

ROUGHNESS MEASUREMENT SYSTEM AND METHOD THEREOF BASED ON DATA FUSION AND HYBRID TECHNOLOGY

TECHNICAL FIELD OF THE INVENTION

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Invention is related to the field of metrology hybrid tool which is flexible to use multiple measurement technologies and its integration, particularly for surface characterization of sidewall of holes, vias and trenches of micro and nano meter scales.

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BACKGROUND OF THE INVENTION

There are different technologies to measure and quantify the topography of a surface in micro and nanometric-level precision. The different sensors and the relevant technologies have limitations subjected to the surface they measure. For example, a sensor, based on technology like coherent scanning interferometry (CSI) has an inherent limitation to measure a surface with a maximum slant of more than 86degree when measuring optically smooth surfaces. another sensor based on technology like confocal microscopy (CM) can be used to solve the issue but, has limitations in providing correct reflection values and make it unusable on smooth surfaces due to the optical property of the components that is necessary to realize the technology. Thus, it can measure the vias or trenches with a minimum of tens of micrometres diameter or opening only. The limitations from independent parameters or components in each technology restrict the particular single sensor technologies from being used in different sub-nano level measurement applications.

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Prior art devices for roughness metrology fall into three general categories: integrated roughness metrology Systems (IRMs); Stylus profilometers, including mechanical profilers and atomic force microscopes (AFM), and combined interferometers (CSI)/optical microscopes including confocal systems (CM). However, prior art devices are inadequate for solving the particular problem at hand due to the lack of: measuring the higher slopes greater than 86 degrees; inaccuracy due to contrast variations in reflection signals from sub-micron level holes, via and trench opening; and sub nano level roughness measurement from sidewalls.

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There is a need of a Surface-Sidewall-Hole, Via and Trenches (SSHVT) hybrid technology that mainly focuses on precision and accuracy improvement by the combination of multiple metrology tools. This is addressed by the present invention, which uses a combination of
5 confocal microscopy (CM), through focus scanning microscopy (TSOM) and focus variation (FV) have been implemented within the same illumination and detection path of the optical system setup. Pixel by pixel illumination and detection followed by whole pixel illumination and detection from each Z planes will result in multiple data acquisition simultaneously. A data fusion algorithm is used to fill the “no data,” to replace by “high standard deviation data”
10 and “smoothening large variation data” or from technique A with data from another technique B with data. From a single focal plane itself, a detail profile data can be collected by TSOM which can be well fused with confocal and FV data points.

15 SUMMARY OF THE INVENTION

The present invention features a system for measuring surface roughness of a sample, comprising a light source for providing a light of multiple wavelength illumination to the sample, a scanning system positioned between one or more objective lenses and a focusing
20 lens for scanning the light from the objective lens at fractions of a nano-meter level, wherein the objective lens is positioned between a sample holder and the scanning system for passing the light that is reflected from the sample placed on the sample holder, and the focusing lens coupled with a detector for focusing the light from the objective lens and the scanning system to the detector.

25 This system is characterized in that it further comprises an acquisition module stored in a computer-readable medium that is linked to the detector for producing pixels from light signals detected by the detector, wherein the pixels are used by the acquisition module for generating a focus variation signal, for forming a colour-map through focus scanning microscopy signal and for getting a spatial filtered confocal microscopy signal, and a contrast ratio fusion module
30 stored in the computer-readable medium for merging information from the focus variation signal, the confocal microscopy signal, and the through focus scanning optical microscopy signal produced by the acquisition module for providing a three-dimensional image of the

sample.

Further, the number of the objective lens corresponds to numerical apertures and magnifications needed.

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Preferably, there is a relay lens system connected the light source and coupled to a micro-display that is programmed and controlled using a software for controlling illumination of the light.

10 Preferably, an X plane, a Y plane and a Z plane of the sample is scanned by the scanning system.

Further, an optical sectioning and line profiles of optical intensity from each of the X, Y and Z planes are provided by the spatial filtered confocal microscopy signal.

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Preferably, the colour-map through focus scanning microscopy image is an XY intensity colour map image.

Another embodiment of the present invention features a method for measuring surface roughness of a sample, comprising steps of: setting the sample is set on a sample holder and illuminating a target area of a surface of the sample with a light using a light source; scanning the sample at a plane using a scanning system and collecting the light reflected from the sample using one or more objective lenses and a focusing lens; detecting light signals from each point of the target area as pixels using a detector linked to an acquisition module stored in a computer-readable medium, wherein a first signal from all the pixels in the detector is produced by the acquisition module for focus variation, a second signal from all of the pixels in the detector is produced by the acquisition module for through focus scanning optical microscopy, and a third signal from a certain activated pixel region from all pixels in the detector is produced by the acquisition module for confocal microscopy; making one or more two-dimensional images from each of the X, Y and Z planes; and stacking the two-dimensional images and forming a three-dimensional image.

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There is a contrast ratio fusion module stored in the computer-readable medium that utilizes a data fusion approach to merge information from the first signal, the second signal, and the

third signal produced by the acquisition module for providing the three-dimensional image of the sample.

Further, the third signal produced from a certain activated pixel region is a spatial filtered
 5 confocal microscopy signal that is created from a virtual pinhole by cutting down several neighbouring pixels from all the pixels.

The method further comprises storing a pixel-wise signal data for the first signal, the second
 10 signal, and the third signal.

The method further comprises saving the three-dimensional image and signal values of the
 first signal and the third signal.

Further, an optical intensity profile data from each of the planes is extracted and stacked for
 15 constructing a colour-map intensity X-Z through focus scanning microscopy image from the second signal.

In a preferred embodiment of the method, the data fusion approach utilized by the contrast
 ratio fusion module is a pixel-by-pixel approach for merging information from the first signal,
 20 the second signal, and the third signal, comprising steps of: defining a threshold value for
 comparing to a contrast ratio of the first signal, the second signal, and the third signal;
 evaluating the contrast ratio of the third signal to the threshold value for preserving accurate
 areas; evaluating the contrast ratio of the first signal to the threshold value for preserving areas
 where the focus variation signal is good; evaluating the contrast ratio of the second signal to
 25 the threshold value for preserving areas where the through focus scanning optical microscopy
 signal is good; refixing the threshold value to a new threshold value if the first signal, the
 second signal, and the third signal are below the threshold value; and considering all CR values
 of the first signal, the second signal, and the third signal for the contrast ratio fusion module
 to provide a final result.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 schematically depicts the hybrid tool system setup which combines individual imaging modalities like confocal microscopy (CM), through focus scanning microscopy (TSOM) and focus variation (FV) within a single hardware.

Figure 2A and Figure 2B show flow charts of the method of image acquisition using multiple technologies and the data fusion in detail respectively.

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DETAILED DESCRIPTION OF THE INVENTION

The present invention is a system for measuring surface roughness of a sample. In specific, it is a hybrid tool which is flexible to use multiple measurement technologies and its integration, particularly for surface characterization of sidewall of holes, vias and trenches of micro and nano meter scales.

The hybrid technology-based approach, SSHVT: Surface-Sidewall-Hole, Via and trenches provides a solution and enables the single sensor hardware to be used in different applications. This comprises different technologies incorporated into a single hardware and the novel algorithm which leverages the benefits of each individual technology provides the robust roughness measurement solution, SSHVT.

The working of the hybrid system is realized by the combination of potential metrology technologies like confocal microscopy (CM), through focus scanning (TSOM) and focus variation (FV) in a single illumination and detection arm. These techniques can be utilized individually and collectively with the use of advanced data fusion algorithm.

Confocal microscopy (CM) is working under the principle of elimination the out of focus light from each scan on a particular plane, which results in an optically sectioned image. Focus variation (FV) is a microscopy technique that tightly focus on each plane for imaging without filtering the out of focus signals. This method is significant in the measurement of

those regions where the slopes are high and the surface is very rough. Through focus scanning optical microscopy (TSOM) is a scanning-based imaging technology that provides three-dimensional information about micro or nano scale structures. The unique characteristic of TSOM to provide dimensional differences made it as a competitor to scanning electron microscopy (SEM) or atomic force microscopy (AFM) with a non-destructive approach. The added advantage of this technique is, it does not need an extra hardware apart from a conventional microscope.

Combination of these technologies can result an advanced metrology tool which is capable of utilizing the unique advantages of each methods and give more accurate and precise measurement of critical dimensions in micro or nano sizes structures. A well-defined data fusion algorithm is supporting in it for filling the signal values of unknown or non-measured points from one technology with another. For example, if a high slope rough area in a nano structure will not give any signal while measurement using confocal microscopy (CM) whereas that regions can be filled by the measurement values from focus variation (FV) or through focus scanning microscopy (TSOM) data. The reflection from each position, as a light signal, will be analyzed and with higher contrast ratio in signal will be fused with the data from previous pixel and the total signal data will be reconstructed together also individually by the algorithm.

Working of individual imaging modalities:

Confocal microscope

A confocal microscope (CM) is a type of advanced microscope that is used to generate high-resolution, three-dimensional images of specimens. It works by using a laser/LED beam to focus on a specific point within the specimen, and then detecting the reflected light emitted by that point. The key components of a confocal microscope include a laser/LED, a pinhole aperture, a detector, and a computer. The laser emits a beam of light that is focused onto a single point within the specimen by a series of mirrors and lenses. The light that is reflected or emitted by the specimen then passes through a pinhole aperture, which eliminates any out-of-focus light. The remaining light is detected by a highly sensitive detector, which converts the light into an electrical signal that is sent to a computer. The computer then uses this information to create a highly detailed, three-dimensional image of the specimen. One of the

key advantages of a confocal microscope is that it can generate very high-resolution images, with resolutions down to a few nanometers. This is because the pinhole aperture allows only a very thin section of the specimen to be in focus at any given time, which eliminates any blur caused by out-of-focus light.

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Below is a step-by-step overview of how a confocal microscope works:

Light source: The confocal microscope uses a laser as its light source, which is typically a high-intensity, monochromatic light that is focused onto a single point in the sample.

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Scanning system: The laser beam is then directed onto the sample through a scanning system, which moves the laser beam across the sample in a pre-defined pattern. The pattern can be controlled by the user and can be a single point, a line, or a larger area of the sample.

15 Pinhole aperture: The emitted light from the sample is collected through a pinhole aperture, which is positioned in front of the detector. This pinhole aperture helps to eliminate out-of-focus light, making the image more sharp and clear.

Detector: The detector collects the emitted light that passes through the pinhole aperture and generates an image of the sample. The image is generated by scanning the laser across the sample and collecting the emitted light at each point, which is then used to build up an image.

Image processing: The images obtained from a confocal microscope are typically grayscale, but can be colored using computer software. The images can also be processed to remove noise or enhance contrast, making it easier to identify specific structures within the sample.

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Focus variation microscope

A focus variation (FV) microscope is an advanced type of optical microscope that uses a technique called focus variation to generate high-resolution 3D images of surfaces. It works by measuring the height variations of a surface using a small depth of field, and then combining these measurements to create a highly detailed image of the surface. The key components of a focus variation microscope include a light source, an objective lens, and a detector. The light source emits a beam of light that is focused onto the surface being imaged by the objective lens. The lens is designed to have a very small depth of field, which means

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that only a small section of the surface is in focus at any given time. As the lens moves across the surface, the height variations of the surface are measured by a detector, which typically consists of a camera, such as charge-coupled device (CCD) camera. The measurements are then combined using specialized software to generate a highly detailed 3D image of the surface. One of the key advantages of a focus variation microscope is that it can generate very high-resolution images of surfaces with height variations ranging from a few nanometers to several hundred micrometers. This makes it an essential tool for many applications, such as surface metrology, quality control, and material science. Additionally, the technique is non-destructive, which means that it can be used to image delicate or sensitive surfaces without causing damage.

Through-focus scanning optical microscope

A through-focus scanning optical microscope (TSOM) is an advanced type of microscope that uses a technique called scanning axially through focus to generate high-resolution X-Z images of samples. TSOM works by scanning a sample through a series of focus positions, acquiring multiple images at each position, and then combining the images to create a high-resolution optical intensity profile of the sample. The key components of a TSOM include a light source, an objective lens, a scanning mechanism, and a detector. The light source emits a beam of light that is focused onto the sample by the objective lens. The scanning mechanism is used to move the sample through a series of focus positions, and at each position, the detector records multiple images at different focal planes. The images are then combined using specialized software to create a high-resolution optical intensity profile of the sample. One of the key advantages of TSOM is that it can generate high-resolution 3D images of samples with sub-nanometer precision. This makes it an essential tool for many applications, such as surface metrology, semiconductor inspection.

Most of the single optical measurement technologies or tools are facing challenges in retaining the accuracy and precision in surface characteristic measurements of micro/nano sized holes, vias and trenches with high slope sidewalls and narrow openings. To overcome these limitations, a novel hybrid surface measurement tool has been introduced by integrating multiple measurement principles or technologies into one hardware setup incorporate within one optical illumination and detection hardware. Here the integration is done by the combination of confocal microscopy (CM), through focus scanning microscopy (TSOM) and

focus variation (FV). A simple algorithm can be used to fuse the data from each pixel point which is most suitable for the particular position dynamically. The tool will provide wide applications in the field of surface characteristic measurement of micro/nano level holes, vias and trenches with high slope sidewalls.

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Figure 1 illustrates the hybrid system setup comprises of a light source (101) which can provide multiple wavelength illumination (here a white light laser or LED is used and alternative usage of band-pass filters (102) will provide corresponding wavelength illumination), a ring illumination device (103), relay lens system (104) for beam expansion and propagation, beam splitting devices (105), a micro-display (106) which can be programmable and can be controlled using a software, a scanning system (107) which is capable of fraction of nano-meter level XYZ scanning (scanning at X-, Y- and Z-planes), one or more multiple objective objective lenses (108) which correspond to numerical aperture and magnification needed, a sample holder (109), a focusing lens (110) and a detector (111), such as high-speed CCD camera, and whole tool post (112) on a breadboard (113) as major components.

The illumination is done as required or as per the character of surface to be scanned. The micro-display acts as an illumination controller as well as a programmable scanning system without any moving parts in the illumination arm for precise scanning. The illumination beam shape from the micro-display passes through the objective lens, which decides the field of view, depth of field, magnification, *etc.* The light reflected back from the sample holder with a stage scanning device then passes through the focusing lens in the detection arm to the CCD camera. An acquisition module is stored in the same computer-readable medium as the a high contrast ratio fusion module and is linked to the CCD camera to work along with the acquisition process and to allow CCD pixels to collect signals from three different optical measurement technologies simultaneously. The whole active pixels will give the focus variation (FV), the virtual pinhole that created by cut down several neighbouring pixels to get a spatial filtered confocal microscopy (CM) signal which provide optical sectioning to acquired signal and line profiles of optical intensity from each plane are captured and an XY or an X-Z intensity colour-map TSOM image is also formed using same detection arm. The critical dimensional differences are calculated by direct comparison of experimental TSOM images with simulated values from TSOM library files created earlier using ideal boundary

conditions. These FV, CM and TSOM signals are passed on to the high contrast ratio fusion module for data fusion as described below.

Figure 2A and **Figure 2B** illustrate detailed flow charts describing the signal acquisition procedure and data fusion process respectively. Signal level data fusion is a technique that involves merging topographical data from the same sensor on the same instrument that can be operated simultaneously. By acquiring the data on the same instrument along the same scan, most of the data registration is avoided, resulting in higher linearity and accuracy. However, when fusing signal data from different sensors, several sensor characteristics need to be taken into account before registration can be achieved.

- The first characteristic to consider is leveling. This step is straightforward if the surface under inspection is relatively flat, but it becomes more challenging if step-like structures are present. Precise leveling is carried out by extracting features from the two topographies and correlating them. However, on rough random surfaces, precise leveling is almost impossible.
- The second characteristic is the calibration of the lateral scale. If structures are present on the surface, they can be extracted and registered between them. Still, precise calibration of the optical magnification and field distortion is necessary before data fusion can occur.
- The third characteristic is data post-processing, which involves outlier removal, missing points, filling non-measured regions, and smoothing. These steps are carried out differently for different measuring technologies, and data correlation, registration, and interpolation are again necessary.
- The fourth characteristic is the linear amplification coefficient. If data is coming from two different technologies, calibration of the linear amplification should be done with great care. This is typically done with a set of several traceable Step Height standards by measuring all of them and calibrating the slope of the linear scan to minimize the accuracy error for all of them. This also needs to be taken into account within the same instrument with different sensors, as stepping the scanner, while Coherence Scanning Interferometry or focus variation are moving the scanner at a continuous speed. The scanner linear amplification coefficient could be different in those cases.
- The fifth and final characteristic to consider is stage linearity. Even with precise linear

amplification calibration, non-linearities of the scanner are superimposed on the topographical data. Different pixels at different measured heights will have different accuracy errors, which will confuse the data registration, providing lower accuracy on the fused topography than on the single ones.

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Overall, careful consideration and calibration of these sensor characteristics are essential for successful signal level data fusion in topographical measurements. This ensures that the topographical data acquired from different sensors can be accurately registered and fused to provide high-accuracy measurements of the sample under inspection.

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A (high) contrast ratio (CR) fusion module stored in a computer-readable medium to process the signals from the acquisition module utilizes a pixel-by-pixel approach to merge the information obtained from confocal microscopy (CM), focus variation (FV), and through focus scanning optical microscopy (TSOM). This approach offers superior results compared to the use of a single technique. In this technique, the selection of the best axial response or contrast ratio is carried out dynamically for each pixel. The axial response is determined by computing the intensity value of one pixel from each optical sectioning image. This leads to the creation of a three-dimensional topography that incorporates accurate confocal information, as well as the focus variation and TSOM information when the confocal signal is weak. Moreover, the technique reduces noise in pixels with weak peaks in both techniques by averaging both axial responses and generating a well-defined peak. This fusion of information enhances the signal-to-noise ratio (SNR) and contrast ratio. Overall, the high contrast ratio fusion technique offers a powerful tool for imaging and analyzing samples with superior accuracy and precision. To fuse the three axial responses at each pixel of the three series of images, the mean and maximum value of the three responses is computed. The axial response from the focus variation (FV) or through focus scanning optical microscopy (TSOM) is then adjusted to match the offset and maximum value to the confocal image. The selection of the best axial response is carried out using a higher contrast ratio criterion. An axial response is considered well-defined when there is a clear difference between the values of the images in focus and out of focus. The algorithm takes into account that the confocal technique has better depth discrimination than the FV or TSOM, and thus selects the best axial response accordingly. This approach allows for the accurate fusion of information obtained from the three different imaging techniques, providing a highly accurate and

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detailed three-dimensional representation of the sample being analyzed.

Steps of simultaneous signal acquisition (illustrated in Figure 2A):

- (211) The light source is made parallel and focused onto a micro-display that is positioned
5 at the field diaphragm location of a microscope objective, sample is set on stage of sample holder, and target area of sample surface is illuminated using a light source.
- (212) Scanning is carried out at one or more of X plane, Y plane and Z plane, and reflected light from sample is collected using one or more objective lenses and a focusing lens, and light signals from each point of the target area are detected as pixels using
10 a detector, such as camera.
- (213) Signals from all the pixels (whole activated pixels) in detector are considered as signals for FV and TSOM, and these first and second signals, respectively, from each point of the whole pixels is produced by the acquisition module linked to the detector.
- (214) Signals from only certain activated pixel regions are considered as spatial filtered
15 signals for confocal microscopy, and this third signal from each point of the certain pixel regions is produced by the acquisition module. (This pixel activation and deactivation can be done by micro second level switching ON and OFF of pixels in detector.) The same step is repeated for multiple axial planes.
- (215) Two-dimensional (2D) images from each plane can be made for CM, FV and TSOM.
20 Pixel-wise signal data for CM, FV and TSOM is stored.
- (216) 2D images from each plane are stacked, three-dimensional (3D) image is formed in CM, FV and TSOM.
- (217) For CM and FV images, 3D image and value from each point is saved.
- (218) For TSOM X-Z image, optical intensity profile data from each plane is extracted
25 and stacked to construct a colour-map intensity X-Z image (TSOM image) for comparison with library data and the values are saved.

Steps of data fusion (illustrated in Figure 2B):

- (221) The contrast ratio (CR) fusion is driven through a decision process for each pixel
30 (pixel-by-pixel approach).
- (222) One threshold with a high value (A) is defined to compare to the CR of the focus variation signal, the confocal microscopy signal, and the through focus scanning optical microscopy signal.

- (223) On a first step, the CR of the confocal axial response (CM signal) is evaluated to threshold A to preserve accurate areas.
- (224) If this condition is not fulfilled, the FV is compared to threshold A to preserve areas where its signal is good.
- 5 (225) If this condition is also not fulfilled, the TSOM is compared to threshold A to preserve areas where its signal is good.
- (226) If three signals are below threshold A, they are refixed to a higher CR value (new threshold).
- (227) All CR values of all signals are considered for the fusion to provide the final result
- 10 (axial response). If the CR values are very much lower than prefixed minimum value of CR threshold, then that pixel is taken as non-measured.

The steps (221)-(227) above will continue for each pixel in each plane through the entire 3D data.

CLAIMS

1. A system for measuring surface roughness of a sample, comprising:
a light source (101) for providing a light of multiple wavelength illumination to the
5 sample;
a scanning system (107) positioned between one or more objective lenses (108) and a
focusing lens (110) for scanning the light from the objective lens (108) at fractions of a nano-
meter level,
wherein the objective lens (108) is positioned between a sample holder (109) and the
10 scanning system (107) for passing the light that is reflected from the sample placed on the
sample holder (109); and the focusing lens (110) coupled with a detector (111) for focusing
the light from the objective lens (108) and the scanning system (107) to the detector (111),
characterized in that the system further comprises an acquisition module stored in a
computer-readable medium that is linked to the detector (111) for producing pixels from light
15 signals detected by the detector (111), wherein the pixels are used by the acquisition module
for generating a focus variation signal, for forming a colour-map through focus scanning
microscopy signal and for getting a spatial filtered confocal microscopy signal, and a contrast
ratio fusion module stored in the computer-readable medium for merging information from
the focus variation signal, the confocal microscopy signal, and the through focus scanning
20 optical microscopy signal produced by the acquisition module for providing a three-
dimensional image of the sample.
2. The system for measuring surface roughness of a sample according to claim 1,
wherein the number of the objective lens (208) corresponds to numerical apertures and
25 magnifications needed.
3. The system for measuring surface roughness of a sample according to claim 1,
wherein there is a relay lens system (204) connected to the light source (101) and coupled to
a micro-display (206) that is programmed and controlled using a software for controlling
30 illumination of the light.
4. The system for measuring surface roughness of a sample according to claim 1,
wherein an X plane, a Y plane and a Z plane of the sample is scanned by the scanning system

(207).

5 5. The system for measuring surface roughness of a sample according to claim 4, wherein an optical sectioning and line profiles of optical intensity from each of the X, Y and Z planes are provided by the spatial filtered confocal microscopy signal.

6. The system for measuring surface roughness of a sample according to claim 4, wherein the colour-map through focus scanning microscopy image is an XY intensity colour map image.

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7. A method for measuring surface roughness of a sample, comprising steps of:
 setting the sample is set on a sample holder and illuminating a target area of a surface of the sample with a light using a light source (211);

15 scanning the sample at a plane using a scanning system and collecting the light reflected from the sample using one or more objective lenses and a focusing lens (212);

 detecting light signals from each point of the target area as pixels using a detector linked to an acquisition module stored in a computer-readable medium (212),

20 wherein a first signal from all the pixels in the detector is produced by the acquisition module for focus variation (213), a second signal from all of the pixels in the detector is produced by the acquisition module for through focus scanning optical microscopy (213), and a third signal from a certain activated pixel region from all pixels in the detector is produced by the acquisition module for confocal microscopy (214);

 making one or more two-dimensional images from each of the X, Y and Z planes (215);
 and

25 stacking the two-dimensional images and forming a three-dimensional image (216),

 characterized in that a contrast ratio fusion module stored in the computer-readable medium utilizes a data fusion approach to merge information from the first signal, the second signal, and the third signal produced by the acquisition module for providing the three-dimensional image of the sample.

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8. The method for measuring surface roughness of a sample according to claim 7, wherein the third signal produced from a certain activated pixel region is a spatial filtered confocal microscopy signal that is created from a virtual pinhole by cutting down several neighbouring pixels from all the pixels.

9. The method for measuring surface roughness of a sample according to claim 7, further comprising storing a pixel-wise signal data for the first signal, the second signal, and the third signal.

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10. The method for measuring surface roughness of a sample according to claim 7, further comprising saving the three-dimensional image and signal values of the first signal and the third signal (217).

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11. The method for measuring surface roughness of a sample according to claim 7, wherein an optical intensity profile data from each of the planes is extracted and stacked for constructing a colour-map intensity X-Z through focus scanning microscopy image from the second signal (218).

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12. The method for measuring surface roughness of a sample according to claim 7, wherein the data fusion approach utilized by the contrast ratio fusion module is a pixel-by-pixel approach for merging information from the first signal, the second signal, and the third signal (221), comprising steps of:

defining a threshold value for comparing to a contrast ratio of the first signal, the second signal, and the third signal (222);

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evaluating the contrast ratio of the third signal to the threshold value for preserving accurate areas (223);

evaluating the contrast ratio of the first signal to the threshold value for preserving areas where the focus variation signal is good (224);

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evaluating the contrast ratio of the second signal to the threshold value for preserving areas where the through focus scanning optical microscopy signal is good (225);

refixing the threshold value to a new threshold value if the first signal, the second signal, and the third signal are below the threshold value (226); and

considering all CR values of the first signal, the second signal, and the third signal for the contrast ratio fusion module to provide a final result (227).

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