# Preface

The rapid development of scanning probe microscopy (SPM) has made possible investigations of morphological and physical properties of insulating surfaces with unprecedented resolution. Since the 'father' of the SPM family — the scanning tunneling microscope (STM) — can only be applied to image ultrathin insulating films grown on conducting surfaces, most of the SPM investigations on insulators have been performed using the atomic force microscope (AFM). The principle of AFM is simple: an ultrasharp tip is driven over a surface, and the tip-surface interaction is reconstructed by monitoring the deflection of a flexible cantilever supporting the tip. Thanks to the extraordinary sensitivity of the piezo-elements used for positioning the tip with respect to the surface, atomically resolved images of several insulating crystal surfaces can be readily obtained in such a way.

Before introducing the AFM and STM techniques, we briefly discuss the crystallographic structures and preparation methods of various insulating surfaces in the first two chapters. Our attention will be limited to alkali halide surfaces and to oxide surfaces with large band gaps. We will not address other insulating surfaces, such as those of polymers, plastics, glasses and minerals like mica, where the interpretation of the SPM results is often not so conclusive. We will also not cover issues like chemical reactivity of the surfaces except when they become relevant to interpret SPM images.

Alkali halide surfaces have a simple structure and can be easily prepared and characterized in an ultra high vacuum environment (UHV). For these reasons, they have quickly become reference models to investigate crystal growth processes on the nanometer scale. Alkali halide surfaces are also important playgrounds for nanoscale phenomena such as self-assembly of metal clusters and large organic molecules, or friction and wear processes.

Insulating oxide surfaces find a broad use in several applications, ranging from interfaces for electronic ceramics to chemical catalysis. Even if they are more difficult to characterize, these surfaces are still amenable to fundamental investigations on the nanoscale, and high-resolution SPM images can be obtained after the surfaces have been carefully prepared.

The central part of the book begins with Chapters 4 and 5. Here we will focus on bulk and ultrathin insulating surfaces as imaged by SPM. Atomic resolution is unquestionable when single defects are imaged, which is now commonly achieved on several structures studied by AFM. Some defects like vacancies can be even created and subsequently imaged by the same AFM tip, which gives important information on the scanning process itself. Several experimental results have been also complemented by theoretical simulations of the imaging process, which allowed to identify the main forces responsible for atomic resolution.

Chapters 6, 7 and 8 introduce the interaction of ions, electrons and photons with halide surfaces, with special emphasis on the nanostructures created by the interaction processes. The discussion of the basic mechanisms responsible for crystal erosion and large surface nanopatterning with nanometer precision is supplemented by recent experimental results obtained by means of high resolution AFM imaging.

Chapters 9 and 10 deal with self-assembly of metals and organic molecules on bare and nanopatterned insulating surfaces. Once again the discussion of the experimental results is complemented by theoretical interpretations of the imaging process. Since the ordering of metal and molecular adsorbates is often hindered by the weak interaction between adsorbate and substrate, nanopatterns play an important role in improving the stability of the adsorbed species. For instance, self-assembly can be readily achieved along monatomic step edges or inside nanometer-sized pits produced by electron irradiation. As a further step, connecting well-defined molecular assemblies to external electrodes via metal nanowires grown on insulating surfaces might become feasible in the near future.

In Chapter 11 we discuss force spectroscopy measurements on insulating surfaces. In such cases, the response of the SPM tip is monitored at different separations between tip and surface, which gives important information on the tip-surface interaction. If a current flow between tip and sample can be established, by decreasing the band gap in the material, scanning tunneling spectroscopy (STS) is also possible. With this technique metals and organic molecules deposited on thin insulating films can be also investigated, and different electronic states of single molecules have been even identified.

The last two chapters deal with mechanical phenomena induced and observed using SPM on insulating surfaces. These processes include friction, wear, indentation and manipulation of tiny nano-objects. While several important results have been obtained in the first three topics — last but not least the achievement of superlubricity — nanomanipulation on insulating surfaces is still in its embryonic phase. However, nanomanipulation has such potential applications to molecular electronics and nanomechanics that exciting experiments are on sight, once again driven by theoretical models.

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