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Title of the Invention

D-644

STEREOSCOPIC DISPLAY METHOD FOR A SCANNING TYPE
PROBE MICROSCOPE

Background of the Invention and Related Art Statement

The invention relates to a stereoscopic display method for a scanning type probe microscope, more particularly, a display method for displaying data of a surface shape of an object obtained by a scanning type probe microscope to be stereoscopically seen.

A scanning type probe microscope, such as a scanning type tunnel microscope and an interatomic power microscope, is known as a surface analyzing device for analyzing a surface shape, and a surface shape of an object is measured by the scanning type probe microscope as three-dimensional data. In the scanning type probe microscope of this type, it is desired that the surface shape of the object is stereoscopically observed. According to such a requirement, in conventional display methods, a three-dimensional shape is displayed by, for example, a shading image where the object is viewed from the upper direction thereof, a line image for displaying outlines thereof, a mesh image for displaying a surface shape by means of a mesh or bird's eye image.

In the shading image, line image, mesh image and bird's eye image which are employed for a stereoscopic display in the conventional scanning type probe microscope, when the images are displayed as a single display image, there have been defects such that a three-dimensional shape of a surface of the object is not easily grasped. Therefore, there has been used a method wherein, for example, by displaying a shading image and a sectional image at the same place of an object and comparing them, a three-dimensional

shape of the surface of the object is grasped. However, in case a three-dimensional shape of the surface of the object is grasped by comparing and referring to a plurality of displayed images, an observer has to assume the surface shape of the object from the displayed images, which requires considerable skill.

Therefore, it has not been able to obtain the surface shape of the object by the display method using the displayed single image, such as the shading image, line image, mesh image or bird's eye image, and by comparing and referring to a plurality of displayed images. Thus, the surface shape of the object has not been three-dimensionally observed.

Accordingly, an object of the present invention is to obviate the defects of the prior art and to provide a stereoscopic display method for a scanning type probe microscope, wherein a surface shape of an object is displayed to be stereoscopically observed.

Further objects and advantages of the invention will be apparent from the following description of the invention.

Summary of the Invention

A stereoscopic display method of the present invention is designed to be used for a scanning type probe microscope for obtaining three-dimensional data of a surface shape of an object. In the scanning type probe microscope, the obtained three-dimensional data are converted into at least two two-dimensional data obtained by observing from different sight line directions corresponding to a predetermined parallax angle, and a display position when the at least two converted two-dimensional data are displayed on a display surface is determined to correspond to the

parallax angle to thereby display the two-dimensional data on the display position. Thus, the surface shape of the object is displayed to be stereoscopically seen.

In regard to the reasons why a person senses a distance between himself and an object, it is generally known that, for example, (1) an approximate distance can be grasped from a difference between an apparent size of the object and a real size of the object known through experiences; (2) a relative positional relationship can be grasped from shadings of a plurality of objects; and (3) a distance to the object can be known by a parallax angle of eyes.

The stereoscopic display method of the present invention employs the parallax angle, wherein at least two two-dimensional shapes when an object is observed from sight line directions corresponding to the parallax angle are obtained, and the obtained two-dimensional shapes are displayed at display positions corresponding to the parallax angle. By positioning eyes on the sight lines corresponding to the parallax angle with respect to images displayed by the display method and observing the images in the respective sight line directions, an image equivalent to the image obtained when a three-dimensional object is observed is formed in the eyes to thereby observe the object stereoscopically. Incidentally, the parallax angle stands for an angle formed by two lines connecting both eyes to an object, and is determined by a distance between the two eyes and a distance between the object and the eyes.

According to a first aspect of the present invention, two-dimensional data viewed from a right eye sight line direction and

two-dimensional data viewed from a left eye sight line direction are obtained from three-dimensional data according to the parallax angle, and the two two-dimensional data are displayed on a display surface as two separated images corresponding to the parallax angle. The displayed images are positioned away from each other for a distance corresponding to the parallax angle, and the two-dimensional data viewed from the right eye sight line direction are observed with the right eye and the two-dimensional data viewed from the left eye sight line direction are observed with the left eye. As a result, an image equivalent to the image obtained when the three-dimensional object is observed is formed in the eyes to thereby stereoscopically be seen.

According to a second aspect of the present invention, two-dimensional data viewed from a right eye sight line direction and two-dimensional data viewed from a left eye sight line direction are obtained from the three-dimensional data according to a parallax angle in the same manner as in the first embodiment, and the two two-dimensional data are alternately displayed on a display surface at the same position. By observing the displayed images from a position separated by a distance corresponding to the parallax angle, an image equivalent to the image obtained when the three-dimensional object is observed is formed in the eyes to thereby stereoscopically be seen.

According to a third aspect of the present invention, instead of displaying on the display surface as described in the first and second aspects, the two two-dimensional data are printed on a sheet of paper. As in the first aspect of the present invention, by observing the two two-dimensional data with the right and left eyes

from the respective sight line directions, an image equivalent to the image obtained when the three-dimensional object is observed is formed in the eyes to thereby stereoscopically be seen.

According to a fourth aspect of the present invention, at least two two-dimensional data are divided into a plurality of portions, and both the divided two-dimensional data are alternately displayed on a display surface as images. A cylindrical convex lens array is disposed on an upper part of the displayed images, and by observing the displayed images through the lens array from a position separated by a distance corresponding to the parallax angle, an image equivalent to the image obtained when a three-dimensional object is observed is formed in the eyes to thereby stereoscopically be seen.

According to a fifth aspect of the present invention, instead of alternately displaying on the display surface in the fourth aspect of the invention, both the divided two-dimensional data are printed on a sheet of paper. As in the fourth aspect, the cylindrical convex lens array is disposed on an upper part of the printed image, and by observing the printed image through the lens array from a position separated by the distance corresponding to the parallax angle, an image equivalent to the image obtained when the three-dimensional object is observed is formed in the eyes to thereby stereoscopically be seen.

Brief Description of the Drawings

Fig. 1 is a diagram for showing a procedure of a stereoscopic display method for a scanning type probe microscope according to the present invention;

Fig. 2 is a block diagram for showing a structure performing the stereoscopic display method for the scanning type probe microscope according to the present invention;

Fig. 3(a) is an explanatory diagram for showing a relationship between a parallax angle and an object;

Fig. 3(b) is an explanatory diagram for showing a relationship between a parallax angle and two-dimensional data;

Fig. 4(a) shows an example where an object is observed from two sight line directions with a light source in one direction;

Fig. 4(b) shows an example where images of two-dimensional data in the right and left eye sight line directions are independently shown at the same time;

Fig. 4(c) shows an example where images of two-dimensional data in the right and left eye sight line directions are alternately displayed at the same place;

Fig. 4(d) shows another example where an image of two-dimensional data in the right and left eye sight line directions are independently displayed at the same time;

Fig. 5 is a coordinate diagram for obtaining two-dimensional data from three-dimensional data;

Fig. 6 is a flow chart for explaining a procedure of data conversion; and

Figs. 7(a)-7(f) show flow charts for explaining a procedure for obtaining shading due to a light source and positional coordinates viewed from a sight line direction.

Detailed Description of Preferred Embodiments

Embodiments of a stereoscopic display method for a scanning

type probe microscope of the present invention are explained in detail referring to the drawings, wherein Fig. 1 is a diagram for showing a procedure of the stereoscopic display method for the scanning type probe microscope; Fig. 2 is a block diagram for showing a structure of the scanning type probe microscope for performing the stereoscopic display method; Fig. 3 is a diagram for explaining a relationship between a parallax angle and a distance; and Figs. 4(a)-4(d) show an example of a stereoscopic display.

The structure of the scanning type probe microscope for performing the stereoscopic display method of the present invention is formed of, as shown in Fig. 2, a display process device 1 for inputting three-dimensional data measured by a scanning type probe microscope 10 and converting the three-dimensional data into two-dimensional data for a stereoscopic display. An input device 11 for inputting a parameter for converting the data, and a display device 12, such as CRT and a printing device, may be attached to the display process device 1.

The display process device 1 is formed of a memory device 2, a data converting device 3 for converting the three-dimensional data into the two-dimensional data, and a display driver 4 for displaying the two-dimensional data on the display device 12. The memory device 2 includes a first memory 21 for storing the three-dimensional data from the scanning type probe microscope 10, a second memory 22 for storing the converted two-dimensional data, and a third memory 23 for storing the parameter. Incidentally, control of the respective devices in the display process device 1 is carried out by a control device, such as CPU and the like, not shown.

The stereoscopic display method for the scanning type probe microscope 10 is carried out by a procedure as shown in Fig. 1. The scanning type probe microscope 10 measures a surface shape of an object to obtain the three-dimensional data. Incidentally, since a structure of the scanning type probe microscope 10 and a procedure for obtaining the three-dimensional data have been well known, e.g. U.S. Patent No. Re 33,387 which corresponds to Japanese Patent Publication (KOKAI) No. 62-130302, explanations thereof are omitted (Step S1). The memory device 2 stores the obtained three-dimensional data in the first memory 21 (Step S2). The data converting device 3 reads the three-dimensional data from the first memory 21, and converts to the two-dimensional data obtained when the object is viewed from sight line directions corresponding to a parallax angle. At this time, data conversion is carried out by taking into consideration the sight line direction and an angle of light for lightening the object. As a parameter to be used for converting data, such as a parallax angle 2θ and an angle of a light source, such as a main light source and sub-light source, for lightening the object, the parameter stored in the third memory 23 from the input device 11 can be used (Step S3). The converted two-dimensional data are stored in the second memory 22 of the memory device 2 (Step S4).

In the display driver 4, a position for displaying the two-dimensional data on the display device 12 is obtained according to the parallax angle. Fig. 3(a) shows a relationship between the object and the parallax angle, wherein assuming that the parallax angle is 2θ , right eye and left eye observe the object from the respective sight line directions for forming the 2θ angle. On the

other hand, Fig. 3(b) shows a case where images displayed by the two-dimensional data instead of the object are observed.

In case images of the two-dimensional data are displayed at the same time to be stereoscopically seen, images of the two-dimensional data in the respective sight line directions of the right and left eyes are displayed independently or to be spaced apart from each other. This case is shown by an image A in Fig. 3(b). An image A1 formed of the two-dimensional data in the sight line direction of the right eye and an image A2 formed of the two-dimensional data in the sight line direction of the left eye are displayed in positions parallel to both eyes and spaced apart from each other. The right and left eyes observe the image A1 and image A2 to form an image equivalent to the image obtained when a three-dimensional object is observed. Incidentally, a relationship among a distance between both the images, the parallax angle 2θ , and a distance L_A between eyes and the images can be geometrically determined.

Also, in case the images of the two-dimensional data are alternately displayed to stereoscopically be seen, the images of the two-dimensional data in the respective sight line directions of the right and left eyes are displayed at the same position. This case is shown by an image B in Fig. 3(b). An image B1 formed of the two-dimensional data in the sight line direction of the right eye and an image B2 formed of the two-dimensional data in the sight line direction of the left eye are alternately displayed at the same position. At this time, a shutter mechanism, not shown, is disposed in front of the right and left eyes, and opened and closed in synchronism with the displays of the right image and left image.

The right and left eyes observe the image B1 and image B2 to form an image equivalent to the image obtained when a three-dimensional object is observed, by the remaining images. Incidentally, a distance LB between the eyes and images can be geometrically determined by the parallax angle 2θ and a distance between two eyes.

The display position at the display device for displaying the two-dimensional data converted at the Step S3 as described above is obtained according to the parallax angle (Step S5).

The display driver 4 displays the two-dimensional data obtained at the Step S3 on the display position obtained at the Step S5 at the display device 12. Incidentally, in case images are alternately displayed at the same position as shown in Fig. 3(b), a display device, such as CRT, is used as the display device 12, and the display of the images is shifted by a shifting device, not shown (Step S6).

The display examples are described referring to Figs. 4(a)-(d). Fig. 4(a) shows a case, wherein with respect to an object having coordinates of X, Y, Z, a light source is disposed in an arrow L direction, and the object is observed from arrows VR and VL directions. Incidentally, the shaded portion of the object in the drawing shows a shadow portion due to the light source. As described above, the three-dimensional data with respect to the object are obtained by the scanning type probe microscope, and converted into two-dimensional data through the data conversion to display through the display device.

Fig. 4(b) shows an example, wherein as shown by the image A in Fig. 3(b), an image by the two-dimensional data in the right eye

sight line direction and an image by the two-dimensional data in the left eye sight line direction are spaced apart from each other and displayed at the same time. An observer observes the displayed two images with his right and left eyes and forms an image equivalent to the image obtained when the observer observes the three-dimensional object to be stereoscopically seen.

Also, Fig. 4(c) shows an example, wherein as shown by the image B in Fig. 3(b), the image of the two-dimensional data in the right eye sight line direction and the image of the two-dimensional data in the left eye sight line direction are alternately displayed at the same position through the shifting device. The observer observes the displayed two images to form an image equivalent to the image obtained when a three-dimensional object is observed, to be stereoscopically seen.

Also, Fig. 4(d) shows another example, wherein an image by the two-dimensional data in the right eye sight line direction and an image by the two-dimensional data in the left eye sight line direction are independently displayed at the same time. In this case, images are divided into small areas, and the images by the two-dimensional data in the right eye sight line direction and images by the two-dimensional data in the left eye sight line direction are spaced apart from each other and displayed in the alternate positions. Then, a cylindrical convex lens alley is disposed on the displayed images, and by observing the images through the lens alley at a position away therefrom by a distance corresponding to the parallax angle, an image equivalent to the image obtained when the three-dimensional object is observed is formed in the eyes of an observer, to thereby be stereoscopically

seen. Incidentally, in the drawings, the shaded portions show shadow portions.

Next, an example of data conversion from three-dimensional data to two-dimensional data is explained. In the data conversion, as shown by coordinate diagram of Fig. 5, the three-dimensional data are converted to the two-dimensional data at coordinate surfaces X , Z in a fixed coordinate Y , and while consecutively scanning the coordinate Y , the data conversion is repeatedly carried out from the three-dimensional data in the coordinate surfaces X , Z to the two-dimensional data. Incidentally, θM stands for an angle of a main light source M ; θS stands for an angle of a sub-light source S ; θ stands for an angle in the right eye sight line direction VR ; and $-\theta$ stands for an angle of the left eye sight line direction VL .

An example of a data conversion procedure is shown in Fig. 6. In Fig. 6, three-dimensional data (x , y , z) are obtained (Step S11); and positions (θM , θS) of the main light source M and the sub-light source S , and positions (θ , $-\theta$) of the right eye sight line direction VR and the left eye sight line direction VL are obtained (Steps S12 and S13).

Next, a scanning start point y_0 is fixed on a Y axis (Step S14); positional coordinates on the object surface observed from the right eye sight line direction VR and brightness thereat are obtained in every predetermined interval Δy from the starting point y_0 so that data (x_v , y , z_v , BMR) by the main light source and data (x_v , y , z_v , BSR) by the sub-light source in the right eye sight line direction VR are obtained (Step S15); and data (x_v , y , z_v , BML) by the main light source and data (x_v , y , z_v , BSL) by the sub-

light source in the left eye sight line direction VL are obtained (Step S16).

By repeating the Steps S15, S16 in every predetermined interval Δy (Step S17, Step S18), the two-dimensional data (x_v , y_v , z_v , BMR) observed from the right eye sight line direction VR and two-dimensional data (x_v , y_v , z_v , BML) observed from the left eye sight line direction VL are obtained. At this time, weighing with respect to data MBR, BML of the brightness from the main light source and data BSR, BSL of the brightness from the sub-light source is rated, and shading is adjusted. The parameter of the weighing can be inputted through the input device 11 (Step S19).

Next, a display position of the two-dimensional data on the display device according to the parallax angle is obtained (Step S20), and an image obtained when observed from the right eye sight line direction VR and an image obtained when viewed from the left eye sight line direction VL are displayed on the display device (Step S21).

The shadings by the light sources and positional coordinates on the object which can be seen from the sight line directions can be obtained from, for example, a flow chart as shown in Figs. 7(a)-7(f). Incidentally, the following processes are examples of the processes in Steps S15 and S16, wherein the coordinate Y is fixed.

As shown in Fig. 7(a), assuming that θ stands for a sight line direction and $-\theta_L$ stands for a light source direction (Step S31), coordinates (x_v , z_v) viewed from the sight line direction θ are obtained (Step S32).

In the process of Step S32, as shown in Fig. 7(b), the coordinates (x , z) are rotated by $-\theta$ to thereby obtain coordinates

(x', z') in a rotational coordinate type, and by selecting larger data in a direction of axis Z with respect to the positional data, the coordinate conversion of which has been made, coordinates viewed from the sight line direction θ can be obtained. Incidentally, thick lines in Fig. 7(b) show portions which can be seen from the sight line direction θ . Next, as shown in Fig. 7(c), by rotating with θ , the coordinates (x', z') of the rotational coordinate type which can be seen from the sight line direction θ are returned to the coordinates (x_v, z_v) at the original coordinate type.

Next, the brightness of a surface lightened by a light source L is obtained (Step S33). In the process of the Step S33, as shown in Fig. 7(d), the coordinates (x, z) are rotated by θ_L to thereby obtain coordinates (x'', z'') of the rotational coordinate type, and by selecting larger data in the direction of the axis Z with respect to position data where the coordinate change has been made, coordinates irradiated by the light source L is obtained. Further, the brightness B'' on the lightened surface can be obtained from an inclination in the coordinate position. The data on the rotational coordinate type are shown as (x'', z'', B'') . Furthermore, as shown in Fig. 7(e), through rotation of the data (x'', z'', B'') in the rotational coordinate type by $-\theta_L$, the data (x, z, B) in the original coordinate type can be obtained.

By obtaining the brightness on the coordinates which can be seen from the sight line direction θ obtained in Step S32 with reference to the data obtained at Step S33, two-dimensional data (x_v, z_v, B) viewed from the sight line direction θ as shown in Fig. 7(f) can be obtained.

As described above, in the scanning type probe microscope, the surface shape of an object can be displayed to be stereoscopically seen.

While the invention has been explained with reference to the specific embodiments of the invention, the explanation is illustrative and the present invention is limited only by the appended claims.

What is claimed is:

1. A stereoscopic display method for a microscope, comprising:
obtaining three-dimensional data of a surface shape of an object by a microscope;

converting said three-dimensional data into at least two two-dimensional data obtained by observing from different sight line directions corresponding to a predetermined parallax angle;

determining on a display surface display positions of the converted at least two two-dimensional data to correspond to the parallax angle; and

displaying said at least two two-dimensional data on the display positions so that an image equivalent to an image obtained when the three-dimensional object is observed is seen.

2. A stereoscopic display method according to claim 1, wherein said at least two two-dimensional data are alternately displayed on the display surface at a same position.

3. A stereoscopic display method according to claim 1, wherein said at least two two-dimensional data are printed on a sheet.

4. A stereoscopic display method according to claim 1, wherein said at least two two-dimensional data are located on lines in said different sight line directions to be spaced apart from each other without overlapping, and are arranged parallel to eyes of an observer.

5. A stereoscopic display method according to claim 4, wherein



said at least two two-dimensional data are divided into a plurality of portions, said divided two-dimensional data being alternately displayed on the display surface as images, and said displayed images being observed through a lens.

6. A stereoscopic display method according to claim 5, wherein said divided two-dimensional data are printed on a sheet as images, said printed images being observed through the lens.

7. A stereoscopic display method according to claim 5, wherein said lens is a cylindrical convex lens array.

8. A stereoscopic display method according to claim 1, wherein said microscope is a scanning type probe microscope.

