes F to I from Country D are each attenuated gradually from the infrared range, and significantly around 400 nm. This is presumably because the polymer banknotes E to I are made of a composite material, not of pure polypropylene. These results show that changing the emission wavelength of the emitter element of the optical sensor from the infrared range to the ultraviolet range enables detection of the sheet using the inexpensive, simple configuration, which is a feature of the optical sensor technique, and the conventional control method, without being influenced by the transparent portion transmitting visible light. The results also show that with light having a wavelength of 400 nm or shorter, i.e., light in the ultraviolet range, the sheet can be detected based on transmission or blocking of light. The transmittance of the clear window at the center of the polymer banknote F is attenuated at some wavelengths in the infrared range because the clear window is coated to block infrared light.

[0058] In use of the sheet detection device 10 in an actual sheet handling machine, the transmittance of the transparent portion is preferably approximately 70% or lower in consideration of factors such as fluctuation attributed to the material of the sheet, sticking of dust, environmental changes, and adjustment errors of the optical sensor. Figs. 6-1, 6-2 and 7 show that use of light having a wavelength of 350 nm or shorter in the ultraviolet range enables detection of polymer banknotes from some countries with a higher degree of accuracy. The present inventors found that with light having a wavelength of 280 nm or shorter in the ultraviolet range, the transmittance of the clear window of every polymer banknote available as of the filing date of the present application, comprising the polymer banknotes shown in Figs. 6-1, 6-2, and 7, is approximately 70% or lower, allowing detection with a higher degree of accuracy.

[0059] The overall configuration of the sheet handling machine comprising the sheet detection device of the present embodiment is described using Figs. 8 and 9.

[0060] As shown in Fig. 8, a sheet handling machine 100 of the present embodiment comprises a hopper 101, two rejectors 102, an operation unit 103, a first overall display 104, a second overall display 105, four stackers 106, and four individual displays 107.

[0061] The hopper 101 receives a stack of sheets placed by an operator. The sheets placed on the hopper 101 are supposed to be fed into the sheet handling machine 100 by the later-described sheet feeding mechanism 110. Each rejector 102 is configured to feed out a sheet fed from the hopper 101 when the sheet is determined as a reject sheet (e.g., counterfeit note). One of the two rejectors 102 disposed at the lower position may be used to feed out a reject sheet such as a counterfeit note, for example, while the other rejector 102 disposed at the upper position may be used to keep a sheet which is recognized by the later-described sheet recognition device (recognition unit) 220 but fails to be classified.

[0062] The operation unit 103 has an input key used to receive commands from the operator. The first overall display 104 and the second overall display 105 are configured to display predetermined data (e.g., graphic data). Each stacker 106 is configured to stack a sheet that is fed from the hopper 101 by the sheet feeding mechanism 110 and has a certain attribute (e.g., denomination). Each individual display 107 is disposed for the corresponding stacker 106, and configured to display the number of sheets stacked in the corresponding stacker 106. Although Fig. 8 shows two rejectors 102, four stackers 106, and four individual displays 107, the numbers of these members are not limited to these and can be changed.

[0063] Fig. 9 mainly shows a transport system and a sensor system of the sheet handling machine 100. As shown in Fig. 9, the sheet handling machine 100 is provided inside with a transport path 201 configured to transport the sheets from the hopper 101 to the corresponding stackers 106. This transport path 201 is usually constituted by a combination of belt transport mechanisms. Various sensors 202 to 214 are placed along the transport path 201. The sensor 202, which is a sheet feed detection sensor, placed on the outlet of the hopper 101 and the sensor 203 placed on the inlet of a sheet recognition device 220 are configured to detect secure feeding of the sheets. The sheet recognition device 220 provided to the transport path 201 is constituted by a variety of detectors and configured to identify the characteristics such as the newness/oldness, fitness, authenticity, type (denomination in the case of banknotes), orientation, and face/back of the sheets fed from the hopper 101. The transport path 201 is provided with a timing sensor 204 in the

sheet recognition device 220.

[0064] Two diverters 231 are disposed in series downstream of the sheet recognition device 220 in the transport path 201. Each diverter 231 is configured to deliver, to the corresponding rejector 102, a sheet such as a sheet which fails to be recognized by the sheet recognition device 220 or a sheet which is recognized but fails to be classified. The sensors 205 and 206 are each configured to detect delivery of a sheet from the corresponding diverter 231 to the corresponding rejector 102. The transport conditions of a sheet to be classified are detected by the sensor 207, and this sheet is further transported in the transport path 201. Three diverters 232 to 234 are disposed in series downstream of the diverters 231 in the transport path 201. The diverters 232 to 234 are each configured to deliver, for example, the sheets transported from the diverters 231 to the corresponding stackers 106 among the four stackers 106 in accordance with characteristics of the sheets such as the denomination. Thereby, a sheet whose characteristic such as the denomination is recognized by the sheet recognition device 220 is stored in the corresponding stacker 106 among the four stackers 106. The sensors 208 to 214 are configured to detect whether or not the sheets are correctly classified into the corresponding stackers 106 from the transport path 201. Further, as shown in Fig. 9, the hopper 101 is provided with a sensor 215. This sensor 215 is configured to detect storage of a sheet in the hopper 101. The storage conditions of sheets in the stackers 106 are to be detected by residual sheet detection sensors 221 to 224.

[0065] The sheet feeding mechanism 110 is configured to deliver sheets stored in the hopper 101 one by one to the transport path 201 in the sheet handling machine 100.

[0066] The hopper 101 is configured to store sheets such that the sheets are stacked on the bottom of the hopper. As shown in Figs. 8 and 9, the hopper 101 is open at the top and the front (the right side in Fig. 9). Further, as mentioned above, the hopper 101 is provided with the sensor 215 configured to detect storage of even only a single sheet in the hopper 101.

[0067] The sheet feeding mechanism 110 comprises first kicker rollers 116 that are to be in contact with a face of a sheet at the bottom among a plurality of sheets stacked in the hopper 101, second kicker rollers 118 that are upstream of the first kicker rollers 116 in the direction of feeding the sheets, and feed rollers 112 that are downstream of the first kicker rollers 116 in the direction of feeding the sheets and are configured to feed the sheets discharged by the first kicker rollers 116. Gate rollers (reverse rollers) 114 are also disposed opposite to the feed rollers 112, and the feed rollers 112 and the gate rollers 114 constitute a gate therebetween. The sheets discharged by the first kicker rollers 116 are to be fed one by one through the gate into the transport path 201.

[0068] As shown in Fig. 9, the sheet feed detection sensor 202 disposed at the outlet of the sheet feeding mechanism 110 is configured to detect a trouble such as a jam in feeding of sheets by the sheet feeding mechanism 110. Specifically, this sheet feed detection sensor 202 is configured to detect occurrence of a trouble such as a jam in feeding of sheets by the sheet feeding mechanism 110 when the sheet feed detection sensor 202 fails to detect feeding of a sheet even after a predetermined feeding error detection period has passed from when it detected feeding of the previous sheet during feeding of sheets by the sheet feeding mechanism 110.

[0069] The sensors 202 to 214 and 221 to 224 are each constituted by the sheet detection device 10 described above, and therefore can detect a sheet even when the sheet comprises a transparent portion transmitting visible light.

(Embodiment 2)

[0070] In the present embodiment, the features unique to the present embodiment are mainly described, and the same contents as those in Embodiment 1 are not elaborated upon here. The components having a similar or the same function in both the present embodiment and Embodiment 1 are provided with the same reference sign, and these components are not elaborated upon in the present embodiment. The present embodiment is substantially the same as Embodiment 1, except for the following points.

[0071] As shown in Fig. 10, the sheet detection device of the present embodiment comprises a plurality of pairs of the ultraviolet light sources 20 and the photodetectors 30, and the detector 40 is configured to detect the sheets 1 based on the output signals from the photodetectors 30. The sheet detection device of the present embodiment therefore can properly detect arrival of the sheet 1 even when the sheet 1 is delivered with a significantly high degree of skew.

(Embodiment 3)

[0072] In the present embodiment, the features unique to the present embodiment are mainly described, and the same contents as those in Embodiment 1 are not elaborated upon here. The components having a similar or the same function in both the present embodiment and Embodiment 1 are provided with the same reference sign, and these components are not elaborated upon in the present embodiment. The present embodiment is substantially the same as Embodiment 1, except for the following points.

[0073] As shown in Fig. 11, in the present embodiment, the ultraviolet light source 20 and the photodetector 30 are disposed on the same side of the transport path 11 with a predetermined space in between along the transport direction

of the sheets 1. A reflector 50 is disposed on the opposite side of the transport path 11. The sheets 1 are sequentially transported between the ultraviolet light source 20 and the reflector 50 and between the photodetector 30 and the reflector 50.

[0074] The reflector 50 is a prism and has a first face 50a on which ultraviolet light emitted by the ultraviolet light source 20 is to be incident, a second face 50b configured to reflect the ultraviolet light incident on the first face 50a toward a third face 50c, and the third face 50c configured to reflect the ultraviolet light reflected on the second face 50b toward the first face. Thus, the ultraviolet light emitted by the ultraviolet light source 20 passes through the transport path 11, travels within the reflector 50, passes through the transport path 11 again, and eventually reaches the photodetector 30. The present embodiment also enables detection of the sheet 1 based on transmission or blocking of ultraviolet light as in Embodiment 1.

[0075] The reflector 50, which is to be irradiated with ultraviolet light, is preferably made of a material less likely to deteriorate under ultraviolet light. Specifically, the reflector 50 is preferably made of fluorite mainly containing CaF_2 (calcium fluoride) or quartz glass containing substantially only SiO_2 (glass with approximately 100% SiO_2 content).

[0076] In the present embodiment, the sheet 1 may be transported from the photodetector 30 side to the ultraviolet light source 20 side as shown in Fig. 11 or may be transported in the opposite direction.

[0077] As shown in Fig. 12, the ultraviolet light source 20 and the photodetector 30 may be disposed in the direction crossing the transport direction of the sheet 1, or in the direction perpendicular to the transport direction of the sheets 1, i.e., in the width direction of the transport path 11. This enables detection of arrival of the sheet 1 transported with a significantly high degree of skew as in Embodiment 2 using only one pair of the ultraviolet light source 20 and the photodetector 30.

[0078] Also, the reflector 50 may not be a prism and may be constituted by a mirror.

(Embodiment 4)

[0079] In the present embodiment, the features unique to the present embodiment are mainly described, and the same contents as those in Embodiment 1 are not elaborated upon here. The components having a similar or the same function in both the present embodiment and Embodiment 1 are provided with the same reference sign, and these components are not elaborated upon in the present embodiment. The present embodiment is substantially the same as Embodiment 1, except for the following points.

[0080] In the present embodiment, the photodetector 30 contains a phosphor to be excited by ultraviolet light applied by the ultraviolet light source 20 and thereby emit visible light. The photodetector element 31 is configured to detect the visible light emitted by the phosphor and output a signal corresponding to the detected amount of the visible light.

[0081] The present embodiment also enables detection of the sheet 1 based on transmission or blocking of ultraviolet light as in Embodiment 1. This provides more options for the photodetector element 31 since any material reactive to visible light is usable as the photodetector element 31.

[0082] As described above, the sheet detection devices 10 of the above embodiments each comprise at least one ultraviolet light source 20 configured to apply ultraviolet light to the transport path 11 or 201; at least one photodetector 30 configured to detect the ultraviolet light applied by the ultraviolet light source 20; and the detector 40 configured to detect the sheet based on an output signal from the photodetector 30. This enables detection of a sheet that is to be detected and transported along the transport path 11 or 201 even when the sheet includes a transparent portion transmitting visible light. This is because ultraviolet light can be blocked by the transparent portion as well as the opaque portion of the sheet. The sheet detection device 10 therefore can detect the sheet including a transparent portion regardless of the position, size, shape, or other conditions of the transparent portion. In other words, the sheet detection device 10 can detect a variety of sheets including a variety of transparent portions.

[0083] In the above embodiments, the ultraviolet light source 20 applies light having a peak wavelength λ_p in the ultraviolet range or only ultraviolet light having a peak wavelength λ_p in the ultraviolet range. This can increase the detection accuracy of the sheets.

[0084] In the above embodiments, the peak wavelength λ_p is 350 nm or shorter. This enables detection of polymer banknotes from some countries with a higher degree of accuracy.

[0085] In the above embodiments, the peak wavelength λ_p is 280 nm or shorter. This enables detection of all the polymer banknotes available as of the filing date of the present application with a higher degree of accuracy.

[0086] In the above embodiments, the ultraviolet light source 20 includes an ultraviolet LED as an emitter element. This enables easy embodiment of these preferred configurations.

[0087] In the above embodiments, the sheet detection device 10 functions as a timing sensor of the sheet recognition device 220. This can prevent the sheet recognition device 220 from performing the recognition process for a sheet to be detected at a wrong time even when the sheet includes a transparent portion transmitting visible light.

[0088] In the above embodiments, the sheet detection device 10 detects a sheet transported inside the sheet handling machine 100. This can prevent defects such as a fake jam in the sheet handling machine 100.

[0089] In the above embodiments, the sheet detection device 10 comprises a plurality of pairs of the ultraviolet light sources 20 and the photodetectors 30, and the detector 40 detects sheets based on the output signals from the photodetectors 30. This enables detection of arrival of a sheet even when the sheet is transported with a significantly high degree of skew.

[0090] In the above embodiments, the ultraviolet light source 20 comprises the emitter element 21 configured to emit ultraviolet light and the protector 22c containing at least one of fluorite or quartz glass and facing the emission surface of the emitter element 21. This enables protection of the emitter element 21 using the protector 22c while reducing or eliminating deterioration of the protector 22c due to ultraviolet light.

[0091] In the above embodiments, the photodetector 30 contains a phosphor to be excited by the ultraviolet light applied by the ultraviolet light source 20 and thereby emit visible light, and the photodetector element 31 configured to detect the visible light emitted by the phosphor. This provides more options for the photodetector element 31 since any material reactive to visible light is usable as the photodetector element 31.

(Variation)

[0092] Although the cases were described in the above embodiments where the sheets 1 are long edge fed, the sheets 1 may be short edge fed. This embodiment is preferred in the case where the transparent portion 2 is provided from one edge to the other edge of each sheet 1 in the transport direction (long edge direction).

INDUSTRIAL APPLICABILITY

[0093] As described above, the present invention provides a useful technique to detect a sheet including a transparent portion transmitting visible light.

REFERENCE SIGNS LIST

[0094]

1:	sheet
2:	transparent portion
2a, 2b:	clear window
3:	opaque portion
10:	sheet detection device
11, 201:	transport path
20:	ultraviolet light source
21:	emitter element
22, 32:	case
22a, 32a:	substantially quadrilateral member
22b, 32b:	cylindrical member
22c, 32c:	protector
23, 33:	terminal
30:	photodetector
31:	photodetector element
40:	detector
41:	memory
50:	reflector
50a:	first face
50b:	second face
50c:	third face
100:	sheet handling machine
101:	hopper
102:	rejector
103:	operation unit
104:	first overall display
105:	second overall display
106:	stacker
107:	individual display
110:	sheet feeding mechanism

112: feed roller
 114: gate roller (reverse roller)
 116: first kicker roller
 118: second kicker roller
 5 202 to 215: sensor
 220: sheet recognition device (recognition unit)
 221 to 224: residual sheet detection sensor
 231 to 234: diverter

Claims

1. A sheet detection device configured to detect a sheet transported along a transport path, the device comprising:
 - 15 at least one ultraviolet light source configured to apply ultraviolet light to the transport path;
 - at least one photodetector configured to detect the ultraviolet light applied by the at least one ultraviolet light source; and
 - a detector configured to detect the sheet based on an output signal from the photodetector.
- 20 2. The sheet detection device according to claim 1, wherein the detector detects the sheet based on an attenuation rate of the output signal from the photodetector.
3. The sheet detection device according to claim 1 or 2, wherein the detector detects the sheet based on an attenuation rate of the ultraviolet light applied by the at least
 - 25 one ultraviolet light source.
4. The sheet detection device according to any one of claims 1 to 3, wherein the at least one ultraviolet light source applies light having a peak wavelength in an ultraviolet range.
- 30 5. The sheet detection device according to any one of claims 1 to 4, wherein the at least one ultraviolet light source applies only ultraviolet light having a peak wavelength in an ultraviolet range.
6. The sheet detection device according to claim 4 or 5,
 - 35 wherein the peak wavelength is 350 nm or shorter.
7. The sheet detection device according to claim 6, wherein the peak wavelength is 280 nm or shorter.
- 40 8. The sheet detection device according to any one of claims 1 to 7, wherein the at least one ultraviolet light source comprises an ultraviolet LED as an emitter element.
9. The sheet detection device according to any one of claims 1 to 8, wherein the sheet to be detected is a sheet comprising a transparent portion that transmits light in a visible range.
- 45 10. The sheet detection device according to any one of claims 1 to 9, which functions as a timing sensor of a sheet recognition device.
11. The sheet detection device according to any one of claims 1 to 10, which is configured to detect a sheet transported
 - 50 inside a sheet handling machine.
12. The sheet detection device according to any one of claims 1 to 11, wherein the at least one ultraviolet light source comprises a plurality of ultraviolet light sources, the at least one photodetector comprises a plurality of photodetectors paired with the plurality of ultraviolet light
 - 55 sources, and
 - the detector is configured to detect the sheet based on output signals from the plurality of photodetectors.
13. The sheet detection device according to any one of claims 1 to 12,

wherein the at least one photodetector faces the at least one ultraviolet light source, and
the sheet is transported between the at least one ultraviolet light source and the at least one photodetector.

5 **14.** The sheet detection device according to any one of claims 1 to 12, further comprising a reflector facing the at least
one ultraviolet light source and the at least one photodetector,
wherein the reflector is configured to reflect the ultraviolet light applied by the at least one ultraviolet light source to
the at least one photodetector, and
the sheet is transported between the at least one ultraviolet light source and the reflector and between the at least
10 one photodetector and the reflector.

15 **15.** The sheet detection device according to claim 14,
wherein the reflector comprises at least one of fluorite or quartz glass.

16 **16.** The sheet detection device according to any one of claims 1 to 15,
15 wherein the at least one ultraviolet light source comprises
an emitter element configured to emit the ultraviolet light, and
a protector containing at least one of fluorite or quartz glass and facing an emission surface of the emitter element.

20 **17.** The sheet detection device according to any one of claims 1 to 16,
wherein the at least one photodetector includes
a phosphor to be excited by the ultraviolet light applied by the ultraviolet light source and thereby emit visible light, and
a photodetector element configured to detect the visible light emitted by the phosphor.

FIG.1

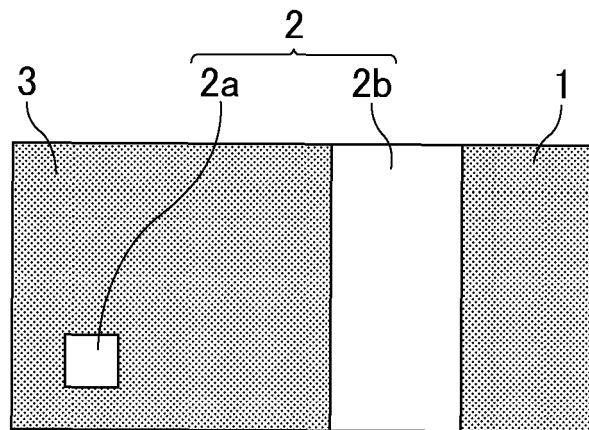


FIG.2

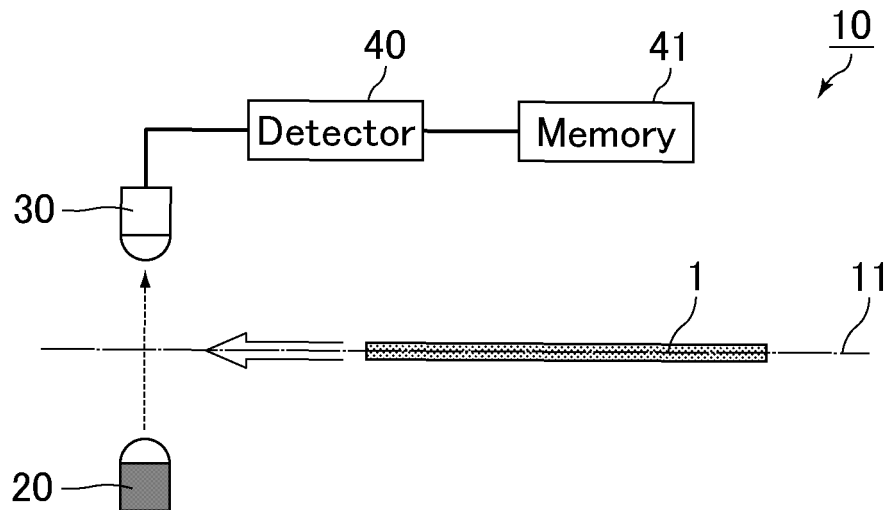
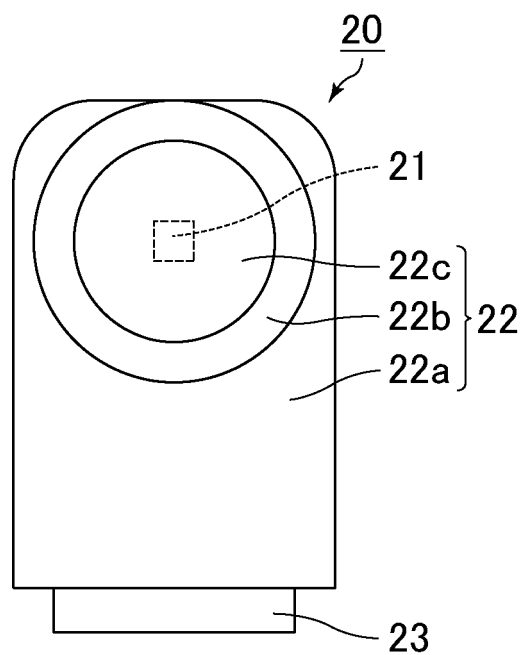


FIG.3

(a)



(b)

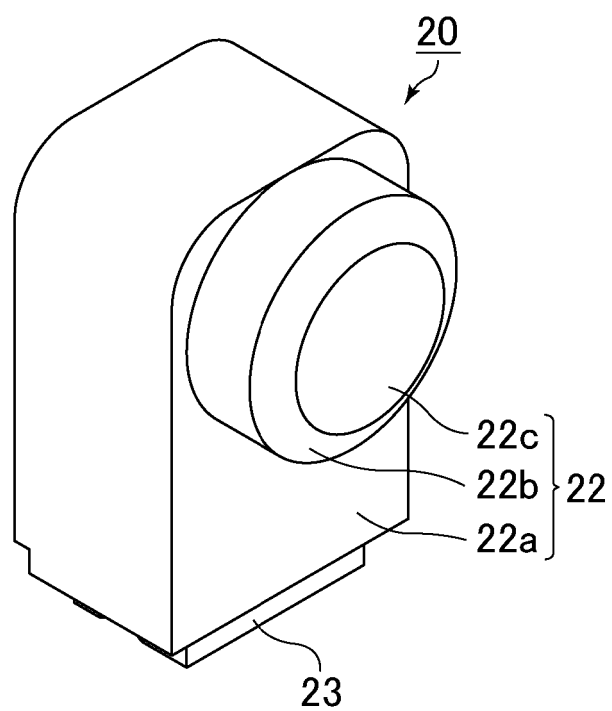


FIG.4

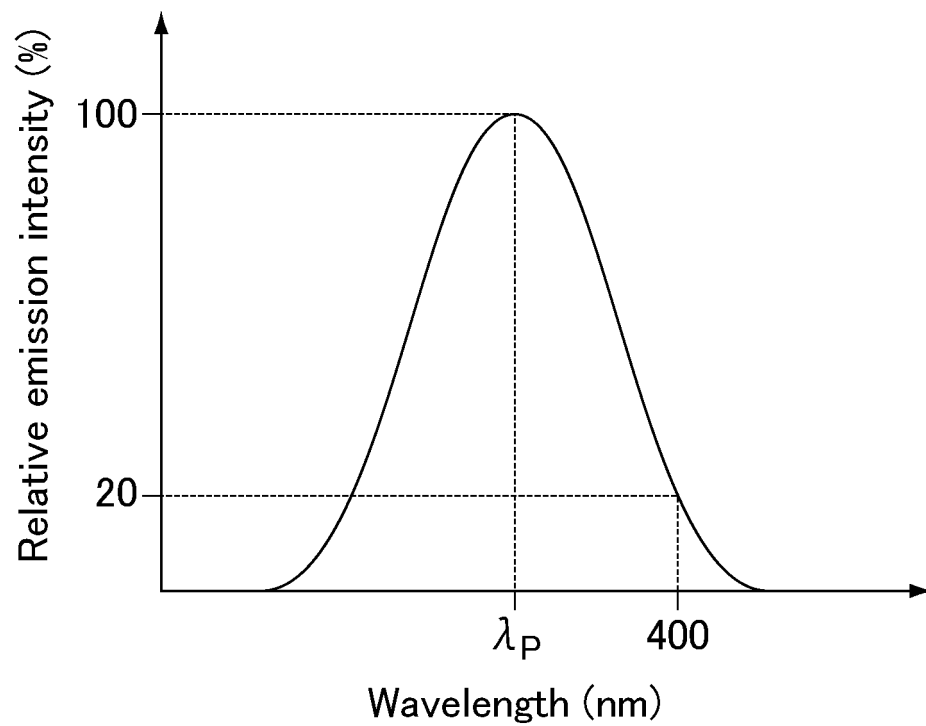
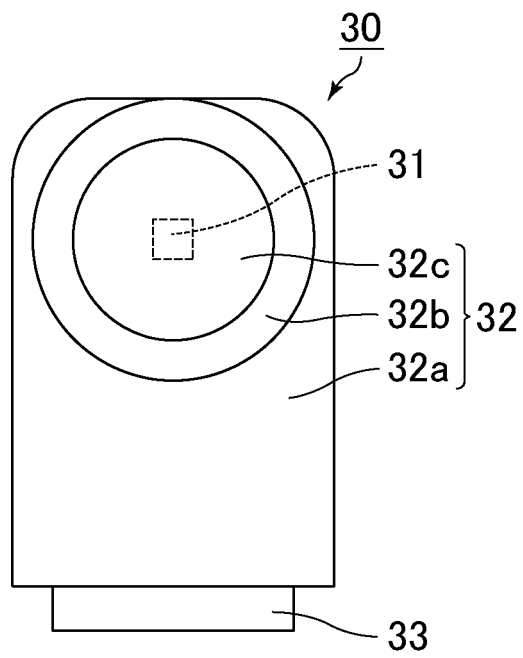


FIG.5

(a)



(b)

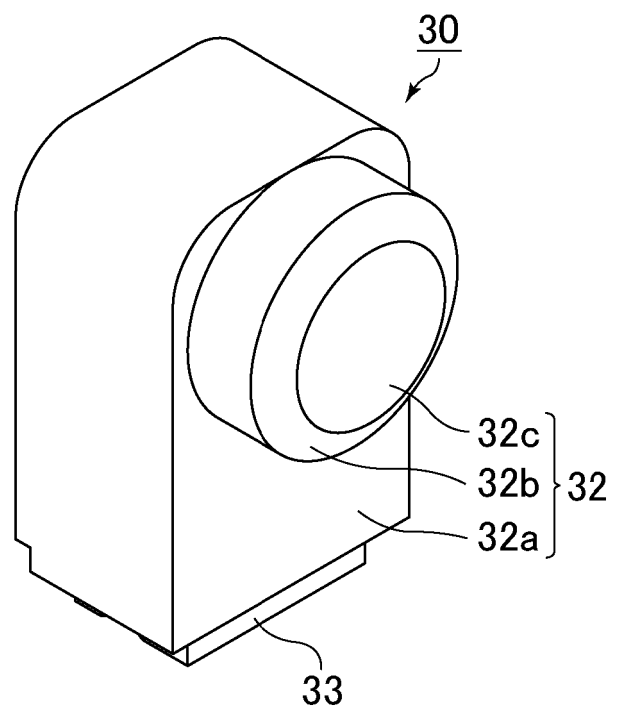


FIG.6-1

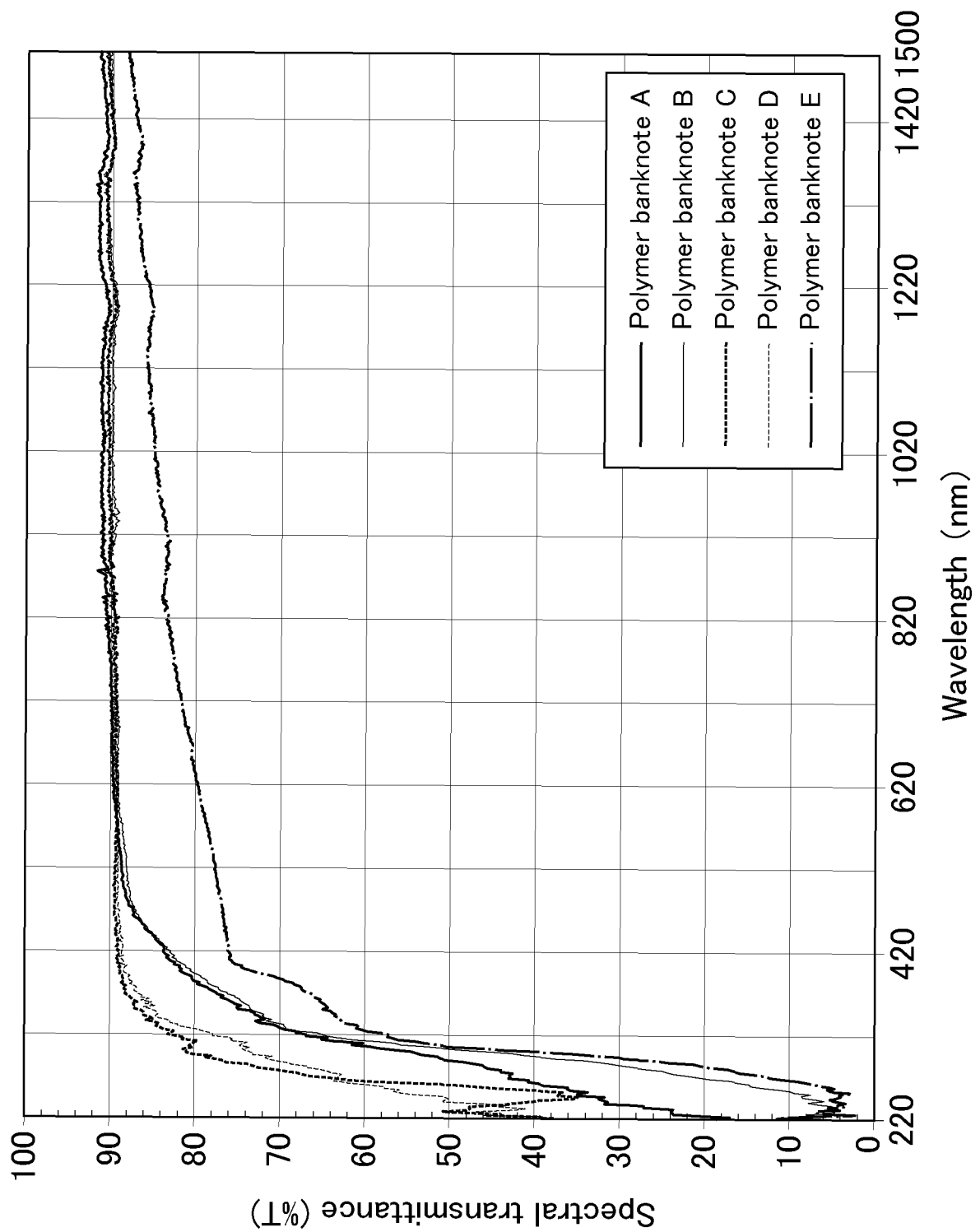


FIG.6-2

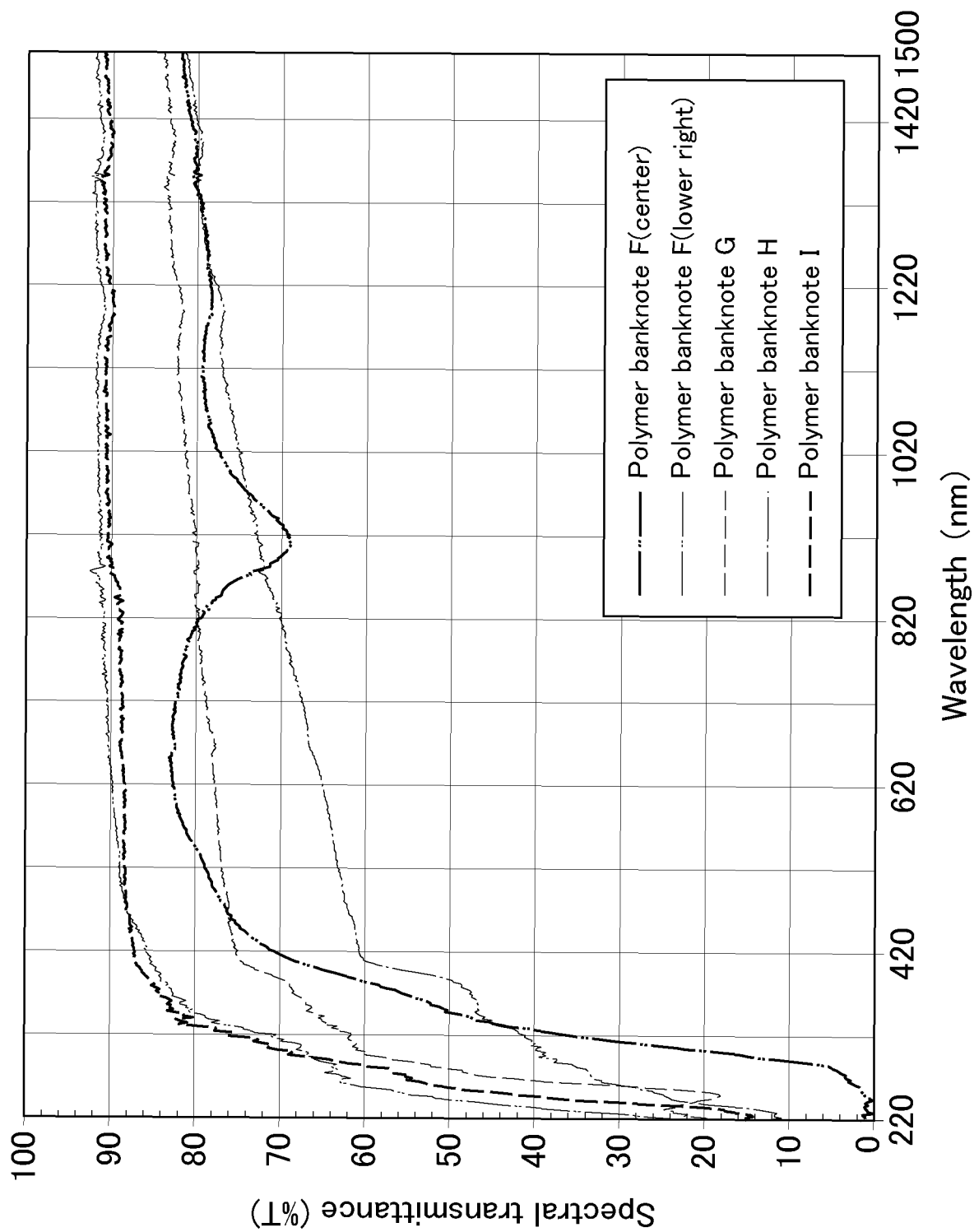


FIG. 7

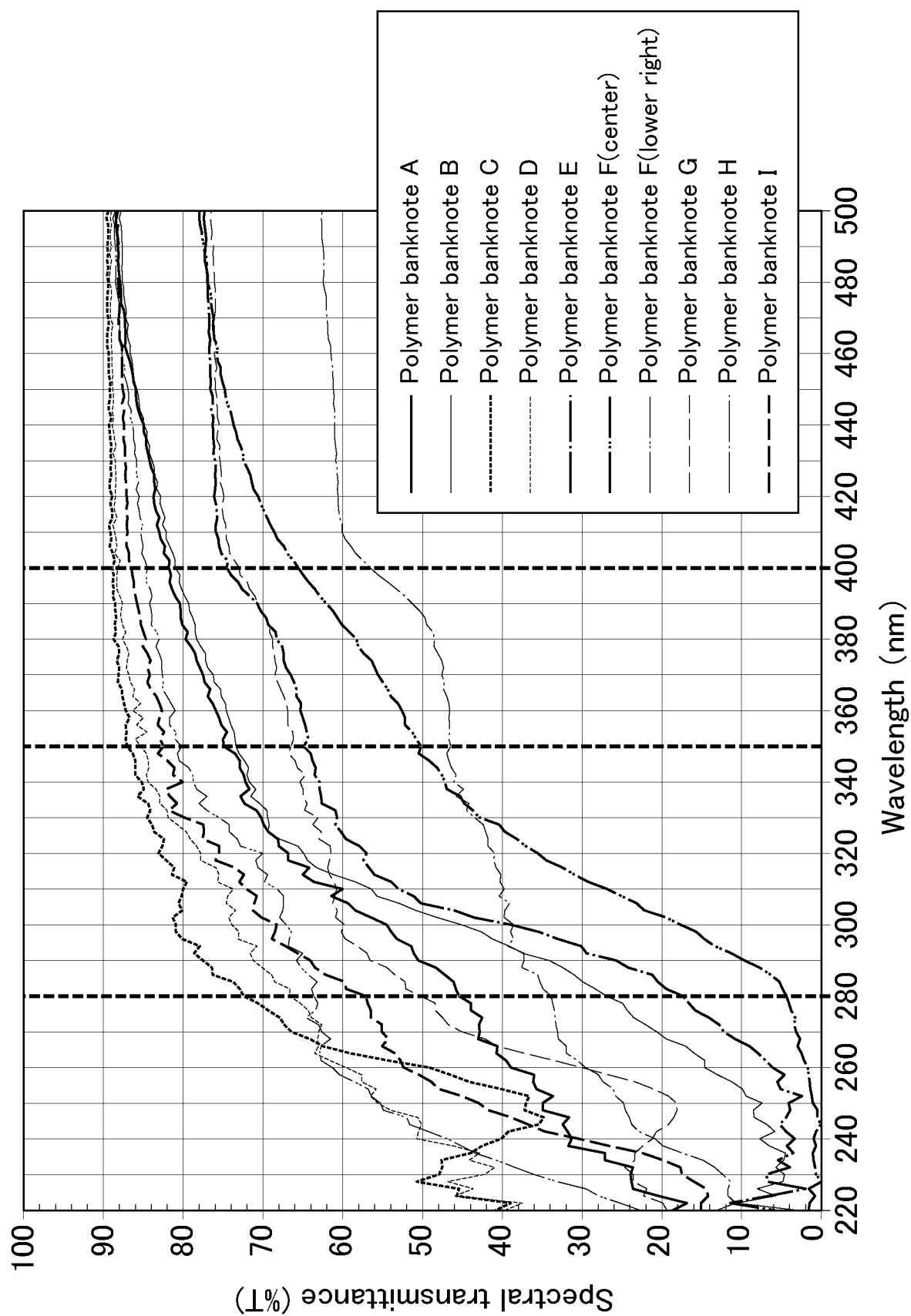


FIG.8

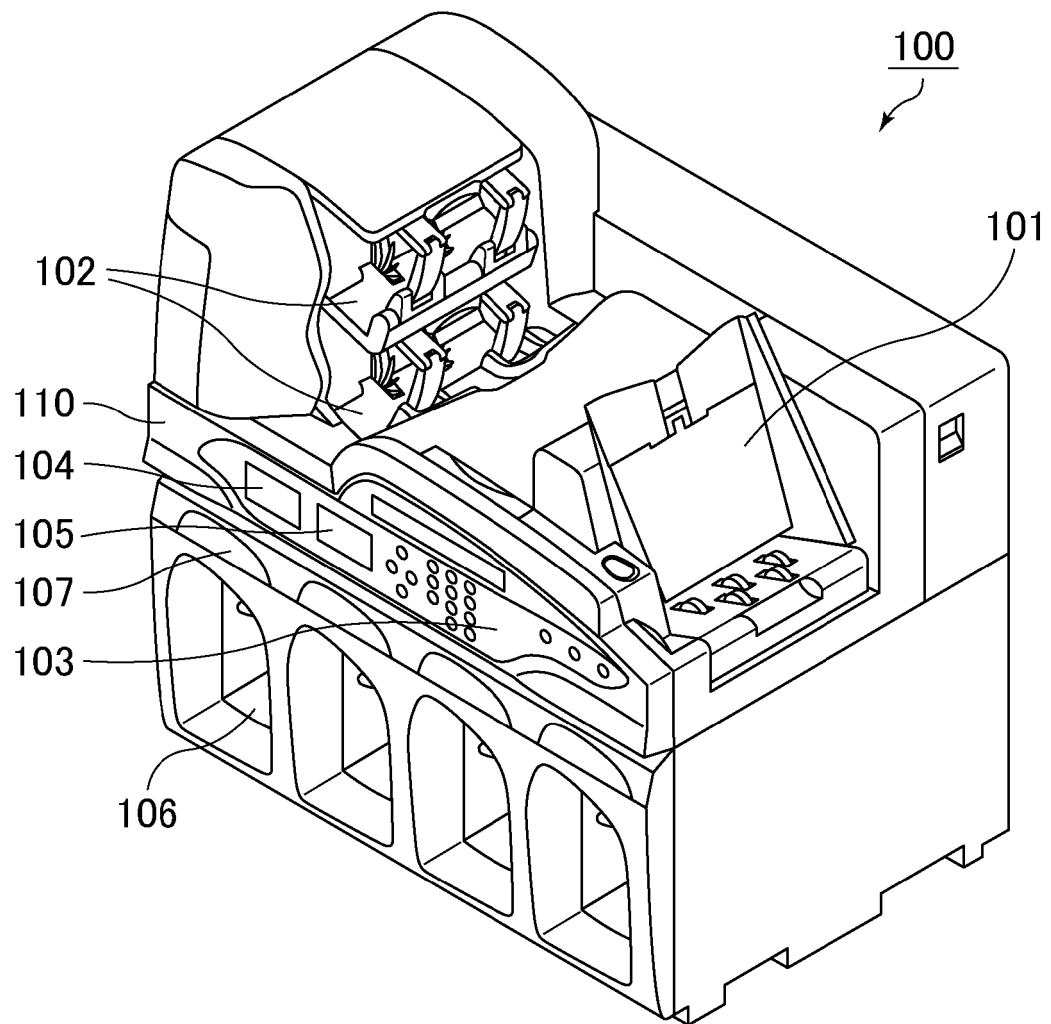


FIG. 9

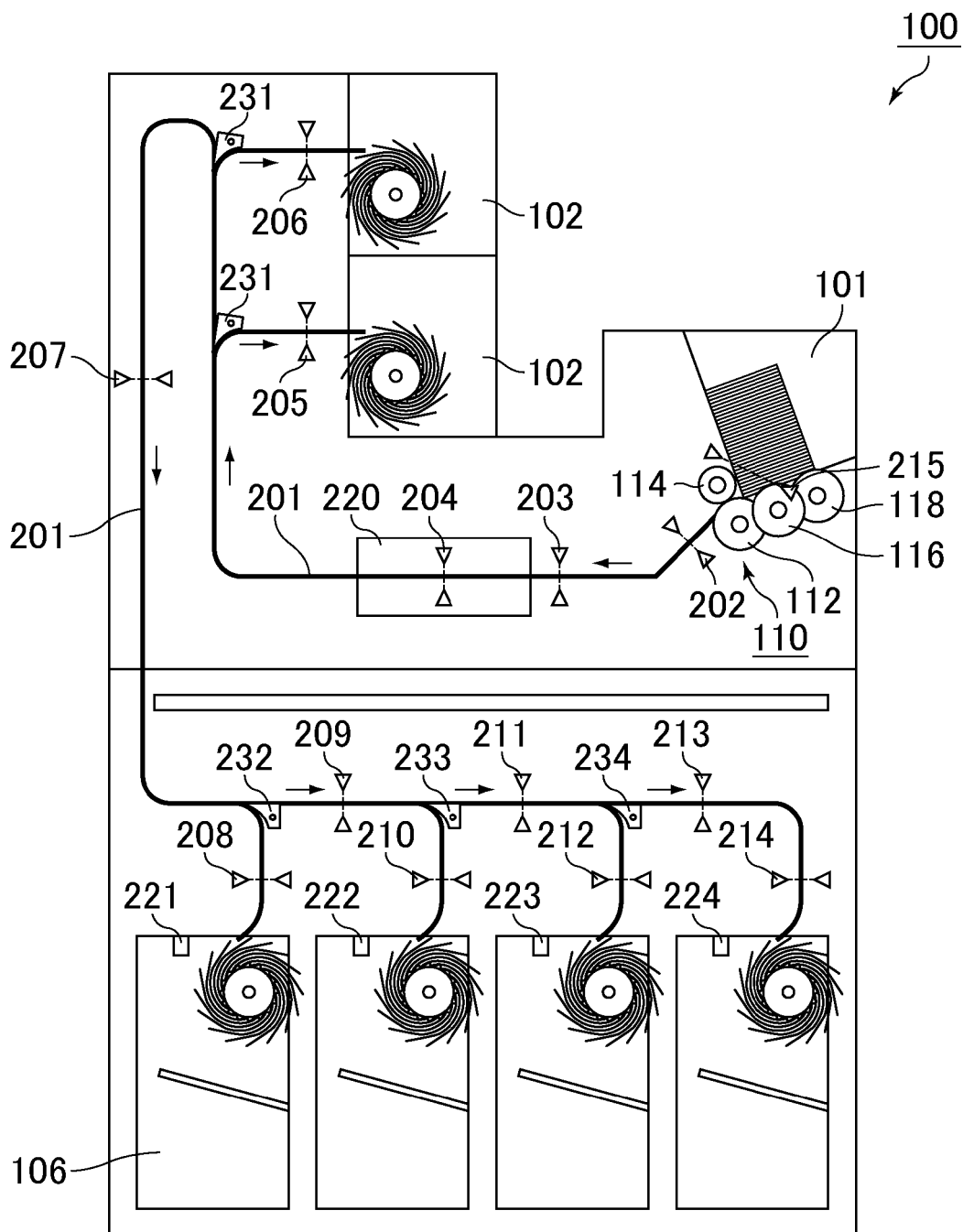


FIG.10

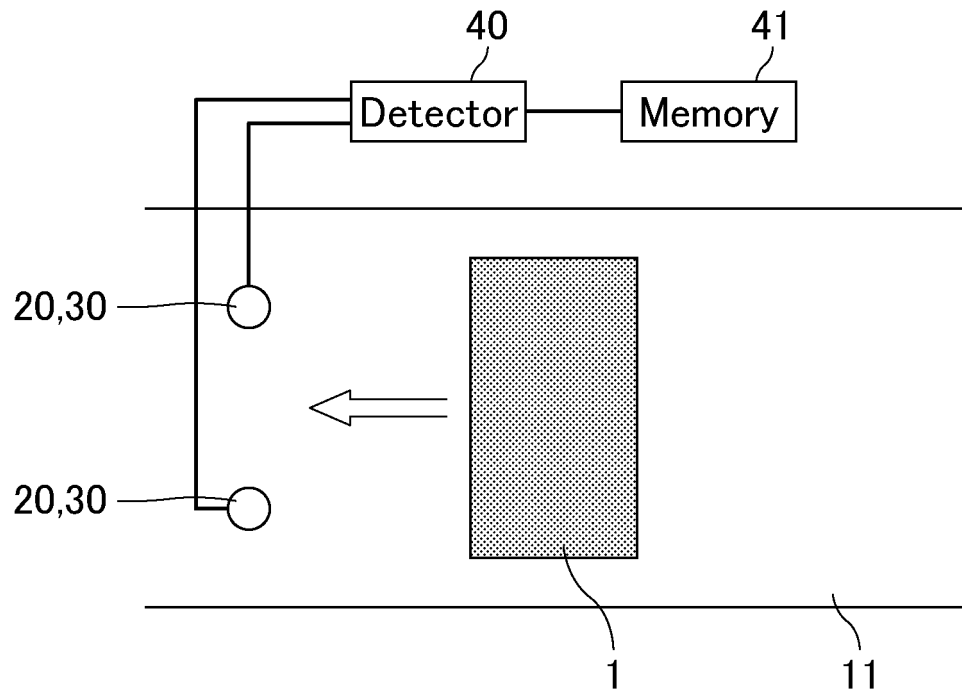


FIG.11

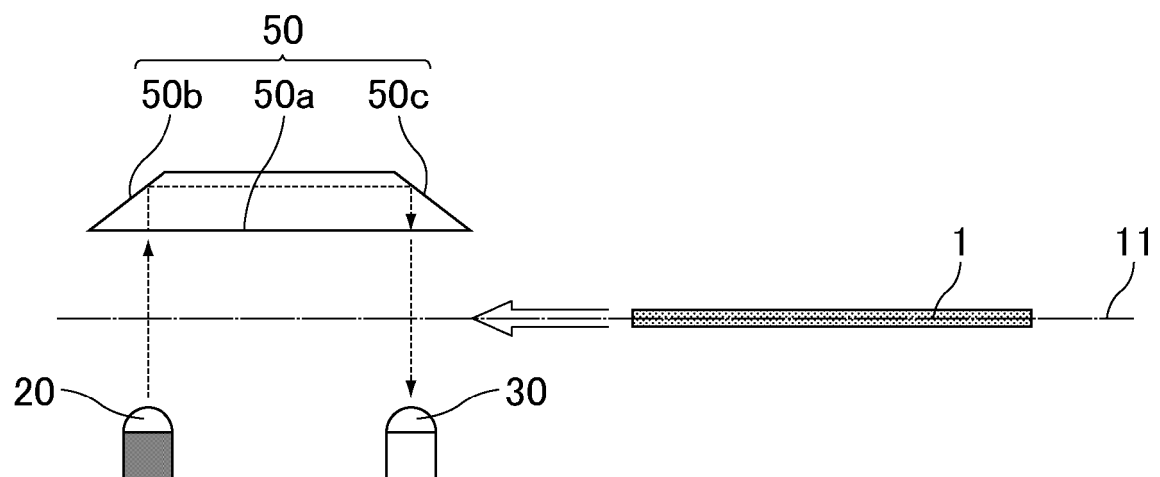
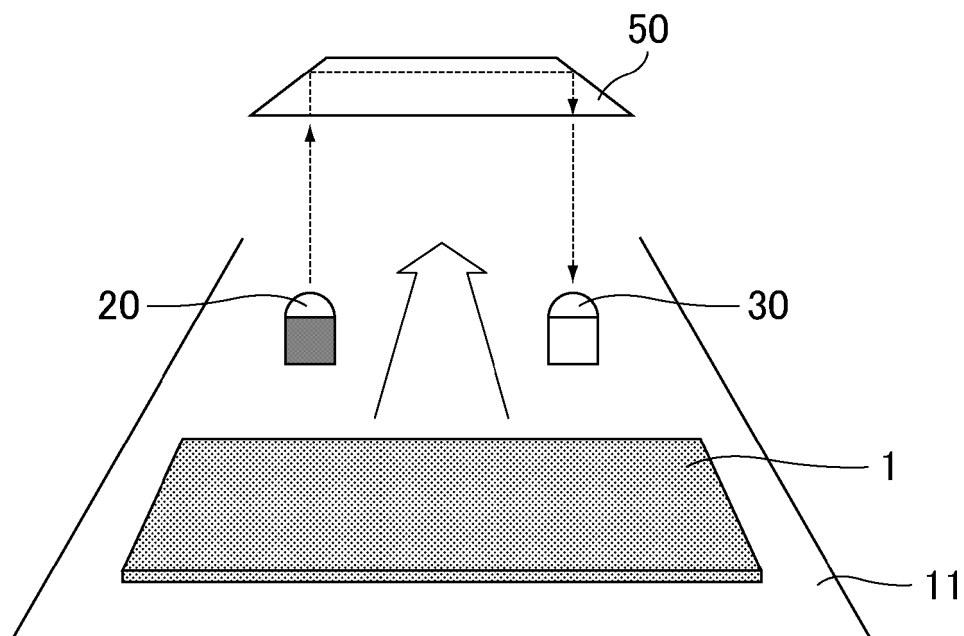


FIG.12



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/025116

A. CLASSIFICATION OF SUBJECT MATTER

G07D9/00(2006.01)i, G01N21/33(2006.01)i, G01N21/59(2006.01)i, G07D7/12
(2016.01)i, G07D7/121(2016.01)i

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)
G07D9/00, G01N21/33, G01N21/59, G07D7/12, G07D7/121

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2017
Kokai Jitsuyo Shinan Koho 1971-2017 Toroku Jitsuyo Shinan Koho 1994-2017

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.
Y A	JP 2009-140389 A (Panasonic Corp.), 25 June 2009 (25.06.2009), paragraphs [0001] to [0062]; fig. 1 to 6 (Family: none)	1, 4-15, 17 2-3, 16
Y A	JP 2001-357429 A (Glory Ltd.), 26 December 2001 (26.12.2001), paragraphs [0001] to [0028]; fig. 1 to 19 (Family: none)	1, 4-15, 17 2-3, 16
Y A	JP 2014-199242 A (Vienex Corp.), 23 October 2014 (23.10.2014), paragraphs [0001] to [0059]; fig. 1 to 6 (Family: none)	4-15, 17 1-3, 16

☒ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search
04 August 2017 (04.08.17)

Date of mailing of the international search report
22 August 2017 (22.08.17)

Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/025116

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2014-29301 A (Nidec Copal Corp.), 13 February 2014 (13.02.2014), paragraphs [0001] to [0050]; fig. 1 to 16 (Family: none)	9-15,17 1-8,16
Y A	JP 2016-141065 A (Toppan Printing Co., Ltd.), 08 August 2016 (08.08.2016), paragraphs [0001] to [0086]; fig. 1 to 16 (Family: none)	10-15,17 1-9,16
Y A	JP 2000-285278 A (Fujitsu Kiden Ltd.), 13 October 2000 (13.10.2000), paragraphs [0001] to [0050]; fig. 1 to 9 (Family: none)	14-15,17 1-13,16
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Y A	JP 10-40436 A (The Furukawa Electric Co., Ltd.), 13 February 1998 (13.02.1998), paragraphs [0001] to [0021]; fig. 1 to 3 (Family: none)	17 1-16
A	JP 10-142163 A (Mitsubishi Plastics, Inc.), 29 May 1998 (29.05.1998), paragraphs [0001] to [0020]; fig. 1 (Family: none)	1-17

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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