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(54) **GENUINE/COUNTERFEIT DISTINGUISHING UNIT, GENUINE/COUNTERFEIT DISTINGUISHING METHOD, AND FLUORESCENT SENSOR**

(57) Fluorescent substances having similar peak wavelengths for fluorescence excited by irradiation of excitation light are to be detected in distinction. In order to solve this issue, a UV_LED irradiates excitation light to a leaf of paper, a first light-reception unit receives light having a first wavelength range that includes the peak wavelength of fluorescence excited by a fluorescent substance due to irradiation of excitation light, and a second light-reception unit receives light emitted from the same area as the area on the leaf of paper that emitted light to

be received by the first light-reception unit, said light having a second wavelength range that is positioned near the first wavelength range. Then, a fluorescent substance specifying unit specifies the type of fluorescent substance added to the leaf of paper on the basis of outputs from the first light-reception unit and the second light-reception unit, and an evaluation unit evaluates whether the leaf of paper is genuine or counterfeit on the basis of the result evaluated by the fluorescent substance specifying unit.

FIG.4A

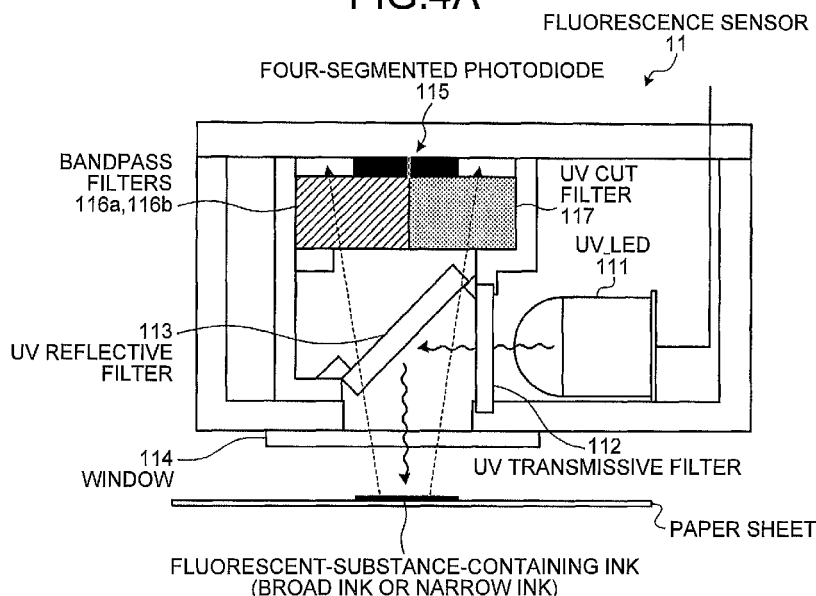
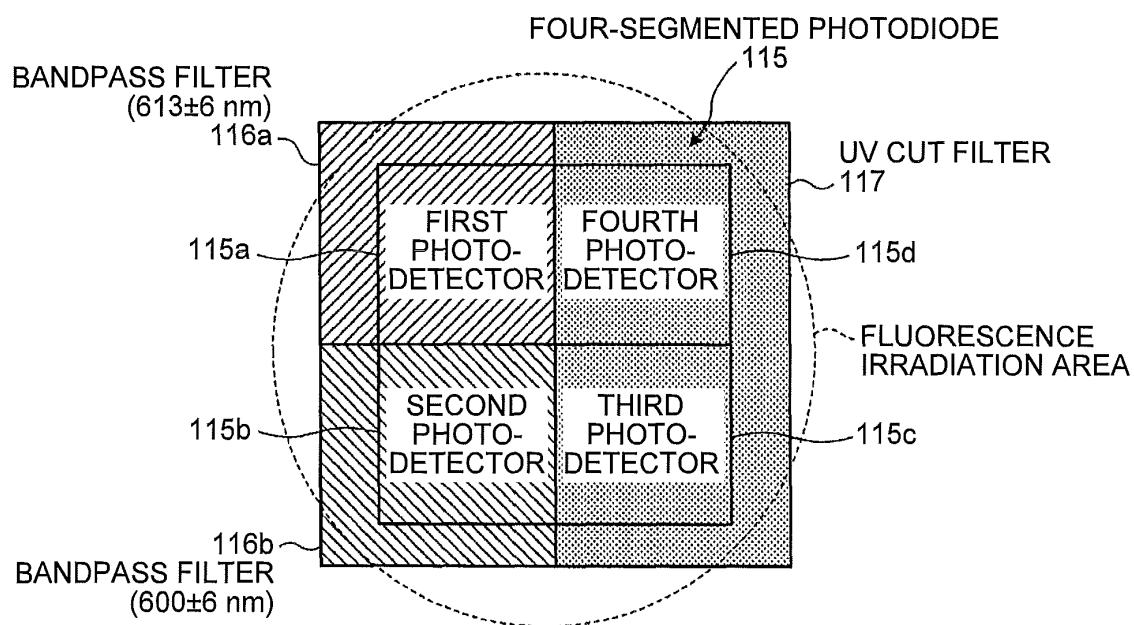


FIG.4B



Description

[Conventional Art Documents]

TECHNICAL FIELD

[Patent Documents]

[0001] The present invention relates to an authentication apparatus, an authentication method, and a fluorescence sensor that are used for determining authenticity of paper sheets containing a fluorescent substance. The present invention particularly relates to an authentication apparatus, an authentication method, and a fluorescence sensor that can differentiate and detect fluorescent substances that, when excited by irradiation of an excitation light, output fluorescent lights having peak wavelengths that are near each other.

BACKGROUND ART

[0002] Authentication apparatuses that use a transport mechanism to transport paper sheets, such as, gift vouchers and an optical sensor that transmits and receives a visible light, infrared light, etc., to determine authenticity of the paper sheets being transported are known in the art.

[0003] In recent times, characters or designs have come to be printed onto paper sheets with a fluorescent-substance-containing ink which is not verifiable by naked eye to prevent counterfeiting. When irradiated with a predetermined excitation light (for example, ultraviolet light), the fluorescent-substance-containing ink emits fluorescent light having a peak wavelength that depends on the type of the fluorescent substance contained in the ink.

[0004] This has led to presentation of authentication apparatuses that make use of this characteristics of the fluorescent-substance-containing ink. Specifically, a paper sheet already having a latent image marking with an anti-counterfeiting ink, such as, the fluorescent-substance-containing ink, printed thereon is irradiated with an excitation light having a predetermined wavelength, and the latent image marking is detected by an authentication apparatus by photodetection of the fluorescent light emanating from the fluorescent-substance-containing ink. Authenticity of the paper sheet is determined based on whether the latent image marking is detected.

[0005] For example, disclosed in Patent Document 1 is a technology in which a barcode that is not visually perceivable and that is formed with an anti-counterfeiting ink containing a fluorescent substance of which peak wavelength is between 800 nanometers (nm) and 900 nm printed on a printed matter is read to determine the authenticity of the printed matter.

[0006] Specifically, in the technology disclosed in Patent Document 1, an excitation light is irradiated on the barcode, and the barcode is read by detecting the fluorescent light emanating from the barcode by using a detector that detects a light in a predetermined wavelength band that includes the peak wavelength (800 nm to 900 nm) of the fluorescent substance.

5 **[0007]** [Patent Document 1] Japanese Patent Application Laid-open No. 2007-136838

Disclosure of the Invention

10 Problems to be Solved by the Invention

[0008] However, the technology disclosed in Patent Document 1 cannot be used to differentiate and detect fluorescent substances having peak wavelengths that are near each other. The reason for this is that the technology disclosed in Patent Document 1 can only be used to determine whether the certain fluorescent substance is applied onto the paper sheet by detecting light, of which peak wavelengths are within a detection range of the detector, emanating from the fluorescent substances.

20 **[0009]** Therefore, if multiple fluorescent substances are applied onto the paper sheet, and if the peak wavelengths of lights emanating from these fluorescent substances are near each other, the technology disclosed in Patent Document 1 cannot be used to identify the fluorescent substance among the multiple fluorescent substances detected by the detector.

25 **[0010]** Because there are also cases where multiple fluorescent substances are applied onto a single paper sheet for an additional anti-counterfeiting measure, a problem arises as to how to differentiate between the fluorescent substances emanating lights of which the peak wavelengths are near each other.

30 **[0011]** The present invention has been made to provide a solution to the problem posed by the conventional technology, and it is an object of the present invention to provide an authentication apparatus, an authentication method, and a fluorescence sensor that can differentiate and detect fluorescent substances that, when excited by irradiation of an excitation light, output fluorescent lights having the peak wavelengths that are near each other.

MEANS FOR SOLVING THE PROBLEM

35 **[0012]** To solve the above problems and to achieve the above objects, according to an aspect of the present invention, an authentication apparatus that authenticates a paper sheet with a fluorescent substance applied thereon includes an irradiation unit that irradiates an excitation light on the paper sheet; a first photodetector that performs photodetection in a first wavelength band that includes a peak wavelength of fluorescent light excited from the fluorescent substance by the irradiation of the excitation light; a second photodetector that detects a light that emanates from the same area on the paper sheet from which the light to be detected by the first photodetector emanates and that is in a second wavelength band that is located near the first wavelength band; an

identifying unit that identifies, based on an output of the first photodetector and an output of the second photodetector, a type of the fluorescent substance that is applied onto the paper sheet; and an authenticity determining unit that determines authenticity of the paper sheet based on an identification result obtained by the identifying unit.

[0013] In the above aspect, the first photodetector and the second photodetector are arranged on the same plane so as to perform photodetection of the fluorescent light excited from the same area on the paper sheet.

[0014] In the above aspect, the identifying unit identifies the type of the fluorescent substance applied onto the paper sheet if a comparison value obtained from the output of the first photodetector and the output of the second photodetector is greater than or equal to a predetermined threshold value.

[0015] In the above aspect, the identifying unit identifies the fluorescent substance applied onto the paper sheet as a first fluorescent substance if a comparison value obtained from the output of the first photodetector and the output of the second photodetector is less than a predetermined threshold value, and as a second fluorescent substance emanating a narrower bandwidth spectrum than that of the first fluorescent substance if the comparison value is greater than or equal to the predetermined threshold value.

[0016] The authentication apparatus further includes a third photodetector that performs photodetection of a light that emanates from the same area on the paper sheet from where the light to be detected by the first photodetector emanates and that is in a third wavelength band that includes the first wavelength band and the second wavelength band. The identifying unit identifies the type of the fluorescent substance after correcting the output of the first photodetector and the output of the second photodetector based on output of the third photodetector.

[0017] In the above aspect, the identifying unit identifies the type of the fluorescent substance after correcting the output of the first photodetector and the output of the second photodetector based on a comparison result obtained from the output of the third photodetector and a previously set reference value.

[0018] In the above aspect, the identifying unit identifies the fluorescent substance applied onto the paper sheet as a first fluorescent substance if a comparison value obtained from an output of the third photodetector based on a light from an area where the fluorescent substance is applied and an output of the third photodetector based on a light from an area where the fluorescent substance is not applied is greater than or equal to a predetermined threshold value, and as a second fluorescent substance having a narrower bandwidth spectrum than that of the first fluorescent substance if the comparison value is less than the predetermined threshold value.

[0019] In the above aspect, the identifying unit identifies the type of the fluorescent substance applied onto the paper sheet based on a first evaluation value that is the comparison value obtained from the output of the first

photodetector and the output of the second photodetector, and a second evaluation value that is the comparison value obtained from the output of the third photodetector based on a light from an area where the fluorescent substance is applied and the output of the third photodetector based on a light from an area where the fluorescent substance is not applied.

[0020] According to still another aspect of the present invention, a method for determining authenticity of a paper sheet having a fluorescent substance applied thereon includes irradiating the paper sheet with an excitation light; photodetecting, of the lights emanating from the same area on the paper sheet by the irradiation of the excitation light, a light in a first wavelength band that includes a peak wavelength of a fluorescent light excited by the excitation light by a first photodetector, and a light in a second wavelength band that is located near the first wavelength band by a second photodetector; identifying a type of the fluorescent substance applied onto the paper sheet based on an output of the first photodetector and an output of the second photodetector; and determining the authenticity of the paper sheet based on an identification result obtained by the identifying.

[0021] According to still another aspect of the present invention, a fluorescence sensor that detects a fluorescent substance applied onto a paper sheet includes an irradiation unit that irradiates the paper sheet with an excitation light; a first photodetector that performs photodetection of a light in a first wavelength band that includes a peak wavelength of a fluorescent light excited from the fluorescent substance by irradiation of the excitation light; and a second photodetector that performs photodetection of a light that emanates from the same area on the paper sheet from where the light to be detected by the first photodetector emanates and that is in a second wavelength band that is located near the first wavelength band.

[0022] In the above aspect, the first photodetector includes a first photodetecting element and a first filter that allows to pass through, from among the lights emanating from the paper sheet, only the light in the first wavelength band that includes the peak wavelength of the fluorescent light excited from the fluorescent substance, the second photodetector includes a second photodetecting element and a second filter that allows to pass through, from the light emanating from the paper sheet, only the light in the second wavelength band that is located near the first wavelength band, and the first photodetecting element and the second photodetecting element are arranged on the same plane so as to perform photodetection of the fluorescent light excited from the same area on the paper sheet by irradiation of the excitation light.

[0023] The fluorescence sensor further includes a third photodetector that performs photodetection of a light that emanates from the same area on the paper sheet from where the light to be detected by the first photodetector emanates and that is in a third wavelength band that includes the first wavelength band and the second wave-

length band.

[0024] The fluorescence sensor includes a frame made of an electrically conductive material and that houses a core unit that includes the first photodetector, the second photodetector, the third photodetector, and the irradiation unit.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0025] According to an aspect of the present invention, an irradiation unit irradiates an excitation light on a paper sheet, a first photodetector performs photodetection in a first wavelength band that includes a peak wavelength of fluorescent light excited from a fluorescent substance by the irradiation of the excitation light, a second photodetector performs photodetection of a light that emanates from the same area on the paper sheet from which the light to be detected by the first photodetector emanates and that is in a second wavelength band that is located near the first wavelength band, an identifying unit identifies, based on an output of the first photodetector and an output of the second photodetector, a type of the fluorescent substance that is applied onto the paper sheet, and an authenticity determining unit determines authenticity of the paper sheet based on an identification result of the identifying unit. Therefore, the fluorescent substances that, when excited by irradiation of an excitation light, output fluorescent lights having peak wavelengths that are near each other can be differentiated and detected.

[0026] According to another aspect of the present invention, the first photodetector and the second photodetector are arranged on the same plane so as to perform photodetection of the fluorescent light excited from the same area on the paper sheet. Therefore, photodetection of the fluorescence from the same area on the paper sheet by the first photodetector and the second photodetector is made possible with a simple structure.

[0027] According to yet another aspect of the present invention, the identifying unit identifies the type of the fluorescent substance applied onto the paper sheet if a comparison value obtained from the output of the first photodetector and the output of the second photodetector is greater than or equal to a predetermined threshold value. Therefore, among the fluorescent substances having the peak wavelengths that are near each other, the fluorescent substance having a narrow bandwidth can be differentiated and detected.

[0028] According to yet another aspect of the present invention, the identifying unit identifies the fluorescent substance applied onto the paper sheet as a first fluorescent substance if the comparison value obtained from the output of the first photodetector with the output of the second photodetector is less than the predetermined threshold value, and as a second fluorescent substance emanating a narrower bandwidth spectrum than that of the first fluorescent substance if the comparison value is greater than or equal to the predetermined threshold val-

ue. Therefore, even if the fluorescent substances having the peak wavelengths that are near each other are applied onto the paper sheet, the fluorescent substances can be differentiated and detected.

[0029] According to yet another aspect of the present invention, further included is a third photodetector that performs photodetection of a light that emanates from the same area on the paper sheet from where the light to be detected by the first photodetector emanates and that is in a third wavelength band that includes the first wavelength band and the second wavelength band, and the identifying unit identifies the type of the fluorescent substance after correcting the output of the first photodetector and the output of the second photodetector based on an output of the third photodetector. Therefore, the fluorescent substances having the peak wavelengths that are near each other can be differentiated with greater accuracy.

[0030] According to yet another aspect of the present invention, the identifying unit identifies the type of the fluorescent substance after correcting the output of the first photodetector and the output of the second photodetector based on a comparison result obtained from the output of the third photodetector and a previously set reference value. Therefore, the fluorescent substances having the peak wavelengths that are near each other can be differentiated with greater accuracy.

[0031] According to yet another aspect of the present invention, the identifying unit identifies the fluorescent substance applied onto the paper sheet as a first fluorescent substance if a comparison value obtained from an output of the third photodetector is based on a light from an area where the fluorescent substance is applied and an output of the third photodetector based on a light from an area where the fluorescent substance is not applied is greater than or equal to a predetermined threshold value, and as a second fluorescent substance having a narrower bandwidth than that of the first fluorescent substance if the comparison value is less than the predetermined threshold value. Therefore, even if two types of the fluorescent substances having the peak wavelengths that are near each other are applied onto the paper sheet, the fluorescent substances can be differentiated and detected.

[0032] According to yet another aspect of the present invention, the identifying unit identifies the type of the fluorescent substance applied onto the paper sheet based on a first evaluation value that is a comparison value obtained from the output of the first photodetector and the output of the second photodetector and a second evaluation value that is a comparison value obtained from an output of the third photodetector based on a light from an area where the fluorescent substance is applied and an output of the third photodetector based on a light from an area where the fluorescent substance is not applied. Therefore, the fluorescent substances having the peak wavelengths that are near each other can be differentiated with greater accuracy.

BRIEF DESCRIPTION OF DRAWINGS

[0033]

FIGS. 1A and 1B are a set of drawings showing an overview of an authentication procedure according to the present invention.

FIG. 2 is a block diagram of an authentication apparatus according to an embodiment of the present invention.

FIGS. 3A and 3B are a set of drawings showing spectral characteristics of a narrow ink and a broad ink.

FIGS. 4A and 4B are a set of drawings showing a structure of a fluorescence sensor.

FIG. 5 is a drawing showing a structure of a photodetector circuit of the fluorescence sensor.

FIGS. 6A to 6D are a set of drawings showing output of a four-segmented photodiode.

FIGS. 7A to 7C are a set of drawings of an example of an operation performed by a fluorescent-substance identifying unit.

FIG. 8 is a drawing of an overall structure of the authentication apparatus.

FIGS. 9A and 9B are a set of drawings showing a structure of a recognition and counting unit.

FIG. 10 is a flowchart of a fluorescent-substance identifying process according to the present embodiment.

FIG. 11 is a flowchart of another process procedure performed by the authentication apparatus according to the present embodiment.

FIGS. 12A and 12B are a set of drawings showing a structure of a frame unit of the fluorescence sensor.

FIG. 13 is a drawing of a structure of a core unit of the fluorescence sensor.

FIG. 14 is a drawing showing how the core unit is housed within the frame unit.

BEST MODE(S) FOR CARRYING OUT THE INVENTION

[0034] Exemplary embodiments of an authentication apparatus, an authentication method, and a fluorescence sensor according to the present invention are explained in detail below with reference to the accompanying drawings.

[0035] Prior to explaining the present embodiment in detail, an overview of an authentication procedure according to the present invention is explained first with reference to FIGS. 1A and 1B. FIGS. 1A and 1B are a set of drawings showing an overview of the authentication procedure according to the present invention. FIG. 1A is a drawing of an overview of a fluorescence sensor and FIG. 1B is a drawing of a determination method of a narrow ink and a broad ink used in the authentication procedure according to the present invention.

[0036] The term "narrow ink" refers to a fluorescent-substance-containing ink that contains a fluorescent sub-

stance that produces a narrowband fluorescence spectrum when irradiated with ultraviolet light. In contrast, the term "broad ink" refers to a fluorescent-substance-containing ink that contains a fluorescent substance that produces a broadband fluorescence spectrum when irradiated with the ultraviolet light.

[0037] As shown in FIG. 1A, there are cases where, from the viewpoint of prevention of counterfeiting, a fluorescent-substance-containing ink that is not identifiable by naked eye is applied onto paper sheets, such as, gift vouchers. Such a fluorescent-substance-containing ink, when irradiated with a predetermined excitation light (for example, the ultraviolet light), emits fluorescent light having a peak wavelength that depends on the fluorescent substance present in the ink. Conventionally, the fluorescent-substance-containing ink applied onto the paper sheet is detected by detecting a light having the peak wavelength.

[0038] However, there are cases in recent years where a broad ink and a narrow ink that are fluorescent-substance-containing inks having peak wavelengths that are near each other are applied onto the paper sheets. In such a case, the conventional technology cannot be used to differentiate and detect the broad ink and the narrow ink respectively.

[0039] It is well known that a bandwidth of the fluorescent light excited from the narrow ink is narrow compared to the bandwidth of the fluorescent light excited from the broad ink. Accordingly, in the authentication procedure according to the present invention, the broad ink and the narrow ink are differentiated and detected by detecting a difference in the bandwidths (that is, degree of steepness of the peak).

[0040] In the authentication procedure according to the present invention, as shown in FIG. 1A, the light excited from the same area on the paper sheet by irradiation of the excitation light is caused to be detected by a first photodetector via a first filter and a second photodetector via a second filter.

[0041] Specifically, the first filter is a bandpass filter that allows to pass through the light having a first wavelength that is the peak wavelength of the broad ink and the narrow ink (see (A-1) of FIG. 1A); the second filter is a bandpass filter that allows to pass through the light having a second wavelength that is located near the first wavelength (see (A-2) of FIG. 1A).

[0042] That is, in the authentication procedure according to the present invention, the first photodetector performs photodetection of the light having the first wavelength that includes the peak wavelengths of the broad ink and the narrow ink, and the second photodetector performs photodetection of the light having the second wavelength that is located near the first wavelength.

[0043] The fluorescent light excited from the fluorescent substance is known to diffuse over a relatively wide area by its nature. In the authentication procedure according to the present invention, this property of the fluorescent light is exploited, and by arranging the first pho-

photodetector and the second photodetector within an irradiation range of the fluorescent light excited from the same area on the paper sheet, photodetection of the fluorescent light from the same area on the paper sheet by each photodetector is made possible with a simple structure.

[0044] In the authentication procedure according to the present invention, the types of the fluorescent substances applied onto the paper sheet can be identified based on an output of the first photodetector and an output of the second photodetector.

[0045] Specifically, as shown in FIG. 1B, the bandwidth of the fluorescent light excited from the narrow ink is narrower than the bandwidth of the fluorescent light excited from the broad ink. Therefore, the difference between a spectral intensity of the peak wavelength and a spectral intensity of a near-peak wavelength would be greater for the narrow ink compared to the broad ink. That is, when the narrow ink is irradiated with the excitation light, a comparison value (for example, the difference value) obtained from the output of the first photodetector and the output of the second photodetector would be greater than that of the broad ink.

[0046] That is, if the comparison value obtained from the output of the first photodetector and the output of the second photodetector is greater than or equal to a predetermined threshold value, the fluorescent-substance-containing ink applied onto the paper sheet is identified as the narrow ink, and if the comparison value is less than the threshold value, the fluorescent-substance-containing ink is identified as the broad ink. In the authentication procedure according to the present invention, the authenticity of the paper sheet is determined based on an identification result of the fluorescent-substance-containing ink.

[0047] Thus, in the authentication procedure according to the present invention, from among the lights outputted from the same area on the paper sheet, the first photodetector detects the light belonging to a first wavelength band that includes the peak wavelength of the fluorescent light excited from the fluorescent substance by irradiation of the excitation light and the second photodetector detects the light having a second wavelength band that is located near the first wavelength band.

[0048] Furthermore, in the authentication method according to the present invention, the type of the fluorescent substance applied onto the paper sheet can be identified based on the output of the first photodetector and the output of the second photodetector. Accordingly, the fluorescent substances that, when excited by irradiation of an excitation light, output fluorescent lights having the peak wavelengths that are near each other can be differentiated and detected.

[0049] In the present case, the position of the second wavelength is merely specified as near the first wavelength; however, it can be more specifically specified based on spectral waveforms of the narrow ink and the broad ink. For example, in the authentication procedure

according to the present invention, the wavelength for which the comparison value obtained from the output of the first detector and the output of the second detector is greatest between the narrow ink and the broad ink can be specified as the second wavelength. Consequently, the narrow ink and the broad ink can be differentiated with greater accuracy.

[0050] In the authentication procedure according to the present invention, a third photodetector that detects a light in a wavelength band that includes the first wavelength and the second wavelength is provided. An output of the third photodetector is further used in the authentication procedure according to the present invention to improve an accuracy with which the fluorescent-substance-containing ink is identified.

[0051] An embodiment of the authentication apparatus, the authentication method, and the fluorescence sensor in which the authentication procedure is explained with reference to FIGS. 1A and 1B is explained in detail below. A case is presented below in which two types of ink, namely, the broad ink and the narrow ink, have been applied onto the paper sheet that is an authentication target. The paper sheet can be a gift voucher, a security, a bond, a check, a banknote, etc.

[Embodiment]

[0052] A structure of an authentication apparatus 1 is explained first with reference to FIG. 2. FIG. 2 is a block diagram of the authentication apparatus 1. As shown in FIG. 2, the authentication apparatus 1 includes a fluorescence sensor 11, other sensors 12, a storage unit 13, and a control unit 14. The control unit 14 includes a fluorescent-substance identifying unit 14a and a determining unit 14b.

[0053] Only the constituent elements that are necessary for explaining the salient features of the authentication apparatus 1 are shown in FIG. 2. A more specific structure of the authentication apparatus 1 is explained later with reference to FIG. 8, etc.

[0054] The fluorescence sensor 11 detects the fluorescent-substance-containing ink applied onto the paper sheet by irradiating the paper sheet with the excitation light. In the present embodiment, the narrow ink and the broad ink have been applied as the fluorescent-substance-containing ink onto the paper sheet.

[0055] Spectral characteristics of the narrow ink and the broad ink are explained with reference to FIGS. 3A and 3B. FIGS. 3A and 3B are a set of drawings showing the spectral characteristics of the narrow ink and the broad ink. FIG. 3A is a drawing showing an example of the paper sheet with the narrow ink and the broad ink applied thereto. FIG. 3B is a set of drawings showing the spectral characteristics of the narrow ink and the broad ink.

[0056] As shown in FIG. 3A, the narrow ink and the broad ink are applied onto predetermined areas on the paper sheet. The areas to which the narrow ink is applied

and the areas to which the broad ink is applied are previously stored as templates for each type of the paper sheet in the authentication apparatus 1.

[0057] For example, in the present embodiment, as shown in FIG. 3B, the fluorescent light excited from either of the narrow ink and the broad ink has the peak wavelengths of 613 nm. While the fluorescent light excited from the narrow ink exhibits a narrow peak that is a narrow (steep) bandwidth peak (see (B-1) of FIG. 3B), the fluorescent light excited from the broad ink exhibits a broad peak that is a broad (gradual) bandwidth peak (see (B-2) of FIG. 3B).

[0058] The first wavelength band and the second wavelength band shown in FIG. 3B correspond to the wavelength bands of the lights detected by a first photodetector 111a and a second photodetector 111b, respectively, that are explained later.

[0059] A structure of the fluorescence sensor 11 is explained with reference to FIGS. 4A and 4B. FIGS. 4A and 4B are a set of drawings showing the structure of the fluorescence sensor 11. FIG. 4A is a schematic cross-sectional view of the fluorescence sensor and FIG. 4B is a drawing showing an arrangement relation of a four-segmented photodiode, bandpass filters, and a UV cut filter.

[0060] As shown in FIG. 4A, the fluorescence sensor 11 includes a UV_LED 111, a UV transmissive filter 112, a UV reflective filter 113, and a window 114. The fluorescence sensor 11 further includes a four-segmented photodiode 115, two types of bandpass filters 116a and 116b, and a UV cut filter 117.

[0061] The UV_LED 111 is a light source that irradiates the excitation light to cause the fluorescent-substance-containing ink to emit fluorescent light. Specifically, the UV_LED 111 irradiates ultraviolet light as the excitation light. The UV transmissive filter 112 allows the ultraviolet light to pass through but blocks the visible light, and is arranged between the UV_LED 111 and the UV reflective filter 113.

[0062] The UV reflective filter 113 reflects the ultraviolet light that has been irradiated from the UV_LED 111 and passed through the UV transmissive filter 112, and irradiates the paper sheet with the reflected ultraviolet light. Furthermore, the UV reflective filter 113 allows the visible light from among the lights emanating from the paper sheet owing to irradiation of the ultraviolet light to pass through and be detected by the four-segmented photodiode 115. The window 114 allows transmission of light and is arranged between the UV reflective filter 113 and the paper sheet.

[0063] That is, the ultraviolet light irradiated from the UV_LED 111, after passing through the UV transmissive filter 112, is reflected by the UV reflective filter 113 in a direction so as to be perpendicularly incident on the paper sheet, and reaches the paper sheet. The fluorescent light that is excited by the irradiation of the ultraviolet light and diffused by the paper sheet, after passing through the UV reflective filter 113, reaches the four-segmented pho-

todiode 115 via the bandpass filter 116a or the bandpass filter 116b or the UV cut filter 117.

[0064] The four-segmented photodiode 115 is a photodetecting unit including four photodetectors that are arranged in the form of a 2×2 square (see FIG. 4B). For example, a segmented-type photodiode S5980 manufactured by Hama Photonics can be used as the four-segmented photodiode 115. The segmented photodiode can simultaneously detect light in the same wavelength bands at four spots, and can be used, for example, for position detection, laser light axis alignment, etc. All the segments of this four-segmented photodetector are arranged on the same plane, as shown in FIG. 4B.

[0065] In the present embodiment, each of the photodetectors 115a to 115d can be made to detect the light in a different wavelength band because of the arrangement of the bandpass filter 116a or the bandpass filter 116b or the UV cut filter 117 over each of the photodetectors 115a to 115d of the four-segmented photodiode 115.

[0066] The bandpass filters 116a and 116b allow the visible lights, which are different wavelength from among the visible lights entered from the paper sheet to the four-segmented photodiode 115 via the UV reflective filter 113, to pass through, and are arranged on the near side and the far side, respectively, above the paper sheet surface.

[0067] Specifically, the bandpass filter 116a allows to pass through the visible light of the wavelength band (first wavelength band) of 12 nm centered at 613 nm, which is the peak wavelength of the narrow ink and the broad ink; and the bandpass filter 116b allows to pass through the visible light of the wavelength band (second wavelength band) of 12 nm centered at 600 nm, which is near 613 nm.

[0068] The UV cut filter 117 blocks the ultraviolet light, and allows the visible light from all visible light bands, including the first wavelength band and the second wavelength band, to pass through.

[0069] The four-segmented photodiode 115 includes a first photodetector 115a, a second photodetector 115b, a third photodetector 115c, and a fourth photodetector 115d. The bandpass filter 116a is arranged corresponding to the first photodetector 115a and the bandpass filter 116b is arranged corresponding to the second photodetector 115b. The UV cut filter 117 is arranged corresponding to both the third photodetector 115c and the fourth photodetector 115d.

[0070] With the above structure, the visible lights in each of the three different wavelength bands are detected by the four-segmented photodiode 115. Specifically, in the four-segmented photodiode 115, the first photodetector 115a detects the visible light in the first wavelength band that includes the peak wavelength (613 nm) of the narrow ink and the broad ink, the second photodetector 115b detects the visible light in the second wavelength band that is located near the first wavelength band, while the third photodetector 115c and the fourth photodetector

115d detect the visible light of the entire visible light band.

[0071] In the fluorescence sensor according to the present embodiment, the fact that the fluorescent light excited from the fluorescent substance diffuses over a wide area is exploited, and the four photodetectors 115a to 115d are arranged within the irradiation area of the fluorescent light excited from the paper sheet. That is, in the fluorescence sensor according to the present embodiment, the four photodetectors 115a to 115d are arranged on the same plane so as to be able to detect the fluorescence that is excited from the same area on the paper sheet. Thus, the fluorescent light excited from the same area on the paper sheet can be detected by each of the photodetectors 115a to 115d with a simple structure.

[0072] By having such a structure, there is no need for arranging a lens to converge the fluorescent light that is excited from the paper sheet, a beam splitter to project the fluorescence that is converged by the lens, and such-like. Consequently, a compact fluorescent sensor can be realized and a manufacturing cost can be kept down.

[0073] A structure of a photodetector circuit of the fluorescence sensor 11 is explained below with reference to FIG. 5. FIG. 5 is a drawing of the structure of the photodetector circuit of the fluorescence sensor 11.

[0074] As shown in FIG. 5, signals outputted from the first photodetector 115a are amplified by an amplifier 120a, converted to digital signals by an AD (Analog-Digital) converter 122a, and stored in the storage unit 13 as 613 nm band data, of which the center is at 613 nm. Hereinafter, the 613 nm band data shall be referred to as "output value A". Similarly, signals outputted from the second photodetector 115b are amplified by an amplifier 120b, converted to digital signals by an AD converter 122b, and stored in the storage unit 13 as 600 nm band data, of which the center is at 600 nm. Hereinafter, the 600 nm band data shall be referred to as "output value B".

[0075] Signals outputted from the third photodetector 115b and the fourth photodetector 115d are amplified by an amplifier 120c, converted to digital signals by an AD converter 122c, and stored in the storage unit 13 as entire visible light band data. Hereinafter, the entire visible band area data shall be referred to as "output value C".

[0076] As shown in FIG. 5, gain adjusters 121a to 121c that adjust gain values of the amplifiers 120a to 120c, respectively, are arranged in the photodetector circuit. The fluorescence sensor 11 appropriately elicits the output values A to C from the photodetectors 115a to 115d, of which photodetection conditions vary owing to the effect cast by the bandpass filters 116a and 116b, and the UV cut filter 117, by adjusting the gain values of the amplifiers 120a to 120c individually by using the gain adjusters 121a to 121c.

[0077] Returning to FIG. 2, the other constituent elements are explained below. The other sensors 12 are sensors other than the fluorescence sensor 11 and are used to authenticate the paper sheet. For example, the other sensors 12 can be a tracking sensor that detects

the passage of the paper sheet, a line sensor that acquires image data of the paper sheet, a magnetic sensor that reads magnetic information from the paper sheet, etc. The storage unit 13 is a storage device that stores therein the output values A to C outputted from the fluorescence sensor 11.

[0078] The control unit 14 is a processing unit that identifies the type of the fluorescent substance, and authenticates the paper sheet based on the identification result. The fluorescent-substance identifying unit 14a retrieves the output values A to C from the storage unit 13, and based on the retrieved output values A to C, identifies whether the fluorescent-substance-containing ink applied onto the paper sheet is the narrow ink or the broad ink. The fluorescent-substance identifying unit 14a performs the process of transmitting the identification result of the fluorescent-substance-containing ink to the determining unit 14b.

[0079] The determining unit 14b is a processing unit that determines the authenticity of the paper sheet based on the identification result of the fluorescent-substance-containing ink obtained by the fluorescent-substance identifying unit 14a and output results of the other sensors 12.

[0080] A fluorescent-substance identification process performed by the fluorescent-substance identifying unit 14a is explained next with reference to FIGS. 6A to 6D and FIGS. 7A to 7C. The results outputted from the four-segmented photodiode 115 are explained first with reference to FIGS. 6A to 6D. FIGS. 6A to 6D are a set of drawings showing the results outputted from the four-segmented photodiode 115.

[0081] In FIGS. 6A to 6D, photodetection results of the fluorescent light excited from the narrow ink are shown on the left side, and photodetection results of the fluorescent light excited from the broad ink are shown on the right side. FIG. 6A shows graphs of the output values A (the 613 nm band data of FIG. 5), FIG. 6B shows graphs of the output values B (the 600 nm band data of FIG. 5), FIG. 6C shows graphs obtained when the output values B are subtracted from the output values A, and FIG. 6D shows graphs of the output values C (the entire visible light band data of FIG. 5). In the graphs shown in FIG. 6A to 6D, the horizontal axis represents the position on the paper sheet and the vertical axis represents a voltage.

[0082] As shown in FIG. 6A, as to the output values A that is the output result for the first wavelength band, the output values A are high values in both narrow-ink applied area and broad-ink applied area. This is because, as shown in FIG. 3B, the fluorescent light excited from both the narrow ink and the broad ink has the peak in the first wavelength band.

[0083] On the other hand, as shown in FIG. 6B, as to the output values B that is the output result for the second wavelength band, the output value B of the narrow-ink applied area is comparatively lower than the output value B of the broad-ink applied area. This is because of the difference in the degree of steepness of the spectrums

waveform of the narrow ink and the broad ink. That is, as shown in FIG. 3B, the spectral intensity of the near-peak wavelength of the narrow ink is less than that of the broad ink because the bandwidth of the narrow ink is narrower than that of the broad ink.

[0084] Consequently, as shown in FIG. 6C, when the output values B are subtracted from the respective output values A, the obtained values of the narrow-ink-applied area are greater than the values of the broad-ink-applied area.

[0085] The fluorescent-substance identifying unit 14a identifies whether the fluorescent substance is narrow ink or broad ink based on the comparison result of the output values A and the output values B. The fluorescent-substance identification process performed by the fluorescent-substance identifying unit 14a is explained below with reference to FIGS. 7A to 7C.

[0086] FIGS. 7A to 7C are a set of drawings showing an example of judgment performed by the fluorescent-substance identifying unit 14a. FIG. 7A is a drawing showing an example of judgment of a case where the fluorescent substance is identified based on an evaluation value 1, FIG. 7B is a drawing showing an example of process of a case where the fluorescent substance is identified based on an evaluation value 2, and FIG. 7C is a drawing showing an example of judgment of a case where the fluorescent substance is identified based on a total evaluation value.

[0087] As shown in FIG. 7A, the evaluation value 1 is a value evaluated based on the degree of steepness of the spectrum waveform. Specifically, the evaluation value 1 is obtained by subtracting the output value B from the output value A, and dividing the obtained remainder by the output value C (see (A-1) of FIG. 7A).

[0088] If the evaluation value 1 is large, that is, if the evaluation value 1 is greater than or equal to a predetermined threshold value, the fluorescent-substance identifying unit 14a identifies the fluorescent substance applied onto the paper sheet to be the narrow ink. On the other hand, if the evaluation value 1 is small, that is, if the evaluation value 1 is less than the predetermined threshold value, the fluorescent-substance identifying unit 14a identifies the fluorescent substance applied onto the paper sheet to be the broad ink (see (A-2) of FIG. 7A).

[0089] Instead of using the value as the evaluation value 1 obtained by merely subtracting the output value B from the output value A, the fluorescent-substance identifying unit 14a uses the value obtained by dividing the subtraction result by the output value C that is the entire visible light band data. Thus, in the present embodiment, the fluorescent-substance identifying unit 14a identifies the type of the fluorescent substance after correcting (normalizing) the output value A outputted from the first photodetector 115a and the output value B outputted from the second photodetector 115b based on the output value C of the third photodetector 115c and the fourth photodetector 115d. Therefore, the comparison of the evaluation value 1 to the predetermined threshold value

can be performed with greater accuracy, and thereby the differentiation between the narrow ink and the broad ink can be made with greater accuracy.

[0090] Although a case where the output value B is subtracted from the output value A is cited as an example, the present embodiment is not limited to this. An absolute value of a value obtained by subtracting the output value A from the output value B can be used. Alternatively, a value obtained by dividing the output value A by the output value B or by dividing the output value B by the output value A can be used; that is, a ratio between the output value A and the output value B can be used. It is sufficient that the evaluation value 1 represents a comparison of the output value A and the output value B.

[0091] Although a case where correction is performed by dividing the comparison value of the output value A and the output value B by the output value C is cited as an example, the correction method is not limited to this. For example, the comparison value of the output value A and the output value B can be corrected based on a comparison result of the output value C to a previously set reference value.

[0092] That is, if the output value C is 2/3rd of the reference value, the fluorescent-substance identifying unit 14a can regard a value that is 3/2 times the remainder obtained by subtracting the output value B from the output value A as an evaluation value 1'. This method can also be used to perform the comparison of the evaluation value 1' and the threshold value with greater accuracy, and thereby differentiation between the narrow ink and the broad ink can be performed with greater accuracy.

[0093] Although a case where the differentiation of the narrow ink and the broad ink is performed based on the evaluation value 1 that is the comparison value between the output value A and the output value B is explained above, the fluorescent-substance identifying unit 14a can use solely the output value C to perform the differentiation of the narrow ink and the broad ink. This is explained below.

[0094] As shown in FIG. 6D, of the output values C that is the entire visible light band data, it is evident that, when compared, the difference between a value of the broad ink applied area (see (D-1) of FIG. 6D) and a value of the adjacent area where the broad ink is not applied (see (D-2) of FIG. 6D) is greater than the difference between a value of the narrow ink applied area (see (D-3) of FIG. 6D) and a value of the adjacent area where the narrow ink is not applied (see (D-4) of FIG. 6D). This is because of the difference in spectral areas of the narrow ink and the broad ink.

[0095] That is, as shown in FIG. 3B, a spectral area of the narrow ink is less than the spectral area of the broad ink. Therefore, a difference between the spectral area of the fluorescent-substance-containing ink applied area on the paper sheet and the area of the paper sheet where the fluorescent-substance-containing ink is not applied will be greater for the broad ink. Consequently, the fluorescent-substance-identifying unit 14a can also identify

the fluorescent substance based on the output value.

[0096] Specifically, as shown in FIG. 7B, the evaluation value 2 obtained from the spectral area is obtained by subtracting the output value C of the adjacent area where the ink is not applied from the output value C of the ink applied area (see (B-1) of FIG. 7B).

[0097] If the evaluation value 2 is large, that is, if the evaluation value 2 is greater than or equal to a predetermined threshold value, the fluorescent-substance identifying unit 14a identifies the fluorescent substance applied onto the paper sheet as the broad ink. On the other hand, if the evaluation value 2 is small, that is, if the evaluation value 2 is less than the threshold value, the fluorescent-substance identifying unit 14a identifies the fluorescent substance applied onto the paper sheet as the narrow ink (refer to (B-2) of FIG. 7B).

[0098] Thus, of the output values C (entire visible light band data of FIG. 5), if a comparison value of the value C obtained from the light in the fluorescent-substance applied area and the value C obtained from the light in the area where the fluorescent substance is not applied is greater than or equal to the predetermined threshold value, the fluorescent-substance identifying unit 14a identifies the fluorescent substance applied onto the paper sheet as the broad ink. If the comparison value is less than the predetermined threshold value, the fluorescent-substance identifying unit 14a identifies the fluorescent substance applied onto the paper sheet as the narrow ink. Thus, differentiation between the fluorescent substances having the peak wavelengths that are near each other can be performed with a single light detector.

[0099] Furthermore, the fluorescent-substance identifying unit 14a can also perform identification of the fluorescent-substance-containing ink by taking both the evaluation value 1 and the evaluation value 2 into consideration. Specifically, as shown in FIG. 7C, a comprehensive evaluation value obtained by taking both the evaluation value 1 and the evaluation value 2 into consideration is obtained by subtracting a value obtained by multiplying the evaluation value 2 by a weighting factor m2 from a value obtained by multiplying the evaluation value 1 by a weighting factor m1.

[0100] Because a more reliable evaluation value 1 is used as the main evaluation value in the present embodiment, the value of the weighting factor m1 is set larger than that of the weighting factor m2. Meanwhile, m1 and m2 are both positive numbers.

[0101] Thus, the narrow ink and the broad ink can be differentiated with greater accuracy if the type of the fluorescent substance applied onto the paper sheet can be identified based on the evaluation value 1 and the evaluation value 2. That is, because the evaluation is performed comprehensively by also including the evaluation value 2, even in a case where the broad ink is likely to be mistakenly identified as the narrow ink because the evaluation value 1 is only slightly greater than the threshold value, the ink is correctly identified as the broad ink.

[0102] As explained above, in the present embodi-

ment, the UV_LED 111 irradiates the paper sheet with the excitation light, the first photodetector detects the light in the first wavelength band that includes the peak wavelength of the fluorescent light excited from the fluorescent substance by the irradiation of the excitation light, and the second photodetector detects the light in the second wavelength band located near the first wavelength band and also the light that emanates from the same area on the paper sheet from where the light to be detected by the first photodetector emanates.

[0103] Furthermore, in the present embodiment, the fluorescent-substance identifying unit identifies the type of the fluorescent substance applied onto the paper sheet based on the outputs from the first photodetector and the second photodetector, and the determining unit determines the authenticity of the paper sheet based on the identification result by the fluorescent-substance identifying unit. Thus, the fluorescent substances that when excited by irradiation of an excitation light, output fluorescent lights having the peak wavelengths that are near each other can be differentiated and detected.

[0104] An overall structure of the authentication apparatus 1 is explained next with reference to FIG. 8. FIG. 8 is a drawing showing the overall structure of the authentication apparatus 1. The authentication apparatus 1 according to the present embodiment shown in FIG. 8 not only determines the authenticity of the paper sheet (that is, authenticates the paper sheet), but also serves as a recognition and counting apparatus that also performs counting of the paper sheets.

[0105] As shown in FIG. 8, the authentication apparatus 1 includes a hopper 24 where multiple paper sheets P that are to be subjected to recognition and counting are placed in a stack, a feeding unit 26 that feeds the paper sheets P placed in a stack on the hopper 24 one at a time into the inside of a housing 22 from the bottommost paper sheet P, and a transport unit 32 that transports, one at a time, the paper sheet P fed into the inside of the housing 22 by the feeding unit 26.

[0106] A recognition and counting unit 34 that includes the fluorescence sensor 11 according to the present embodiment and the other sensors 12 are arranged in the transport unit 32. The recognition and counting unit 34 is the recognition and counting apparatus that performs the recognition of the paper sheet P, fed from the hopper 24 into the inside of the housing 22, by using the fluorescence sensor 11 and the other sensors 12. A structure of the recognition and counting unit 34 is explained later with reference to FIG. 9.

[0107] The feeding unit 26 includes a kicker roller 26a that abuts a surface of the bottommost paper sheet P of the multiple paper sheets P placed in a stack on the hopper 24 and a feed roller 26b that is arranged on a downstream side of the kicker roller 26a in a feeding direction of the paper sheet P and that feeds the paper sheet P that is sent along by the kicker roller 26a into the inside of the housing 22. A gate roller (reverse-rotating roller) 26c is arranged at a position opposing the feed roller 26b,

and a gate unit is formed between the feed roller 26b and the gate roller 26c.

[0108] The paper sheets P fed along by the kicker roller 26a pass through the gate unit and are transported by the transport unit 32 inside the housing 22 one at a time. As shown in FIG. 8, the transport unit 32 forms two transport paths at a place on the downstream side of the recognition and counting unit 34. One transport path is connected to a stacking unit 36 and the other transport path is connected to a reject unit 40.

[0109] After the paper sheet P goes past the recognition and counting unit 34, it is selectively sent to the stacking unit 36 or the reject unit 40 by the transport unit 32. An opening is provided on a front side of the stacking unit 36 (right side surface in FIG. 8) through which an operator can take out the paper sheets P stacked therein. Similarly, an opening is provided on a front side of the reject unit 40 through which the operator can take out paper sheets P' stacked therein.

[0110] As shown in FIG. 8, a diverting unit 41 that includes a not shown diverting member and a not shown driving unit therefor is arranged at the place where the transport unit 32 is diverted into the two transport paths. The diverting unit 41 selectively sends the paper sheet P that comes to the diverting unit 41 from an upstream side to one of the two diverging transport paths.

[0111] In the stacking unit 36, a stacking-wheel type stacking mechanism 38 is arranged on a backside of the housing 22 (to the left of the stacking unit 36 in FIG. 8). The stacking-wheel type stacking mechanism 38 includes a stacking wheel 38a and a not shown driving unit therefor. The stacking wheel 38a rotates in a clockwise direction in FIG. 8 (in the direction of the arrow shown in FIG. 8) about a shaft that is orthogonal to the sheet surface of FIG. 8 and that extends in a substantially horizontal direction. The stacking wheel 38a includes multiple vanes 38b that extend outward from an outer peripheral surface of the stacking wheel 38a in a direction opposite to (in a counter-clockwise direction in FIG. 8) the rotation direction. The vanes are arranged on the outer peripheral surface of the stacking wheel 38a at regular intervals, as shown in FIG. 8.

[0112] When the authentication apparatus 1 is in operation, the stacking wheel 38a of the stacking-wheel type stacking mechanism 38 is always driven clockwise in FIG. 8 by the driving unit and the paper sheet P is sent to the stacking wheel 38a, one at a time, from the transport unit 32. The stacking wheel 38a receives the paper sheet P that is sent from the transport unit 32 between two vanes 38b, and sends the paper sheet P that is caught between the vanes 38b to the stacking unit 36. In this manner, the paper sheet P is sent, one at a time, from the stacking wheel 38a to the stacking unit 36, and multiple paper sheets P are stacked in the stacking unit 36.

[0113] In the authentication apparatus 1, a shutter 50 is provided that closes the opening on the front side of the stacking unit 36. The opening on the front side of the

stacking unit 36 is selectively closed by the shutter 50. The shutter 50 is moved by a not shown shutter driving unit that drives the shutter 50 between an open position in which the shutter 50 is in a retreated state from the opening on the front side of the stacking unit 36, leaving the opening in an open state, and a closed position in which the shutter 50 closes the opening on the front side of the stacking unit 36. That is, when the shutter 50 is in the open position, the shutter 50 is in a retreated state from the opening on the front side of the stacking unit 36 and the opening is open, enabling the operator to access the paper sheets P stacked in the stacking unit 36.

[0114] When the shutter is in the closed position, the opening on the front side of the stacking unit 36 is closed by the shutter 50, and the operator cannot access the paper sheets P stacked in the stacking unit 36. In FIG. 8, the shutter 50 is shown as a solid line in the open position and a two-dot chain line in the closed position.

[0115] Furthermore, as shown in FIG. 8, various types of sensors are provided in the authentication apparatus 1. Specifically, a hopper left-over paper sheet detection sensor 62 that is a reflective optical sensor and that detects whether any paper sheet P is left behind on the hopper 24 is provided in the hopper 24. A diversion timing sensor 64 that is an optical sensor is provided on the upstream side of the diverting unit 41 in the transport unit 32. The diverting member of the diverting unit 41 is shifted to either a position whereby the paper sheet P is sent to the stacking unit 36 or a position whereby the paper sheet P is sent to the reject unit 40 at a timing detected by the diversion timing sensor 64.

[0116] Of the two transport paths that diverge from the place where the diverting unit 41 is arranged, in the transport path that leads to the stacking unit 36 is arranged a paper-sheet passage detection sensor 66 that is an optical sensor and that detects the paper sheet P being transported over the transport path. The paper-sheet passage detection sensor 66 detects the paper sheet P when the paper sheet P is being transported over the transport path toward the stacking unit 36 through the diverting unit 41.

[0117] A stacking unit paper-sheet detection sensor 68 that is an optical sensor and that detects whether the paper sheet P is stacked in the stacking unit 36 is provided in the stacking unit 36. A reject unit paper-sheet detection sensor 70 that is an optical sensor and that detects whether the paper sheet P' is stacked in the reject unit 40 is provided in the reject unit 40.

[0118] Furthermore, as shown in FIG. 2, the control unit 14 that controls all the constituent elements of the authentication apparatus 1 is arranged in the authentication apparatus 1. Specifically, the feeding unit 26, the transport unit 32, the recognition and counting unit 34, the stacking unit 36 that includes the stacking-wheel type stacking mechanism 38, the diverting unit 41, etc., are all connected to the control unit 14.

[0119] The fluorescent-substance identifying unit 14a of the control unit 14 identifies the fluorescent-substance-

containing ink that is applied onto the paper sheet based on the output result of the fluorescence sensor 11 arranged in the recognition and counting unit 34. The determining unit 14b of the control unit 14 determines the authenticity of the paper sheet based on the identification result of the fluorescent-substance-containing ink outputted by the fluorescent-substance identifying unit 14a and the output results of the other sensors 12.

[0120] The control unit 14 exerts control over the feeding unit 26, the transport unit 32, the stacking unit 36, the diverting unit 41, etc., by sending command signals to these constituent elements based on an authentication result of the paper sheet.

[0121] Furthermore, the hopper left-over paper sheet detection sensor 62, the diversion timing sensor 64, the paper-sheet passage detection sensor 66, the stacking unit paper-sheet detection sensor 68, and the reject unit paper-sheet detection sensor 70 are connected to the control unit 14, and the output results of these sensors are sent to the control unit 14. An operation/display unit 42 is connected to the control unit 14. As shown in FIG. 8, the operation/display unit 42 is an operation/display device arranged on the front face of the housing 22. A processing state of the paper sheet P processed by the authentication apparatus 1, more specifically, information, such as, denomination-wise number of the paper sheets P counted by the recognition and counting unit 34 and total amount are displayed on the operation/display unit 42. The operator can give various commands to the control unit 14 by using the operation/display unit 42.

[0122] A structure of the recognition and counting unit 34 shown in FIG. 8 is explained below with reference to FIGS. 9A and 9B. FIGS. 9A and 9B are a set of drawings showing the structure of the recognition and counting unit 34. FIG. 9A is a drawing of the structure of the recognition and counting unit 34. And FIG. 9B is a drawing showing an example of arrangement of the fluorescence sensor 11.

[0123] As shown in FIG. 9A, the recognition and counting unit 34 includes tracking sensors 301a to 301d, a line sensor 302, a magnetic sensor 303, a thickness detection sensor 304, and the fluorescence sensor 11. The tracking sensors 301a to 301d, the line sensor 302, the magnetic sensor 303, and the thickness detection sensor 304 correspond to the other sensors 12 shown in FIG. 2.

[0124] The tracking sensors 301a to 301d detect the passage of the paper sheet. Specifically, the tracking sensors 301a and 301b are arranged on the upstream side of the transport unit 32, and the tracking sensors 301c and 301d are arranged on the downstream side of the transport unit 32. Upon detecting the paper sheet, the tracking sensors 301a to 301d send a detection result to the control unit 14. Following the detection of the paper sheet by the tracking sensors 301a and 301b, samplings from the fluorescence sensor 11, the line sensor 302, the magnetic sensor 303, and the thickness detection sensor 304 are commenced by the control unit 14.

[0125] The line sensor 302 acquires the image data of the paper sheet. The line sensor 302 stores the acquired image data of the paper sheet in a not shown memory. The magnetic sensor 303 reads magnetic information from the paper sheet. Similar to the line sensor 302, the magnetic sensor 303 also stores the information read from the paper sheet in the not shown memory.

[0126] The thickness detection sensor 304 detects a thickness of the paper sheet, and similar to the line sensor 302 and the magnetic sensor 303, stores a detection result in the not shown memory. The determining unit 14b of the control unit 14 authenticates the paper sheet based on the detection results of each of the sensors stored in the memory and the identification result outputted by the fluorescent-substance identifying unit 14a.

[0127] As shown in FIG. 9B, in the recognition and counting unit 34, an LED light source 305 is arranged at a position opposing the line sensor 302 (see (B-1) of FIG. 9B). The line sensor 302 acquires the image data based on a reflected light obtained from the paper sheet irradiated by the line sensor 302 and a transmitted light obtained from the paper sheet irradiated by the LED light source 305 when the paper sheet passes therein.

[0128] Furthermore, in the recognition and counting unit 34, an ultraviolet transmitted-light sensor 306 is arranged at a position opposing the fluorescence sensor 11 (see (B-2) of FIG. 9B). The ultraviolet transmitted-light sensor 306 detects the ultraviolet light that passes through the paper sheet when the ultraviolet light emanates from the fluorescence sensor 11.

[0129] Concrete operations of the authentication apparatus 1 according to the present embodiment are explained next. A process procedure of a fluorescent-substance identification process performed by the fluorescent-substance identifying unit 14a is explained first with reference to FIG. 10. FIG. 10 is a flowchart of the fluorescent-substance identifying process according to the present embodiment.

[0130] As shown in FIG. 10, in the authentication apparatus 1, upon detection of the paper sheet by the tracking sensors 301a and 301b (Step S101), the fluorescence sensor 11 commences irradiation of the ultra violet light that is the excitation light (Step S102). Each of the photodetectors 115a to 115d of the four-segmented photodiode 115 detects, via the bandpass filter 116a or the bandpass filter 116b or the UV cut filter 117, the light emanating from the paper sheet by the irradiation of the ultraviolet light. The output signals from each of the photodetectors 115a to 115d are stored in the storage unit 13 as output values A to C after being processed, respectively, by the amplifiers 120a to 120c and the AD converters 122a to 122c.

[0131] Thereafter, in the authentication apparatus 1, the fluorescent-substance identifying unit 14a acquires the output values A to C from the storage unit 13 (Step S103), and calculates the evaluation value 1 and the evaluation value 2 (Step S104). The fluorescent-substance identifying unit 14a then calculates the comprehensive

evaluation value from the calculated evaluation value 1 and the evaluation value 2 (Step S105).

[0132] Thereafter, the fluorescent-substance identifying unit 14a judges whether the calculated comprehensive evaluation value is greater than or equal to the predetermined threshold value (Step S106), and if so, identifies the fluorescent-substance-containing ink that is applied onto the paper sheet as the narrow ink (Step S107) and ends the process. However, if the comprehensive evaluation value is less than the predetermined threshold value, the fluorescent-substance identifying unit 14a identifies the fluorescent-substance-containing ink that is applied onto the paper sheet as the broad ink (Step S108) and ends the process.

[0133] A case where the fluorescent-substance identifying unit 14a identifies the fluorescent-substance-containing ink by comparing each type of evaluation value calculated based on the output values A to C from the four-segmented photodiode 115 and the predetermined threshold value is explained above. However, the identification method is not limited to this. The authentication apparatus 1 can, for example, match the output values A to C with previously stored templates and determine the authenticity of the paper sheet based on a match result.

[0134] A process procedure of the authentication mentioned above is explained next with reference to FIG. 11. Fig. 11 is a flowchart of another process procedure performed by the authentication apparatus 1 according to the present embodiment. The above-mentioned templates, which correspond to match judging data, are previously stored in a predetermined storage area of the authentication apparatus 1 for each type of the paper sheet.

[0135] As shown in FIG. 11, in the authentication apparatus 1, upon detection of the paper sheet by the tracking sensors 301a and 301b (Step S201), the samplings of the paper sheet by different types of sensors, namely, the fluorescence sensor 11, the line sensor 302, and the magnetic sensor 303, are commenced by the control unit 14 (Step S202). By this process, the fluorescence sensor 11 commences the irradiation of the excitation light as described in Step S102 of FIG. 10.

[0136] Thereafter, in the authentication apparatus 1, after the identification of the type of the paper sheet based on the output result from each sensor (Step S203), the control unit 14 performs a binning process (Step S204). In the binning process, sampling data from each sensor is processed in blocks, each block being composed of sampling data of a predetermined number of lines multiplied by a predetermined number of channels. Specifically, the control unit 14 performs calculation by regarding a total value of sampling values of a predetermined transport distance (for example, 10 millimeter (mm)) of the paper sheet as a block value.

[0137] The control unit 14 can also perform normalization by dividing each block value by an average value of the calculated block values. When calculating the block

value of the output value A or the output value B, the control unit 14 can also correct the normalized block values of the output value A and the output value B by using a normalized block value of the output value C.

[0138] Thereafter, in the authentication apparatus 1, the determining unit 14b reads the template corresponding to the identified type of the paper sheet from the predetermined storage area (Step S205), and calculates a matching degree between the block value calculated based on the output result from each sensor and the template (Step S206). The determining unit 14b then judges whether the calculated matching degree is greater than or equal to a predetermined value (Step S207), and if so (Yes at Step S207), judges that the paper sheet is a genuine note (Step S208) and ends the process. However, if the matching degree is less than the predetermined value (No at Step S207), the determining unit 14b judges that the paper sheet is a counterfeit note (Step S209) and ends the process.

[0139] The fluorescence sensor 11 shown in FIG. 4 is formed by housing a core unit including the UV_LED 111, the four-segmented photodiode 115, etc., within a frame unit that forms a housing. A more concrete structure of the fluorescence sensor 11 is explained below with reference to FIGS. 12A and 12B, FIG. 13, and FIG. 14.

[0140] A structure of the frame unit is explained first with reference to FIGS. 12A and 12B. FIGS. 12A and 12B are a set of drawings showing the structure of the frame unit of the fluorescence sensor 11. FIG. 12A is a schematic diagram of the frame unit with the surface opposing the paper sheet faces downward, while FIG. 12B is a schematic diagram of the frame unit with the surface opposing the paper sheet faces upward.

[0141] As shown in FIG. 12A, a frame unit 11a is formed by arranging the UV transmissive filter 112 and the UV reflective filter 113 within an electrically conductive casing 118. As shown in FIG. 12B, the window 114 is arranged on a surface of the electrically conductive casing 118 opposing the paper sheet. The electrically conductive casing 118 is made of electrically conductive plastic to prevent garbled data in the output values A to C from the four-segmented photodiode 115 due to electrostatic noise.

[0142] A structure of the core unit of the fluorescence sensor 11 is explained next with reference to FIG. 13. FIG. 13 is a drawing showing the structure of the core unit of the fluorescence sensor 11. As shown in FIG. 13, a core unit 11b includes the UV_LED 111, the bandpass filters 116a and 116b, the UV cut filter 117, and a substrate 119. The photodetector circuit (including the four-segmented photodiode 115) shown in FIG. 5 is mounted on a back side of the substrate 119.

[0143] FIG. 14 is a drawing showing how the core unit 11b is housed within the frame unit 11a. As shown in FIG. 14, the fluorescence sensor 11 is formed to contain the core unit 11b within the frame unit 11a. When the core unit 11b is housed within the frame unit 11a, an open part of the frame unit 11a is closed by the substrate 119

fitted in the core unit 11b, substantially tightly sealing the UV_LED 111, the bandpass filters 116a and 116b, the UV cut filter 117, the four-segmented photodiode, etc., within the frame unit 11a.

[0144] In this manner, in the present embodiment, the output values A to C from the four-segmented photodiode 115 are prevented from being adversely affected by the electrostatic noise by housing the core unit 11b that includes the four-segmented photodiode 115 and the UV_LED 111 with the frame unit 11a made of electrically conductive material.

INDUSTRIAL APPLICABILITY

[0145] As explained above, the authentication apparatus, the authentication method, and the fluorescence sensor according to the present invention are useful for differentiating and detecting the fluorescent substances that when excited by irradiation of an excitation light output fluorescent lights having the peak wavelengths that are near each other, and are particularly suited for differentiating and detecting the fluorescent substances applied onto a single paper sheet.

EXPLANATIONS OF LETTERS OR NUMERALS

[0146]

1: Authentication apparatus
 11: fluorescence sensor
 11a: Frame unit
 11b: Core unit
 111: UV_LED
 112: UV transmissive filter
 113: UV reflective filter
 114: Window
 115: Four-segmented photodiode
 115a: First photodetector
 115b: Second photodetector
 115c: Third photodetector
 115d: Fourth photodetector
 116a, 116b: Bandpass filter
 117: UV cut filter
 120a to 120c: Amplifiers
 121a to 121c: Gain adjuster
 122a to 122c: AD converter
 12: Other sensors
 13: Storage unit
 14: Control unit
 14a: Fluorescent-substance identifying unit
 14b: Determining unit
 34: Recognition and counting unit
 301a to 301d: Tracking sensor
 302: Line sensor
 303: Magnetic sensor
 304: Thickness detection sensor
 305: LED light source
 306: Ultraviolet transmissive-light sensor

Claims

1. An authentication apparatus that authenticates a paper sheet with a fluorescent substance applied thereon, the authentication apparatus comprising:

an irradiation unit that irradiates an excitation light on the paper sheet;
 a first photodetector that performs photodetection in a first wavelength band that includes a peak wavelength of fluorescent light excited from the fluorescent substance by the irradiation of the excitation light;
 a second photodetector that detects a light that emanates from the same area on the paper sheet from which the light to be detected by the first photodetector emanates and that is in a second wavelength band that is located near the first wavelength band;
 an identifying unit that identifies, based on an output of the first photodetector and an output of the second photodetector, a type of the fluorescent substance applied onto the paper sheet; and
 an authenticity determining unit that determines authenticity of the paper sheet based on an identification result obtained by the identifying unit.

2. The authentication apparatus according to Claim 1, wherein the first photodetector and the second photodetector are arranged on the same plane so as to perform photodetection of the fluorescent light excited from the same area on the paper sheet.

3. The authentication apparatus according to Claim 1, wherein the identifying unit identifies the type of the fluorescent substance applied onto the paper sheet if a comparison value obtained from the output of the first photodetector and the output of the second photodetector is greater than or equal to a predetermined threshold value.

4. The authentication apparatus according to Claim 1, wherein the identifying unit identifies the fluorescent substance applied onto the paper sheet as a first fluorescent substance if a comparison value obtained from the output of the first photodetector and the output of the second photodetector is less than a predetermined threshold value, and as a second fluorescent substance emanating a narrower bandwidth spectrum than that of the first fluorescent substance if the comparison value is greater than or equal to the predetermined threshold value.

5. The authentication apparatus according to Claim 1, further comprising a third photodetector that performs photodetection of a light that emanates from the same area on the paper sheet from where the

light to be detected by the first photodetector emanates and that is in a third wavelength band that includes the first wavelength band and the second wavelength band,

wherein the identifying unit identifies the type of the fluorescent substance after correcting the output of the first photodetector and the output of the second photodetector based on an output of the third photodetector.

6. The authentication apparatus according to Claim 5, wherein the identifying unit identifies the type of the fluorescent substance after correcting the output of the first photodetector and the output of the second photodetector based on a comparison result obtained from the output of the third photodetector and a previously set reference value.

7. The authentication apparatus according to Claim 5, wherein the identifying unit identifies the fluorescent substance applied onto the paper sheet as a first fluorescent substance if a comparison value obtained from an output of the third photodetector based on a light from an area where the fluorescent substance is applied and an output of the third photodetector based on a light from an area where the fluorescent substance is not applied is greater than or equal to a predetermined threshold value, and as a second fluorescent substance having a narrower bandwidth spectrum than that of the first fluorescent substance if the comparison value is less than the predetermined threshold value.

8. The authentication apparatus according to Claim 5, wherein the identifying unit identifies the type of the fluorescent substance applied onto the paper sheet based on a first evaluation value that is the comparison value obtained from the output of the first photodetector and the output of the second photodetector, and a second evaluation value that is the comparison value obtained from the output of the third photodetector based on a light from an area where the fluorescent substance is applied and the output of the third photodetector based on a light from an area where the fluorescent substance is not applied.

9. A method for authenticating a paper sheet having a fluorescent substance applied thereon, the method comprising:

irradiating the paper sheet with an excitation light;
photodetecting, of the lights emanating from the same area on the paper sheet by the irradiation of the excitation light, a light in a first wavelength band that includes a peak wavelength of a fluorescent light excited by the excitation light by a first photodetector, and a light in a second wave-

length band that is located near the first wavelength band by a second photodetector;
identifying a type of the fluorescent substance applied onto the paper sheet based on an output of the first photodetector and an output of the second photodetector; and
determining the authenticity of the paper sheet based on an identification result obtained at the identifying.

10. A fluorescence sensor that detects a fluorescent substance applied onto a paper sheet, the fluorescence sensor comprising:

an irradiation unit that irradiates the paper sheet with an excitation light;
a first photodetector that performs photodetection of a light in a first wavelength band that includes a peak wavelength of a fluorescent light excited from the fluorescent substance by irradiation of the excitation light; and
a second photodetector that performs photodetection of a light that emanates from the same area on the paper sheet from where the light to be detected by the first photodetector emanates and that is in a second wavelength band that is located near the first wavelength band.

11. The fluorescence sensor according to Claim 10, wherein
the first photodetector includes a first photodetecting element and a first filter that allows to pass through, from among the lights emanating from the paper sheet, only the light in the first wavelength band that includes the peak wavelength of the fluorescent light excited from the fluorescent substance,
the second photodetector includes a second photodetecting element and a second filter that allows to pass through, from the light emanating from the paper sheet, only the light in the second wavelength band that is located near the first wavelength band, and
the first photodetecting element and the second photodetecting element are arranged on the same plane so as to perform photodetection of the fluorescent light excited from the same area on the paper sheet by irradiation of the excitation light.

12. The fluorescence sensor according to Claim 10, further comprising a third photodetector that performs photodetection of a light that emanates from the same area on the paper sheet from where the light to be detected by the first photodetector emanates and that is in a third wavelength band that includes the first wavelength band and the second wavelength band.

13. The fluorescence sensor according to Claim 12, fur-

ther comprising a frame made of an electrically conductive material and that houses a core unit that includes the first photodetector, the second photodetector, the third photodetector, and the irradiation unit.

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FIG.1A

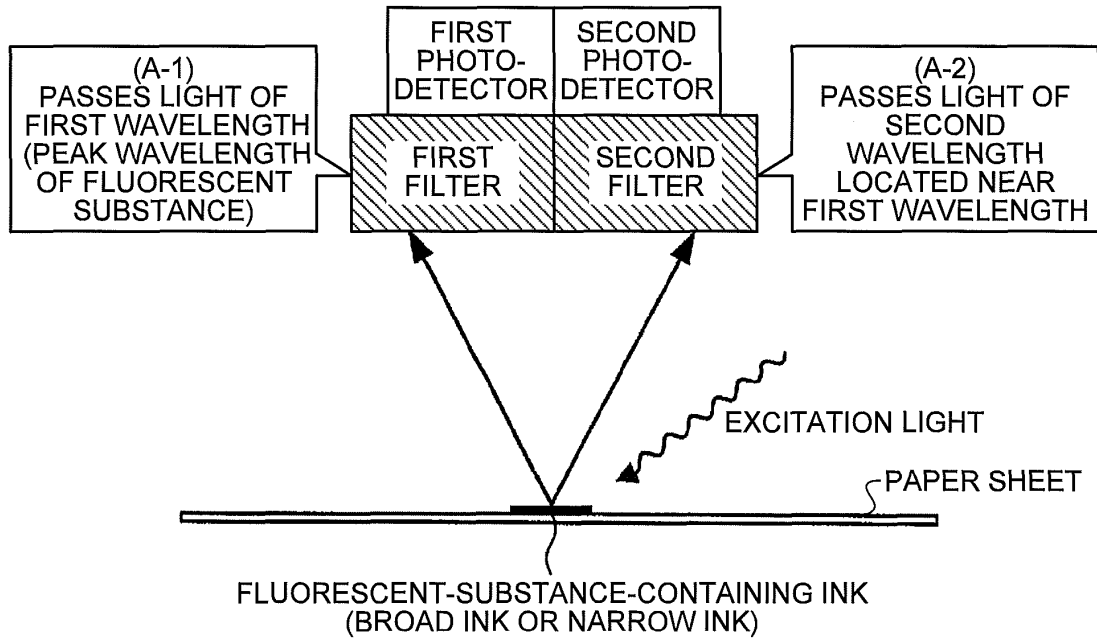


FIG.1B

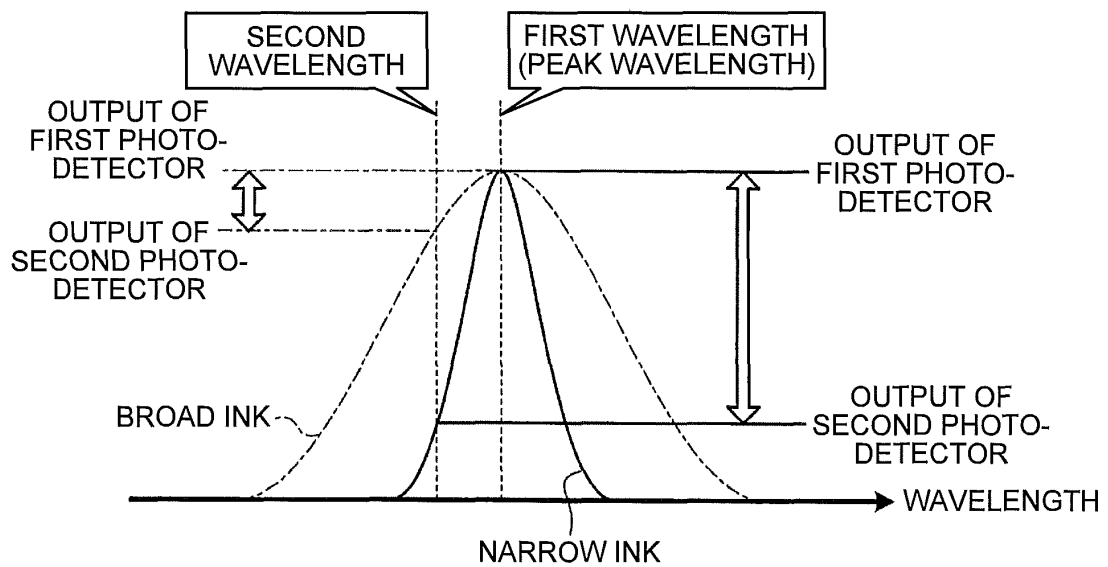


FIG.2

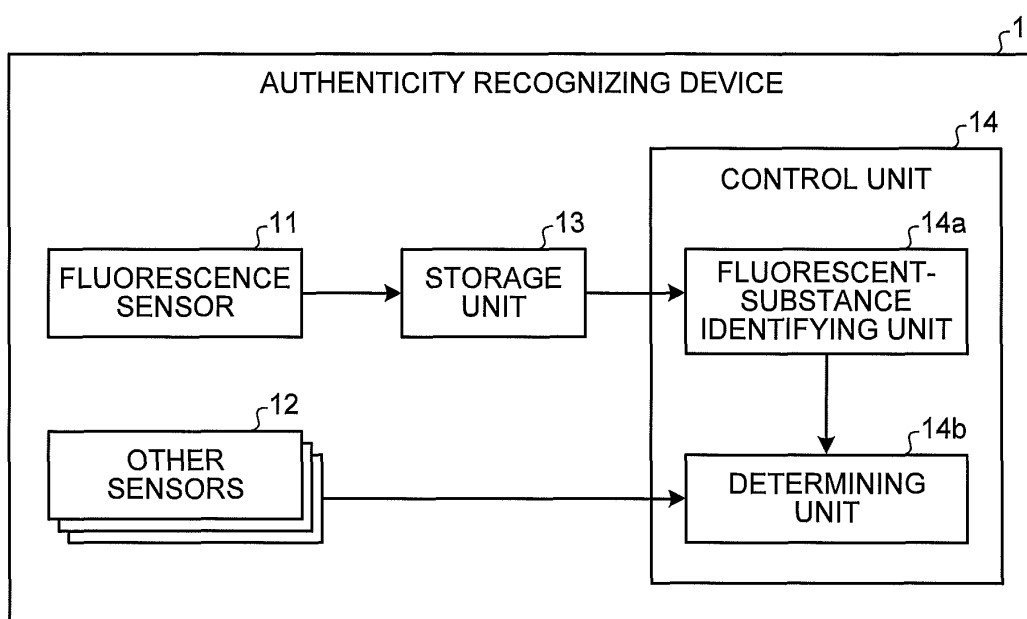


FIG.3A

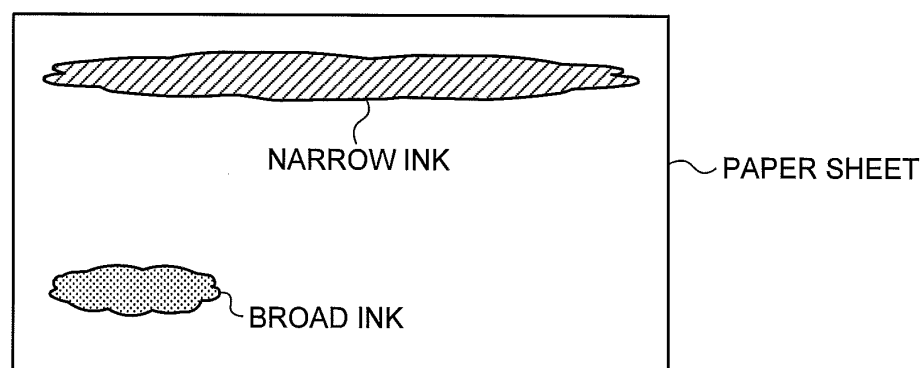


FIG.3B

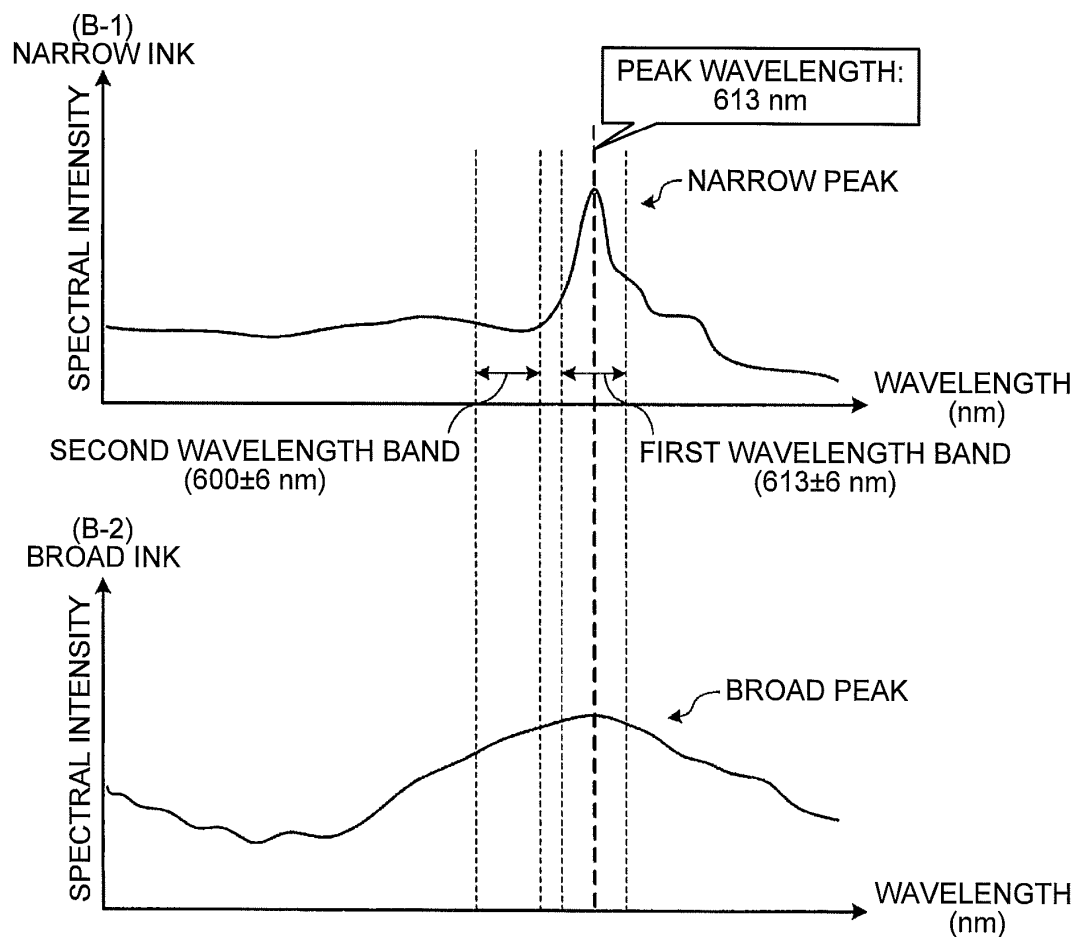


FIG.4A

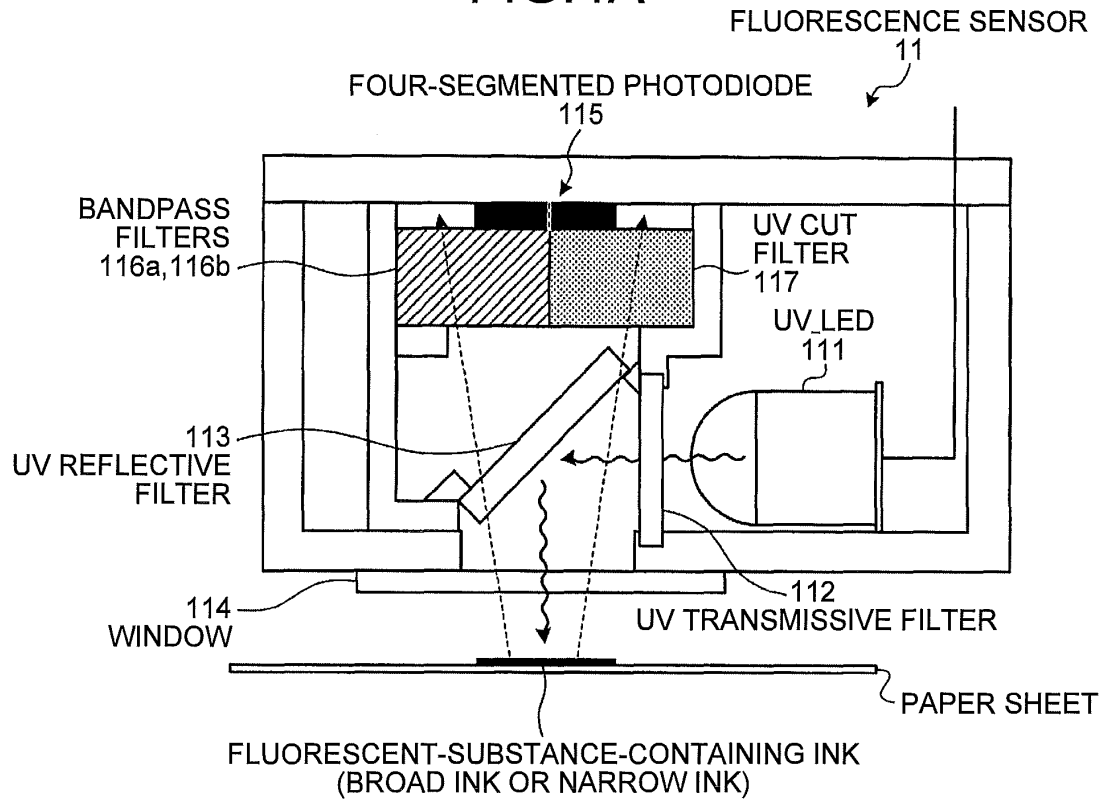


FIG.4B

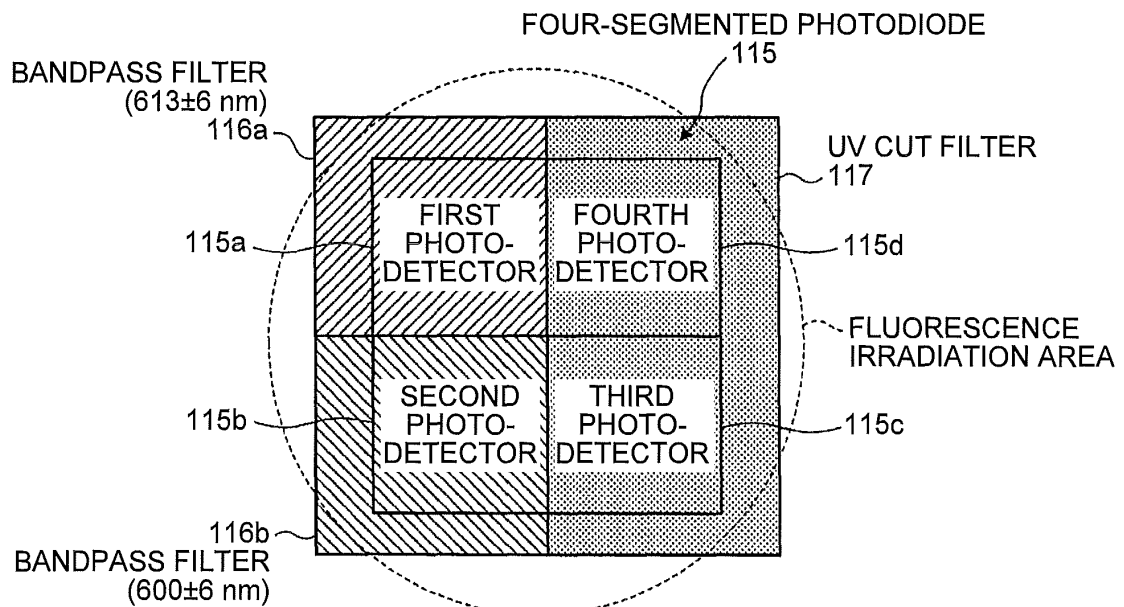


FIG.5

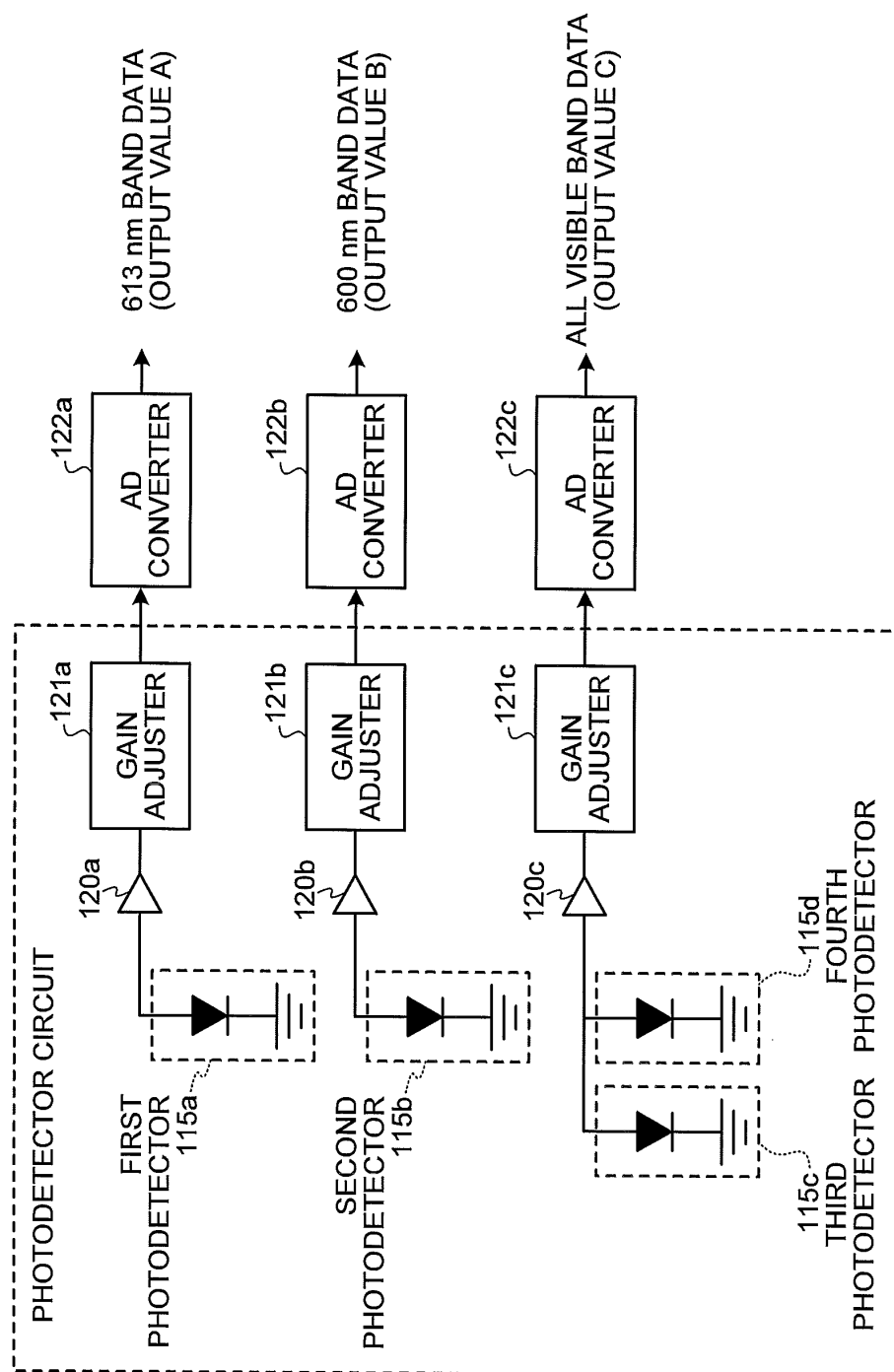


FIG.6

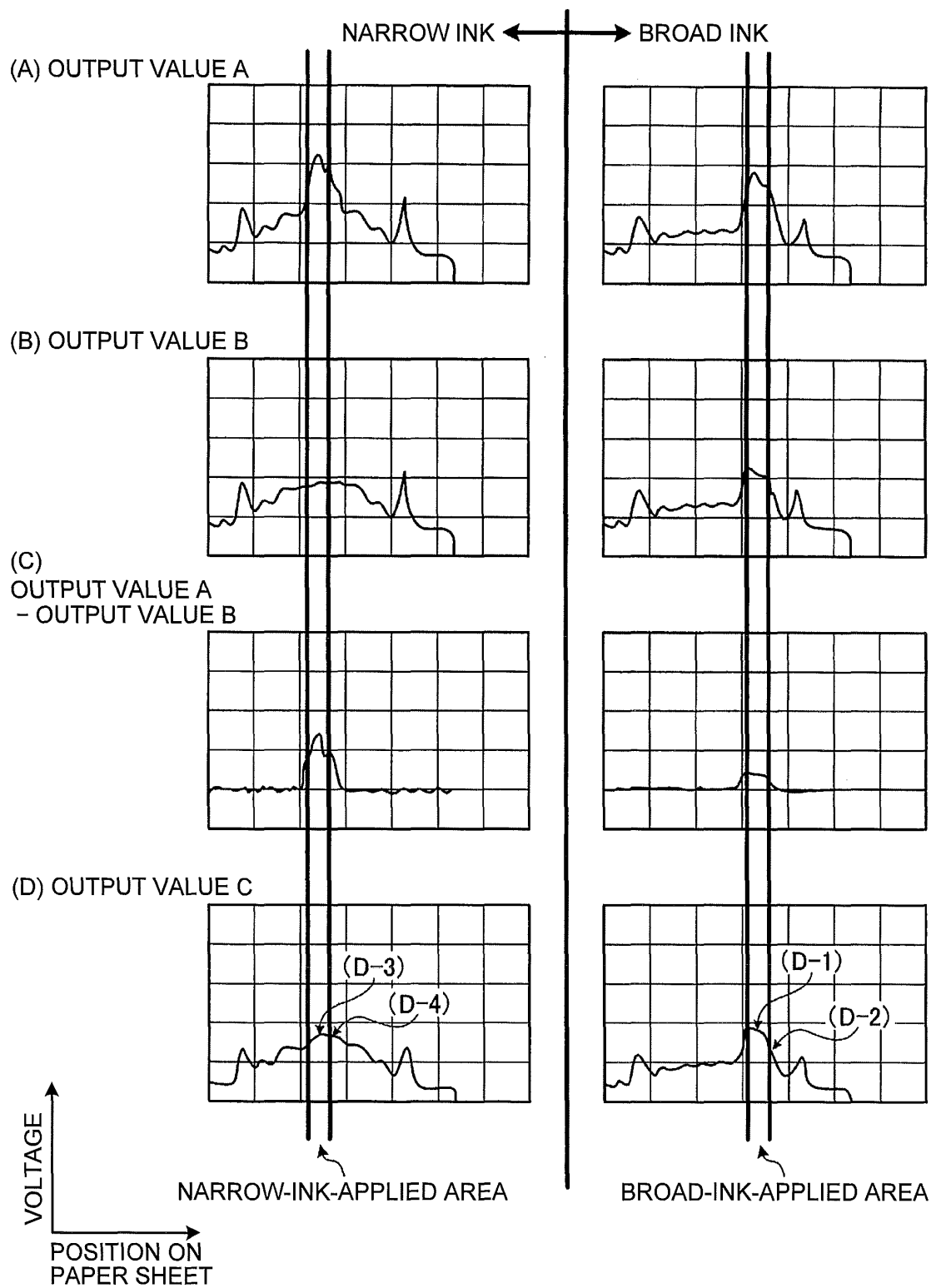


FIG.7A

(A-1)
EVALUATION VALUE 1 (DEGREE OF STEEPNESS OF SPECTRUM WAVEFORM)
= (OUTPUT VALUE A — OUTPUT VALUE B) / OUTPUT VALUE C

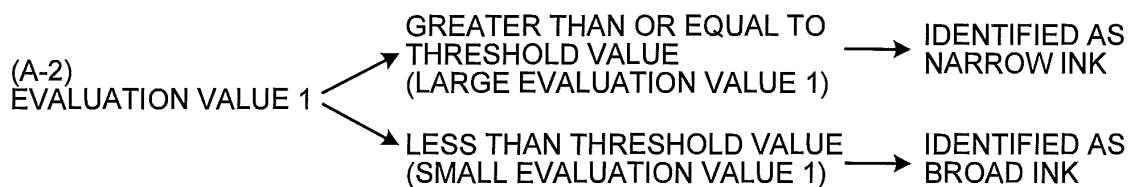


FIG.7B

(B-1)
EVALUATION VALUE 2 (SPECTRAL AREA)
= OUTPUT VALUE C OF INK ADDED AREA — OUTPUT VALUE C OF ADJACENT AREA

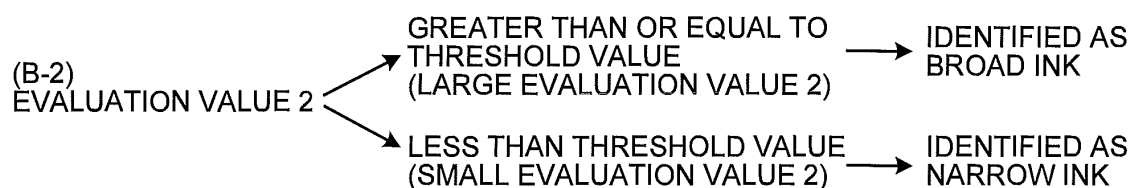


FIG.7C

COMPREHENSIVE EVALUATION VALUE
= $m_1 \times \text{EVALUATION VALUE 1} - m_2 \times \text{EVALUATION VALUE 2}$
($m_1 > m_2$, AND m_1 AND m_2 ARE POSITIVE)

FIG.8

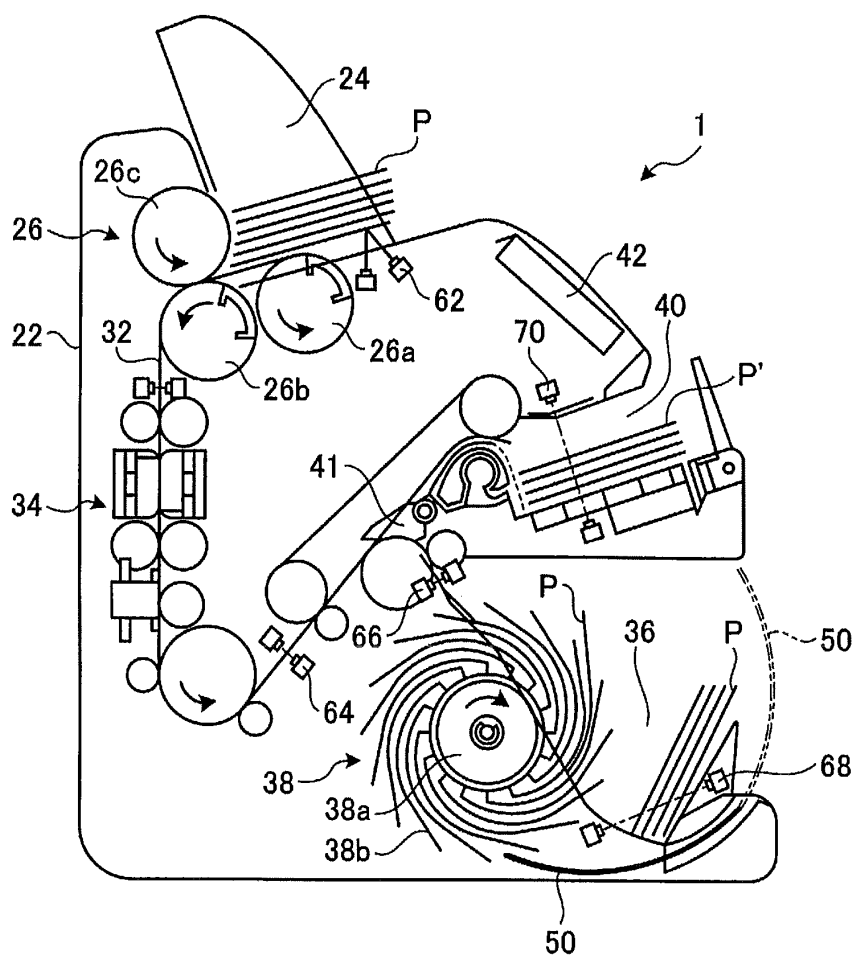


FIG.9A

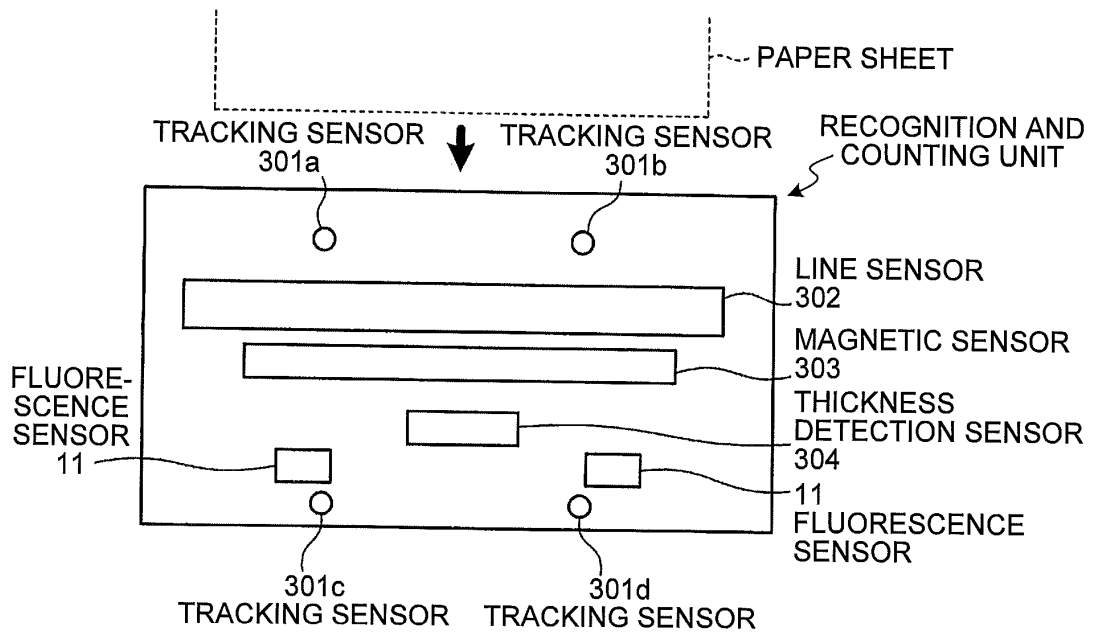


FIG.9B

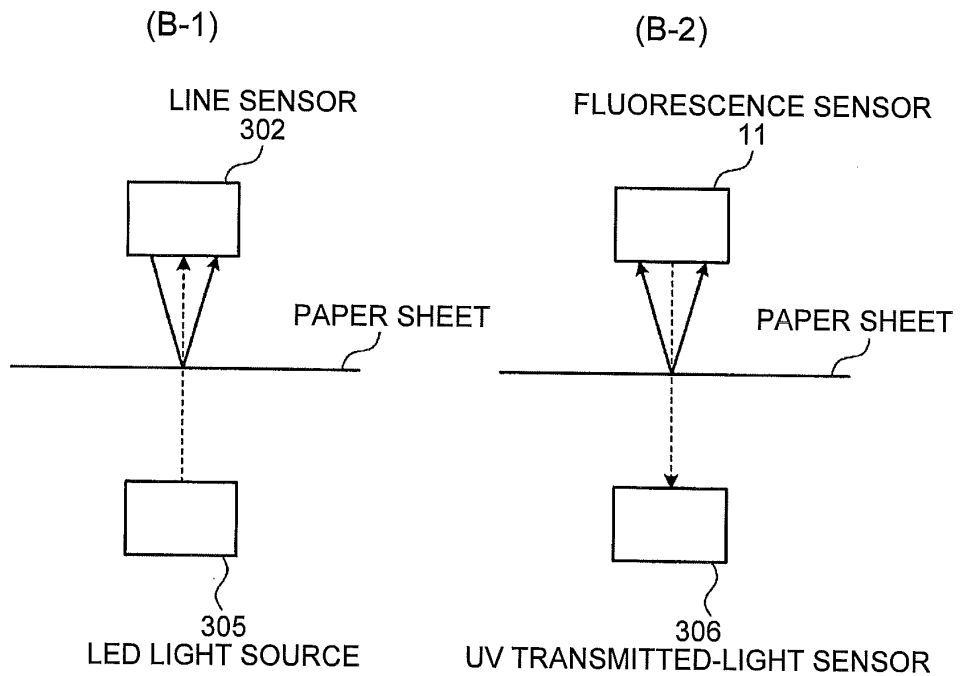


FIG.10

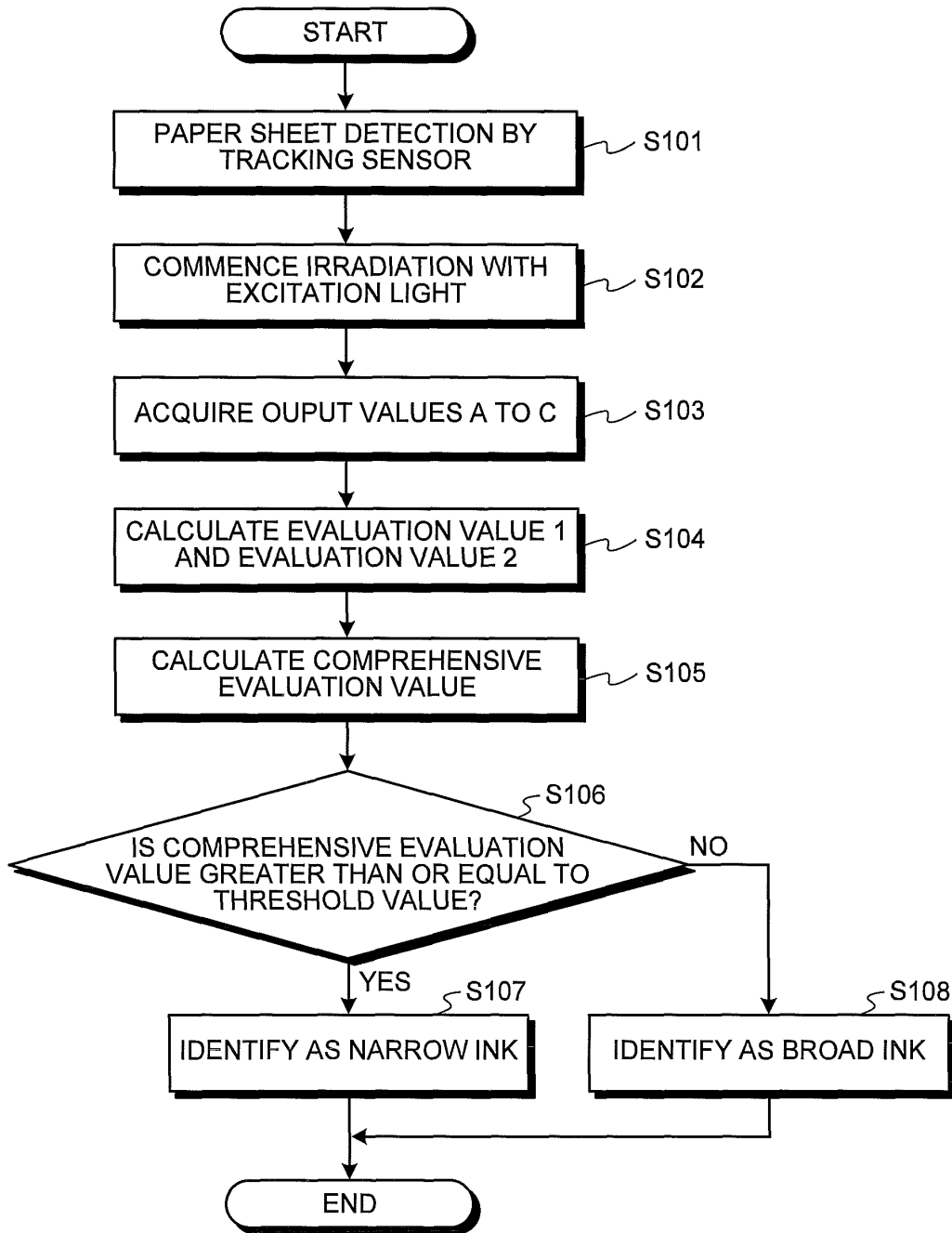


FIG.11

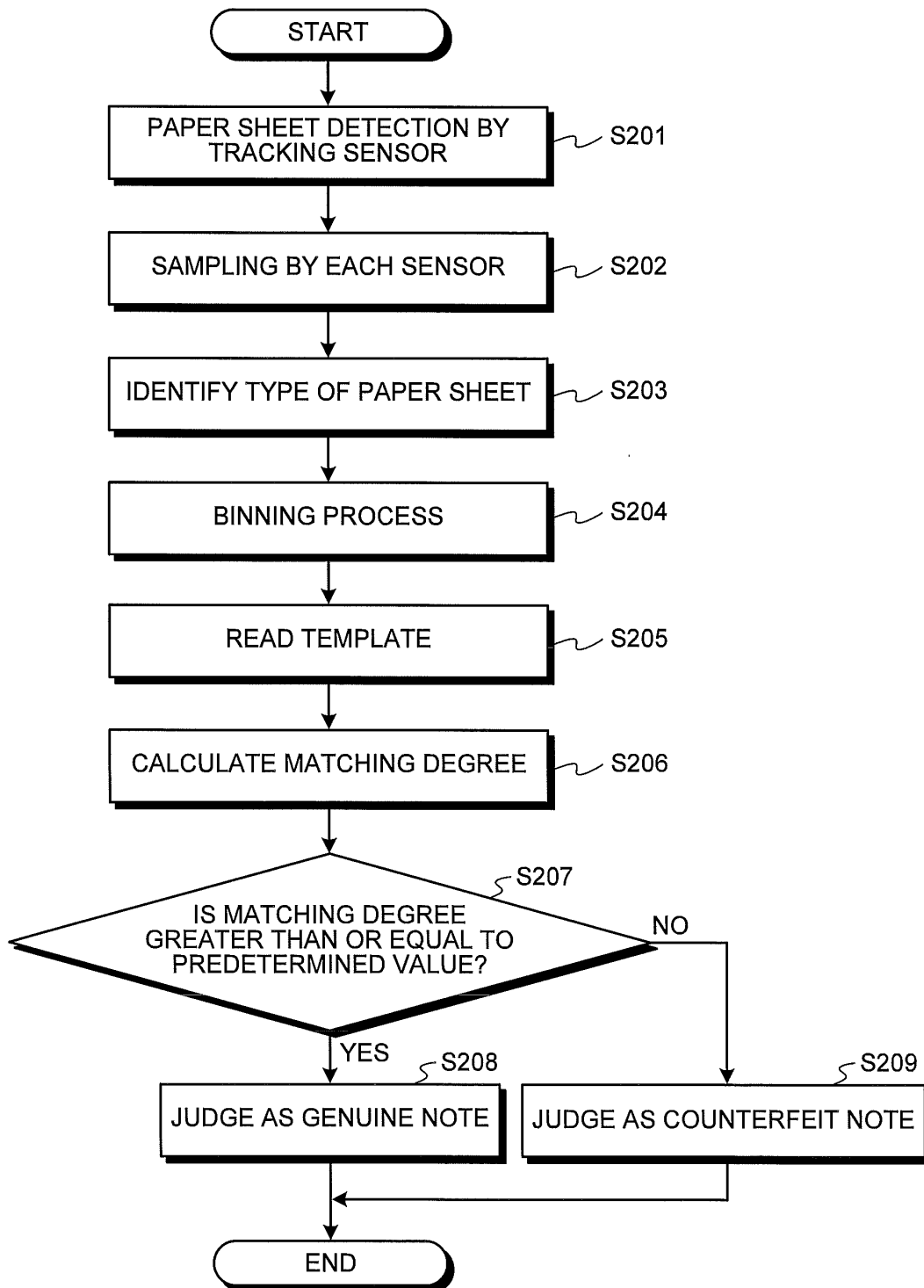


FIG.12A

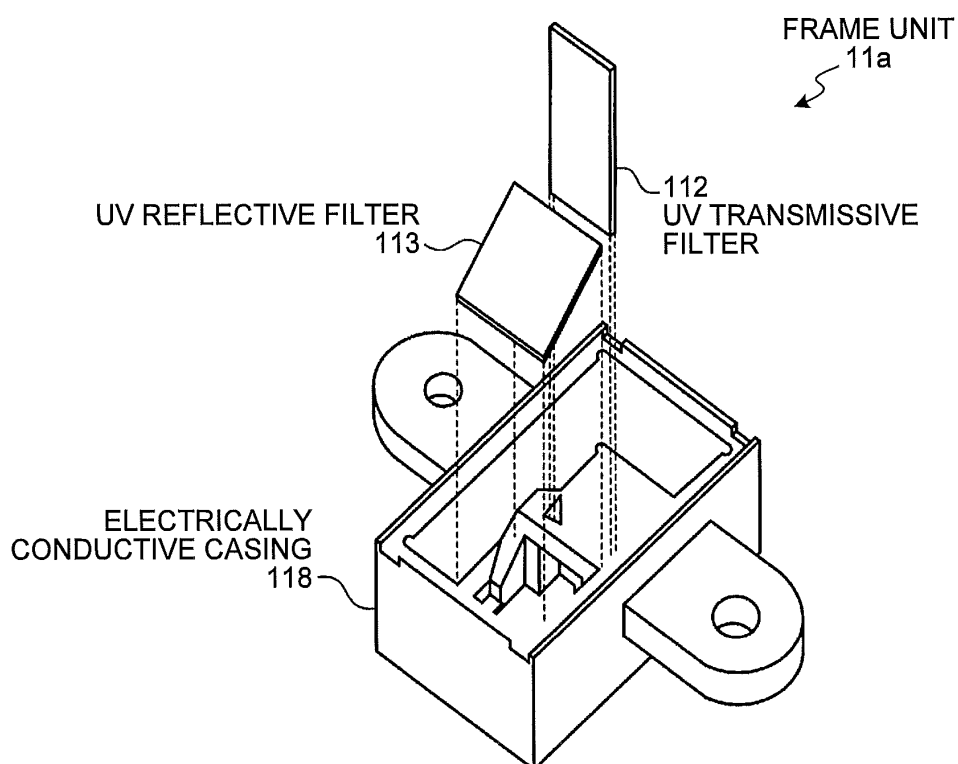


FIG.12B

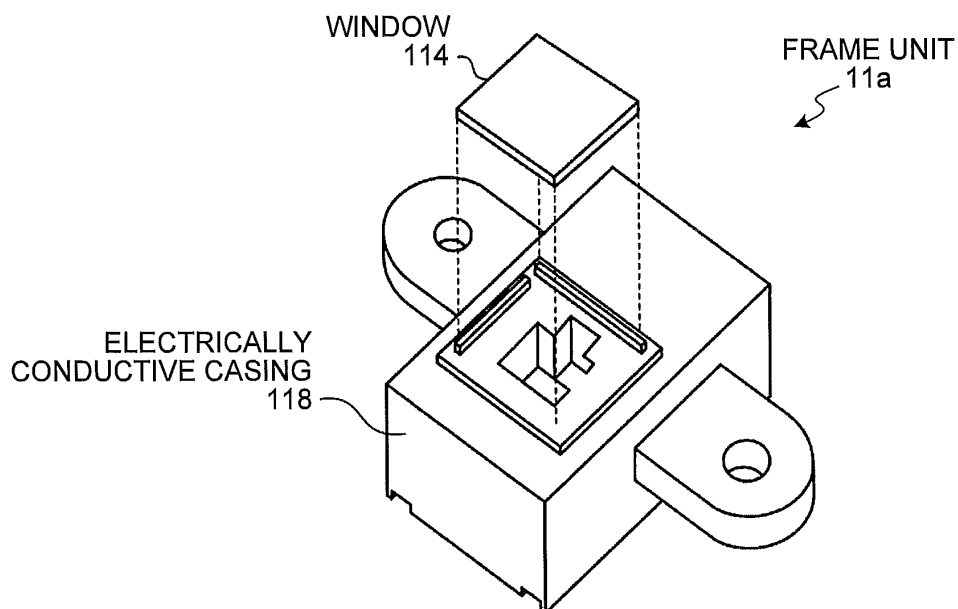


FIG.13

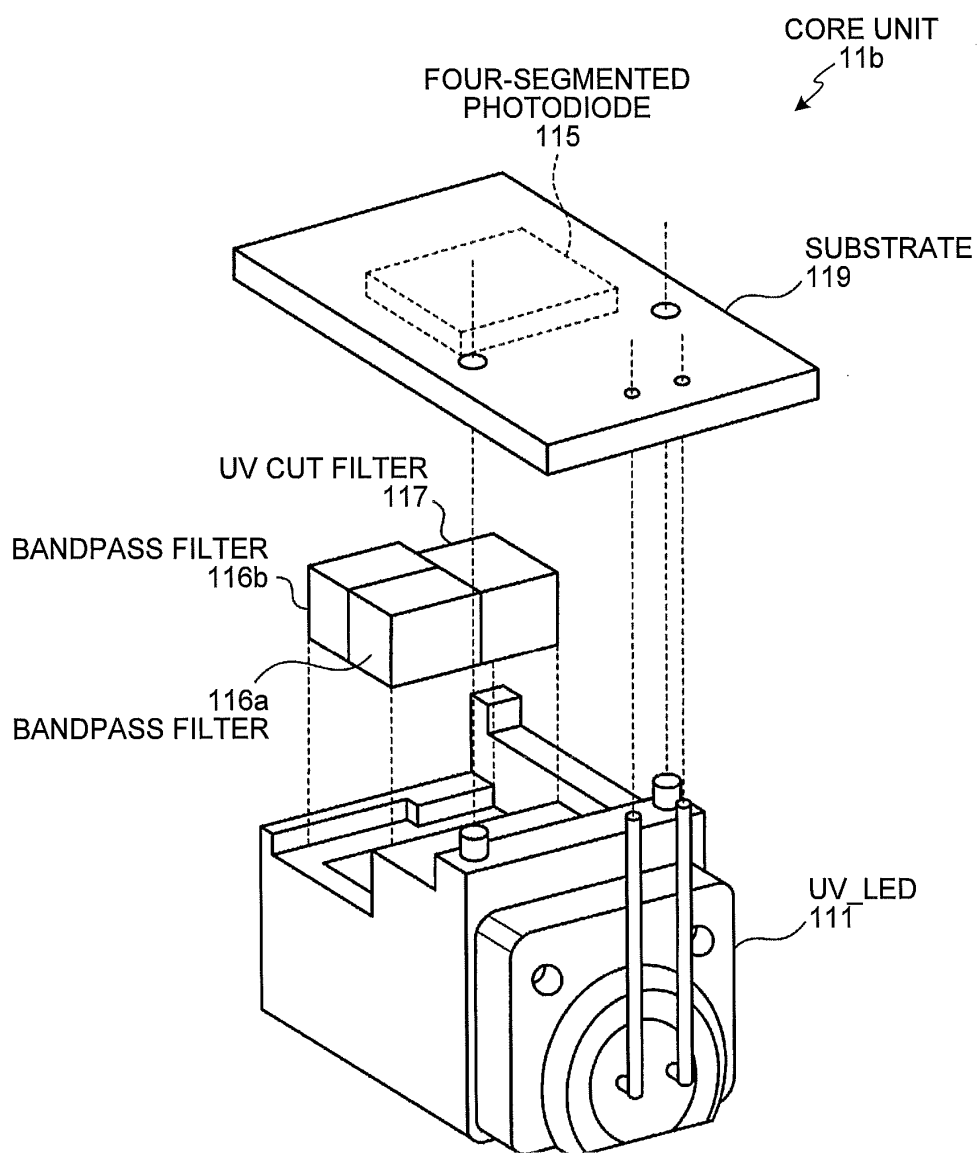
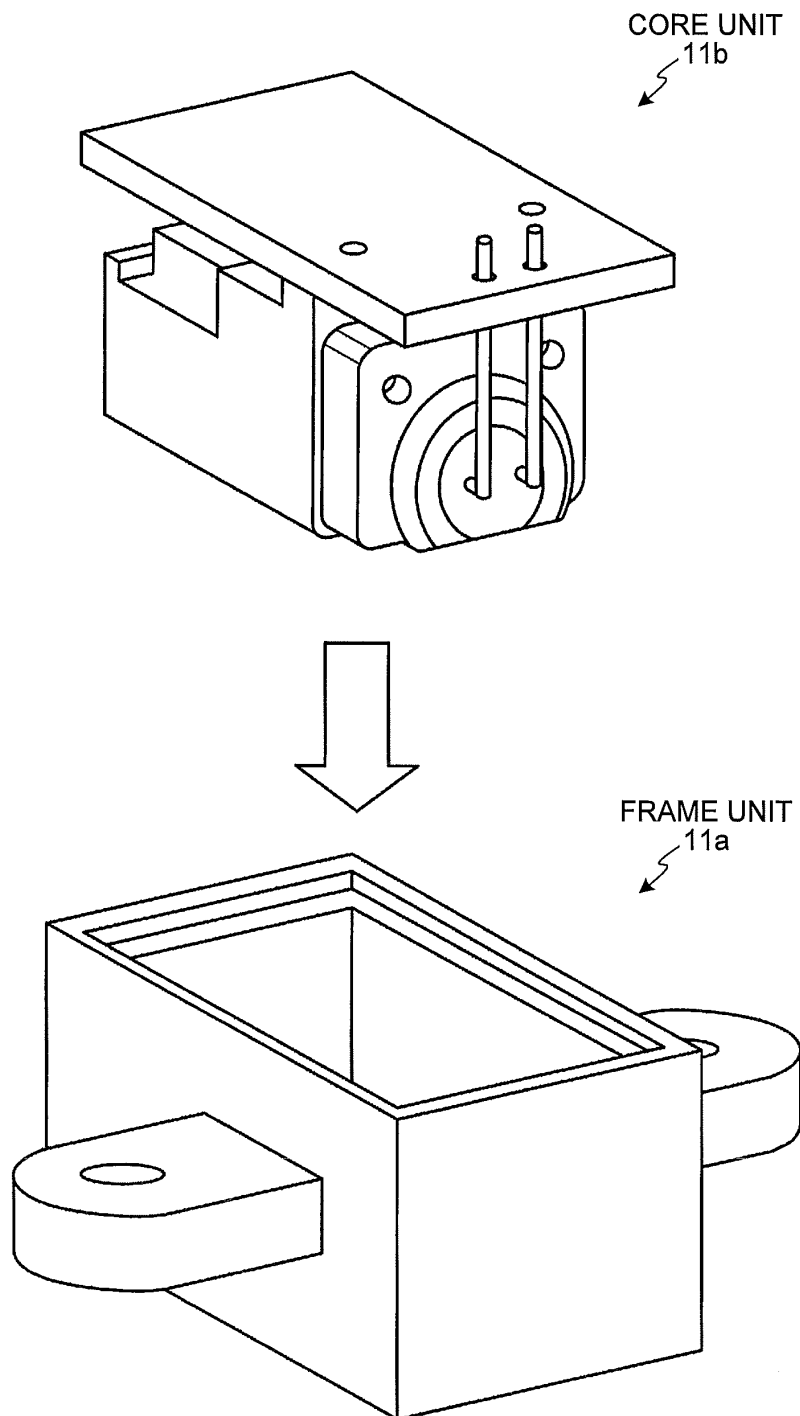


FIG.14



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2010/054537

A. CLASSIFICATION OF SUBJECT MATTER

G07D7/12 (2006.01) 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)

G07D7/12

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	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

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.
X	JP 2001-52232 A (Fuji Electric Co., Ltd.),	1-4, 9-12
Y	23 February 2001 (23.02.2001),	13
A	paragraphs [0023] to [0045]; fig. 1 to 6 (Family: none)	5-8
Y	JP 10-143705 A (SEL Inc.),	13
	29 May 1998 (29.05.1998),	
	paragraphs [0025] to [0031]; fig. 4 (Family: none)	
A	JP 2002-109598 A (Fuji Electric Co., Ltd.),	1-13
	12 April 2002 (12.04.2002),	
	entire text; all drawings (Family: none)	

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

* Special categories of cited documents:

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

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"&" document member of the same patent family

Date of the actual completion of the international search
06 May, 2010 (06.05.10)Date of mailing of the international search report
18 May, 2010 (18.05.10)Name and mailing address of the ISA/
Japanese Patent Office

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2007136838 A [0007]