7 Scanning probe microscopy

Scanning probe microscopes generate a highly-resolved image of the specimen by scanning it with a small mechanical, electrical, optical, thermal, or other probe.

7.1 Atomic force microscope (AFM)

The AFM was invented by Gerd Binnig, Christoph Gerber, and Calvin F. Quate in the mid-eighties (Binnig et al., 1986), and is one type of the so-called scanning

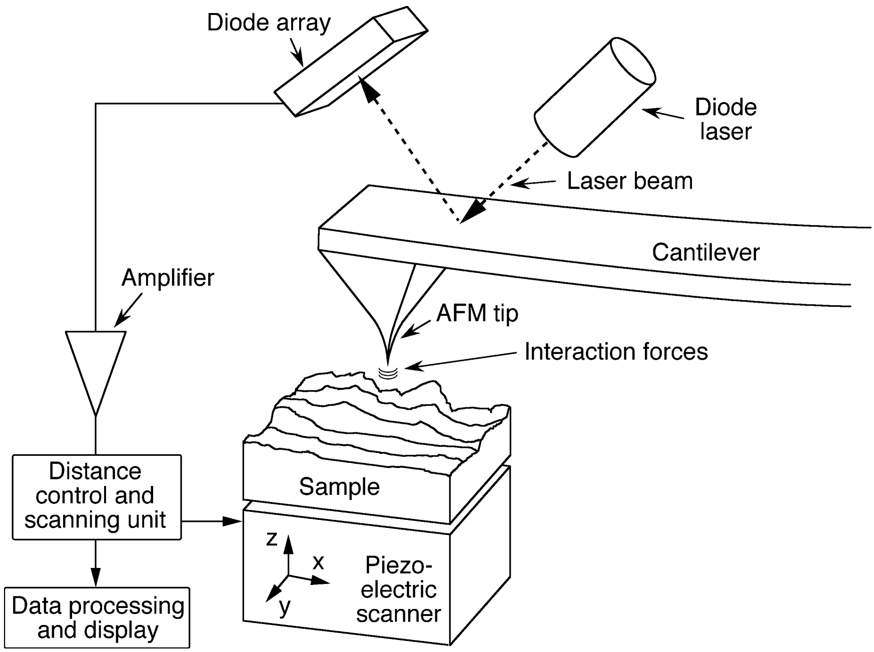

Fig. 7.1 Principle of operation of an atomic force microscope. A very sharp tip attached to a tiny cantilever probes the sample surface. An optical system comprised of diode laser and detector, e.g., a diode array or a position-sensitive diode, senses the bending of the cantilever and thereby the distance-dependent tip-sample interaction force. For scanning the surface, the sample is moved by the piezoelectric scanner (Binnig et al., 1986)

probe microscopes (SPMs) which also include scanning tunneling microscope (STM; Sect. 7.2; Binnig et al., 1982a, 1982b, 1983; Binnig and Rohrer, 1987), scanning near-field optical microscope (SNOM; Sect. 7.3), scanning thermal microscope (SThM; Sect. 7.4), and the scanning ion conductance microscope (SICM; Sect. 7.4). The AFM is used in both industrial and fundamental research to obtain atomic-scale images of metal surfaces and nanometer-scale images of the three-dimensional profile of the surface of biological specimens. It is a very useful tool for determining the size and conformation of single molecules and aggregates adsorbed on solid surfaces. The AFM scans the sample with a tiny tip mounted on a small cantilever (Fig. 7.1). It measures the small force of interaction between tip and sample surface by sensing the reflection changes of a laser upon cantilever movement caused by interaction with the sample. An image of the sample surface relief is recorded using piezoelectric translation stages that move the sample beneath the tip, or the tip over the sample surface, and are accurate to a few Å.

Note the similarity of the AFM (Fig. 7.1) to the stylus profilometer (Fig. 7.2) and to the STM (Fig. 7.19). Actually, the idea of AFM is based on the design of stylus profilometers, but the AFM can reveal the sample relief with subnanometer resolution.

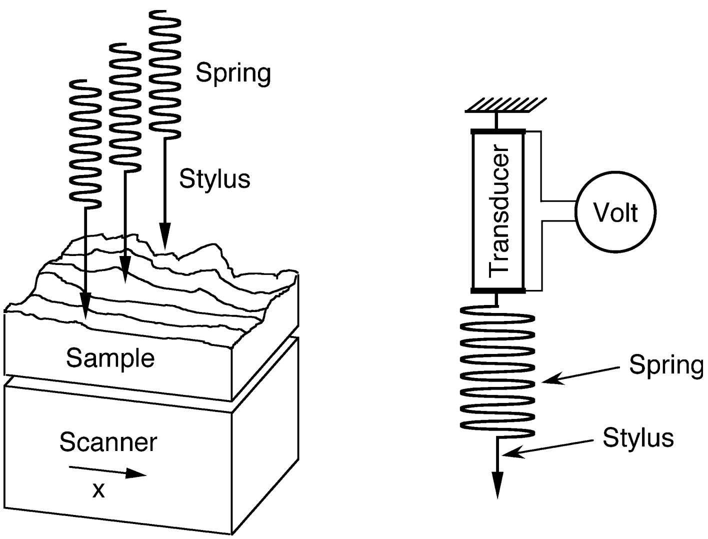

Fig. 7.2 Stylus profilometer for comparison with the AFM. A set of styli probes the sample which is drawn below the set of styli. The small motions of the styli are transformed into an electrical signal by linear, variable transducers. Step heights of down to a few 10 nm are resolvable

The force of tip-sample interaction (Fig. 7.3) has a magnitude of typically only a few pN – nN. That is why the cantilever must have a small mass, and the