1 Friction Force Microscopy

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1.1 Introduction

Friction Force Microscopy (FFM) is a sub-field of scanning force microscopy addressing the measurement of lateral forces in small sliding contacts. In line with all scanning probe methods, the basic idea is to exploit the local interactions with a very sharp probe for obtaining microscopic information on surfaces in lateral resolution. In FFM, the apex of a sharp tip is brought into contact with a sample surface, and the lateral forces are recorded while tip and sample slide relative to each other. There are several areas of motivation to study FFM. First, the understanding of friction between sliding surfaces in general is a very complex problem due to multiple points of contact between surfaces and the importance of lubricants and third bodies in the sliding process. By reducing one surface to a single asperity, preparing a well-defined structure of the sample surface, and controlling the normal load on the contact the complexity of friction studies is greatly reduced and basic insights into the relevant processes can be obtained. Furthermore, with the decrease of the size of mechanical devices (MEMS) the friction and adhesion of small contacts becomes a technological issue. Finally, the lateral resolution allows to reveal tribological contrasts caused by material differences on heterogenous surfaces.

The experimental field of FFM has been pioneered by Mate, McClelland, Erlandsson, and Chiang [1]. The group built a scanning force microscope where the lateral deflection of a tungsten wire could be measured through optical interferometry. When the etched tip of the tungsten wire slid over a graphite surface, lateral forces exhibited a modulation with the atomic periodicity of the graphite lattice. Furthermore, a essentially linear load dependence of the lateral force could be established.

In this chapter we will describe aspects of instrumentation and measurement procedures. In the course of this description, a series of critical issues in FFM will be discussed which are summarized in Fig. 1.1.
1.2 Instrumentation

1.2.1 Force sensors

The force sensor in the original presentation of FFM by Mate et al. was a tungsten wire [1]. Its deflection was detected by an interferometric scheme where the wire constituted one mirror of the interferometer. A similar concept was later implemented by Hirano et al., who optically detected the deflection of the tungsten wire in a Scanning Tunneling Microscope when scanning the tip in close proximity to the surface [2]. Mate and Hirano report lateral spring constants from 1.5 to 2500 N/m, depending on the wire thickness and length. Etching the wire to form a tip at its end, mounting the wire, aligning of the light beam, and determination of the spring constant comprise some experimental difficulties. These difficulties are greatly reduced by the use of dedicated micro-fabricated force sensors. A very sophisticated instrumental approach to the solution of those problems has been realized by Dienwiebel et al. [3]. The group has attached a stiff tungsten wire to a micro-fabricated force sensor made of silicon. The central part of the sensor is a pyramid holding the tip. The position of the pyramid is detected in all three dimensions by means of four optical interferometers directed towards the faces of the pyramid. It is suspended in four symmetric high-aspect ratio legs which serve as springs with isotropic spring constant in both lateral directions and a higher spring constant in normal direction. The symmetric design of the instrument allows