LASER GUIDED TIP APPROACH WITH 3D REGISTRATION TO A SURFACE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] Reference is made and priority claimed to U.S. Provisional Application Ser. No. 61/231,402 by T. Perkins et al. entitled "LASER GUIDED TIP APPROACH WITH 3D REGISTRASTION TO A SURFACE", filed Aug. 5, 2009, the disclosure of which is incorporated herein by reference.

STATEMENT AS TO RIGHTS TO INVENTIONS MADE UNDER FEDERALLY-SPONSORED RESEARCH AND DEVELOPMENT

[0002] The Laser Guided Tip Approach with 3D Registration to a Surface was developed with funds from the National Institute of Standards and Technology.

FIELD OF THE INVENTION

[0003] The present invention relates to a method of rapidly and repeatably bringing sharp objects into close proximity to a particular region of a surface with high precision and accuracy in one, two or three dimensions.

BACKGROUND OF THE INVENTION

[0004] In a typical atomic force microscope, coarse approach between tip and sample is achieved via a translation by a long range stage followed by a fine stage movement (0.1-1000 nm). If a specific surface is not found, this process is repeated. Often, optical microscopes are used to aid in this process.

[0005] Prior art does not allow registered tip exchange due to the lack of a reliable method to yield precise three dimensional, simultaneous localization of a tip and a sample surface. This knowledge is necessary in order to bring these objects into close proximity or contact with high registration.

[0006] There was a previous need in the art for a method and system of alignment, stabilization and registration that minimizes apparent or real drill. This need was satisfied by Pat. Appl. No. 60/725,203, entitled "REAL-TIME, ACTIVE PICOMETER-SCALE ALIGNMENT, STABILIZATION, AND REGISTRATION IN ONE OR MORE DIMENSIONS", incorporated herein by reference. The invention provides a process for positioning two or more structures to picometer-scale precision over short (typically approximately 0.01 s) and long (typically approximately >100 s) time scales. In addition, the invention also provides a method for picometer-scale alignment. The method provides a one, or more dimensional positional stabilizing technique, which is particularly effective when used with structures that either contain a fiducial mark that is firmly coupled to the sample, or a sample which has an inherent property that interacts with light to act as though it is a fiducial mark (e.g. a lens or a rough surface). This method, while useful as part of the present technique, does not address the replacement of tips or describe how to return to a previous position.

[0007] Carter, A. R., King, G. M. & Perkins, T. T. *Back-scattered detection provides atomic-scale localization precision, stability, and registration in* 3*D*. Opt Express 15, 13434-13445 (2007) discloses stabilization of the sample, but fails to disclose any data on scanning probe tips as described in the present invention.

[0008] Carter, A. R., King, G. M., et al., *Stabilization of an Optical Microscope in Three Dimensions*. Appl. Opt. 46(3): 421-7 (2007) discloses stabilization of the sample, but fails to disclose any data on scanning probe tips as described in the present invention.

[0009] King, G. M., Carter, A. R., Churnside, A. B., Eberle, L. S. & Perkins, T. T. *Ultrastable atomic force microscopy: atomic-scale lateral stability and registration in ambient condition*. Nano Lett. 9, 1451-1456 (2009) discloses 3D control of an AFM tip, but fails to disclose registered exchange or tip approach as described in the present invention.

[0010] Moon, E. E., Smith, H. I., *Nanometer-precision Pattern Registration for Scanning-probe Lithographies Using Interferometric-spatial-phase Imaging*. J. Vac. Sci. Technol. B 24(6): 3083-3087 (2006) discloses a method to stabilize a tip with respect to a sample with nanometer scale using interferometric gratings, but fails to disclose registered exchange or tip approach with other than interferometric techniques based on a grating affixed to the cantilever base and embedded in the sample as described in the present invention.

PROBLEM TO BE SOLVED

[0011] In atomic force microscopy (AFM), it is currently not possible to reliably exchange tips and return to the same nanoscale feature. This is exacerbated by samples that lack surface height variation. The present invention demonstrates that an individual nanoscale object can be successfully imaged by the same tip after retraction and re-approach, as well as after an exchange of tips. Finally, different types of tips can be exchanged and the same feature imaged and reimaged.

SUMMARY OF THE INVENTION

[0012] The present invention relates to a method for rapidly and repeatably bringing sharp objects into close proximity to a particular region of interest of a surface comprising projecting laser light onto a first tip region of a scanning probe microscope to produce back-scattered light, projecting laser light onto a region of interest of a sample to produce back-scattered light, receiving the back-scattered light by a photosensitive device, the photosensitive device converting the received back-scattered light into one of electrical or optical signals capable of identifying the dimensional positions of the first tip region and the region of interest, aligning the positions with respect to the laser light, providing an output control signal related to the signal output from the photosensitive device from a feedback algorithm/process to a precision positioner to stably maintain the positions over a time interval, removing the first tip of the scanning probe microscope, replacing the first tip of the scanning probe microscope with a second tip, and returning the second tip to the identified dimensional positions of the first tip and the region of interest with the precision positioner. The present invention also relates to a method for rapidly and repeatably bringing sharp objects into close proximity to a particular region of a surface comprising projecting laser light onto a tip region of a scanning probe microscope to produce back-scattered light, projecting laser light onto a first region of interest of a sample to produce back-scattered light, receiving the back-scattered light by a photosensitive device, the photosensitive device converting the received back-scattered light into one of electrical or optical signals capable of identifying the dimensional positions of the tip region and the first region of interest of a