ATOMIC FORCE MICROSCOPE EMPLOYING BEAM TRACKING

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of U.S. patent application Ser. No. 08/190,948 filed Feb. 3, 1994, now U.S. Pat. No. 5,440,920.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to the field of scanning probe microscopy and more particularly to a novel scanning force or atomic force microscope having a stationary sample stage and a beam tracking lens which may utilize an S-shaped piezoceramic scanner to provide relative motion between the probe tip of the atomic force microscope and the surface of the sample being scanned.

2. The Prior Art

The atomic force microscope ("AFM") belongs to a family of devices known as scanning probe microscopes ("SPMs"). These devices all use a probe with a sharp tip to scan a surface and measure the surface features such as topography as a function of probe-surface interaction at the location of the probe, generally yielding a two-dimensional array of data. SPMs comprise a number of different systems for measuring various types of probe-surface interactions. The first device of this family was the Scanning Tunneling Microscope ("STM") which is described in U.S. Pat. No. 4,724,318 to Binnig et al. The second device of the family is the AFM which this invention is directed to. Since the invention of the STM and the AFM, scanning probe microscopy has found applications in many areas of science and engineering due to its simplicity and high resolution at atomic dimensions.

AFMs typically employ a fine flexible cantilever with a small spring constant (in the range of 10^{-1} to 10^{-3}N/m) and a sharp probe tip disposed at the free end of the cantilever. The bending of the cantilever in an AFM is related to the atomic force exerted on the tip (in the range of 10^{-8} to 10^{-13}N) by the local topography of the sample surface. For measurement of the force, the optical beam deflection method, also known as the optical lever method (or "OLM") is frequently used. Pursuant to the OLM, a laser such as a diode laser is positioned so that its laser beam intersects the reflective side or back of the cantilever which is away from the surface of the sample being scanned ("sample surface"). The angle of reflection of the laser beam reflected off of the reflective back of the cantilever is sensed at a distance by a position sensitive photodetector device such as a bi-cell photodetector. The measured angle of reflection of the laser beam from the cantilever is thus related to the topography of the sample surface. Most AFM systems are designed to move the sample surface relative to a stationary probe tip (see, e.g., Binnig et al., *Phys. Rev. Lett.*, 1982, 49, pp. 57–60; *Phys. Rev. Lett.*, 1986, 56, pp. 930–933; Jahnamir et al., *Scanning Microscopy,* 1992, 6, pp. 625–660) in order to maintain the probe's optical alignment with respect to a stationary laser emitter. Thus, the sample is mounted at the end of a voltage controlled scanner made of a piezoceramic tube (also known as a "PZT"). The characteristics of the PZT and the range of the applied voltages determine the size of the scanned area as well as the resolution of the image of the sample surface. By using various different scanners having different PZTs, areas as small as several square nanometers, or as large as tens of thousands of square micrometers, can be characterized by the AFM.

In AFMs according to most of the prior art, the sample must be attached to the scanner. Such prior art AFMs operate with a stationary probe and moving sample as described above. The sample can be disturbed during operation of such prior art AFMs because the sample must be moved in order to scan an area of the sample surface. According to such prior art, it is also necessary to disturb the sample every time that the scanning range or scanning method (e.g., probe) is changed, because to accomplish such changes, disassembly and reassembly of all or part of the AFM system is required. This process often requires detaching the sample from its mount, adjusting the AFM, and then remounting the sample. Such requirements restrict the size and weight Of the sample to be scanned. Prior art AFMs also often require that the detecting optics (e.g., the bi-cell photodetector) be moved during the scanning process. (See, e.g., Jahnamir et al., Supra). All of these changes and movements required by the prior art devices can affect both the sample and the measurement of its surface properties, limit the quality of the data obtained, and make different measurements of the same sample difficult or inconsistent. Disturbing the sample when changing scanners or scanning modes (e.g., STM, AFM), besides being time consuming, may interfere with the measurement(s) being made. This is usually true when working with adsorbates, or when working in situ in a liquid cell. Imaging under solution in a liquid cell can be performed both with and without electrochemical control. The significance and the application of working under electrochemical control is described and patented by S. Lindsay in U.S. Pat. No. 5,155,361. When working under electrochemical control, disconnecting the sample from the applied voltages for changing scanners or scanning modes can cause severe and irreversible changes to the sample surface.

SUMMARY OF THE INVENTION

According to the present invention the sample need not be disturbed in order to change either the scanners (scanning heads) or the scanning modes. Rather, it is the scanner with beam tracking lens that moves instead of the sample when various areas of the sample surface are to be scanned. Preferably the present invention may comprise one microscope with several interchangeable scanning heads. Tracking and focusing of the laser beam eliminate most errors due to beam deflection and enables AFM imaging of large areas (in the micrometer range) without losing resolution. Preferably the present invention may enable solution/electrochemical imaging of a surface or surfaces emersed in a liquid without moving the sample and disturbing the equilibrium of the sample in solution and may preferably include a stationary sample stage, a beam tracking lens and an S-shaped scanner.

OBJECTS AND ADVANTAGES OF THE INVENTION

Accordingly, it is an object of the present invention to provide a stationary stage atomic force microscope and method of operating same with the ability to map out the topography of a stationary sample substrate in the nanometer to micrometer range using an optical lever method deflection detection system with an S-shaped scanner while allowing for the easy changing of scanning modes and scanning heads without disturbing the sample.