SCANNING FORCE MICROSCOPE WITH REMOVABLE PROBE ILLUMINATOR ASSEMBLY

BACKGROUND

1. Field of the Invention

This invention relates to scanning force microscopes, sometimes referred to as atomic force microscopes, where such microscopes use light beam detection schemes.

2. Description of Prior Art

Scanning force microscopes can resolve features of matter to the atomic level. Scanning force microscopes also are members of one class of a broader category of probe microscopes. When used to image the topography of a sample, the scanning force microscope uses a finely pointed stylus to interact with a sample surface. A scanning mechanism creates relative motion between the stylus and the sample surface. When a measurement of the interaction of the stylus and surface is made, the surface topography of the sample can be imaged in height as well as in the lateral dimensions. Other classes of probe microscopes may use different types of probes to measure sample features other than topography. For example, the interaction of a magnetic probe with the sample may create an image of the magnetic domains of the sample.

Scanning force microscopes used to image topographical features have the stylus mounted orthogonally to the longer dimension of a cantilever. A cantilever is a lever constrained on one end with the other end free to move. The stylus is attached to the free end, and the cantilever will, therefore, deflect, or bend, when forces are applied to the stylus. In force microscopes, the forces acting on the stylus are the result of the interaction of the stylus with the sample surface. The combination of a stylus, cantilever, and inseparable cantilever supporting elements creates a probe assembly. The cantilever, used in a scanning force microscope, has a very weak spring constant and deflects or bends noticeably when forces as small as one nano-newton are applied to the free end. Operation also requires that a detection mechanism provide a signal when the cantilever deflects. This signal is then processed by a feedback loop to create a feedback signal. A vertical drive mechanism moves the fixed end of the cantilever toward and away from the sample surface. This vertical drive mechanism receives the feedback signal and maintains the free end of the cantilever surface at a nearly constant bend angle as detected by the detection mechanism.

A lateral drive mechanism creates relative lateral motion between the stylus and sample. This relative lateral motion between the stylus and the surface creates lateral and vertical forces on the stylus as it interacts with surface features passing under the stylus during scanning. The lateral force applies torque to the stylus and cantilever. The vertical force on the stylus causes the cantilever free end to deflect vertically. The known lateral position of the stylus over the sample can be expressed in terms of x and y coordinates. The vertical deflection of the cantilever defines a height or z value. The x and y coordinates create a matrix of z values which describe the surface topography of the sample. The scanning mechanism is comprised of the vertical and lateral drive mechanisms.

In order to detect the cantilever deflections, a laser beam is directed onto the free end of the cantilever opposite the surface supporting the stylus. The surface illuminated by the laser beam is at least partially reflecting. By measuring the position of the reflected beam, the deflection of the free end of the cantilever is determined. A vertical array of two light-sensitive devices detects the position of the reflected beam. These devices produce electrical signals that represent the bend angle of the free end of the cantilever. The difference of the two signals created by the two light-sensitive devices is proportional to the amount of the cantilever deflection in the vertical direction. By using four light-sensitive devices in a quadrant array, both the cantilever twist and cantilever vertical deflection can be measured. The vertical drive mechanism receives signals processed from the vertical component of the output of the light-sensitive devices.

In probe microscopes, it is often necessary to replace the probe assembly. This may result from a blunted stylus tip caused either by wear of, or by small particles that adhere to, the tip as it scans over the sample. Also, the stylus or the cantilever or both can break necessitating replacement of the probe assembly. When the probe assembly is replaced, the new cantilever often is not in exactly the same position as the previous cantilever relative to the laser and associated optics. Adjustment of either the laser beam angle or the probe assembly position is then required. Alignment mechanisms restore the beam its proper position on the reflecting surface of the cantilever.

The initial adjustment of the laser beam onto the cantilever can be accomplished in various ways. See, for example, copending application titled "Scanning Force Microscope and Method for Beam Detection and Alignment" by Ray.

Prior art devices are shown in U.S. Pat. No. 4,935,634 to Hansma et, al, and U.S. Pat. No. 5,144,833 to Amer et, al. These prior art devices move the sample laterally and vertically under a stationary stylus while detecting the cantilever deflection with the laser beam apparatus described above. This method has a disadvantage stemming from the limited force capability of the lateral and vertical drive mechanisms. The sample mass may be large compared to the force created by the drive mechanisms. It is then possible that the sample will move very slowly or not at all under the stylus. The mechanical resonance of the scanning mechanism is also undesirably low with large moving mass.

Other prior art microscopes as recited in U.S. Pat. No. 5,496,999 to Linker et. al. and U.S. Pat. No. RE 35,514 to Albrecht et. al. have removable assemblies comprising laser, cantilever, and adjustment mechanisms mounted to the fixed reference frame of the microscope base. But, these microscopes also have the disadvantage as described above in that they move the sample under the stationary stylus. Further, the assemblies are too massive to be mounted to the scanning mechanism since they are designed to allow adjustment of the beam path or probe position while the assembly is mounted to the microscope.

Prior art microscopes are also described in U.S. Pat. No. 5,481,908 and its continuation U.S. Pat. No. 5,625,142 to Gamble. These microscopes maintain a fixed sample and move the laser, the cantilever, and all of the associated mechanisms necessary to make initial adjustment of the laser beam. Since the laser moves with the cantilever, the laser beam follows the motion of the cantilever during scanning. The mass associated with the moving part of these microscopes limits the rate of image data collection.

Other prior art microscopes attempt to overcome the disadvantage of moving the sample by using an interferometric method to track a moving cantilever. These microscopes are described in U.S. Pat. No. 5,025,658 and its continuation U.S. Pat. No. 5,189,906 to Elings et al. This