

**TITLE OF INVENTION: INFORMATION PROCESSING APPARATUS,
OPTICAL APPARATUS, INFORMATION PROCESSING METHOD,
METHOD OF USING OPTICAL APPARATUS, AND INFORMATION
PROCESSING PROGRAM**

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BACKGROUND

The present disclosure relates to an information processing apparatus, an optical apparatus, an information processing method, a method of using the optical apparatus, and an information processing program.

10 Japanese Unexamined Patent Application Publication No. 2020-085839 discloses a technique for detecting a defect present in a sample.

SUMMARY

It is required to accurately manage the position of a defect in a sample.

15 The present disclosure is intended to solve such a problem and provide an information processing apparatus, an optical apparatus, an information processing method, a method of using the optical apparatus, and an information processing program that are capable of highly accurately managing the position of a defect.

An information processing apparatus according to the present disclosure
20 includes a size acquisition unit configured to acquire a size of a defect region contained in a sample, and a defect coordinate determination unit configured to determine representative position coordinates of the defect region by performing different information processing based on the size.

The above-described information processing apparatus may further include a
25 storage unit configured to store the defect region in association with the representative position coordinates.

In the above-described information processing apparatus, the defect coordinate determination unit may, as the information processing, determine a luminance peak position in the defect region as the representative position
30 coordinates of the defect region when the size is equal to or smaller than a predetermined threshold, and determine a centroid position of the defect region as the representative position coordinates of the defect region when the size is larger than the predetermined threshold.

In the above-described information processing apparatus, the defect

coordinate determination unit may determine the luminance peak position corrected based on the size as the representative position coordinates of the defect region when the size is equal to or smaller than the predetermined threshold.

In the above-described information processing apparatus, the defect coordinate determination unit may determine the luminance peak position as the representative position coordinates of the defect region when the size is equal to or smaller than the predetermined threshold, the luminance peak position being corrected by using a correction value that uses the size as a parameter and a correction amount of which increases as the size increases.

In the above-described information processing apparatus, the defect coordinate determination unit may, as the information processing, determine a luminance peak position in the defect region as the representative position coordinates of the defect region when the size is equal to or smaller than a first threshold, determine a centroid position of the defect region as the representative position coordinates of the defect region when the size is larger than a second threshold larger than the first threshold, and determine a position as the representative position coordinates of the defect region when the size is larger than the first threshold and equal to or smaller than the second threshold, the position being obtained by correcting the luminance peak position based on the centroid position and the size.

In the above-described information processing apparatus, the defect coordinate determination unit may determine a position as the representative position coordinates of the defect region when the size is larger than the first threshold and equal to or smaller than the second threshold, the position being obtained by correcting the luminance peak position by using a correction value that uses the centroid position and the size as parameters and a correction amount of which increases as the size increases.

In the above-described information processing apparatus, the defect coordinate determination unit may perform correction by using such a correction amount that the position approaches the centroid position as the size increases.

In the above-described information processing apparatus, the defect coordinate determination unit may perform correction by using such a correction amount that the position approaches the luminance peak position as the size decreases.

In the above-described information processing apparatus, the defect coordinate determination unit may determine the luminance peak position corrected based on the size as the representative position coordinates of the defect region when the size is equal to or smaller than the first threshold.

5 An optical apparatus according to the present disclosure includes an optical system configured to illuminate a sample with illumination light and condense detection light from the illuminated sample, a detector configured to detect the detection light, and the above-described information processing apparatus.

10 An information processing method according to the present disclosure includes causing a size acquisition unit to acquire a size of a defect region contained in a sample, and causing a defect coordinate determination unit to determine representative position coordinates of the defect region by performing different information processing based on the size.

15 The above-described information processing method may further include causing a storage unit to store the defect region in association with the representative position coordinates.

20 In the above-described information processing method, in the determination by the defect coordinate determination unit, the defect coordinate determination unit may be caused to, as the information processing, determine a luminance peak position in the defect region as the representative position coordinates of the defect region when the size is equal to or smaller than a predetermined threshold, and determine a centroid position of the defect region as the representative position coordinates of the defect region when the size is larger than the predetermined threshold.

25 In the above-described information processing method, in the determination by the defect coordinate determination unit, the defect coordinate determination unit may be caused to determine the luminance peak position corrected based on the size as the representative position coordinates of the defect region when the size is equal to or smaller than the predetermined threshold.

30 In the above-described information processing method, in the determination by the defect coordinate determination unit, the defect coordinate determination unit may be caused to determine the luminance peak position as the representative position coordinates of the defect region when the size is equal to or smaller than the predetermined threshold, the luminance peak position being corrected by using

a correction value that uses the size as a parameter and a correction amount of which increases as the size increases.

In the above-described information processing method, in the determination by the defect coordinate determination unit, the defect coordinate determination unit may be caused to, as the information processing, determine a luminance peak position in the defect region as the representative position coordinates of the defect region when the size is equal to or smaller than a first threshold, determine the centroid position of the defect region as the representative position coordinates of the defect region when the size is larger than a second threshold larger than the first threshold, and determine a position as the representative position coordinates of the defect region when the size is larger than the first threshold and equal to or smaller than the second threshold, the position being obtained by correcting the luminance peak position based on the centroid position and the size.

In the above-described information processing method, in the determination by the defect coordinate determination unit, the defect coordinate determination unit may be caused to determine a position as the representative position coordinates of the defect region when the size is larger than the first threshold and equal to or smaller than the second threshold, the position being obtained by correcting the luminance peak position by using a correction value that uses the centroid position and the size as parameters and a correction amount of which increases as the size increases.

In the above-described information processing method, in the determination by the defect coordinate determination unit, the defect coordinate determination unit may be caused to perform correction by using such a correction amount that the position approaches the centroid position as the size increases.

In the above-described information processing method, in the determination by the defect coordinate determination unit, the defect coordinate determination unit may be caused to perform correction by using such a correction amount that the position approaches the luminance peak position as the size decreases.

In the above-described information processing method, in the determination by the defect coordinate determination unit, the defect coordinate determination unit may be caused to determine the luminance peak position corrected based on the size as the representative position coordinates of the defect region when the size is equal to or smaller than the first threshold.

A method of using an optical apparatus according to the present disclosure includes illuminating a sample with illumination light and condensing detection light from the illuminated sample with an optical system, detecting the detection light with a detector, and performing the information processing method according to claim 10 or 11.

The information processing program according to the present disclosure causes a computer to execute causing a size acquisition unit to acquire a size of a defect region contained in a sample, and causing a defect coordinate determination unit to determine representative position coordinates of the defect region by performing different information processing based on the size.

According to the present disclosure, it is possible to highly accurately manage the position of a defect.

The above and other objects, features and advantages of the present disclosure will become more fully understood from the detailed description given hereinbelow and the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a block diagram exemplarily illustrating an information processing apparatus according to a first embodiment;

Fig. 2 is a block diagram exemplarily illustrating the information processing apparatus according to the first embodiment;

Fig. 3 is a diagram exemplarily illustrating an image capturing a defect contained in a sample in the information processing apparatus according to the first embodiment;

Fig. 4 is a diagram exemplarily illustrating a low-smoothing image of the defect;

Fig. 5 is a diagram exemplarily illustrating a high-smoothing image of the defect;

Fig. 6 is a diagram exemplarily illustrating a defect region and the size of the defect region in the information processing apparatus according to the first embodiment;

Fig. 7 is a graph exemplarily illustrating detection coordinate errors in the information processing apparatus according to the first embodiment, where the horizontal axis represents the size of the defect region and the vertical axis

represents the detection coordinate error;

Fig. 8 is a flowchart diagram exemplarily illustrating an information processing method according to the first embodiment;

Fig. 9 is a flowchart diagram exemplarily illustrating the information processing method according to the first embodiment;

Fig. 10 is a block diagram exemplarily illustrating the information processing apparatus according to the first embodiment;

Fig. 11 is a configuration diagram exemplarily illustrating an optical apparatus according to a second embodiment; and

Fig. 12 is a flowchart diagram exemplarily illustrating a method of using an optical apparatus according to the second embodiment.

DESCRIPTION OF EMBODIMENTS

Specific configurations of embodiments will be described below with reference to the accompanying drawings. The following description presents preferable embodiments of the present disclosure, and the scope of the present disclosure is not limited to the embodiments described below. In the following description, elements denoted by the same reference sign have the same contents in effect.

<First embodiment>

An information processing apparatus and an information processing method according to a first embodiment will be described below. The information processing apparatus of the present embodiment may be applied to an optical apparatus including an inspection device for inspecting a defect or the like in a sample, and a review device for displaying an image of a sample. Thus, the information processing apparatus of the present embodiment may be connected to or incorporated in the above-described optical apparatus. The inspection device may include an image correction device, a review device, and a storage device, and the like. The review device may include an image correction device, an inspection device, and a storage device, and the like. The information processing apparatus may perform image processing on images input to the image correction device, images detected by the inspection device, images stored in the storage device, and the like.

Figs. 1 and 2 are block diagrams exemplarily illustrating an information

processing apparatus 10 according to the first embodiment. As illustrated in Fig. 1, the information processing apparatus 10 includes a size acquisition unit 11 and a defect coordinate determination unit 12. As illustrated in Fig. 2, the information processing apparatus 10 may further include a storage unit 13 in addition to the size acquisition unit 11 and the defect coordinate determination unit 12. Note that the information processing apparatus 10 may be connected to a non-illustrated storage device provided outside the information processing apparatus 10 in a state allowing information transmission. The information processing apparatus 10 may cause the storage device to function in the same manner as the storage unit 13.

Fig. 3 is a diagram exemplarily illustrating an image G50 capturing a defect 51 contained in a sample 50 in the information processing apparatus 10 according to the first embodiment. Fig. 4 is a diagram exemplarily illustrating a low-smoothing image of the defect. Fig. 5 is a diagram exemplarily illustrating a high-smoothing image of the defect. Fig. 6 is a diagram exemplarily illustrating a defect region 52 and a size SZ of the defect region 52 in the information processing apparatus 10 according to the first embodiment.

As illustrated in Figs. 3 to 6, the size acquisition unit 11 acquires the size SZ of the defect region 52 contained in the sample 50. Specifically, the size acquisition unit 11 acquires the size SZ of the defect region 52 contained in the sample 50 from the image G50 capturing the defect 51 contained in the sample 50. The size acquisition unit 11 acquires the size SZ of the defect region 52 through, for example, a procedure described below. Note that the procedure for acquiring the size SZ of the defect region 52 does not exclude other procedures as long as the size SZ of the defect region 52 containing the defect 51 can be acquired based on a predetermined criterion. For example, the size acquisition unit 11 does not exclude acquiring, as the size SZ of the defect region 52, the size SZ such as a predetermined range from a maximum bright spot of the defect 51, the size SZ such as a predetermined range from the centroid position of the defect 51 on the image G50, or the like. Note that the defect region 52 may be synonymous with the defect 51. Thus, in the following description, the defect region 52 may be appropriately interpreted as the defect 51.

The procedure for acquiring the size SZ of the defect region 52 in the present embodiment is as follows. First, as illustrated in Fig. 4, the image capturing the defect 51 contained in the sample 50 is subjected to low smoothing to acquire a

low-smoothing image of the defect 51. The low smoothing includes slightly blurring the image, that is, a blurring process with a lower degree than high smoothing. Subsequently, as illustrated in Fig. 5, the image capturing the defect 51 contained in the sample 50 is subjected to high smoothing to acquire a high-smoothing image of the defect 51. The high smoothing includes, for example, a smoothing process higher than the low smoothing. In other words, the high smoothing includes a blurring process with a higher degree than the low smoothing. In this manner, a plurality of images with different degrees of blurring are prepared from the image G50 capturing the defect 51 contained in the sample 50.

Subsequently, the size acquisition unit 11 acquires the difference between the luminance of the high-smoothing image and the luminance of the low-smoothing image.

Subsequently, as illustrated in Fig. 6, the size acquisition unit 11 acquires the defect region 52 having, as a boundary line 53, a part where the difference between the low-smoothing image and the high-smoothing image is higher than a predetermined threshold. In other words, the size acquisition unit 11 acquires, as the defect region 52, a region surrounded by the boundary line 53. In illustration of Fig. 6, the boundary line 53 is superimposed on the image of Fig. 3.

Subsequently, the size acquisition unit 11 acquires a smallest frame part 54 among frame parts 54 with a predetermined shape containing the defect region 52. The shape of the frame part 54 is, for example, quadrilateral. Note that the shape of the frame part 54 is not limited to quadrilateral but may be an optional shape such as circle, ellipse, or triangle. The size acquisition unit 11 acquires a predetermined length of the frame part 54 as the size SZ of the defect region 52. For example, in a case where the shape of the frame part 54 is quadrilateral, its diagonal line may be acquired as the size SZ of the defect region 52. In a case where the shape of the frame part 54 is circle, its diameter may be acquired as the size SZ of the defect region 52. In a case where the shape of the frame part 54 is a particular shape such as ellipse or triangle, a particular length may be acquired as the size SZ of the defect region 52.

The defect coordinate determination unit 12 determines representative position coordinates of the defect region 52 by performing a plurality of mutually different pieces of information processing based on the size SZ of the defect region 52. For example, when the size SZ of the defect region 52 is equal to or smaller

than a predetermined threshold, as the information processing, the defect coordinate determination unit 12 determines a luminance peak position P1 in the defect region 52 as the representative position coordinates of the defect region 52. When the size SZ of the defect region 52 is larger than the predetermined threshold, as the information processing, the defect coordinate determination unit 12 determines a centroid position P2 of the defect region 52 as the representative position coordinates of the defect region 52.

The centroid position may be the central position of the frame part 54 or the central position of the defect region 52. Information processing that determines the luminance peak position P1 in the defect region 52 as the representative position coordinates of the defect region 52 is referred to as luminance peak processing. Information processing that determines the centroid position P2 of the defect region 52 as the representative position coordinates of the defect region 52 is referred to as centroid processing. Accordingly, the defect coordinate determination unit 12 switches the luminance peak processing and the centroid processing based on a predetermined threshold.

The storage unit 13 stores various kinds of information (various kinds of data) used by the information processing apparatus 10. The storage unit 13 may store the image G50 and stores information of the defect region 52, the boundary line 53, and the frame part 54. The storage unit 13 stores the defect region 52 in association with the representative position coordinates.

When the size SZ of the defect region 52 is equal to or smaller than the predetermined threshold, the representative position coordinates of the defect region 52 may vary due to individual difference of the optical apparatus. For example, it is assumed that when affected by aberrations of an objective lens of the optical apparatus and environmental conditions depending on the image capturing time or image capturing place of the image G50, the representative position coordinates of the defect region 52 differ between optical apparatuses. Thus, when the size SZ of the defect region 52 is equal to or smaller than the predetermined threshold, the defect coordinate determination unit 12 determines the luminance peak position P1 corrected based on the size SZ of the defect region 52 as the representative position coordinates of the defect region 52 as described below.

Fig. 7 is a graph exemplarily illustrating detection coordinate errors in the

information processing apparatus 10 according to the first embodiment, where the horizontal axis represents the size SZ of the defect region 52 and the vertical axis represents the detection coordinate error. As illustrated with black points (●) in Fig. 7, for example, a detection error ΔX in an X-axis direction and a detection

error ΔY in a Y-axis direction between the representative position coordinates

(luminance peak coordinates) of the defect region 52 of an image G50 captured by an optical apparatus (#1) and the representative position coordinates (luminance peak coordinates) of the defect region 52 of an image G50 captured by an optical apparatus (#2) change with the size SZ of the defect region 52. For example, the

detection errors ΔX and ΔY may increase with the size SZ of the defect region 52. The X-axis and Y-axis directions are the lateral and longitudinal directions,

respectively, of the image G50 in Fig. 6. The detection errors ΔX and ΔY may be, for example, values obtained by subtracting the representative position coordinates

(luminance peak coordinates) of the defect region 52 of the image G50 captured by the optical apparatus (#2) from the representative position coordinates (luminance peak coordinates) of the defect region 52 of the image G50 captured by the optical apparatus (#1).

By using Expressions (1) and (2) below as correction expressions for the representative position coordinates (luminance peak coordinates) for the optical apparatus (#1), the defect coordinate determination unit 12 performs correction such that the coordinates approach the representative position coordinates for the optical apparatus (#2).

$$\Delta X = (Ax) \times \exp[(Dsz)/(Bx)] + Constx \dots (1)$$

$$\Delta Y = (Ay) \times \exp[(Dsz)/(By)] + Consty \dots (2)$$

The value Dsz represents the size SZ of the defect region 52. The values Ax, Ay, Bx, and By are correction coefficients. The values Constx and Consty are constants. The values Ax, Ay, Bx, By, Constx, and Consty may be values equal to or larger than zero or negative values. Expressions (1) and (2) above have the size SZ of the defect region 52 as a parameter. Expressions (1) and (2) above are correction expressions that provide larger correction amounts as the size SZ of the defect region 52 increases. The correction coefficients and constants can be obtained by fitting Expressions (1) and (2) to measurement points (black point ●) in Fig. 7.

When the above-described detection errors due to individual difference exist

between the representative position coordinates (luminance peak coordinates) of the defect region 52 of the image G50 captured by the optical apparatus (#1) and the representative position coordinates (luminance peak coordinates) of the defect region 52 of the image G50 captured by the optical apparatus (#2), for example,

5 luminance peak coordinates obtained by adding (in other words, correction) the detection errors ΔX and ΔY to the representative position coordinates (luminance peak coordinates) of the defect region 52 of the image G50 captured by the optical apparatus (#1) is set as the representative position coordinates of the defect region 52. Accordingly, the difference between the representative position coordinates of

10 the images G50 captured by the optical apparatuses (#1) and (#2) can be reduced. Thus, the position of the defect 51 can be highly accurately managed.

In this manner, when the size SZ of the defect region 52 is equal to or smaller than the predetermined threshold, the defect coordinate determination unit 12 determines the luminance peak position P1 corrected based on the size SZ of the

15 defect region 52 as the representative position coordinates of the defect region 52. Specifically, when the size SZ of the defect region 52 is equal to or smaller than the predetermined threshold, the defect coordinate determination unit 12 may determine the luminance peak position as the representative position coordinates of the defect region 52, the luminance peak position being corrected by using a

20 correction value that uses the size SZ of the defect region 52 as a parameter. The correction value includes, for example, a correction value the correction amount of which increases as the size SZ of the defect region 52 increases as in Expressions (1) and (2). Note that correction expression used to calculate the correction value are not limited to Expressions (1) and (2) above. For example, linear expressions

25 and quadratic expressions with respect to the size SZ of the defect region 52 are not excluded. Instead of using correction expressions, the correction value may be obtained by using a table listing correction values experimentally obtained from measurement values in advance.

In this manner, by using the correction value to the result of the optical

30 apparatus (#1), it is possible to align the result of the optical apparatus (#1) with that of the optical apparatus (#2), thereby compensating the individual difference between the optical apparatuses (#1) and (#2) in terms of the representative position coordinates of the defect region 52.

<Modification>

In a modification, the defect coordinate determination unit 12 performs determination of the luminance peak position P1 in the defect region 52 as the representative position coordinates of the defect region 52 and determination of the centroid position P2 of the defect region 52 as the representative position

5 coordinates of the defect region 52 by weighting based on the size SZ of the defect region 52. For example, the defect coordinate determination unit 12 determines a position as the representative position coordinates of the defect region 52, the position being obtained by correcting the luminance peak position P1 based on the centroid position P2 and the size SZ of the defect region 52. Accordingly, the

10 detection errors between the optical apparatuses (#1) and (#2) can be further reduced. The weighting is performed, for example, in the vicinity of a predetermined threshold at which switching between the centroid processing and the luminance peak processing is performed. Specifically, the defect coordinate determination unit 12 sets a first threshold and a second threshold for switching the

15 information processing. The second threshold is larger than the first threshold.

When the size SZ of the defect region 52 is equal to or smaller than the first threshold, the defect coordinate determination unit 12 performs the luminance peak processing. In this case, processing for correcting the luminance peak position P1 may be performed through the process described above in the first embodiment to

20 mitigate the individual difference. When the size SZ of the defect region 52 is larger than the second threshold, the defect coordinate determination unit 12 performs the centroid processing. When the size SZ of the defect region 52 is larger than the first threshold and equal to or smaller than the second threshold, the defect coordinate determination unit 12 determines the representative position

25 coordinates by performing weighting in accordance with the size SZ of the defect region 52 by using Expressions (3) and (4) below. Note that the first threshold may be (second threshold - first threshold) obtained by subtracting the first threshold from the second threshold. Accordingly, based on Expressions (3) and (4) below, the representative position coordinates are close to the centroid position

30 P2 when the size SZ of the defect region 52 is slightly smaller than the second threshold, which ensures the continuity of the representative position coordinates when the size SZ of the defect region 52 is in the vicinity of the second threshold.

Note that coordinates (X, Y) in Expressions (3) and (4) represent the representative position coordinates after the weighting. Coordinates (Xp, Yp)

represent the coordinates (for example, the luminance peak coordinates) of the luminance peak position P1. Coordinates (Xc, Yc) represent the coordinates of the centroid position P2. Note that the coordinates (Xp, Yp) of the luminance peak position P1 may be coordinates after correction is performed to reduce the

5 individual difference through the process described above in the first embodiment.

$$X = X_p + (X_c - X_p) \times [(D_{sz} - \text{first threshold}) / \text{first threshold}] \dots (3)$$

$$Y = Y_p + (Y_c - Y_p) \times [(D_{sz} - \text{first threshold}) / \text{first threshold}] \dots (4)$$

In this manner, when the size SZ of the defect region 52 is equal to or smaller than the first threshold, as the information processing, the defect coordinate
10 determination unit 12 determines the luminance peak position P1 in the defect region 52 as the representative position coordinates of the defect region 52. Note that the defect coordinate determination unit 12 may determine the luminance peak position P1 corrected based on the size SZ as the representative position coordinates of the defect region 52 when the size SZ of the defect region 52 is
15 equal to or smaller than the first threshold. When the size SZ of the defect region 52 is larger than the second threshold, the defect coordinate determination unit 12 determines the centroid position P2 of the defect region 52 as the representative position coordinates of the defect region. When the size SZ of the defect region 52 is larger than the first threshold and equal to or smaller than the second
20 threshold, the defect coordinate determination unit 12 determines a position as the representative position coordinates of the defect region, the position being obtained by correcting the luminance peak position P1 based on the centroid position P2 and the size SZ of the defect region 52.

Specifically, when the size SZ of the defect region 52 is larger than the first
25 threshold and equal to or smaller than the second threshold, the defect coordinate determination unit 12 determines a position as the representative position coordinates of the defect region 52, the position being obtained by correcting the luminance peak position P1 in the defect region 52 by using a correction value that uses the centroid position P2 (in other words, Xc and Yc in Expressions (3) and
30 (4)) and the size SZ of the defect region 52 (in other words, Dsz in Expressions (3) and (4)) as parameters. The correction value includes a correction value the correction amount of which increase as the size SZ of the defect region 52 increases. For example, the defect coordinate determination unit 12 performs correction by using such a correction amount that the position approaches the

centroid position P2 as the size SZ of the defect region 52 increases.

Alternatively, the defect coordinate determination unit 12 may perform correction by using such a correction amount that the position approaches the luminance peak position P1 as the size SZ decreases. Moreover, based on Expressions (3) and (4),

5 the representative position coordinates are close to the luminance peak position P1 when the size SZ of the defect region 52 is slightly larger than the first threshold, which ensures the continuity of the representative position coordinates when the size SZ of the defect region 52 is in the vicinity of the first threshold. As in this example, the defect coordinate determination unit 12 performs correction by using
10 such a correction amount that the position approaches the luminance peak position P1 as the size SZ of the defect region 52 decreases.

The following describes an information processing method using the information processing apparatus of the present embodiment. Figs. 8 and 9 are flowcharts diagram exemplarily illustrating the information processing method
15 according to the first embodiment. As illustrated in Figs. 8 and 9, at step S11, the size SZ of the defect region 52 is acquired. Specifically, the size acquisition unit 11 is caused to acquire the size SZ of the defect region 52 contained in the image G50 capturing the sample 50.

Subsequently at step S12, the representative position coordinates of the
20 defect region 52 are determined. For example, the defect coordinate determination unit 12 is caused to determine the representative position coordinates of the defect region 52 by performing a plurality of mutually different pieces of information processing based on the size SZ of the defect region 52. Subsequently at step S13, the defect region 52 may be stored in the storage unit 13 in association
25 with the representative position coordinates.

At step S12, the defect coordinate determination unit 12 is caused to, as the information processing, perform the luminance peak processing when the size SZ of the defect region 52 is equal to or smaller than a predetermined threshold, and perform the centroid processing when the size SZ of the defect region 52 is larger
30 than the predetermined threshold. The defect coordinate determination unit 12 may be caused to determine a position as the representative position coordinates of the defect region 52 when the size SZ of the defect region 52 is equal to or smaller than the predetermined threshold, the position being obtained by correcting the luminance peak position P1 based on the size SZ of the defect region 52.

Alternatively, at step S12, the defect coordinate determination unit 12 may be caused to, as the information processing, perform the luminance peak processing when the size SZ of the defect region 52 is equal to or smaller than the first threshold, and perform the centroid processing when the size SZ of the defect region 52 is larger than the second threshold. The defect coordinate determination unit 12 may be caused to determine a position as the representative position coordinates of the defect region 52 when the size SZ of the defect region 52 is larger than the first threshold and equal to or smaller than the second threshold, the position being obtained by correcting the luminance peak position P1 based on the centroid position P2 and the size SZ of the defect region 52.

The information processing apparatus 10 described above may include a computer such as a personal computer or a server. Fig. 10 is a block diagram exemplarily illustrating the information processing apparatus 10 according to the first embodiment. As illustrated in Fig. 10, the information processing apparatus 10 further includes a processor PRC, a memory MMR, and a user interface UI. The storage unit 13 stores processing executed by each component of the information processing apparatus 10 as a program. The processor PRC loads the program from the storage unit 13 onto the memory MMR and executes the program. Accordingly, the processor PRC implements functions of the components of the information processing apparatus 10, such as the size acquisition unit 11 and the defect coordinate determination unit 12. The user interface UI may include an input apparatus such as a keyboard, a mouse, or an image capturing apparatus, and an output apparatus such as a display, a printer, or a speaker.

Each component included in the information processing apparatus 10 may be implemented by dedicated hardware. Moreover, part or the entire of each constituent component may be implemented by a general-purpose or dedicated circuitry, the processor PRC, or combination thereof. These constituent components may be configured as a single chip or a plurality of chips connected through a bus. Part or the entire of each constituent component may be implemented by the above-described circuitry, the processor PRC, and the like in combination with the program. A central processing unit (CPU), a graphics processing unit (GPU), a field-programmable gate array (FPGA), a quantum processor (quantum computer control chip), or the like may be used as the processor PRC.

In a case where part or the entire of each constituent component of the information processing apparatus 10 is implemented by a plurality of information processing apparatuses 10, circuitries, or the like, the plurality of information processing apparatuses 10, circuitries, or the like may be disposed either in a centralized manner or in a distributed manner. For example, the information processing apparatuses 10, circuitries, or the like may be implemented in a form in which they are connected to each other via a communication network through a client-server system, a cloud computing system, or the like. Moreover, the functions of the information processing apparatuses 10 may be provided in the form of SaaS (Software as a Service).

The following describes the effects of the present embodiment. The information processing apparatus 10 of the present embodiment determines the representative position coordinates of the defect region 52 by performing different information processing based on the size SZ of the defect region 52. Thus, the position of the defect can be highly accurately managed. For example, in a case where the sample 50 is a mask blank including a multilayer, highly accurately managing the position of the defect enables defect mitigation, in which a defect in the multilayer is invalidated by an absorber, to be executed more efficiently and highly accurately.

The information processing apparatus 10 determines the representative position coordinates of the defect region 52 by performing the luminance peak processing or the centroid processing in accordance with whether the size SZ of the defect region 52 is larger than a predetermined threshold or is equal to or smaller than the predetermined threshold. Accordingly, the position of the defect can be further highly accurately managed.

When the size SZ of the defect region 52 is equal to or smaller than the predetermined threshold, the representative position coordinates are corrected by using a correction value that uses the size SZ of the defect region 52 as a parameter. Thus, even when the representative position coordinates of the defect region 52 vary due to individual difference of the optical apparatus, it is possible to reduce error due to the individual difference by using a correction value that takes the individual difference into account.

Since the correction value includes a correction value the correction amount of which increases as the size SZ of the defect region 52 increases, it is possible to

further reduce error due to the individual difference.

<Second embodiment>

The following describes an optical apparatus according to a second embodiment. The optical apparatus of the present embodiment includes the

5 above-described information processing apparatus 10. The optical apparatus is, for example, an inspection device for a mask used in a semiconductor manufacturing process. Note that the optical apparatus may be a review device. Fig. 11 is a configuration diagram exemplarily illustrating an optical apparatus 1 according to the second embodiment. As illustrated in Fig. 11, the optical
10 apparatus 1 includes the information processing apparatus 10, an optical system 20, and a detector 30.

The optical system 20 includes a separation means 21, an objective lens 22, and a light condensation lens 23. The optical system 20 may further include other optical members such as a scanning means. Moreover, the optical system 20 may
15 include a light source LS or may guide illumination light L1 from the light source LS separately provided from the optical apparatus 1. The sample 50 is disposed on a stage 55. An $\alpha\beta\gamma$ orthogonal coordinate system is introduced for the convenience of description of the optical apparatus 1. An $\alpha\beta$ surface is defined to be the upper surface of the stage 55, and a γ axial direction is defined to be a
20 direction orthogonal to the upper surface of the sample 50. The α and β axes may correspond to X and Y axes of the image G50.

The illumination light L1 generated from the light source LS is incident on the separation means 21 such as a semi-reflective mirror. The separation means 21 transmits part of the incident illumination light L1 and reflects other part. The
25 illumination light L1 reflected by the separation means 21 is incident on the objective lens 22. The objective lens 22 condenses the incident illumination light L1 onto the sample 50. The sample 50 is illuminated with the illumination light L1 condensed through the objective lens 22. Detection light R1 is emitted from the sample 50 illuminated with the illumination light L1.

30 The detection light R1 may include at least one of reflected light, scattered light, fluorescence, and light emission. The reflected light includes reflected light of the illumination light L1 by the sample 50. The scattered light includes scattered light of the illumination light L1 by the sample 50. The fluorescence includes fluorescence from the sample 50 excited by the illumination light L1.

The light emission includes light emission from the sample 50 excited by the illumination light L1. When the sample 50 contains the defect 51, the detection light R1 includes information of the defect 51 contained in the sample 50.

The detection light R1 is incident on the objective lens 22. The objective lens 22 condenses and transmits the detection light R1. The detection light R1 having transmitted through the objective lens 22 is incident on the separation means 21. The separation means 21 transmits part of the incident detection light R1 and reflects other part. The detection light R1 having transmitted through the separation means 21 is incident on the light condensation lens 23. The light condensation lens 23 condenses the incident detection light R1 onto the detector 30. In this manner, the optical system 20 illuminates the sample 50 with the illumination light L1 and condenses the detection light R1 from the illuminated sample 50.

The detector 30 detects the detection light R1. The detector 30 may be, for example, a camera using TDI. The detector 30 outputs the detected detection result to the information processing apparatus 10. Note that the detector 30 may output the detected detection result to a non-illustrated storage device separately provided from the optical apparatus 1. The information processing apparatus 10 may directly receive the detection result from the detector 30 or receive the detection result from the storage device. The information processing apparatus 10 performs operation described in the first embodiment.

The following describes a method of using the optical apparatus 1. Fig. 12 is a flowchart diagram exemplarily illustrating the method of using the optical apparatus 1 according to the second embodiment. As illustrated in Fig. 12, at step S21, the detection light R1 from the sample 50 is condensed. Specifically, the sample 50 is illuminated with the illumination light L1, and the detection light R1 from the illuminated sample 50 is condensed through the optical system 20. Subsequently at step S22, the detection light R1 is detected by the detector 30. Subsequently at step S23, the above-described information processing is performed by the information processing apparatus 10.

According to the present embodiment, the optical apparatus 1 can process the detection result by the information processing apparatus 10 and thus can highly accurately manage the position of the defect. Other configurations and effects are included in description of the first embodiment.

Although the embodiments of the present disclosure are described above, the present disclosure includes appropriate modifications without losing its intention and advantages and is not limited by the above-described embodiments.

Moreover, the configurations of the first and second embodiments may be

5 combined as appropriate. An information processing program below that causes a computer to execute the above-described information processing method is also within the technological idea of the present disclosure.

(Supplementary note 1)

10 An information processing program configured to cause a computer to execute:

causing a size acquisition unit to acquire a size of a defect region contained in a sample; and

15 causing a defect coordinate determination unit to determine representative position coordinates of the defect region by performing different information processing based on the size.

(Supplementary note 2)

The information processing program according to supplementary note 1, the information processing program being configured to cause a computer to further execute causing a storage unit to store the defect region in association with the
20 representative position coordinates.

(Supplementary note 3)

The information processing program according to supplementary note 1 or 2, in which in the determination by the defect coordinate determination unit, the defect coordinate determination unit is caused to, as the information processing,
25 determine a luminance peak position in the defect region as the representative position coordinates of the defect region when the size is equal to or smaller than a predetermined threshold, and

determine a centroid position of the defect region as the representative position coordinates of the defect region when the size is larger than the
30 predetermined threshold.

(Supplementary note 4)

The information processing program according to supplementary note 3, in which in the determination by the defect coordinate determination unit, the defect coordinate determination unit is caused to determine the luminance peak position

corrected based on the size as the representative position coordinates of the defect region when the size is equal to or smaller than the predetermined threshold.

(Supplementary note 5)

5 The information processing program according to supplementary note 4, in which in the determination by the defect coordinate determination unit, the defect coordinate determination unit is caused to determine the luminance peak position as the representative position coordinates of the defect region when the size is equal to or smaller than the predetermined threshold, the luminance peak position being corrected by using a correction value that uses the size as a parameter and a
10 correction amount of which increases as the size increases.

(Supplementary note 6)

The information processing program according to supplementary note 1, in which in the determination by the defect coordinate determination unit, the defect coordinate determination unit is caused to, as the information processing,
15 determine a luminance peak position in the defect region as the representative position coordinates of the defect region when the size is equal to or smaller than a first threshold,

determine a centroid position of the defect region as the representative position coordinates of the defect region when the size is larger than a second
20 threshold larger than the first threshold, and

determine a position as the representative position coordinates of the defect region when the size is larger than the first threshold and equal to or smaller than the second threshold, the position being obtained by correcting the luminance peak position based on the centroid position and the size.

25 (Supplementary note 7)

The information processing program according to supplementary note 6, in which in the determination by the defect coordinate determination unit, the defect coordinate determination unit is caused to determine a position as the representative position coordinates of the defect region when the size is larger than
30 the first threshold and equal to or smaller than the second threshold, the position being obtained by correcting the luminance peak position by using a correction value that uses the centroid position and the size as parameters and a correction amount of which increases as the size increases.

(Supplementary note 8)

The information processing program according to supplementary note 6 or 7, in which in the determination by the defect coordinate determination unit, the defect coordinate determination unit is caused to perform correction by using the correction amount such that the position approaches the centroid position as the size increases.

(Supplementary note 9)

The information processing program according to supplementary note 6 or 7, in which in the determination by the defect coordinate determination unit, the defect coordinate determination unit is caused to perform correction by using the correction amount such that the position approaches the luminance peak position as the size decreases.

(Supplementary note 10)

The information processing program according to supplementary note 6 or 7, in which in the determination by the defect coordinate determination unit, the defect coordinate determination unit is caused to determine the luminance peak position corrected based on the size as the representative position coordinates of the defect region when the size is equal to or smaller than the first threshold.

The program can be stored and provided to a computer using any type of non-transitory computer readable media. Non-transitory computer readable media include any type of tangible storage media. Examples of non-transitory computer readable media include magnetic storage media (such as floppy disks, magnetic tapes, hard disk drives, etc.), optical magnetic storage media (e.g. magneto-optical disks), CD-ROM (compact disc read only memory), CD-R (compact disc recordable), CD-R/W (compact disc rewritable), and semiconductor memories (such as mask ROM, PROM (programmable ROM), EPROM (erasable PROM), flash ROM, RAM (random access memory), etc.). The program may be provided to a computer using any type of transitory computer readable media. Examples of transitory computer readable media include electric signals, optical signals, and electromagnetic waves. Transitory computer readable media can provide the program to a computer via a wired communication line (e.g. electric wires, and optical fibers) or a wireless communication line.

The first and second embodiments can be combined as desirable by one of ordinary skill in the art.

From the disclosure thus described, it will be obvious that the embodiments

of the disclosure may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the disclosure, and all such modifications as would be obvious to one skilled in the art are intended for inclusion within the scope of the following claims.

WHAT IS CLAIMED IS:

1. An information processing apparatus comprising:
a size acquisition unit configured to acquire a size of a defect region
5 contained in a sample; and
a defect coordinate determination unit configured to determine representative position coordinates of the defect region by performing different information processing based on the size.
- 10 2. The information processing apparatus according to claim 1, further comprising a storage unit configured to store the defect region in association with the representative position coordinates.
- 15 3. The information processing apparatus according to claim 1 or 2, wherein the defect coordinate determination unit, as the information processing,
determines a luminance peak position in the defect region as the representative position coordinates of the defect region when the size is equal to or smaller than a predetermined threshold, and
determines a centroid position of the defect region as the representative
20 position coordinates of the defect region when the size is larger than the predetermined threshold.
- 25 4. The information processing apparatus according to claim 3, wherein the defect coordinate determination unit determines the luminance peak position corrected based on the size as the representative position coordinates of the defect region when the size is equal to or smaller than the predetermined threshold.
- 30 5. The information processing apparatus according to claim 4, wherein the defect coordinate determination unit determines the luminance peak position as the representative position coordinates of the defect region when the size is equal to or smaller than the predetermined threshold, the luminance peak position being corrected by using a correction value that uses the size as a parameter and a correction amount of which increases as the size increases.

6. The information processing apparatus according to claim 1, wherein the defect coordinate determination unit, as the information processing,

determines a luminance peak position in the defect region as the representative position coordinates of the defect region when the size is equal to or smaller than a first threshold,

determines a centroid position of the defect region as the representative position coordinates of the defect region when the size is larger than a second threshold larger than the first threshold, and

determines a position as the representative position coordinates of the defect region when the size is larger than the first threshold and equal to or smaller than the second threshold, the position being obtained by correcting the luminance peak position based on the centroid position and the size.

7. The information processing apparatus according to claim 6, wherein the

defect coordinate determination unit determines a position as the representative position coordinates of the defect region when the size is larger than the first threshold and equal to or smaller than the second threshold, the position being obtained by correcting the luminance peak position by using a correction value that uses the centroid position and the size as parameters and a correction amount of which increases as the size increases.

8. The information processing apparatus according to claim 6 or 7, wherein the defect coordinate determination unit performs correction by using such a correction amount that the position approaches the centroid position as the size increases.

9. The information processing apparatus according to claim 6 or 7, wherein the defect coordinate determination unit performs correction by using such a correction amount that the position approaches the luminance peak position as the size decreases.

10. The information processing apparatus according to claim 6 or 7, wherein the defect coordinate determination unit determines the luminance peak position corrected based on the size as the representative position coordinates of the defect

region when the size is equal to or smaller than the first threshold.

11. An optical apparatus comprising:

an optical system configured to illuminate a sample with illumination light

5 and condense detection light from the illuminated sample;

a detector configured to detect the detection light; and

the information processing apparatus according to claim 1 or 2.

12. An information processing method comprising:

10 causing a size acquisition unit to acquire a size of a defect region contained in a sample; and

causing a defect coordinate determination unit to determine representative position coordinates of the defect region by performing different information processing based on the size.

15

13. The information processing method according to claim 12, further comprising causing a storage unit to store the defect region in association with the representative position coordinates.

20 14. The information processing method according to claim 12 or 13, wherein in the determination by the defect coordinate determination unit, the defect coordinate determination unit is caused to, as the information processing,

determine a luminance peak position in the defect region as the representative position coordinates of the defect region when the size is equal to or
25 smaller than a predetermined threshold, and

determine a centroid position of the defect region as the representative position coordinates of the defect region when the size is larger than the predetermined threshold.

30 15. The information processing method according to claim 14, wherein in the determination by the defect coordinate determination unit, the defect coordinate determination unit is caused to determine the luminance peak position corrected based on the size as the representative position coordinates of the defect region when the size is equal to or smaller than the predetermined threshold.

16. The information processing method according to claim 15, wherein in the determination by the defect coordinate determination unit, the defect coordinate determination unit is caused to determine the luminance peak position as the
5 representative position coordinates of the defect region when the size is equal to or smaller than the predetermined threshold, the luminance peak position being corrected by using a correction value that uses the size as a parameter and a correction amount of which increases as the size increases.

10 17. The information processing method according to claim 12, wherein in the determination by the defect coordinate determination unit, the defect coordinate determination unit is caused to, as the information processing,

determine a luminance peak position in the defect region as the
representative position coordinates of the defect region when the size is equal to or
15 smaller than a first threshold,

determine a centroid position of the defect region as the representative
position coordinates of the defect region when the size is larger than a second
threshold larger than the first threshold, and

determine a position as the representative position coordinates of the defect
20 region when the size is larger than the first threshold and equal to or smaller than the second threshold, the position being obtained by correcting the luminance peak position based on the centroid position and the size.

18. The information processing method according to claim 17, wherein in the
25 determination by the defect coordinate determination unit, the defect coordinate determination unit is caused to determine a position as the representative position coordinates of the defect region when the size is larger than the first threshold and equal to or smaller than the second threshold, the position being obtained by correcting the luminance peak position by using a correction value that uses the
30 centroid position and the size as parameters and a correction amount of which increases as the size increases.

19. The information processing method according to claim 17 or 18, wherein in the determination by the defect coordinate determination unit, the defect

coordinate determination unit is caused to perform correction by using such a correction amount that the position approaches the centroid position as the size increases.

5 20. The information processing method according to claim 17 or 18, wherein
in the determination by the defect coordinate determination unit, the defect
coordinate determination unit is caused to perform correction by using such a
correction amount that the position approaches the luminance peak position as the
size decreases.

10 21. The information processing method according to claim 17 or 18, wherein
in the determination by the defect coordinate determination unit, the defect
coordinate determination unit is caused to determine the luminance peak position
corrected based on the size as the representative position coordinates of the defect
15 region when the size is equal to or smaller than the first threshold.

 22. A method of using an optical apparatus, the method comprising:
 illuminating a sample with illumination light and condensing detection light
from the illuminated sample with an optical system;
20 detecting the detection light with a detector; and
 performing the information processing method according to claim 12 or 13.

 23. An information processing program configured to cause a computer to
execute:
25 causing a size acquisition unit to acquire a size of a defect region contained
in a sample; and
 causing a defect coordinate determination unit to determine representative
position coordinates of the defect region by performing different information
processing based on the size.