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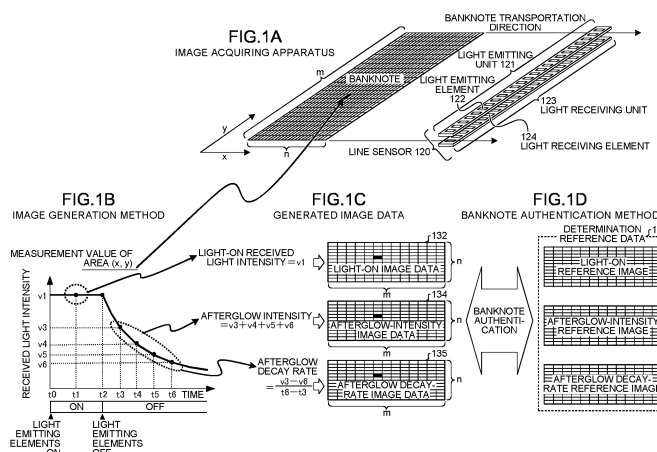
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(54) **PAPER-SHEET AUTHENTICITY DETERMINATION DEVICE AND PAPER-SHEET AUTHENTICITY DETERMINATION METHOD**

(57) An object is to realize a stricter authentication of a banknote while reducing the cost by making a sensor structure simpler. An excitation light is irradiated on a banknote having a characteristic to emit phosphorescence when irradiated with the excitation light, and a transmitted light passing through the banknote and an afterglow of the phosphorescence emitted by the banknote are detected with a line sensor (120). Authentication of the banknote is determined by evaluating the similarity between each of light-on image data (132) acquired

while the excitation light is being irradiated, afterglow-intensity image data (134) generated from an afterglow intensity after the excitation light is turned off, and afterglow decay-rate image data (135) generated from a decay rate of the afterglow intensity after the excitation light is turned off, and a light-on reference image, an afterglow-intensity reference image, and an afterglow decay-rate reference image corresponding to a genuine banknote and stored previously.



Description

[Technical Field]

[0001] The present invention relates to a paper-sheet authentication apparatus and a paper-sheet authentication method that receive a paper sheet, such as a banknote, a check, a gift certificate, a cash voucher, and determines an authentication of the paper sheet.

[Background Art]

[0002] A technique of acquiring from a paper sheet, which contains a material having fluorescence and phosphorescence emission characteristic, information about a fluorescence intensity while an excitation light is being irradiated on the paper sheet and acquiring from the same paper sheet information about a phosphorescence intensity after stopping the irradiation of the excitation light, and determining a kind and an authentication of the paper sheet based on the acquired information is known in the art. For example, Patent Document 1 discloses a technique of acquiring information about the fluorescence intensity and information about the phosphorescence intensity from the paper sheet. Specifically, when a paper sheet is being transported on a transport path, an excitation light is irradiated on the paper sheet in an upstream region that is upstream of the transport path, and the irradiation of the excitation light is cut off in a downstream region that is downstream of the upstream region. A sensor that detects the fluorescence from the paper sheet is arranged in the upstream region in which the excitation light is irradiated on the paper sheet, and a sensor that detects the phosphorescence from the paper sheet is arranged in the downstream region in which the excitation light is cut off.

[0003] In the technique disclosed in Patent Document 1, it is necessary to separately provide the sensor that acquires the information about the fluorescence intensity and the sensor that acquires the information about the phosphorescence intensity, and this makes the structure of the sensors complicated. A technique that can acquire the information about the fluorescence intensity and the information about the phosphorescence intensity by using one sensor is also known in the art. For example, Patent Document 2 discloses a technique that can acquire the information about the fluorescence intensity and the information about the phosphorescence intensity by using one sensor. Specifically, a light source that emits the excitation light is turned on/off at short cycles, and the information about the fluorescence intensity is acquired while the light source is on and the information about the phosphorescence intensity is acquired while the light source is off.

[0004] Moreover, for example, Patent Document 3 discloses a technique of acquiring information about intensity per wavelength range of the fluorescence and the phosphorescence. Specifically, the information about the

fluorescence intensity and the information about the phosphorescence intensity are acquired by using respective sensors each having a filter with a different transmitting wavelength range. It is known that the material having the fluorescence and the phosphorescence characteristic exhibits different emission wavelength characteristic for the fluorescence and the phosphorescence depending on the kind of the material. Accordingly, detection of the characteristics allows stricter determination of the kind and the authentication of the paper sheet.

[0005] In this manner, by acquiring from a paper sheet, which contains a material having fluorescence and phosphorescence characteristic, the information about the fluorescence intensity while the excitation light is being irradiated on the paper sheet and acquiring from the paper sheet the information about the phosphorescence intensity after stopping the irradiation of the excitation light, and determining the kind and the authentication of the paper sheet based on the acquired information, it is possible to detect a counterfeit banknote and the like that is difficult to detect with the human eyes.

[Citation List]

[Patent Document]

[0006]

[Patent Document 1] Japanese Patent No. 5367509

[Patent Document 2] Japanese Patent No. 4048121

[Patent Document 3] Japanese Patent No. 3790931

[Summary of Invention]

[Technical Problem]

[0007] However, it is possible to find out the intensities of the fluorescence and the phosphorescence per wavelength of a genuine paper sheet beforehand and counterfeit a paper sheet accordingly. If this is done, the counterfeit paper sheet may not be detected by the method of determining the authentication based on intensities of the fluorescence and the phosphorescence of a banknote. Moreover, if, like in Patent Document 3, characteristic relating to emission wavelengths of the fluorescence and the phosphorescence are to be determined, a filter that meets the fluorescence and the phosphorescence characteristic of the material used in the paper sheet targeted for the authentication becomes necessary. This makes the structure of the sensor complicated.

[0008] In this manner, in determining the kind and the authentication of the paper sheet containing the material having the fluorescence and the phosphorescence characteristic, there is a need to realize a stricter authentication of a banknote with a simpler sensor structure and reducing the cost.

[0009] The present invention is intended to solve the problems in the conventional technologies and one ob-

ject thereof is to provide a paper-sheet authentication apparatus and a paper-sheet authentication method that can realize a stricter authentication of a banknote while reducing the cost by making a sensor structure simpler.

[Means for Solving Problems]

[0010] To solve the above problem, and to achieve the above object, a paper-sheet authentication apparatus according to a first aspect of the present invention, which determines a kind and/or an authentication of a paper sheet having a characteristic to emit phosphorescence when irradiated with an excitation light, includes a transport unit that transports the paper sheet; an excitation-light irradiating unit that irradiates with the excitation light a small area of the paper sheet being transported by the transport unit; a phosphorescence-intensity acquiring unit that acquires a phosphorescence intensity from the small area on the paper sheet after the excitation-light irradiating unit has irradiated the small area of the paper sheet with the excitation light and then stopped irradiating; a phosphorescence decay-rate calculating unit that calculates a decay rate indicating a decrease rate of the phosphorescence intensity of the small area on the paper sheet based on the phosphorescence intensity acquired a plurality of times by the phosphorescence-intensity acquiring unit from the small area on the paper sheet; a phosphorescence decay-rate pattern generating unit that generates a phosphorescence decay-rate pattern in which the decay rate calculated by the phosphorescence decay-rate calculating unit is associated with a position of the small area on the paper sheet based on a transport state of the paper sheet transported by the transport unit; and an authentication unit that determines the authentication of the paper sheet targeted for determination by comparing a previously generated phosphorescence decay-rate pattern of a genuine paper sheet with the phosphorescence decay-rate pattern of the paper sheet targeted for determination generated by the phosphorescence decay-rate pattern generating unit.

[0011] In the above paper-sheet authentication apparatus, the excitation-light irradiating unit is comprised of a plurality of the excitation-light irradiating units which are arranged in a direction of an intersection line of a surface parallel to a transport surface of the paper sheet and a surface orthogonal to a transport direction of the paper sheet, and the same number of the phosphorescence-intensity acquiring units as the number of the excitation-light irradiating units are arranged in the same direction as the direction in which the excitation-light irradiating units are arranged.

[0012] In the above paper-sheet authentication apparatus, the excitation-light irradiating unit irradiates the paper sheet with the excitation light, and the excitation-light irradiating unit and the phosphorescence-intensity acquiring unit are arranged on opposite sides of a transport path of the paper sheet.

[0013] In the above paper-sheet authentication appa-

ratus, the excitation-light irradiating unit irradiates the paper sheet with the excitation light, and the excitation-light irradiating unit and the phosphorescence-intensity acquiring unit are arranged on the same side with respect to a transport surface of the paper sheet.

[0014] The above paper-sheet authentication apparatus further includes a phosphorescence-intensity pattern generating unit that generates a phosphorescence intensity pattern in which the phosphorescence intensity of the paper sheet acquired by the phosphorescence-intensity acquiring unit is associated with a position of the paper sheet of a transport direction of the paper sheet while transporting the paper sheet with the transport unit; and a second authentication unit that determines the authentication of the paper sheet targeted for determination by comparing a previously generated phosphorescence intensity pattern of a genuine paper sheet generated by the phosphorescence-intensity pattern generating unit with the phosphorescence intensity pattern of the paper sheet targeted for determination generated by the phosphorescence-intensity pattern generating unit.

[0015] The above paper-sheet authentication apparatus further includes a paper-sheet kind determination unit that determines the kind of the paper sheet targeted for determination by comparing the previously generated phosphorescence intensity pattern of the genuine paper sheet generated by the phosphorescence-intensity pattern generating unit with the phosphorescence intensity pattern of the paper sheet targeted for determination generated by the phosphorescence-intensity pattern generating unit.

[0016] In the above paper-sheet authentication apparatus, the excitation-light irradiating unit radiates the excitation light having a wavelength component between 800 nm and 1000 nm, and the phosphorescence-intensity acquiring unit acquires an intensity of light of a wavelength that is longer than a visible light and / or the excitation light.

[0017] In the above paper-sheet authentication apparatus, a relation between a transport speed of the transport unit and a scanning area of the phosphorescence-intensity acquiring unit is such that the small area from which the phosphorescence intensity is acquired is 50% or more of the area irradiated by the excitation-light irradiating unit.

[0018] The above paper-sheet authentication apparatus further includes a transmitted-light intensity acquiring unit that acquires a transmitted-light intensity of a light passing through the small area of the paper sheet while the excitation-light irradiating unit is irradiating the small area of the paper sheet with the excitation light; a transmission-intensity pattern generating unit that generates a transmission intensity pattern in which the transmitted-light intensity of the paper sheet acquired by the transmitted-light intensity acquiring unit is associated with a transport direction of the paper sheet while the transport unit is transporting the paper sheet; and a third authentication unit that determines the authentication of the pa-

per sheet targeted for determination by comparing a previously generated transmission intensity pattern of a genuine paper sheet generated by the transmission-intensity pattern generating unit with the transmission intensity pattern of the paper sheet targeted for determination generated by the transmission-intensity pattern generating unit.

[0019] A paper-sheet authentication method according to a second aspect of the present invention, which is for determining a kind and/or an authentication of a paper sheet having a characteristic to emit phosphorescence when irradiated with an excitation light, includes transporting the received paper sheet; irradiating a small area of the paper sheet being transported with the excitation light at the transporting; acquiring a phosphorescence intensity from the small area on the paper sheet after the excitation light has irradiated the small area of the paper sheet and then stopped irradiating; calculating a decay rate indicating a decrease rate of the phosphorescence intensity of the small area on the paper sheet based on the phosphorescence intensity acquired a plurality of times from the small area on the paper sheet at the acquiring; generating a phosphorescence decay-rate pattern in which the decay rate calculated at the calculating with a position of the small area on the paper sheet based on a transport state of the paper sheet transported at the transporting; and determining the authentication of the paper sheet targeted for determination by comparing a previously generated phosphorescence decay-rate pattern of a genuine paper sheet with the phosphorescence decay-rate pattern of the paper sheet targeted for determination generated at the generating.

[Advantageous Effects of Invention]

[0020] According to the present invention, the excitation light is irradiated in a small area of the paper sheet when the paper sheet is being transported, a phosphorescence intensity from the small area on the paper sheet is acquired after the irradiation of the excitation light is stopped, a decay rate indicating a decrease rate of the phosphorescence intensity of the small area on the paper sheet is calculated based on the phosphorescence intensity of the small area on the paper sheet and acquired a plurality of times, based on a transport state, a phosphorescence decay-rate pattern that contains a pattern of the phosphorescence decay rate with a position of the small area on the paper sheet is generated, and the authentication of the paper sheet targeted for determination is determined by comparing a phosphorescence decay-rate pattern generated previously of a genuine paper sheet with the phosphorescence decay-rate pattern of the paper sheet targeted for determination. Therefore, a stricter authentication of the banknote while reducing the cost by making the sensor structure simpler can be realized

[Brief Description of Drawings]

[0021]

FIG. 1 is a schematic explanatory view for explaining a paper-sheet authentication method according to one embodiment of the present invention.

FIG. 2 is a view for explaining phosphorescence emission characteristic of a banknote on which a particular region has been printed with a phosphorescence ink.

FIG. 3 is a block diagram of an internal configuration of a banknote authentication apparatus that performs banknote authentication according to the present embodiment.

FIG. 4 is a view for explaining a configuration of a line sensor shown in FIG. 1 including a light emitting unit and a light receiving unit.

FIG. 5 is a view for explaining a data structure of the banknote authentication apparatus shown in FIG. 3.

FIG. 6 is a view for explaining a processing timing of an image acquisition of a banknote by the banknote authentication apparatus shown in FIG. 3 according to the present embodiment.

FIG. 7 is a flowchart of a processing procedure of an image-data acquisition processing performed by the banknote authentication apparatus shown in FIG. 3.

FIG. 8 is a flowchart of a processing procedure of a banknote authentication processing performed by the banknote authentication apparatus shown in FIG. 3.

[Description of Embodiments]

[0022] Exemplary embodiments of a paper-sheet authentication apparatus and a paper-sheet authentication method according to the present invention are explained below in detail with reference to the accompanying drawings. The following embodiments will be explained by using a "banknote" as a representative of a "paper sheet".

EMBODIMENT

[0023] At first, an outline of a banknote authentication method according to the present embodiment is explained by using FIG. 1. In FIG. 1, (a) indicates an outline of a relation between a banknote targeted for authentication and a structure of a line sensor 120 of a banknote authentication apparatus 100 according to the present embodiment that acquires an image of the banknote. In FIG. 1, (b) indicates an example of information acquired by the line sensor 120 in each area on the banknote shown in (a) of FIG. 1 that has been divided into (m x n) target areas. In FIG. 1, (c) indicates a method of generating, based on the acquired information shown in (b) of FIG. 1, an image to be used in the banknote authentication. In FIG. 1, (d) is a view for explaining a concept of the authentication performed by using the image data

generated in (c) of FIG. 1.

[0024] As shown in (a) of FIG. 1, the line sensor 120 sandwiches a transport path of a banknote and includes a light emitting unit 121 arranged above the transport path and a light receiving unit 123 arranged below the transport path. The light emitting unit 121 includes "m" light emitting elements 122 arranged at a regular interval in the y-axis direction. Each of the light emitting elements 122 radiates infrared light on the front surface of the banknote. Moreover, the light receiving unit 123 includes "m" light receiving elements 124 arranged at a regular interval in the y-axis direction. Each of the "m" light receiving elements 124 is arranged at a position corresponding to each of the "m" light emitting elements 122. Each of the light receiving elements 124 detects a light passing through the banknote and a light emitted by the banknote that is being transported on the transport path.

[0025] The banknote is transported in the positive direction of the x-axis. While the banknote is passing through the line sensor 120, the line sensor 120 acquires information from the banknote at "n" positions in the x-axis direction. That is, when the banknote passes through the line sensor 120, the line sensor 120 acquires information in each of "n" unit detection areas in the x-axis direction and "m" unit detection areas in the y-axis direction.

[0026] In FIG. 1, (b) is a graph that shows a relation between a time and a received light intensity acquired by the light receiving element 124 corresponding to an area (x, y) that is one of the unit detection areas shown in (a) of FIG. 1. The light emitting unit 121 of the line sensor 120 is turned on at a time point t0 and turned off at a time point t2 at each of the "n" positions on the banknote in the x-axis direction. From the time point t0 up to the time point t2 during which the light emitting element 122 corresponding to the area (x, y) is on, the received light intensity acquired by the light receiving element 124 is v1. After the light emitting element 122 is turned off at the time point t2, the received light intensity acquired by the light receiving element 124 decreases with time. The acquired information corresponding to the area (x, y) includes the received light intensity v1 at the time point t1 as a received light intensity while the excitation light is being irradiated, and a received light intensity v3 at a time point t3, a received light intensity v4 at a time point t4, a received light intensity v5 at a time point t5, and a received light intensity v6 at a time point t6 as received light intensities after the excitation light is turned off.

[0027] In FIG. 1, (c) shows a method of generating light-on image data 132 from the information acquired while the excitation light is being irradiated, and afterglow-intensity image data 134 and afterglow decay-rate image data 135 from the information acquired after the excitation light is turned off. These data are generated from the one received light intensity (v1) acquired while the excitation light is being irradiated and the four received light intensities (v3, v4, v5, and v6) acquired after the excitation light is turned off as shown in (b) of FIG. 1.

[0028] The light-on image data 132 is an image containing (m x n) pixels corresponding to the (m x n) areas on the banknote shown in (a) of FIG. 1. Moreover, a pixel value of each of the pixels of the light-on image data 132 represents the received light intensity v1 at a time point t1 shown in the graph in (b) of FIG. 1 that is the received light intensity acquired while the excitation light is being irradiated in each of the areas corresponding to each of the pixels.

[0029] The afterglow-intensity image data 134 is an image containing (m x n) pixels corresponding to the (m x n) areas on the banknote shown in (a) of FIG. 1. Moreover, a pixel value of each of the pixels of the afterglow-intensity image data 134 represents a sum of the received light intensities v3, v4, v5, and v6 shown in the graph in (b) of FIG. 1 that are the received light intensities acquired after the excitation light is turned off in each of the areas corresponding to each of the pixels.

[0030] The afterglow decay-rate image data 135 is an image containing (m x n) pixels corresponding to the (m x n) areas on the banknote shown in (a) of FIG. 1. Moreover, a pixel value of each of the pixels of the afterglow decay-rate image data 135 represents a decay-rate of the received light intensities between the time point t3 and the time point t6 after the excitation light is turned off shown in the graph in (b) of FIG. 1 in each of the areas corresponding to each of the pixels. The decay-rate of the received light intensities between the time point t3 and the time point t6 can be calculated by subtracting the received light intensity v6 at the time point t6 from the received light intensity v3 at the time point t3 and then dividing the obtained value by a value obtained by subtracting t3 from t6. Here, the sampling has been performed four times; however, the decay-rate can be calculated by performing the sampling for two or more times.

[0031] The manner shown in (b) of FIG. 1 in which the afterglow intensity decreases with the passage of time after the excitation light has been turned off varies depending on the kind and the amount of the phosphorescence ink and the like included in the banknote. Therefore, even if it is difficult to determine such a variation merely by using the received light intensity of the phosphorescence ink, by evaluating a variation in the manner in which the afterglow intensity of the phosphorescence ink used to print a genuine banknote decreases due to the variation in the manner in which the phosphorescence ink has been used, a stricter authentication of the banknote can be performed.

[0032] Moreover, the banknote authentication apparatus 100 previously stores therein determination reference data 131 corresponding to a light-on reference image, an afterglow-intensity reference image, and an afterglow decay-rate reference image. The light-on reference image, the afterglow-intensity reference image, and the afterglow decay-rate reference image are images generated previously from the information acquired by the line sensor 120, with the same procedure as shown in (b) and (c) of FIG. 1, from genuine banknotes per denomi-

nation and direction targeted for the determination. When performing a banknote authentication processing, the light-on image data 132, the afterglow-intensity image data 134, and the afterglow decay-rate image data 135 shown in (d) of FIG. 1 are generated based on the information acquired by the line sensor 120 from the banknote targeted for the authentication. The generated data are compared with the determination reference data 131 that is stored previously and contains the light-on reference image, the afterglow-intensity reference image, and the afterglow decay-rate reference image corresponding to the genuine banknote. The authentication of the banknote is determined based on this comparison.

[0033] Furthermore, in order to receive and evaluate an afterglow from a region, in which the infrared light is irradiated as the excitation light, after the irradiation of the infrared light is turned off from this region, it is necessary that a light receiving sensor receives the afterglow from at least 50% or more of the region in which the infrared light is irradiated. To achieve this, it is necessary to appropriately design a transport speed, a light receiving region of the light receiving sensor, and an irradiation surface area of the infrared light.

[0034] In this manner, the excitation light is irradiated on the banknote having a characteristic to emit the phosphorescence when irradiated with the excitation light, and a transmitted light passing through the banknote and the afterglow of the phosphorescence emitted by the banknote are detected with the line sensor 120. The authentication of the banknote is determined by evaluating the similarity between each of the light-on image data 132 acquired while the excitation light is being irradiated, the afterglow-intensity image data 134 generated from the afterglow intensity after the excitation light is turned off, and the afterglow decay-rate image data 135 generated from the decay rate of the afterglow intensities after the excitation light is turned off, and the light-on reference image, the afterglow-intensity reference image, and the afterglow decay-rate reference image corresponding to the genuine banknote and stored previously. Accordingly, a stricter authentication of the banknote while reducing the cost by making the sensor structure simpler can be realized.

[0035] Subsequently, phosphorescence emission characteristic of a banknote on which a particular region has been printed with the phosphorescence ink is explained using FIG. 2. Here, (a) and (b) of FIG. 2 show examples of banknotes in which the phosphorescence ink has been used in similar regions. Moreover, in these two banknotes, the afterglow emission intensity after stopping the irradiation of the infrared light is same but the decay rate is different.

[0036] On the banknote shown in (a) of FIG. 2, the phosphorescence ink is used in a lower-left portion. The graph shown in the central part in (a) of FIG. 2 is a graph of the afterglow received light intensity, from the area shown in (a) of FIG. 2 in which the phosphorescence ink has been used, on a scanning line parallel to the x-axis

at a scanning position y1 in the y-axis direction. Moreover, the shown graph in the lower part in (a) of FIG. 2 is a graph of the afterglow decay rate, from the area shown in (a) of FIG. 2 in which the phosphorescence ink has been used, on the scanning line parallel to the x-axis at the scanning position y1 in the y-axis direction.

[0037] On the banknote shown in (b) of FIG. 2, the phosphorescence ink is used in a lower-left portion similar to that of the banknote shown in (a) of FIG. 2. The graph shown in the central part in (b) of FIG. 2 is a graph of the afterglow received light intensity, from the area shown in (b) of FIG. 2 in which the phosphorescence ink has been used, on a scanning line parallel to the x-axis at a scanning position y1 in the y-axis direction. Moreover, the graph shown in the lower part in (b) of FIG. 2 is a graph of the afterglow decay rate, from the area shown in (b) of FIG. 2 in which the phosphorescence ink has been used, on the scanning line parallel to the x-axis at the scanning position y1 in the y-axis direction.

[0038] From the graphs shown in the central part in (a) and (b) of FIG. 2, there is a possibility that it will be determined that both the banknotes in (a) and (b) of FIG. 2 have a high similarity, because, a strong afterglow received light intensity is detected in the range of x1 and x2 in the x-axis direction, and the detected afterglow received light intensity has a peak near v1 in both the graphs in (a) and (b) of FIG. 2.

[0039] However, from the graphs shown in the lower part in (a) and (b) of FIG. 2, there is a possibility that it will be determined that both the banknotes in (a) and (b) of FIG. 2 have a low similarity, because, although the afterglow decay rate is similar for both the graphs as the position of the high afterglow decay rate is similar in the range of x1 and x2 in the x-axis direction, there is a considerable difference with respect to a peak (r1) of the decay rate in (a) of FIG. 2 and a peak (r2) of the decay rate in (b) of FIG. 2.

[0040] In the present embodiments, as shown in FIG. 2, because the authentication of the banknote is determined by using the afterglow received light intensity per area and the afterglow decay rate per area, a stricter authentication can be performed.

[0041] Subsequently, an internal configuration of the banknote authentication apparatus 100 that performs the banknote authentication according to the present embodiment is explained. FIG. 3 is a block diagram of the internal configuration of the banknote authentication apparatus 100.

[0042] As shown in FIG. 3, the banknote authentication apparatus 100 includes a transport unit 110 that transports banknotes one by one, the line sensor 120 that is attached to the transport unit 110 and that acquires image information from a banknote that is transported by the transport unit 110, a memory 130, and a control unit 140.

[0043] The memory 130 is a storage device constituted by a nonvolatile memory and the like. The memory 130 stores therein the determination reference data 131, the light-on image data 132, afterglow sampling data 133,

the afterglow-intensity image data 134, and the afterglow decay-rate image data 135.

[0044] The determination reference data 131 is stored previously before performing the banknote authentication processing. The determination reference data 131 includes reference image data used to determine the authentication of the banknote transported to the banknote authentication apparatus 100 and a threshold of an evaluation value relating to the banknote authentication calculated by using the reference image data.

[0045] The light-on image data 132 is data indicating a transmitted-light intensity, of the banknote, received by the light receiving unit 123 while the light emitting unit 121 is on, from each of the unit detection areas shown in FIG. 1.

[0046] The afterglow sampling data 133 is data indicating an afterglow intensity, of the banknote, received by the light receiving unit 123 after turning the light emitting unit 121 off, from each of the unit detection areas shown in FIG. 1. The afterglow sampling data 133 indicates, for example, four sampling values of the afterglow intensity acquired at four time points after turning the light emitting unit 121 off. The four time points include the time point after elapse of time t_3 , after elapse of time t_4 , after elapse of time t_5 , and after elapse of time t_6 from when the light emitting unit 121 is turned off (it is assumed $t_3 < t_4 < t_5 < t_6$). The number of the samples to be acquired is not limited to four, two or five or more samples can be acquired. That is, the afterglow sampling data 133 is obtained by sampling two or more times after elapse of a predetermined time from when the light emitting unit 121 is turned off.

[0047] The afterglow-intensity image data 134, for example, is data generated from the afterglow sampling data 133. The afterglow-intensity image data 134 is an image with each pixel value thereof being a sum of the four sampling values acquired at the four timings and included in the afterglow sampling data 133. In the present embodiment, in this manner, each pixel value of the afterglow-intensity image data 134 is taken as the sum of the four sampling values acquired at the four timings and included in the afterglow sampling data 133; however, the present invention is not limited to this. As another example, it is allowable to take an average of the four sampling values acquired at the four timings and included in the afterglow sampling data 133 as the pixel value of the afterglow-intensity image data 134. Moreover, for example, it is allowable to take one of the four sampling values acquired at the four timings and included in the afterglow sampling data 133 as the pixel value of the afterglow-intensity image data 134.

[0048] The afterglow decay-rate image data 135 is data generated from the afterglow sampling data 133. The afterglow decay-rate image data 135 is an image with each pixel value thereof being obtained by calculating a subtraction value by subtracting from a sampling value of the afterglow sampling data 133 acquired at the time point t_3 , which is the time point after the elapse of the

predetermined time from when the light emitting unit 121 is turned off, a sampling value at the time point t_6 from turning the light emitting unit 121 off, and dividing the subtraction value by $(t_6 - t_3)$. In the present embodiment, in this manner, each pixel value of the afterglow decay-rate image data 135 is taken as a reduction amount per unit time of the afterglow intensity between the time points t_3 and t_6 from turning off the light emitting unit 121; however, the present invention is not limited to this. For example, based on the information acquired as the afterglow sampling data 133 by performing sampling at any two time points, it is allowable to take a reduction amount per unit time of the afterglow intensities at the two time points as the pixel value of the afterglow decay-rate image data 135. Moreover, it is allowable to take a ratio of the afterglow intensity at the time point t_6 from turning off the light emitting unit 121 as the pixel value of the afterglow decay-rate image data 135 to the afterglow intensity at the time point t_3 that is the time point after the elapse of the predetermined time from when the light emitting unit 121 is turned off.

[0049] The control unit 140 controls the entire banknote authentication apparatus 100. The control unit 140 includes a transport control unit 141, an emission control unit 142, an image acquisition control unit 143, an afterglow-image generating unit 144, a denomination acquiring unit 145, and an authentication determination unit 146. In reality, computer programs corresponding to these functional parts are stored in a not-shown ROM or a nonvolatile memory. A corresponding computer program is loaded in a CPU (Central Processing Unit) and executed to realize a corresponding process.

[0050] The transport control unit 141 provides a control to transport the fed banknote so that it passes through the line sensor 120 at a predetermined transport speed. Authentication is determined based on the information acquired by the line sensor 120 when the banknote passes through the line sensor 120, and the authentication result is sent to the host control unit.

[0051] The emission control unit 142 instructs the light emitting unit 121 of the line sensor 120 to repeat turning on/off at a predetermined cycle. Moreover, following an instruction to turn on the light emitting unit 121, the emission control unit 142 instructs the light receiving unit 123 to lower a gain of a circuit for lighting. Moreover, following an instruction to turn off the light emitting unit 121, the emission control unit 142 instructs the light receiving unit 123 to increase a gain of a circuit for afterglow detection.

[0052] The image acquisition control unit 143, when the banknote passes through the line sensor 120, writes in the light-on image data 132 the information acquired by the light receiving unit 123 at a timing after elapse of a predetermined time from when the light emitting unit 121 is turned on. Moreover, the image acquisition control unit 143 writes in the afterglow sampling data 133 the sampling values acquired by the light receiving unit 123 at the four timings after elapse of a predetermined time from when the light emitting unit 121 is turned off. One

image in the light-on image data 132 and the four sampling values in the afterglow sampling data 133 are respectively the image containing the number of pixels obtained by multiplying the number of scanning lines and the number of the light receiving elements 124 in the light receiving unit 123. The number of scanning lines is decided based on an on/off cycle of the light emitting unit 121, the transport speed of the transport unit 110, and a length of the banknote in the transport direction.

[0053] The afterglow-image generating unit 144 generates the afterglow-intensity image data 134 and the afterglow decay-rate image data 135 based on four afterglow images included in the afterglow sampling data 133 and acquired at different elapsed times after stopping the irradiation of the excitation light. Each pixel value of the afterglow-intensity image data 134 is a sum of the pixel values of the pixel at the same position of the four afterglow images included in the afterglow sampling data 133 and acquired at different elapsed times after stopping the irradiation of the excitation light. Each pixel value of the afterglow decay-rate image data 135 is a value obtained by calculating a subtraction value by subtracting a sampled pixel value of a pixel at the same position of the afterglow image included in the afterglow sampling data 133 and at which the elapsed time after stopping the irradiation of the excitation light is the shortest from a sampled pixel value at the same position of the afterglow image at which the elapsed time after stopping the irradiation of the excitation light is the longest and dividing the subtraction value by a difference between the elapsed times.

[0054] The denomination acquiring unit 145 is a processing unit that acquires a denomination and a direction of the banknote recognized by a not-shown denomination recognition unit that is arranged upstream of the transport path.

[0055] The authentication determination unit 146 selects the reference image data per denomination and direction included in the determination reference data 131 based on the afterglow-intensity image data 134, the afterglow decay-rate image data 135, and the information about of the denomination and the direction of the banknote targeted for the determination and acquired by the denomination acquiring unit 145, and determines whether the banknote of which the image data is acquired by the line sensor 120 is the genuine banknote having the denomination and the direction acquired by the denomination acquiring unit 145.

[0056] Subsequently, a configuration of the line sensor 120 that includes the light emitting elements 122 and the light receiving elements 124 shown in FIG. 1 is explained by using FIG. 4. FIG. 4 is a cross-sectional view of the line sensor 120 along a surface that is orthogonal to the transport direction of the banknote.

[0057] The line sensor 120 includes the light emitting unit 121 above the transport path of the banknote and the light receiving unit 123 below the transport path thereby sandwiching the transport path. The light emitting unit

121 includes the light emitting elements 122 arranged at the regular interval. Moreover, the light receiving unit 123 includes the light receiving element 124 arranged at a position corresponding to each of the light emitting elements 122 of the light emitting unit 121. Each of the light emitting elements 122 radiates an excitation light on a banknote that is being transported on the transport path, and the light receiving elements 124 placed in the positions corresponding to the light emitting elements 122 detect the transmitted light while the excitation light is being irradiated and the afterglow after the irradiation is stopped.

[0058] The light emitting element 122 includes a light source 122b such as an LED that emits an infrared light, a light-emitting element substrate 122a that performs acts such as controlling on/off and adjusting the emission intensity of the light source 122b, and a transparent member 122d constituted by a transparent glass or resin. The light receiving element 124 includes a transparent member 124a constituted by a transparent glass or resin, a light receiving sensor 124d that detects the light that has passed through the transparent member 124a, and a light receiving element substrate 124e that performs acts such as amplifying the information detected by the light receiving sensor 124d and performing digital conversion of the information. Moreover, because the difference between the intensity of the transmitted light when the light source 122b is on and the intensity of the afterglow when the light source 122b is off is too large, the light receiving element substrate 124e has a function to adjust the gain (light receiving sensitivity) of an amplifier circuit of the light receiving sensor 124d. The gain of the amplifier circuit can be changed by sending an instruction to that effect from the control unit 140.

[0059] When the banknote that is being transported on the transport path is irradiated with the infrared light emitted by the light source 122b of the light emitting element 122, the light that has passed through the banknote enters the light receiving sensor 124d, and the light receiving sensor 124d detects the transmitted light. Moreover, after the light source 122b is turned off, the afterglow from the banknote enters the light receiving sensor 124d, and the light receiving sensor 124d detects the afterglow. In this manner, the intensity information when the banknote is irradiated with the excitation light and the intensity information of the afterglow after the irradiation of the excitation light is stopped can be acquired.

[0060] Although no explanation has been given above about a light receiving filter 124b and a condenser lens 124c, the light receiving filter 124b and the condenser lens 124c can be provided when certain conditions are satisfied. When measuring the phosphorescence, the light source 122b is turned off so that there is no need to arrange a filter of the light emission side. If the excited phosphorescence is weak, the condenser lens 124c can be provided to condense the light. Moreover, if the excited phosphorescence includes both of a visible light component and an infrared light component, and if only one of

the light components is to be evaluated, the light receiving filter 124b may be provided.

[0061] Subsequently, a data structure of the banknote authentication apparatus 100 shown in FIG. 3 is explained by using FIG. 5.

[0062] The determination reference data 131 includes authentication reference information to be used in the authentication processing of the transported banknote. Moreover, the authentication reference information includes afterglow-intensity image reference information and afterglow decay-rate image reference information. The afterglow-intensity image reference information includes a determination threshold and reference image data per denomination and direction. The reference image data is the afterglow-intensity image data 134 acquired by using the genuine banknote. Moreover, the determination threshold indicates a lower limit of an evaluation value, indicating the similarity between two images calculated from the afterglow-intensity image data 134 of the transported banknote and the reference image data, to determine the transported banknote as a genuine banknote of a certain denomination.

[0063] Moreover, the afterglow decay-rate image reference information includes a determination threshold and reference image data per denomination and direction. The reference image data is the afterglow decay-rate image data 135 acquired by using the genuine banknote. Moreover, the determination threshold indicates a lower limit of an evaluation value, indicating a similarity between two images calculated from the afterglow decay-rate image data 135 of the transported banknote and the reference image data, to determine the transported banknote as a genuine banknote of a certain denomination.

[0064] An example of the determination reference data 131 shown in FIG. 5 is given below. As the afterglow-intensity image reference information for a denomination 1 in a direction "A", there are the determination threshold value "v11A" for the determination, and the afterglow-intensity image data 134 that is a reference for the denomination 1 in the direction "A" of a genuine banknote as the reference image data. For the denomination 1 in a direction "B", there are the determination threshold value "v11B" for the determination, and the afterglow-intensity image data 134 that is a reference for the denomination 1 in the direction "B" of a genuine banknote as the reference image data. For a denomination 2 in the direction "A", there are the determination threshold value "v12A" for the determination, and the afterglow-intensity image data 134 that is a reference for the denomination 2 in the direction "A" of a genuine banknote as the reference image data. For a denomination 3 in the direction "A", there are the determination threshold value "v13A" for the determination, and the afterglow-intensity image data 134 that is a reference for the denomination 3 in the direction "A" of a genuine banknote as the reference image data. Moreover, as the afterglow decay-rate image reference information for the denomination 1 in the di-

rection "A", there are the determination threshold value "v21A" for the determination, and the afterglow decay-rate image data 135 that is a reference for the denomination 1 in the direction "A" of a genuine banknote as the reference image data. For the denomination 1 in the direction "B", there are the determination threshold value "v21B" for the determination, and the afterglow decay-rate image data 135 that is a reference for the denomination 1 in the direction "B" of a genuine banknote as the reference image data. For the denomination 2 in the direction "A", there are the determination threshold value "v22A" for the determination, and the afterglow decay-rate image data 135 that is a reference for the denomination 2 in the direction "A" of a genuine banknote as the reference image data. For the denomination 3 in the direction "A", there are the determination threshold value "v23A" for the determination, and the afterglow decay-rate image data 135 that is a reference for the denomination 3 in the direction "A" of a genuine banknote as the reference image data. Here, the four directions of the transport direction are expressed as the direction "A", the direction "B", a direction "C", and a direction "D".

[0065] The afterglow sampling data 133 is four sampling data acquired at the four timings with different elapsed times after stopping the irradiation of the excitation light. The afterglow sampling data 133 includes, in an ascending order of the value of the elapsed time after stopping the irradiation of the excitation light, an afterglow sampling value 1, an afterglow sampling value 2, an afterglow sampling value 3, and an afterglow sampling value 4.

[0066] Subsequently, a processing timing of image acquisition of a banknote by the banknote authentication apparatus 100 shown in FIG. 3 according to the present embodiment is explained by using FIG. 6. FIG. 6 shows, for one cycle of turning on/off of the light emitting unit 121 of the line sensor 120, switching of the gain of the amplifier circuit of the light receiving unit 123 and an image data acquisition timing of the light receiving unit 123.

[0067] As shown in FIG. 6, the light emitting unit 121 is turned on at a time point t1, turned off at a time point t4, and again turned on at a time point t13. Thus, one cycle of the light emitting unit 121 is from the time point t1 to the time point t13. The time length of the one cycle is fixed and it is L1. A light-on time length, i.e., from turning the light emitting unit 121 on to turning it off, is L2. A light-off time length, i.e., from turning the light emitting unit 121 off to turning it on, is L3. It is allowable that the time lengths L2 and L3 are equal. Moreover, the switching of the gain of the amplifier circuit of the light receiving unit 123 is performed in synchronization with turning on/off of the light emitting unit 121. Specifically, the gain of the amplifier circuit of the light receiving unit 123 is lowered in synchronization with turning on of the light emitting unit 121 at the time points t1 and t13. Moreover, the gain of the amplifier circuit of the light receiving unit 123 is increased in synchronization with turning off of the light emitting unit 121 at the time point t4.

[0068] Moreover, from a time point t2, which is after elapse of a predetermined time (L4) from the on timing (t1), to a time point t3, which is after elapse of a predetermined time (L6), the information detected by the light receiving unit 123 is acquired as a part of the light-on image data 132. The data corresponding to the light-on image of the area on one scanning line that is orthogonal to the transport direction of the banknote can be acquired in one information acquisition.

[0069] Moreover, from a time point t5, which is after elapse of a predetermined time (L5) from the off timing (t4), to a time point t6, which is after the elapse of the predetermined time (L6), the information detected by the light receiving unit 123 is acquired as a part of the afterglow sampling value 1 of the afterglow sampling data 133. From a time point t7, which is after elapse of a predetermined time (L7) from the time point t6, to a time point t8, which is after the elapse of the predetermined time (L6), the information detected by the light receiving unit 123 is acquired as a part of the afterglow sampling value 2 of the afterglow sampling data 133. From a time point t9, which is after the elapse of the predetermined time (L7) from the time point t8, to a time point t10, which is after the elapse of the predetermined time (L6), the information detected by the light receiving unit 123 is acquired as a part of the afterglow sampling value 3 of the afterglow sampling data 133. From a time point t11, which is after the elapse of the predetermined time (L7) from the time point t10, to a time point t12, which is after the elapse of the predetermined time (L6), the information detected by the light receiving unit 123 is acquired as a part of the afterglow sampling value 4 of the afterglow sampling data 133.

[0070] Subsequently, a processing procedure of an image-data acquisition processing performed by the banknote authentication apparatus 100 shown in FIG. 3 is explained. FIG. 7 is a flowchart of the processing procedure of the image-data acquisition processing performed by the banknote authentication apparatus 100.

[0071] Whether the banknote transported by the transport unit 110 has reached a reading start position of a banknote image is detected (Step S101). Upon detecting that the banknote has not reached the reading start position of a banknote image (Step S101: NO), the detection is repeated until such detection is affirmative. Upon detecting reaching of the banknote (Step S101: YES), the image acquisition control unit 143 performs preparation processing for the image acquisition of the transported banknote (Step S102). This preparation processing includes initialization of the light-on image data 132, the afterglow sampling data 133, the afterglow-intensity image data 134, and the afterglow decay-rate image data 135, and the like.

[0072] The emission control unit 142 instructs to lower the gain of the amplifier circuit of the light receiving unit 123 of the line sensor 120 (Step S103), and to turn on the light emitting unit 121 of the line sensor 120 (Step S104). Subsequently, the image acquisition control unit

143 determines if it is acquisition timing of the light-on image data 132 (Step S105). If it is the acquisition timing of the light-on image data 132 (Step S105: YES), the image acquisition control unit 143 acquires the information detected by the light receiving unit 123 as a part of the light-on image data 132 (Step S106). If it is not the acquisition timing of the light-on image data 132 (Step S105: NO), the system control is returned to Step S105 to wait until the acquisition timing of the light-on image data 132 is reached.

[0073] Subsequently, the emission control unit 142 determines if it is the timing to turn off the light emitting unit 121 (Step S107). If it is the timing to turn off the light emitting unit 121 (Step S107: YES), the emission control unit 142 instructs to turn off the light emitting unit 121 of the line sensor 120 (Step S108) and to increase the gain of the amplifier circuit of the light receiving unit 123 of the line sensor 120 (Step S109). If it is not the timing to turn off the light emitting unit 121 (Step S107: NO), the system control is returned to Step S107 to wait until the timing to turn off the light emitting unit 121 is reached.

[0074] Subsequently, the image acquisition control unit 143 determines if it is the acquisition timing of the afterglow sampling data 133 (Step S110). If it is not the acquisition timing of the afterglow sampling data 133 (Step S110: NO), the system control is returned to Step S110 to wait until the acquisition timing of the afterglow sampling data 133 is reached. Moreover, if it is the acquisition timing of the afterglow sampling data 133 (Step S110: YES), the image acquisition control unit 143 acquires the information detected by the light receiving unit 123 as a part of the afterglow sampling data 133 (Step S111). The acquisition timings of the afterglow image, as shown in FIG. 6, come four times in the turning-off period of one cycle of the turning on/off of the light emitting unit 121. Which among the afterglow sampling values 1 to 4 of the afterglow sampling data 133 is acquired is determined by the timing to acquire.

[0075] Subsequently, it is determined whether the four sampling values at the four acquisition timings of the afterglow sampling values in one cycle of the turning on/off of the light emitting unit 121 have been acquired (Step S112). If an afterglow image that has not been acquired yet is present (Step S112: NO), the system control is returned to Step S110 to wait until the acquisition timing of the non-acquired afterglow sampling value is reached. Moreover, if all the information of the four sampling values at the four acquisition timings of the afterglow sampling values have been acquired (Step S112: YES), the afterglow-image generating unit 144 calculates the pixel value corresponding to the afterglow-intensity image data 134 based on the afterglow sampling data 133 acquired at the previous Steps S110 to S112, and updates the afterglow-intensity image data 134 based on the result of the calculation (Step S113). Moreover, the afterglow-image generating unit 144 calculates the pixel value corresponding to the afterglow decay-rate image data 135 based on the afterglow sampling data 133 acquired at

the previous Steps S110 to S112, and updates the afterglow decay-rate image data 135 based on the result of the calculation (Step S114).

[0076] Subsequently, the image acquisition control unit 143 determines whether the entire banknote has passed through the line sensor 120 (Step S115). If the entire banknote has not passed through the line sensor 120 (Step S115: NO), the system control is returned to Step S103. Moreover, if the entire banknote has passed through the line sensor 120 (Step S115: YES), the processing is finished.

[0077] Subsequently, a processing procedure of the banknote authentication processing performed by the banknote authentication apparatus 100 shown in FIG. 3 is explained. FIG. 8 is a flowchart of the processing procedure of the banknote authentication processing performed by the banknote authentication apparatus 100.

[0078] The banknote authentication processing shown in FIG. 8 is performed in after the image-data acquisition processing of the banknote shown in FIG. 7. The denomination acquiring unit 145 acquires the information of a denomination and a direction of the banknote recognized by the denomination recognition unit arranged in an upstream side of the transport path (Step S201).

[0079] If being successful in acquiring the information of the denomination and the direction at Step S201 (Step S202: YES), the authentication determination unit 146 calculates, from the afterglow-intensity image data 134 and the reference image data corresponding to the denomination and the direction, acquired at Step S201, of the afterglow-intensity image reference information of the determination reference data 131, an evaluation value indicating a similarity between the two images (Step S203). The authentication determination unit 146 compares the evaluation value calculated at Step S203 and the determination threshold corresponding to the denomination and the direction, acquired at Step S201, of the afterglow-intensity image reference information of the determination reference data 131 (Step S204). If the evaluation value calculated at Step S203 is equal to or higher than the determination threshold (Step S204: YES), the system control proceeds to Step S205. A correlation coefficient, for example, can be used as the evaluation value.

[0080] The authentication determination unit 146 calculates, from the afterglow decay-rate image data 135 and the reference image data corresponding to the denomination and the direction, acquired at Step S201, of the afterglow decay-rate image reference information of the determination reference data 131, an evaluation value indicating a similarity between the two images (Step S205). The authentication determination unit 146 compares the evaluation value calculated at Step S205 and the determination threshold corresponding to the denomination and the direction, acquired at Step S201, of the afterglow decay-rate image reference information of the determination reference data 131 (Step S206). If the evaluation value calculated at Step S205 is equal to or

higher than the determination threshold (Step S206: YES), the banknote whose image has been acquired by the line sensor 120 is determined to be a genuine banknote (Step S207), and the processing is finished.

[0081] If the evaluation value calculated at Step S205 is lower than the corresponding determination threshold (Step S206: NO), the banknote whose image has been acquired by the line sensor 120 is determined to be a counterfeit banknote (Step S208), and the processing is finished. Moreover, if the evaluation value calculated at Step S203 is lower than the corresponding determination threshold (Step S204 : NO), the banknote whose image has been acquired by the line sensor 120 is determined to be a counterfeit banknote (Step S208), and the processing is finished. Moreover, if being unsuccessful in acquiring the information of the denomination and the direction at Step S201 (Step S202: NO), the banknote whose image has been acquired by the line sensor 120 is determined to be a counterfeit banknote (Step S208), and the processing is finished.

[0082] As another embodiment, at Step S201, it is allowable to perform the recognition of the denomination based on transmission infrared-light image data that has been stored in the light-on image data 132 and a denomination recognition reference transmission infrared-light data that has been previously stored in the determination reference data 131.

[0083] As explained above, according to the present embodiment, the excitation light is irradiated on the banknote having the characteristic to emit the phosphorescence when irradiated with the excitation light, and the transmitted light passing through the banknote and the afterglow of the phosphorescence emitted by the banknote are detected with the line sensor 120. The authentication of the banknote is determined by evaluating the similarity between the afterglow-intensity image data 134 generated from the afterglow intensity after the excitation light is turned off and the afterglow decay-rate image data 135 generated from the decay rate of the afterglow intensity after the excitation light is turned off, and the afterglow-intensity reference image and the afterglow decay-rate reference image corresponding to the genuine banknote and stored previously. Accordingly, a stricter authentication of the banknote while reducing the cost by making the sensor structure simpler can be realized.

[0084] Moreover, because the light-on image data 133 is acquired while the excitation light is being irradiated, the denomination recognition becomes possible. Furthermore, because transmission infrared image data, an afterglow intensity image, and an afterglow decay-rate image at the same location on the banknote can be acquired, it is possible to identify the location on the banknote by using the transmission infrared image data and evaluate an afterglow intensity image value and an afterglow decay-rate image value corresponding to the identified location. Accordingly, the authentication can be determined precisely, and it is possible to improve the capability to authenticate a counterfeit banknote ob-

tained by patch working by cutting a part and pasting a new one for the phosphorescence ink part area.

[0085] In the above embodiment, an example of performing the banknote authentication by employing the phosphorescence emitted in the infrared wavelength band by exciting with the infrared light is explained; however, the present invention is not limited to this. Because the existence of the ink emitting the phosphorescence when irradiated with the visible light or the ultraviolet light is known, the visible light or the ultraviolet light can be used instead of the infrared light. For example, when the target banknotes has a characteristic of emitting the phosphorescence in the visible wavelength band when excited with the ultraviolet light, a line sensor that allows irradiation of the ultraviolet light and detection of the visible light can be used as the line sensor. Moreover, because, unlike the infrared light that easily passes through a paper sheet, the ultraviolet light does not easily pass through a paper sheet, a reflection-type line sensor that detects a light reflected from the surface on which the ultraviolet light is irradiated is often used as a line sensor that irradiates the ultraviolet light and detects the visible light. Moreover, in the present embodiment, a transmission-type sensor is used as an example; however, a reflection-type sensor in which a light emitting unit and a light receiving unit are installed on one side of the banknote transport path can be used. Which one between the transmission-type sensor and the reflection-type sensor is to use can be decided based on whether the wavelength of the excitation light is the infrared light, the visible light, and the ultraviolet light. However, which one between the transmission-type sensor and the reflection-type sensor is better, can be decided at the designing site after considering the long-short property of the wavelength.

[0086] Moreover, in the present embodiment, the image data of the entire surface of the paper sheet is acquired with the line sensor 120 and the recognition of the denomination and the determination of the authentication is performed based on the image data of the entire surface of the paper sheet; however, the present invention is not limited to this. For example, in an apparatus that targets a paper sheet whose determination of the denomination and the authentication can be performed by using a particular area of the paper sheet, only the image data of the particular area of the paper sheet can be acquired without acquiring the image data of the entire surface, and the recognition of the denomination and the determination of the authentication can be performed based on a comparison of the acquired image data with reference image data of the particular area.

[0087] Moreover, the various structural components mentioned in the above embodiments are schematic functional and are not necessarily present physically. That is, decentralization and/or unification of various components are not limited to that shown in the drawings. All of or some of the components can be decentralized and/or unified in desired units, functionally or physically,

depending on various load, operating conditions, and the like.

[Industrial Applicability]

[0088] As explained above, the paper-sheet authentication apparatus and the paper-sheet authentication method according to the present invention is suitable for realizing a stricter authentication of the banknote while reducing the cost by making the sensor structure simpler.

[Explanation of Reference Numerals]

[0089]

100	Banknote authentication apparatus
110	Transport unit
120	Line sensor
121	Light emitting unit
122	Light emitting element
122a	Light-emitting element substrate
122b	Light source
122d, 124a	Transparent member
123	Light receiving unit
124	Light receiving element
124b	Light receiving filter
124c	Condenser lens
124d	Light receiving sensor
124e	Light receiving element substrate
130	Memory
131	Determination reference data
132	Light-on image data
133	Afterglow sampling data
134	Afterglow-intensity image data
135	Afterglow decay-rate image data
140	Control unit
141	Transport control unit
142	Emission control unit
143	Image acquisition control unit
144	Afterglow-image generating unit
145	Denomination acquiring unit
146	Authentication determination unit

Claims

1. A paper-sheet authentication apparatus that determines a kind and/or an authentication of a paper sheet having a characteristic to emit phosphorescence when irradiated with an excitation light, comprising:

a transport unit that transports the paper sheet;
an excitation-light irradiating unit that irradiates with the excitation light a small area of the paper sheet being transported by the transport unit;
a phosphorescence-intensity acquiring unit that acquires a phosphorescence intensity from the

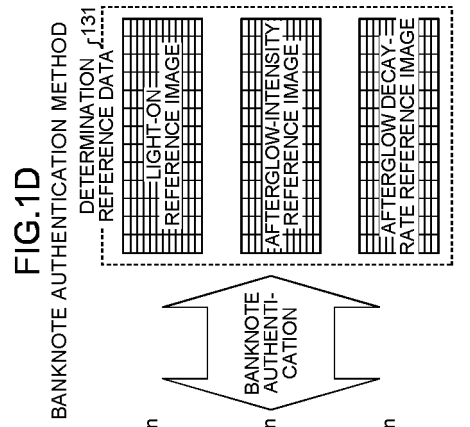
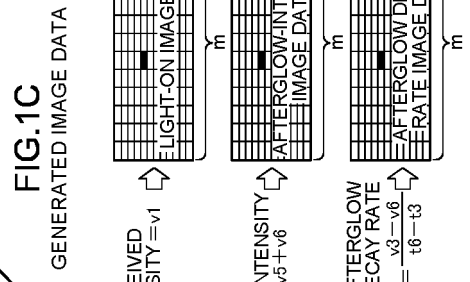
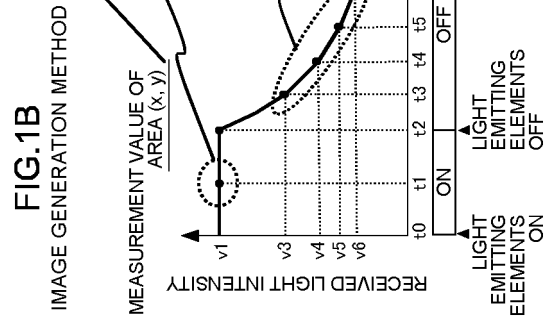
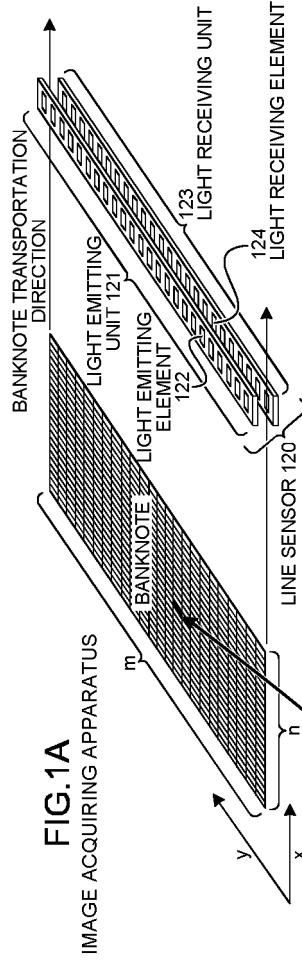
- small area on the paper sheet after the excitation-light irradiating unit has irradiated the small area of the paper sheet with the excitation light and then stopped irradiating;
 a phosphorescence decay-rate calculating unit that calculates a decay rate indicating a decrease rate of the phosphorescence intensity of the small area on the paper sheet based on the phosphorescence intensity acquired a plurality of times by the phosphorescence-intensity acquiring unit from the small area on the paper sheet;
 a phosphorescence decay-rate pattern generating unit that generates a phosphorescence decay-rate pattern in which the decay rate calculated by the phosphorescence decay-rate calculating unit is associated with a position of the small area on the paper sheet based on a transport state of the paper sheet transported by the transport unit; and
 an authentication unit that determines the authentication of the paper sheet targeted for determination by comparing a previously generated phosphorescence decay-rate pattern of a genuine paper sheet with the phosphorescence decay-rate pattern of the paper sheet targeted for determination generated by the phosphorescence decay-rate pattern generating unit.
2. The paper-sheet authentication apparatus as claimed in claim 1, wherein
 the excitation-light irradiating unit is comprised of a plurality of the excitation-light irradiating units which are arranged in a direction of an intersection line of a surface parallel to a transport surface of the paper sheet and a surface orthogonal to a transport direction of the paper sheet, and
 the same number of the phosphorescence-intensity acquiring units as the number of the excitation-light irradiating units are arranged in the same direction as the direction in which the excitation-light irradiating units are arranged.
3. The paper-sheet authentication apparatus as claimed in claim 1 or 2, wherein
 the excitation-light irradiating unit irradiates the paper sheet with the excitation light, and
 the excitation-light irradiating unit and the phosphorescence-intensity acquiring unit are arranged on opposite side of a transport path of the paper sheet.
4. The paper-sheet authentication apparatus as claimed in claim 1 or 2, wherein
 the excitation-light irradiating unit irradiates the paper sheet with the excitation light, and
 the excitation-light irradiating unit and the phosphorescence-intensity acquiring unit are arranged on the same side with respect to a transport surface of the paper sheet.
5. The paper-sheet authentication apparatus as claimed in any one of claims 1 to 4, further comprising:
 a phosphorescence-intensity pattern generating unit that generates a phosphorescence intensity pattern in which the phosphorescence intensity of the paper sheet acquired by the phosphorescence-intensity acquiring unit is associated with a transport position of the paper sheet of a transport direction of the paper sheet while transporting the paper sheet with the transport unit; and
 a second authentication unit that determines the authentication of the paper sheet targeted for determination by comparing a previously generated phosphorescence intensity pattern of a genuine paper sheet generated by the phosphorescence-intensity pattern generating unit with the phosphorescence intensity pattern of the paper sheet targeted for determination generated by the phosphorescence-intensity pattern generating unit.
6. The paper-sheet authentication apparatus as claimed in claim 5, further comprising a paper-sheet kind determination unit that determines the kind of the paper sheet targeted for determination by comparing the previously generated phosphorescence intensity pattern of the genuine paper sheet generated by the phosphorescence-intensity pattern generating unit with the phosphorescence intensity pattern of the paper sheet targeted for determination generated by the phosphorescence-intensity pattern generating unit.
7. The paper-sheet authentication apparatus as claimed in any one of claims 1 to 6, wherein
 the excitation-light irradiating unit radiates the excitation light having a wavelength component between 800 nm and 1000 nm, and
 the phosphorescence-intensity acquiring unit acquires an intensity of light of a wavelength that is longer than a visible light and/or the excitation light.
8. The paper-sheet authentication apparatus as claimed in any one of claims 1 to 7, wherein a relation between a transport speed of the transport unit and a scanning area of the phosphorescence-intensity acquiring unit is such that the small area from which the phosphorescence intensity is acquired is 50% or more of the area irradiated by the excitation-light irradiating unit.
9. The paper-sheet authentication apparatus as claimed in any one of claims 1 to 3 and 5 to 8, further

comprising:

a transmitted-light intensity acquiring unit that
acquires a transmitted-light intensity of a light
passing through the small area of the paper
sheet while the excitation-light irradiating unit is
irradiating the small area of the paper sheet with
the excitation light; 5
a transmission-intensity pattern generating unit
that generates a transmission intensity pattern 10
in which the transmitted-light intensity of the pa-
per sheet acquired by the transmitted-light in-
tensity acquiring unit is associated with a trans-
port direction of the paper sheet while the trans-
port unit is transporting the paper sheet; and 15
a third authentication unit that determines the
authentication of the paper sheet targeted for
determination by comparing a previously gener-
ated transmission intensity pattern of a genu-
ine paper sheet generated by the transmission- 20
intensity pattern generating unit with the trans-
mission intensity pattern of the paper sheet tar-
geted for determination generated by the trans-
mission-intensity pattern generating unit.

- 25
10. A paper-sheet authentication method for determin-
ing a kind and/or an authentication of a paper sheet
having a characteristic to emit phosphorescence
when irradiated with an excitation light, comprising:

30
transporting the received paper sheet;
irradiating a small area of the paper sheet being
transported with the excitation light at the trans-
porting;
acquiring a phosphorescence intensity from the 35
small area on the paper sheet after the excitation
light has irradiated the small area of the paper
sheet and then stopped irradiating;
calculating a decay rate indicating a decrease
rate of the phosphorescence intensity of the 40
small area on the paper sheet based on the
phosphorescence intensity acquired a plurality
of times from the small area on the paper sheet
at the acquiring;
generating a phosphorescence decay-rate pat- 45
tern in which the decay rate calculated at the
calculating is associated with a position of the
small area on the paper sheet based on a trans-
port state of the paper sheet transported at the
transporting; and 50
determining the authentication of the paper
sheet targeted for determination by comparing
a previously generated phosphorescence de-
cay-rate pattern of a genuine paper sheet with
the phosphorescence decay-rate pattern of the 55
paper sheet targeted for determination generat-
ed at the generating.



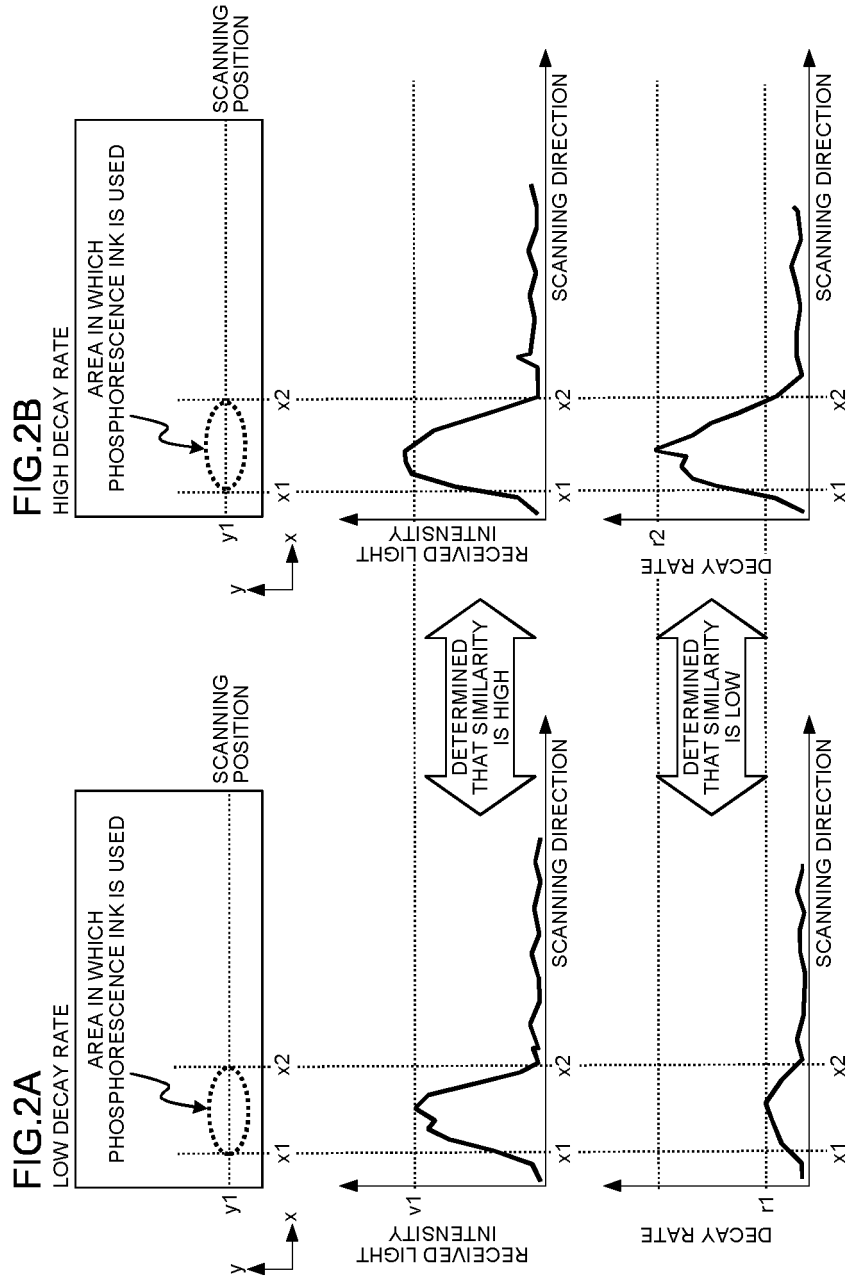


FIG.3

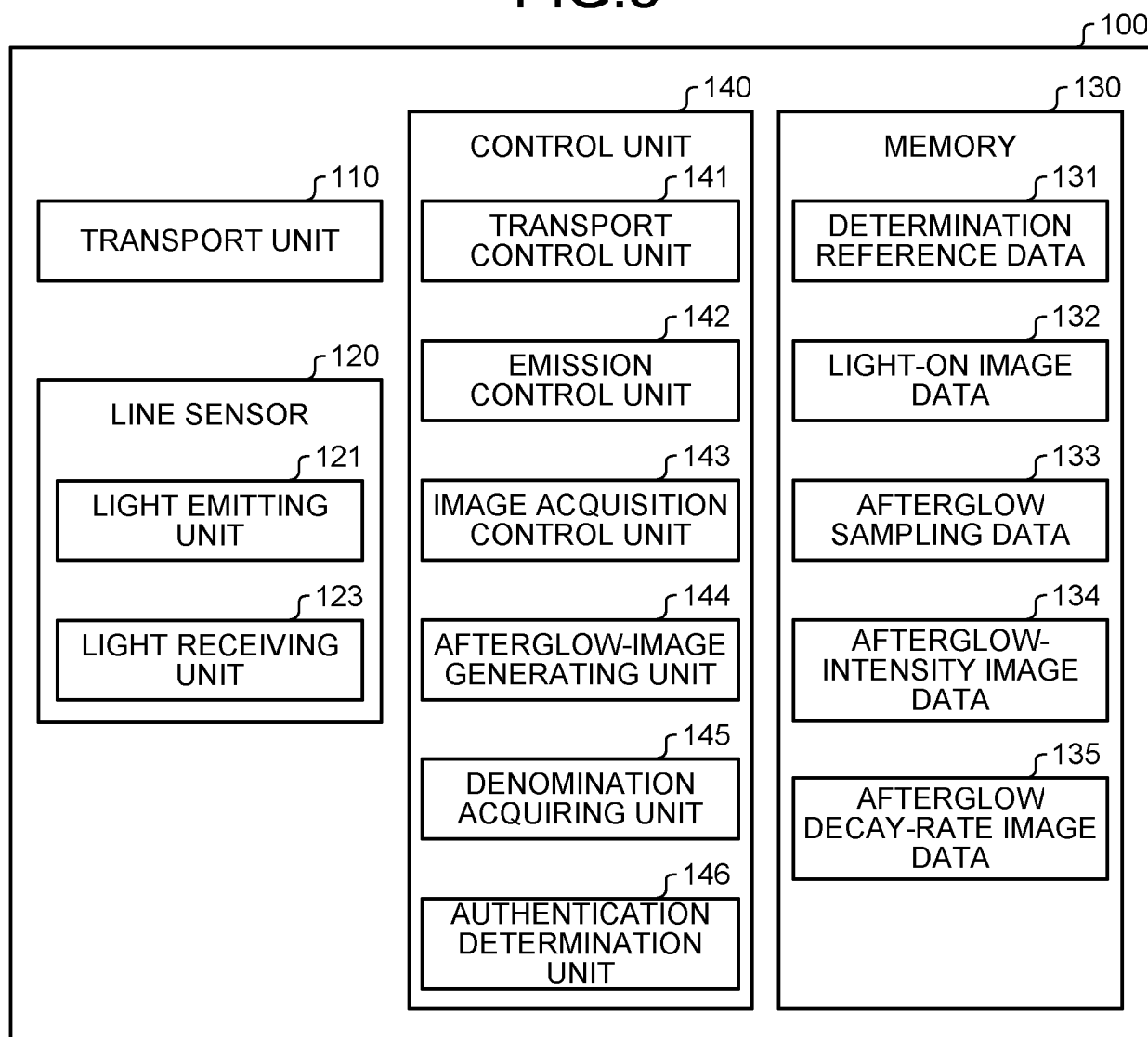


FIG.4

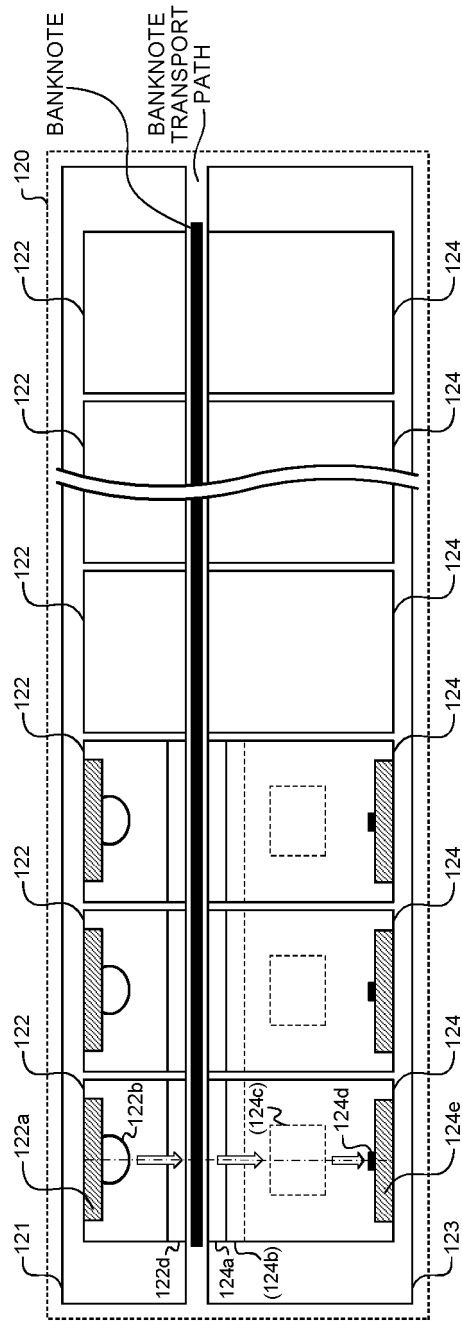


FIG.5

DETERMINATION REFERENCE DATA

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AUTHENTICATION REFERENCE INFORMATION			
AFTERGLOW-INTENSITY IMAGE REFERENCE INFORMATION	DETERMINATION THRESHOLD	REFERENCE IMAGE DATA	
DENOMINATION 1, DIRECTION "A"	v11A	(REFERENCE IMAGE DATA OF AFTERGLOW-INTENSITY FOR DENOMINATION 1, DIRECTION "A")	
DENOMINATION 1, DIRECTION "B"	v11B	(REFERENCE IMAGE DATA OF AFTERGLOW-INTENSITY FOR DENOMINATION 1, DIRECTION "B")	
⋮	⋮	⋮	
DENOMINATION 2, DIRECTION "A"	v12A	(REFERENCE IMAGE DATA OF AFTERGLOW-INTENSITY FOR DENOMINATION 2, DIRECTION "A")	
⋮	⋮	⋮	
DENOMINATION 3, DIRECTION "A"	v13A	(REFERENCE IMAGE DATA OF AFTERGLOW-INTENSITY FOR DENOMINATION 3, DIRECTION "A")	
⋮	⋮	⋮	
AFTERGLOW DECAY-RATE IMAGE REFERENCE INFORMATION	DETERMINATION THRESHOLD	REFERENCE IMAGE DATA	
DENOMINATION 1, DIRECTION "A"	v21A	(REFERENCE IMAGE DATA OF AFTERGLOW DECAY-RATE FOR DENOMINATION 1, DIRECTION "A")	
DENOMINATION 1, DIRECTION "B"	v21B	(REFERENCE IMAGE DATA OF AFTERGLOW DECAY-RATE FOR DENOMINATION 1, DIRECTION "B")	
⋮	⋮	⋮	
DENOMINATION 2, DIRECTION "A"	v22A	(REFERENCE IMAGE DATA OF AFTERGLOW DECAY-RATE FOR DENOMINATION 2, DIRECTION "A")	
⋮	⋮	⋮	
DENOMINATION 3, DIRECTION "A"	v23A	(REFERENCE IMAGE DATA OF AFTERGLOW DECAY-RATE FOR DENOMINATION 3, DIRECTION "A")	
⋮	⋮	⋮	

AFTERGLOW SAMPLING DATA	
AFTERGLOW SAMPLING VALUE 1	(AFTERGLOW SAMPLING DATA 1)
AFTERGLOW SAMPLING VALUE 2	(AFTERGLOW SAMPLING DATA 2)
AFTERGLOW SAMPLING VALUE 3	(AFTERGLOW SAMPLING DATA 3)
AFTERGLOW SAMPLING VALUE 4	(AFTERGLOW SAMPLING DATA 4)

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FIG.6

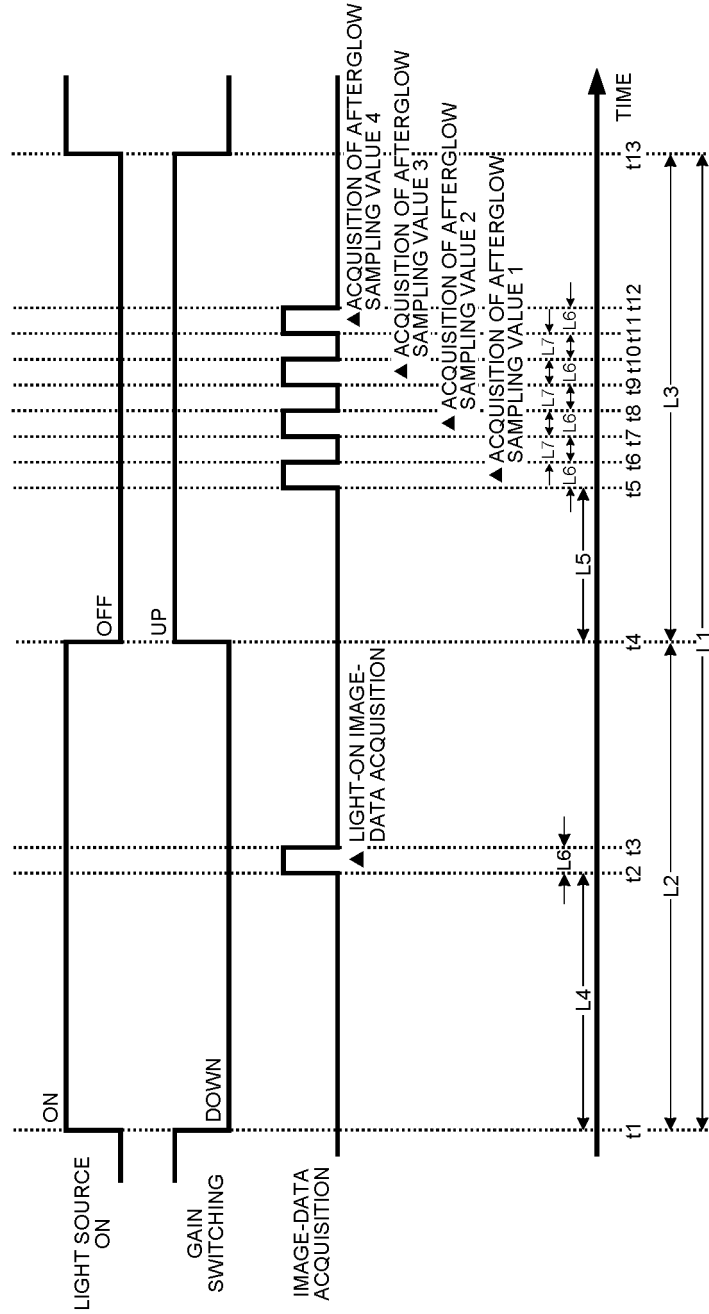


FIG.7

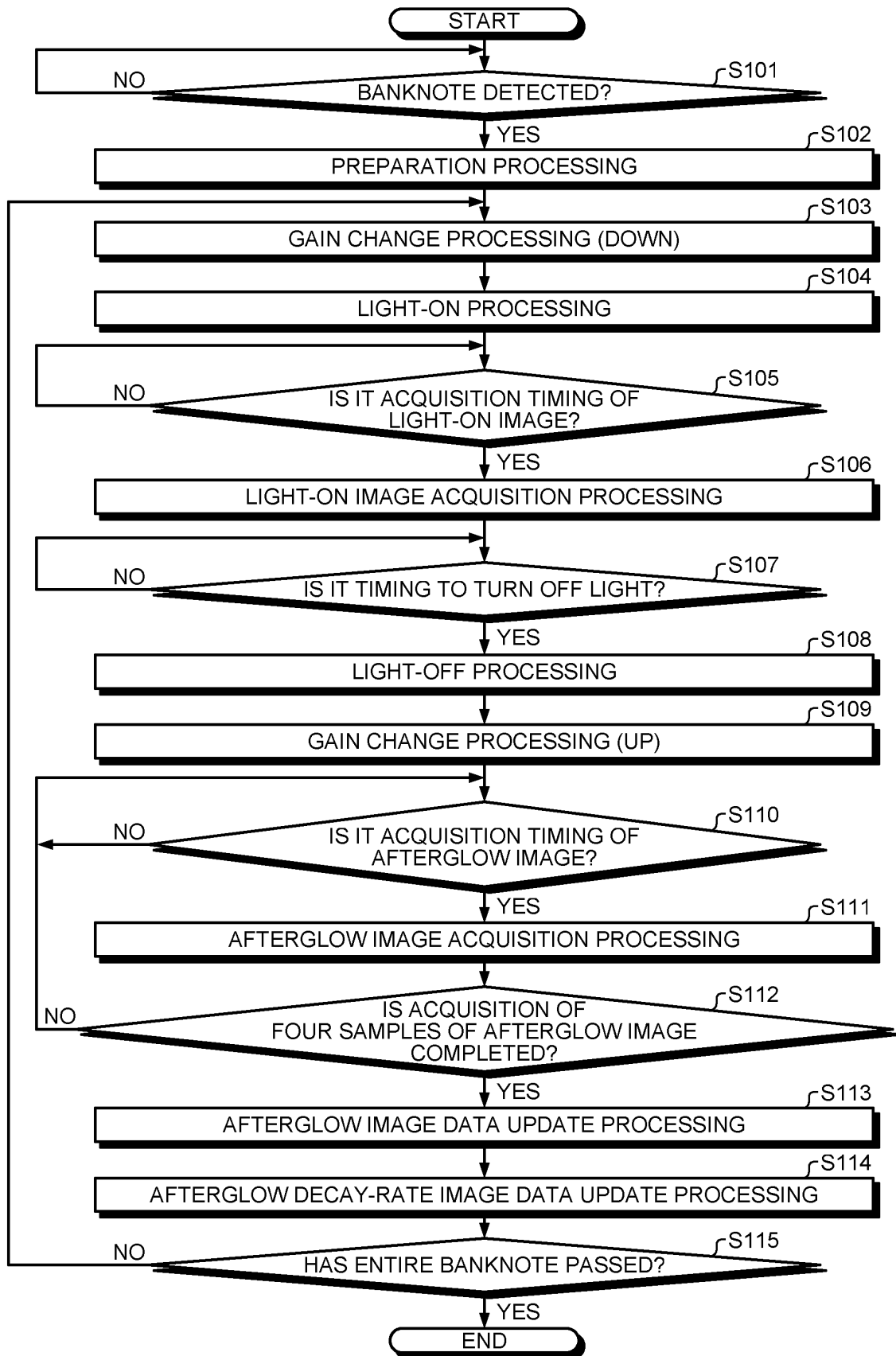
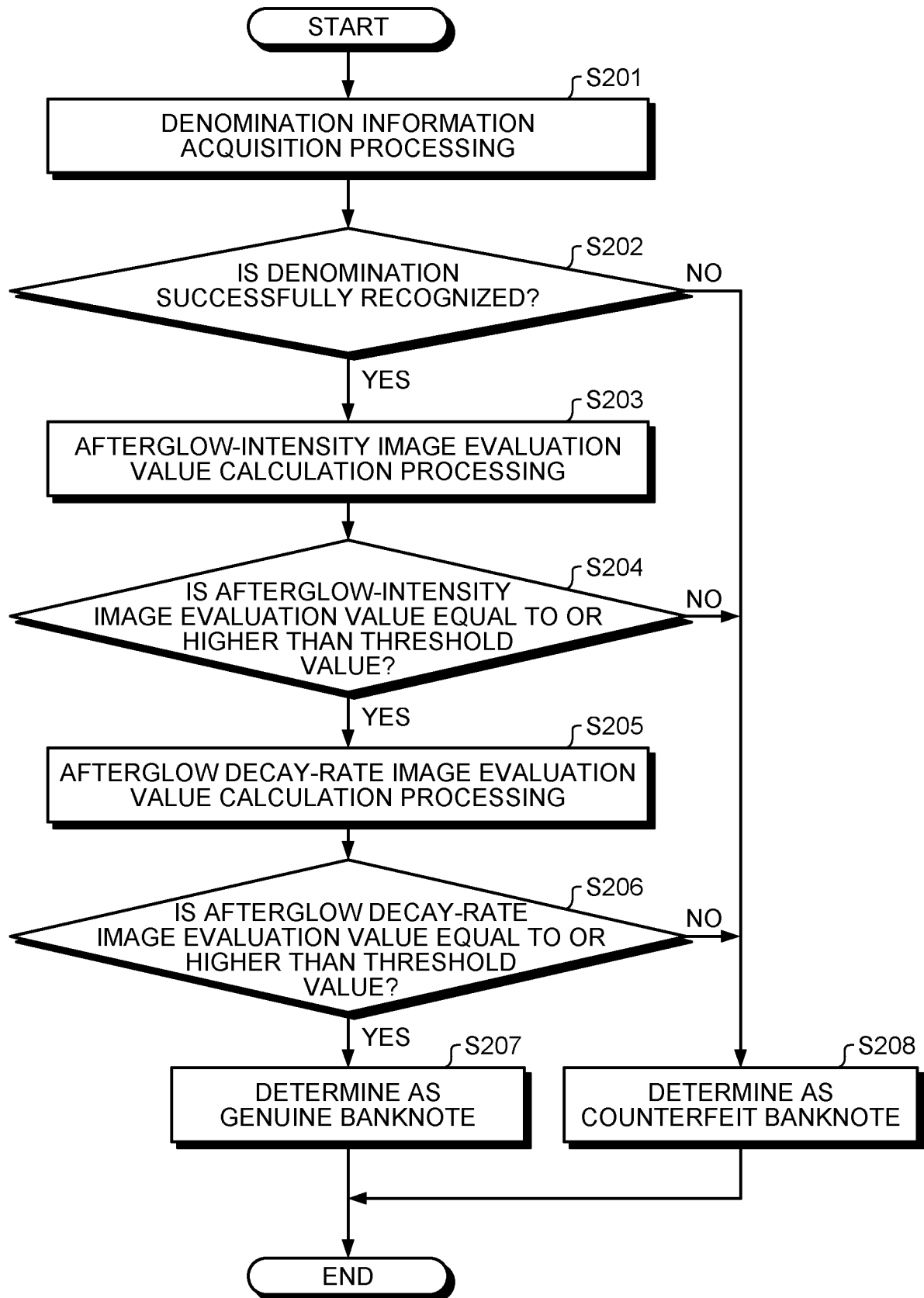


FIG.8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/061096

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 1996-2014

Kokai Jitsuyo Shinan Koho 1971-2014 Toroku Jitsuyo Shinan Koho 1994-2014

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2012-240268 A (Toppan Printing Co., Ltd.), 10 December 2012 (10.12.2012), entire text; all drawings (Family: none)	1-10
A	JP 2013-509631 A (Sicpa Holding S.A.), 14 March 2013 (14.03.2013), entire text; all drawings & US 2012/217416 A1 & EP 2494528 A1	1-10

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search
02 May, 2014 (02.05.14)Date of mailing of the international search report
13 May, 2014 (13.05.14)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 5367509 B [0006]
- JP 4048121 B [0006]
- JP 3790931 B [0006]