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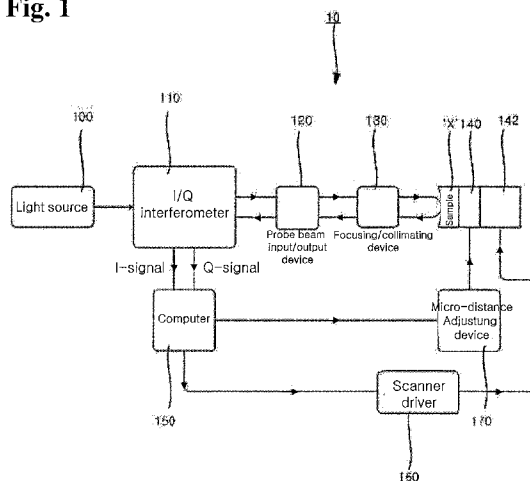
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(54) Title: COMPLEX FUNCTION MICROMETER USING HETERODYNE INTERFEROMETER AND SCANNING METHOD

Fig. 1



(57) Abstract: The present invention relates to a complex function micrometer using an I/Q interferometer. The complex function micrometer includes an I/Q interferometer converting a probe beam which includes information with respect to a sample to I signal and Q signal and outputting the signals, a sample die on which the sample is disposed, an XY scanner, a scanner driver, a up/down lift, a micro-distance adjusting device, a focusing/collimating device, and a computer. The computer transfers a movement control signal for controlling the movement of the XY scanner to the scanner driver or transfers a signal for controlling the movement of the up/down lift to the micro-distance adjusting device, and receives the I signal and Q signal provided from the I/Q interferometer to extract information with respect to the surface or inside of the sample. The complex function micrometer performs a multilayer scanning or a constant phase scanning with respect to the sample to obtain information with respect to structure of surface or inside of the sample.

COMPLEX FUNCTION MICROMETER USING HETERODYNE INTERFEROMETER AND SCANNING METHOD

FIELD OF THE INVENTION

5 The present invention relates to a complex function micrometer using an I/Q interferometer and a scanning method, and more particularly, to a complex function micrometer which is capable of obtaining and analyzing physical and structural information with respect to surface and inside of a sample by combining an I/Q interferometer with a multilayer scanning method and a constant phase scanning
10 method.

DESCRIPTION OF THE RELATED ART

 An interferometric measuring system is a system that combines a probe beam and a reference beam together using a beam splitter (BS) and measures beam
15 intensities outputted from two output terminals respectively with separate photodetectors. At this time, the electric signal outputted from each photodetector is referred to as a beam signal. The system is referred to as a homodyne interferometer in the case that the frequencies of the probe beam and the reference beam are identical, and the system is referred to as a heterodyne interferometer in
20 the case that the frequencies of the probe beam and the reference beam are different.

 In the case of the homodyne interferometer, the intensities of the beams outputted from the two output terminals vary as a phase difference between the probe beam and the reference beam. When a constructive interference occurs in the beam outputted from one output terminal, a destructive interference occurs in the
25 beam outputted from the other output terminal. That is to say, the interference signals outputted from the respective terminals have a phase difference of 180

degrees. Therefore, by subtracting the two beam signals with a differential amplifier, correlated noises on the respective beam signals are removed and the beam signals are doubled thereby raising signal to noise ratio. This measuring method is called as a balanced detection method. The signal outputted from the differential amplifier is
 5 expressed by the mathematical formula 1.

【Mathematical Equation 1】

$$v_{diff} = R \sqrt{I_s} \sqrt{I_{LO}} \cos(\Phi_0 + \Phi_m)$$

wherein, I_s and I_{LO} represent, respectively, the intensities of the probe beam and reference beam, and Φ_m and Φ_0 represent, respectively, a phase value derived in
 10 the probe beam due to partial structure or optical property of a sample to be measured and a phase difference due to difference between optical paths of the probe beam and the reference beam in the interferometer other than the phase value.

A scanning micrometer is the system which optimally measures a variation in the partial optical properties resulted from a structural change of the sample during
 15 scanning process and therefrom restores the shape of surface or inside structure of the sample, and it is thus necessary to optimally measure Φ_m while scanning the sample or the probe beam. Since the magnitude of Φ_m is very small in most cases, the mathematical equation 1 can be rewritten as the mathematical equation 2 by adjusting the path difference between the probe beam and the reference beam so
 20 that Φ_0 is always $n(2n+1)/2$, wherein $n=0, 1, 2, \dots$.

【Mathematical Equation 2】

$$v_{diff} = R \sqrt{I_s} \sqrt{I_{LO}} \sin \Phi_m = R \sqrt{I_s} \sqrt{I_{LO}} \Phi_m$$

Therefore, a magnitude of an interference signal comes to be proportional to Φ_m and it is thus possible to map the partial phase variation of the sample through
 25 scanning. However, in the case that intensity and phase of the probe beam vary at

the same time, i.e. in the case that geometrical structure and material of the surface are changed at the same time, there is a disadvantage that it is impossible to identify them. Therefore, the homodyne interferometer is suitable to analyze a sample of the same material, but has a limitation in combined microscopic analysis for a general
5 sample.

In the case of the heterodyne interferometer, the beam signal detected at each output terminal is given as the mathematical equation 3 since the frequencies of the probe beam and the reference beam are different.

【Mathematical Equation 3】

$$10 \quad v_{diff} = R \sqrt{I_S} \sqrt{I_{LO}} \cos(\Delta\omega t + \Phi_0 + \Phi_m)$$

wherein, $\Delta\omega$ represents a frequency difference between the probe beam and the reference beam. In other words, the interference signal is a beat signal in RF or microwave band corresponding to frequency difference between the two beams, typical signal processing technology used in the field of RF can be used to measure
15 phase variation or amplitude variation derived in the probe beam by the surface.

An interferometer capable of independently measuring the phase variation and the amplitude variation derived in the probe beam has been studied by the present inventor group. In the case of a homodyne I/Q-interferometer, two interferometers have a phase difference of 90 degrees between the interference signals while having
20 the same probe beam path and reference beam path since it uses polarization of the probe beam and reference beam. Therefore, a signal of one interferometer is represented by the mathematical equation 4.

【Mathematical Equation 4】

$$v_I = \frac{R}{2} \sqrt{I_0} \sqrt{I_{LO}} \cos(\Phi_0 + \Phi_m)$$

A signal of the other interferometer is represented by the mathematical equation 5 and it is thus possible to implement I/Q demodulation with respect to the beam signal. In other words, the phase derived in the probe beam can be obtained from the mathematical equation 6, and the magnitude variation of the probe beam is
 5 given by the mathematical equation 7.

【Mathematical Equation 5】

$$v_Q = \frac{R}{2} \sqrt{I_0} \sqrt{I_{LO}} \sin(\Phi_0 + \Phi_m)$$

【Mathematical Equation 6】

$$\Phi_0 + \Phi_m = \tan^{-1} \frac{\sqrt{v_Q}}{\sqrt{v_I}}$$

10 【Mathematical Equation 7】

$$\sqrt{I_0} \sqrt{I_{LO}} = \sqrt{v_I^2 + v_Q^2}$$

Accordingly, it is possible to independently measure the phase variation and the magnitude variation derived in the probe beam at the same time when using the I/Q-interferometer. Details of the interferometer and a surface micrometer using the
 15 same are disclosed in reference document 1 (Heseong Jeong, Jong-Hoi Kim, Kyumann Cho, "Complete mapping of complex reflection coefficient of a surface using a scanning homodyne multiport interferometer.", Optics communication, Vol. 204, pp.45-52 (2002)). Herein, the surface analysis was implemented in a reflection type, and it was possible to analyze the structural and material properties of the surface by
 20 mapping partial variations in phase and magnitude with respect to the probe beam while scanning the sample in x and y axial directions after focusing the probe beam onto one point on the surface. A function of a micrometer using the existing

interferometer is significantly improved in this micrometer, and the present inventor group has shown in the reference document 1 that it is possible to find a material defect using this micrometer which could not be identified by the existing micrometer.

As can be appreciated from the aforementioned study, the homodyne
5 interferometer includes three polarizing beam splitters and four photodetectors. Therefore, the correct operation of the interferometer requires a very difficult and special arrangement process. The present inventor group has developed a technology of a heterodyne interferometer, which can effectively measure the phase derived in the probe beam while having the same function, using a simple optical
10 structure, other than the balanced detection method, in which only two photo diodes (PD) are used to measure single probe beam and a high-pass filter or a band-pass filter is placed at a front end of a I/Q-demodulator. Since information with respect to amplitude and phase variations loaded on the probe beam are down converted to RF or microwave band range by interfering the probe beam and the reference beam
15 having different frequencies from each other using a beam splitter as shown in Fig. 5 and converting the interfered result into an electric signal using a photodetector, it is possible to easily identify and measure the phase and magnitude variations derived in the probe beam when using the I/Q-demodulating method. The present inventor group have implemented a study for measuring a phase signal using an I/Q-
20 demodulator and applying it into a highly sensitive displacement sensor, and the result is disclosed in reference document 2 (MOON Joon, "a hybrid type displacement sensor using a heterodyne I/Q interferometer", Seokang University, 2003).

As described above, the scanning micrometer using the I/Q interferometer become able to independently and simultaneously image the phase variation and
25 magnitude variation derived in the probe beam reflected from the surface or inside of the sample or transmitted through the sample. However, since these micrometers

have various factors by which the phase variation and the magnitude variation occur at the same time, current scanning methods have a limitation in qualitatively analyzing an exact structure of the surface or inside of the sample. For example, in a micrometric analysis for the surface of the sample having a structure with depth variation, since the location of the surface is changed in an area 2 though the material is not partially changed when a scanning area is moved from an area 1 to the area 2 with the probe beam being focused onto the area 1 during scanning process, the amplitude of the probe beam is varied as the depth variation and thus the phase and the amplitude of the probe beam may be varied at the same time. Therefore, the scanning micrometer using the I/Q interferometer still have a limitation in analyzation of the sample.

The present invention suggests a solution to improve ability of analyzing the structure of the surface or inside of the sample by applying a multilayer scanning method and a constant phase scanning method to a micrometer using a scanning I/Q interferometer.

Throughout this application, several patents and publications are referenced and citations are provided in parentheses. The disclosure of these patents and publications is incorporated into this application in order to more fully describe this invention and the state of the art to which this invention pertains.

DETAILED DESCRIPTION OF THIS INVENTION

Therefore, an object of the present invention is to provide a complex function micrometer which is capable of measuring phase and amplitude variations derived in a probe beam transmitted through or reflected from a sample by applying multilayer and constant phase scanning methods to an I/Q interferometer.

To achieve the above and other objects, a complex function micrometer according to an aspect of the present invention includes an I/Q interferometer providing a probe beam to a sample, and converting the probe beam and a reference beam, which are focused and collimated with respect to the sample and the returned thereto, into an I signal and a Q signal and outputting the I and Q signals; a sample die on which the sample is disposed; an XY scanner moving the sample die in two directions perpendicular to a moving direction of the probe beam; a scanner driver controlling the movement of the XY scanner; a up/down lift moving the sample die in a direction parallel to the moving direction of the probe beam; a micro-distance adjusting device controlling the movement of the up/down lift; a focusing/collimating device focusing the probe beam provided from the I/Q interferometer onto a surface of the sample or collimating the probe beam reflected or transmitted by the sample to provide again to the I/Q interferometer; and a computer transferring a movement control signal for controlling the movement of the XY scanner to the scanner driver or transferring a signal for controlling the movement of the up/down lift to the micro-distance adjusting device, and receiving the I signal and Q signal provided from the I/Q interferometer to extract information with respect to the surface or inside of the sample, wherein the computer performs a multilayer scanning with respect to the sample by repeating a process of fixing the up/down lift to an arbitrary position, driving the XY scanner to scan a first layer of the sample, driving the up/down lift to move the sample die, and driving the XY scanner to scan a first layer of the sample.

A complex function micrometer according to an aspect of the present invention includes an I/Q interferometer providing a probe beam to a sample, and converting the probe beam and a reference beam, which are focused and collimated with respect to the sample and the returned thereto, into an I signal and a Q signal and outputting the I and Q signals; a sample die on which the sample is disposed; an XY scanner

moving the sample die in two directions perpendicular to a moving direction of the probe beam; a scanner driver controlling the movement of the XY scanner; a up/down lift moving the sample die in a direction parallel to the moving direction of the probe beam; a micro-distance adjusting device controlling the movement of the up/down lift; 5 a focusing/collimating device focusing the probe beam provided from the I/Q interferometer onto a surface of the sample or collimating the probe beam reflected or transmitted by the sample to provide again to the I/Q interferometer; and a computer transferring a movement control signal for controlling the movement of the XY scanner to the scanner driver or transferring a signal for controlling the movement of 10 the up/down lift to the micro-distance adjusting device, and receiving the I signal and Q signal provided from the I/Q interferometer to extract information with respect to the surface or inside of the sample, wherein the computer sets a reference phase by focusing the probe beam at a predetermined position of the sample, then provides an error signal for feedback control for preventing variation in the reference phase when 15 scanning the sample in the XY direction, then adjusts a distance between the focusing/collimating device and the sample according to the error signal for feedback control, and then measures the unevenness of the surface of the sample using the error signal for feedback control according to the XY position.

In both aspects of the present invention, it is preferable that the computer finds 20 out the point at which an amplitude signal is largest in the scanning result, and connects points having the same phase as the point having the largest amplitude signal to obtain a contour line or a contour surface with respect to a topography, and the computer detects an extent of reflectivity variation from the amplitude signals with respect to the obtained contour line or contour surface and determines heterogeneity 25 of the medium of the sample according to the detected extent of reflectivity variation.

In both aspects of the present invention, it is preferable that the probe beam includes information of phase variation and amplitude variation with respect to respective positions when scanning the surface of the sample.

According to the complex function micrometer as described above, since phase
5 and amplitude variations derived in the probe beam transmitted or reflected from the sample are measured at the same time, it is easy to analyze the surface or inside structure, or material of the sample. Therefore, the complex function micrometer using an I/Q interferometer can be utilized very usefully to a combined diagnosis of bio or semiconductor device or material. Consequently, the present invention has
10 improved the shortcomings of the various existing micrometers and is expected to contribute advance of high technology industry such as semiconductor or bio technology.

The scanning micrometer according to the present invention as described above has a function that can obtain complex information with respect to partial
15 structure or the material of the surface or inside by independently and simultaneously measuring the phase and amplitude variations derived in the probe beam reflected from or transmitted through the surface or inside of the sample, and can perform a combined diagnosis with respect to a desired area by scanning the probe beam.

The present invention has significantly improved the function of various existing
20 optical micrometer technology and is equipped with the most efficient complex diagnosis function in an optical micrometer. Therefore, the present invention can be utilized very useful in an optical diagnosis for semiconductor material and device, material and device consisting of heterogeneous materials, active and passive photoelectronic device, bio material and device, etc. and may have a significant
25 influence on study of basic science or industrial technology in the corresponding field.

The present invention is an apparatus capable of diagnosing combined partial properties of the sample, that could not be identified by the scanning I/Q interferometer or a confocal microscope, by applying the multilayer scanning technology or the constant phase scanning technology of the confocal microscope to the scanning I/Q interferometer having a function capable of independently imaging phase and amplitude variations.

The present invention has largely improved an analysis ability for surface or inside structure of the sample by applying the multilayer and the constant phase scanning method to the micrometer using a scanning I/Q interferometer. In the multilayer scanning method, by scanning the sample in XY directions while moving the sample in Z direction with a predetermined distances, i.e. by scanning the sample on a per layer basis, it is possible to image partial phase and amplitude variation with respect to each layer and therefrom to perform an accurate and combined analysis for surface or inside structure of the sample. In the constant phase scanning method, the focus of the focusing device is always laid on the sample by maintaining a phase variation signal obtained from an interferometer to a constant value during scanning using feedback position control device and it is possible to found a three dimensional structure of the surface from an error signal required to control the position and to found variation in material of the surface from amplitude variation of the probe beam.

In the present invention, the multilayer scanning and constant phase scanning methods are applied to the complex function micrometer using the scanning I/Q interferometer to enlarge the function of the complex function micrometer using the scanning I/Q interferometer. In the multilayer scanning method, by scanning the sample in XY directions at each step while moving the sample in Z direction with predetermined steps, it is possible to obtain more precise information with respect to geometric structure and material of the sample. In the constant phase scanning

method, scanning is performed with controlling a distance between the surface of the sample and the focusing device using the feedback position control device so that the phase value obtained from the I/Q interferometer is always maintained to a constant value. The former may be applied to both reflective and transmissive modes, and the latter may be mainly applied to the reflective mode.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an overall block diagram showing a complex function micrometer according to the present invention;

Fig. 2 is a view illustrating a path through which a probe beam is focused, reflected from the surface of the sample and then collimated by a focusing/collimating device, when the complex function micrometer according to the present invention is operated in a reflective manner;

Fig. 3 is a view illustrating example of the focusing/collimating device 130 and the sample X when the complex function micrometer according to the present invention is operated in a transmissive manner;

Fig. 4 is a conceptual view for explaining an operation of a complex function micrometer employing a multilayer scanning manner according to a first embodiment of the present invention; and

Fig. 5 is a conceptual view for explaining an operation of a complex function micrometer employing a constant phase scanning method according to a second embodiment of the present invention.

[Detailed Description of Main Elements]

10: complex function micrometer

100: light source

110: I/Q interferometer

- 120: probe beam input/output device
- 130: focusing/collimating device
- 140: up/down lift
- 142: XY scanner
- 5 150: computer
- 160: scanner driver
- 170: micro-distance adjusting device
- 302: focusing device
- 304: collimating device
- 10 306: mirror
- X: sample

The present invention will now be described in further detail by examples. It would be obvious to those skilled in the art that these examples are intended to be more concretely illustrative and the scope of the present invention as set forth in the appended claims is not limited to or by the examples.

EXAMPLES

20 First Embodiment

Reference will now be made in detail to a first embodiment of the present invention, examples of which are illustrated in the accompanying drawings.

Fig. 1 is an overall block diagram showing a complex function micrometer according to the present invention. Referring to Fig. 1, the complex function micrometer 10 according to the present invention is provided with a light source 100, an I/Q interferometer 110, a probe beam input/output device 120, a

focusing/collimating device 130, a up/down lift 140, an XY scanner 142, a computer 150, a scanner driver 160 and a micro-distance adjusting device 170. By combining the I/Q interferometer and a multilayer scanning method, the scanning micrometer 10 according to the present invention having the aforementioned configuration can
5 analyze partial optical properties of a surface or an inside of a sample, which cannot be obtained by existing micrometer, and obtain structural and material information with respect to the sample. Hereinafter, components of the complex function micrometer according to the present invention will be described in detail.

The light source 100 provides a beam with an arbitrary frequency to the I/Q
10 interferometer.

When the I/Q interferometer is of a homodyne system or of a heterodyne system using two beams with different frequencies from each other by using a frequency deflector such as an acousto-optic modulator, a stabilized laser which oscillates in a single mode or a stabilized laser which oscillates in a dual mode linear
15 polarized perpendicularly to each other due to oscillation properties of the laser is used as the light source. The beam provided from the light source is utilized as a probe beam and a reference beam by using a beam splitter or a polarizing beam splitter (PBS).

The I/Q interferometer 110 focuses the probe beam onto the sample disposed
20 on the scanner and outputs I signal and Q signal having information with respect to phase and amplitude of the probe beam reflected from the surface or the inside of the sample and the beam transmitted through the sample. The probe beam may be used to evaluate three dimensional structure and material with respect to the sample in the reflective mode or the transmissive mode.

25 The probe beam input/output device 120 provides the probe beam, which is provided from the I/Q interferometer 110, to the focusing/collimating device or

provides the probe beam, which is inputted from the focusing/collimating device, to the I/Q interferometer.

The focusing/collimating device 130 focuses the probe beam onto the sample X or collimates the probe beam reflected from or transmitted through the sample X.

5 The complex function according to the present invention may operate in a reflective manner or a transmissive manner. Fig. 2 is a view illustrating a path through which a probe beam is focused, reflected from the surface of the sample and then collimated by a focusing/collimating device, when the complex function micrometer according to the present invention is operated in a reflective manner. As
10 shown in Fig. 2, the probe beam outputted from the I/Q interferometer 110 is focused onto the surface of the sample X and the beam reflected from the surface or the inside of the sample is collimated through the same optical system to return to the I/Q interferometer 110.

Fig. 3 is a view exemplarily illustrating the focusing/collimating device 130 and
15 the sample X when the complex function micrometer according to the present invention is operated in a transmissive manner. Referring to Fig. 3, the focusing/collimating device is provided with a focusing device 302, a collimating device 304 and a mirror 306, and the focusing device 302 and the collimating device 304 are separately disposed at the front and rear of the sample X. In the transmissive
20 manner, the probe beam is focused at the inside of the sample X by using the focusing device 302 and the transmitted probe beam is collimated by using the collimating device 304 and then inputted again into the I/Q interferometer 110 by using the mirror 306. It is also possible to obtain images of phase variation and amplitude variation with respect to the scan area with the transmissive manner, like
25 the reflective manner, and it is possible to carry out a complex diagnosis with respect to the internal structure of the sample from the images.

The probe beam outputted from the I/Q interferometer is focused onto the sample X, reflected from the sample or transmitted through the sample, and then collimated and inputted into the I/Q interferometer, and the phase variation and the amplitude variation in the probe beam are derived as partial structural and/or optical properties with respect to the surface of the sample X in the process of focusing or collimating. The I/Q interferometer receives the probe beam in which the phase variation and the magnitude variation are derived as the sample, independently measures the phase variation and the amplitude variation in the probe beam using an I/Q-demodulation method and then outputs the measured result as I signal and Q signal.

An object of the present embodiment is to configure a complex function micrometer capable of analyzing partial optical properties of the surface or the inside of the sample in various aspects by combining the I/Q interferometer and a multilayer scanning manner. It is possible to independently and simultaneously measure the phase and amplitude variations of the probe beam reflected from the surface of the sample or transmitted through the sample using the I/Q-interferometer and map partial optical properties of a desired area through the scanning. During the scanning process, it is possible to found a structural shape of the surface from the phase variation of the probe beam reflected from the surface and found a variation in physical property from the amplitude variation. Also, since the phase and amplitude of the probe beam transmitted through the sample is given by a refraction index and an absorption coefficient of a medium which consists the sample, it is possible to diagnose in various aspects with respect to the internal structure and material of the sample by independently measuring the phase and amplitude variations in the transmitted beam using the I/Q interferometer. Therefore, it is possible to found much structural and physical information by carrying out the diagnosis in both

reflective and transmissive manners in diagnosis for general semiconductor or bio sample.

The I/Q interferometer 110 provides the probe beam, and the probe beam is focused and collimated to the sample X to include the surface information of the sample and inputted again into the interferometer 100. After that, the probe beam is converted into the I signal and the Q signal and provided to computer 150.

Meanwhile, the computer 150 transfers a movement control signal to the scanner driver 160 for controlling the movement of the XY scanner 142 on which the sample is placed, and the scanner driver 160 controls the movement of the scanner 142 according to the transferred movement control signal. The XY scanner 142 is configured so as to move a sample die in two directions perpendicular to the moving direction of the probe beam. Also, the computer 150 transfers a location adjustment error signal to the micro-distance adjusting device 170 for controlling a moving distance in the up and down directions of the up/down lift 140 which moves the sample die on which the sample is placed, and the micro-distance adjusting device 170 controls the up/down movement of the up/down lift 140 according to the location adjustment error signal. The up/down lift 140 is configured so as to move the sample die in a direction identical to the moving direction of the probe beam, and a PZT transporting device or a step motor which can transports accurately the sample die in the direction of Z axis may be used as the up/down lift 140.

The phase of a target region and the amplitude variation map may be found by scanning the phase of the region while changing exactly the position by using the XY scanner connected with the computer, and construct the microscope diagnosis corresponding to the surface of the sample, inner structure or material.

Hereinafter, a process of scanning the sample on a per layer basis by applying a multilayer scanning method to the complex function micrometer having the

aforementioned configuration according to the present embodiment with reference to Fig. 4. Fig. 4 is a conceptual diagram for explaining an operation of the complex function micrometer for the multilayer scanning according to the present invention.

Referring to Fig. 4, in the multilayer scanning process according to the present embodiment, the sample X is firstly placed on the sample die and the sample die is fixed to a location on Z axis by the up/down lift. After that, values of the phase and the amplitude varied as the location (x, y) are measured by the I/Q interferometer while scanning in XY directions using the XY scanner, and stored in the computer. Next, the up/down lift is transported by one step in z direction to change the location of the sample die on the z axis and then data with respect to the phase and amplitude variations are obtained while scanning again in the XY directions. As such, obtainment of information with respect to the phase and amplitude variations through the XY directional scanning after the z directional transportation is repeatedly carried out, thereby carrying out the scanning with respect to various layers. At this time, a transportation interval and a transportation number may be manually set according to the sample or may be set by an automatic setting function that controls the interval and number through a software while comparing the scanning results on a per layer basis.

The computer receives and stores the signals of the phase and amplitude variations derived in the probe beam from the I/Q interferometer while scanning the sample on a per layer basis. And, it is possible to obtain a map of partial phase variation and amplitude variation with respect to corresponding layer from the stored scanning results on a per layer basis, and it is possible to quantitatively analyze a three dimensional geometric structure and a material distribution of the sample X by synthesizing the scanning results with respect to various layers.

By applying the multilayer scanning technology, it is possible to perform a combined analysis, on a per layer basis, with respect to the structure of a sample surface in the same level as a focus, and it is possible to qualitatively analyze three dimensional structure and material of the sample by synthesizing the analysis results
5 obtained from the respective layers. At this time, an interval between the layers and a number of layer may be manually determined in consideration of a properties of the sample, a depth of focus of a focusing device and the like, or may be automatically determined by comparing variations between the layers using a software.

When performing a surface diagnosis using the multilayer scanning, a position
10 at which the magnitude of the amplitude signal is largest is firstly found in the layer scanning result using the fact that the magnitude of the amplitude signal is largest when the focus is exactly laid on the surface. Next, the positions having the same phase as the position at which the magnitude of the amplitude signal is largest are connected to obtain a contour line or a contour surface with respect to a topography,
15 and it is possible to obtain information with respect to a reflectivity variation due to a heterogeneity of the surface, etc. from the amplitude signal with respect to the contour line or the contour surface. Also, since the positions are always focused, it is possible to analyze the sample with an optimal resolution of the focusing device at the positions.

20 Second Embodiment

Hereinafter, a complex function micrometer employing a constant phase scanning method according to a second embodiment of the present invention will be described. The complex function micrometer analyzes a surface structure of the sample X using the constant phase scanning method. Fig. 5 is a conceptual view for
25 explaining the process for analyzing the surface structure of the sample by applying

the constant phase scanning method to the complex function micrometer according to the present invention.

The constant phase scanning is a method that focuses the probe beam into a desired position on the sample and then feedback controls the distance between the focusing device and the sample so that the phase has always a constant value when scanning the sample in the XY directions. A unevenness of the surface having a constant phase can be found from an error signal for the feedback control, and information with respect to reflectivity variation given by material variation can be found from the amplitude signal.

For example, in a micro structure having a three dimensional structure, since the error signal is given by the unevenness of the three dimensional structure, it is possible to figure the three dimensional shape of the structure from the error signal stored in the computer. At this time, the measured amplitude signal should always have a constant value if the structure has no variation in material. The amplitude signal is varied when impurities are added to the structure and thus the reflectivity coefficient is partially varied, and therefrom, it is possible to diagnose abnormality of the structure. It is also possible to figure the three dimensional structure of the surface from the error signal when medium consisting the surface is not regular, and it is possible to quantitatively found the heterogeneity of the material according to variation in the magnitude signal. Therefore, it is possible to clearly diagnose the three dimensional structure and material of the surface through this micrometric method.

In the constant phase scanning method, the computer 150 provides an error signal with respect to the feedback control to the micro-distance adjusting device 170 during scanning in reference to a phase value at one position on which the focus is laid so that the phase of the probe beam can always maintain a constant value. The

computer can image a geometric three dimensional structure with respect to the sample structure using the error signal for the feedback control, and homogeneity of the medium consisting the sample can be found from the magnitude signal. Since the focus plane of the probe beam is always laid on the surface of the sample during
5 scanning the surface of the sample, it is possible to maintain an optimal resolution.

The present invention may be used in the reflective type or the transmissive type. The reflective type is a method of diagnosing the surface and the inside of the sample by analyzing the probe beam reflected from the surface or inside of the sample with an I/Q interferometer, and the reflective type is applied to the sample
10 having small optical transmission coefficient when using the reflection on the surface and can be used to perform both surface and inside diagnoses with respect to the sample having suitable transmission coefficient. The transmissive type can be applied to the combined diagnosis of the sample having the transmission coefficient which is not small, and an average optical thickness of the sample and amplitude variation due
15 to absorption and reflection in a region at which the probe beam is focused can be found. Therefore, with this method, together with the reflective type internal probing manner, it is possible to perform the combined diagnosis for important properties such as material constitution of the inside of the sample, variation in the optical thickness and so on with respect to the sample having the transmission coefficient which is not
20 small.

According to the complex function micrometer as described above, since phase and amplitude variations derived in the probe beam transmitted or reflected from the sample are measured at the same time, it is easy to analyze the surface or inside structure, or material of the sample. Therefore, the complex function micrometer
25 using an I/Q interferometer can be utilized very usefully to a combined diagnosis of bio or semiconductor device or material. Consequently, the present invention has

improved the shortcomings of the various existing micrometers and is expected to contribute advance of high technology industry such as semiconductor or bio technology.

Having described a preferred embodiment of the present invention, it is to be understood that variants and modifications thereof falling within the spirit of the invention may become apparent to those skilled in this art, and the scope of this invention is to be determined by appended claims and their equivalents.

What is claimed is:

1. A complex function micrometer, comprising:

an I/Q interferometer providing a probe beam to a sample, and converting the probe beam and a reference beam, which are focused and collimated with respect to the sample and the returned thereto, into an I signal and a Q signal and outputting the I and Q signals;

a sample die on which the sample is disposed;

an XY scanner moving the sample die in two directions perpendicular to a moving direction of the probe beam;

10 a scanner driver controlling the movement of the XY scanner;

a up/down lift moving the sample die in a direction parallel to the moving direction of the probe beam;

a micro-distance adjusting device controlling the movement of the up/down lift;

15 a focusing/collimating device focusing the probe beam provided from the I/Q interferometer onto a surface of the sample or collimating the probe beam reflected or transmitted by the sample to provide again to the I/Q interferometer; and

a computer transferring a movement control signal for controlling the movement of the XY scanner to the scanner driver or transferring a signal for controlling the movement of the up/down lift to the micro-distance adjusting device, and receiving the I signal and Q signal provided from the I/Q interferometer to extract information with respect to the surface or inside of the sample,

20 wherein the computer performs a multilayer scanning with respect to the sample by repeating a process of fixing the up/down lift to an arbitrary position, driving the XY scanner to scan a first layer of the sample, driving the up/down lift to move the sample die, and driving the XY scanner to scan a first layer of the sample.

2. A complex function micrometer, comprising:

an I/Q interferometer providing a probe beam to a sample, and converting the probe beam and a reference beam, which are focused and collimated with respect to the sample and the returned thereto, into an I signal and a Q signal and outputting

5 the I and Q signals;

a sample die on which the sample is disposed;

an XY scanner moving the sample die in two directions perpendicular to a moving direction of the probe beam;

a scanner driver controlling the movement of the XY scanner;

10 a up/down lift moving the sample die in a direction parallel to the moving direction of the probe beam;

a micro-distance adjusting device controlling the movement of the up/down lift;

a focusing/collimating device focusing the probe beam provided from the I/Q interferometer onto a surface of the sample or collimating the probe beam reflected or
15 transmitted by the sample to provide again to the I/Q interferometer; and

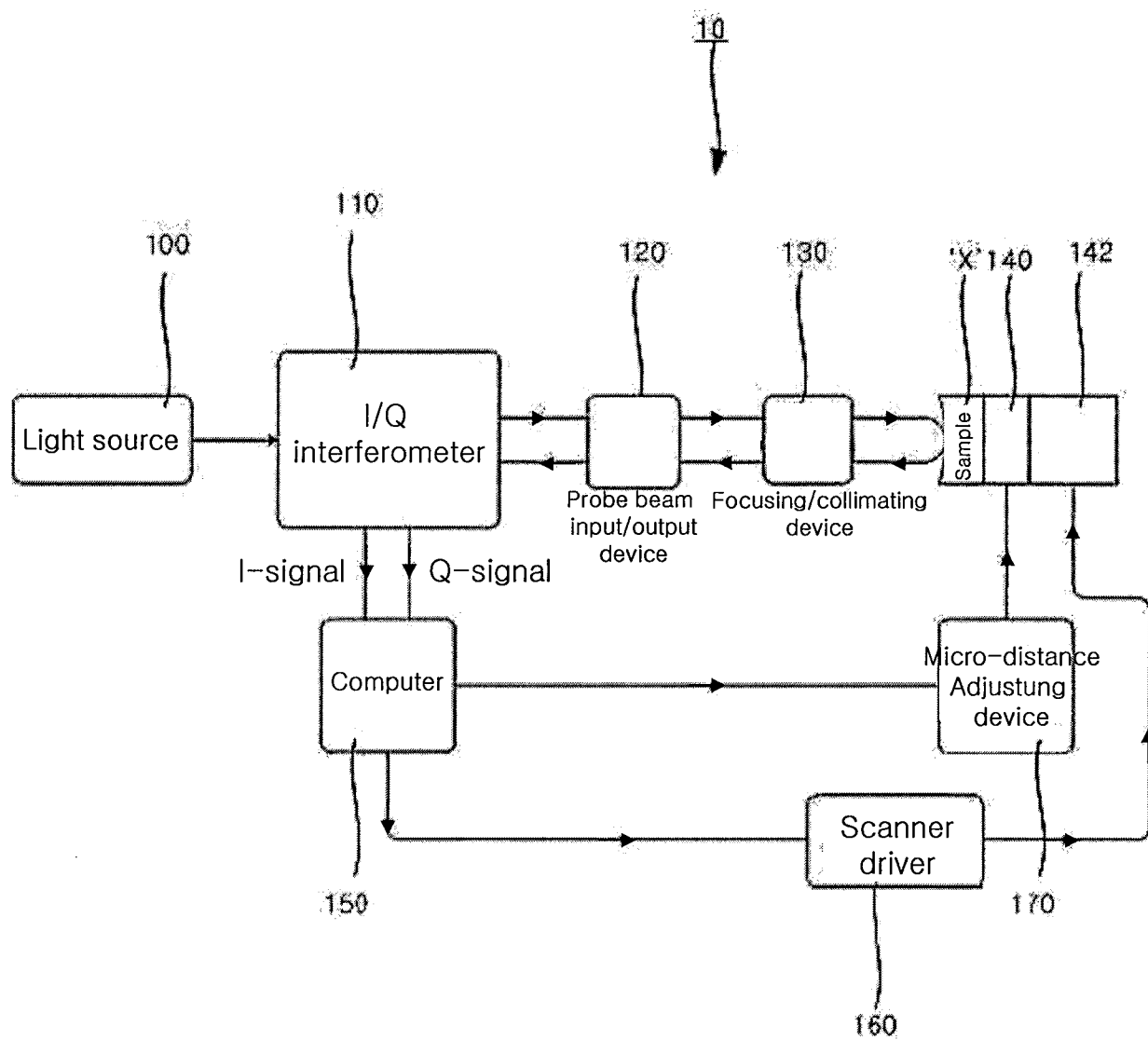
a computer transferring a movement control signal for controlling the movement of the XY scanner to the scanner driver or transferring a signal for controlling the movement of the up/down lift to the micro-distance adjusting device, and receiving the I signal and Q signal provided from the I/Q interferometer to extract
20 information with respect to the surface or inside of the sample,

wherein the computer sets a reference phase by focusing the probe beam at a predetermined position of the sample, then provides an error signal for feedback control for preventing variation in the reference phase when scanning the sample in the XY direction, then adjusts a distance between the focusing/collimating device and
25 the sample according to the error signal for feedback control, and then measures the

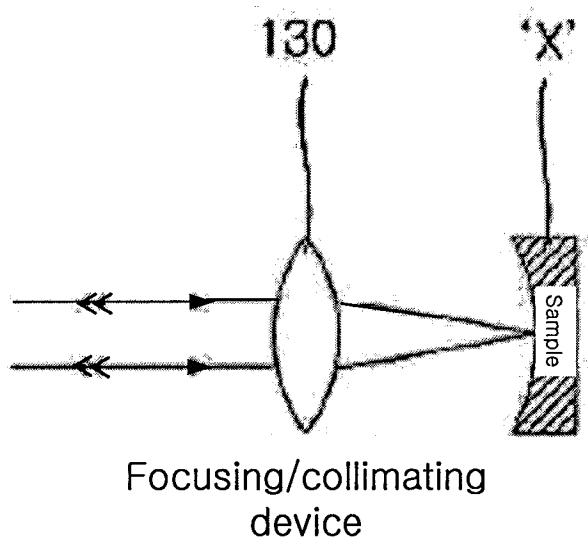
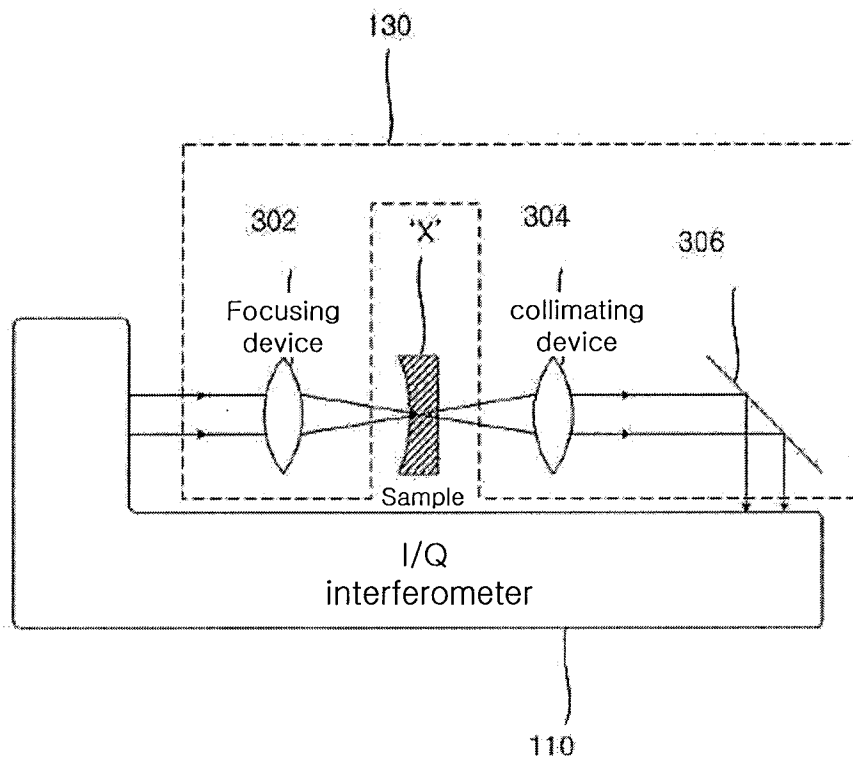
unevenness of the surface of the sample using the error signal for feedback control according to the XY position.

3. The complex function micrometer as set forth in claim 1 or claim 2, wherein the
5 computer finds out the point at which an amplitude signal is largest in the scanning result, and connects points having the same phase as the point having the largest amplitude signal to obtain a contour line or a contour surface with respect to a topography.
- 10 4. The complex function micrometer as set forth in claim 3, wherein the computer detects an extent of reflectivity variation from the amplitude signals with respect to the obtained contour line or contour surface and determines heterogeneity of the medium of the sample according to the detected extent of reflectivity variation.
- 15 5. The complex function micrometer as set forth in claim 1 or claim 2, wherein the probe beam includes information of phase variation and amplitude variation with respect to respective positions when scanning the surface of the sample.

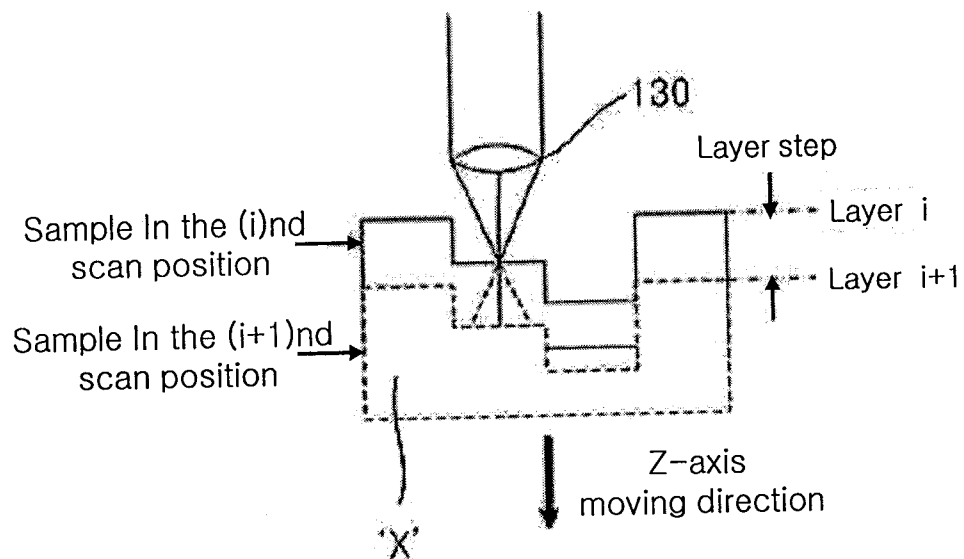
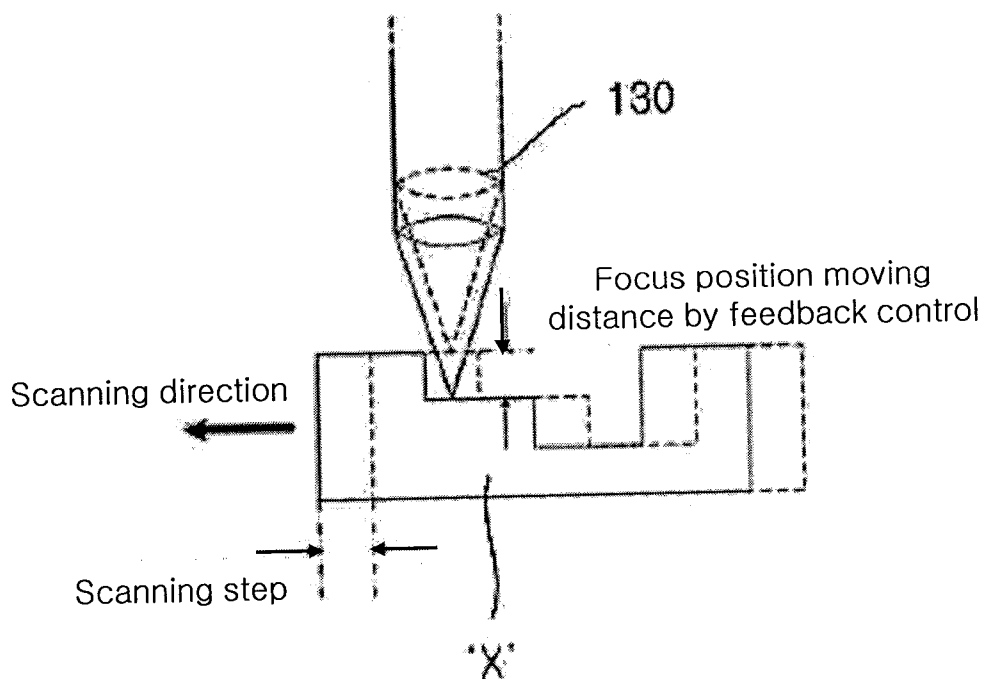
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Fig. 1

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Fig. 2**Fig. 3**

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Fig. 4**Fig. 5**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2008/000672**A. CLASSIFICATION OF SUBJECT MATTER****G01B 9/02(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)

IPC 8 G02B 21/00, G01B 11/30

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

Korean utility models and applications for utility models since 1975
Japanese utility models and applications for utility models since 1975

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

eKIPASS (KIPO internal) & keywords : I/Q interferometer, micrometer, scanning, beam, collimate

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	LEE JAE YONG et al. 'Optical Heterodyne Scanning Microinterferometry for Optical Field Characterization in Micro-Optic Components' Optical Society of Korea Summer Meeting. Korea Optical Society, 2004, pp.76-77.	1,3,4,5 2
Y A	US 06437910 B1 (HIDEO WATANABE) 20 August 2002 See abstract and figs. 9-10	1,3,4,5 2
A	WO 94 00733 A (MONTGOMERY PAUL CHRISTOPHER.et al.) 06 January 1994 See abstract and fig.1	1-5
A	US 05994691 A (TAKESHI KONADA) 30 November 1999 See abstract and fig.1	1-5

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"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

18 SEPTEMBER 2008 (18.09.2008)

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2008/000672

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