Extended Abstracts of the 20th (1988 International) Conference on Solid State Devices and Materials, Tokyo, 1988, pp. 3-4 **P-O-2**

Invited

Imaging with the STM and the AFM

Calvin F. QUATE

Edward L. Ginzton Laboratory
Stanford University
Stanford, California 94305

The Scanning Tunneling Microscope (STM) and Atomic Force Microscope (AFM) can be used to provide new insights into the structure of surfaces. They can both be used to examine the arrangement of atoms on these surfaces. In this talk we will review some of the latest results with these instruments.

The Scanning Tunneling Microscope is a new tool for studying surfaces on the atomic scale. In this talk we will discuss the recent results in this field.

The STM operates in a variety of environments. It can be used in air, liquids, and vacuum. It can be used to examine structures over a wide range of sizes. It has been used to examine the gross structure of CD disk stampers at the upper end of the range and the atomic structure of Bismuth Copper Oxide at the lower end. It is used primarily to study the positions of the atoms on the surface of those materials where the electronic charge density coincides with the atomic positions. But it is also useful for studying CDW's where the spatial distribution of charge density is quite different from the spatial distribution of the atoms. It is useful for studying molecular structures. Hopefully it will be used in the field of biology, but this hope has not yet been realized.

We should bear in mind that the STM is only one member of a class of instruments that are now emerging. These are all based on scanning tips. The Atomic Force Microscope and the Magnetic Force Microscope are representative of this new class. We will include examples to illustrate the utility of these two instruments.

Our primary focus in this talk will be on the surfaces of semiconductors and the structure of metal atoms adsorbed on these surfaces. The (111) surface of Silicon as reconstructed in the 7x7 pattern is the classic surface of choice for the STM operating in UHV. A great deal has been learned about the positional dependence and other properties of metal atoms deposited on this surface.

A variety of atoms such as As, Cs, Cu and Ag as deposited on Si have been examined with the STM. We will use three metals, Ga, Sn and In, to illustrate the wealth of information that can be gathered with the STM. What have we learned ? We have learned the location of the atoms on these surfaces with a precision that is not available in the classic LEED patterns. We have revealed atomic patterns and atomic structures that were not discernible from the symmetry properties of the LEED patterns. We have learned that some of the atoms on the 7x7 surface are more stably bonded to the substrate than the atoms at other sites. And we have learned to identify the filled and unfilled states on these surfaces.

In other related studies the surface of gold (as deposited epitaxially on mica) has been examined in some detail. It is remarkably easy to 'mark' this surface with a high voltage pulse applied to the tip. Unfortunately, the surface is not stable since the rapid diffusion on gold atoms eliminates the marks in a short time. However, the system does allow one to study the diffusion of atoms along this surface and this is interesting in and of itself. Other marking techniques are under study and these will be examined at the conclusion of our talk. With thin monomolecular films of polymers and with "contamination resist" it is now possible to use the scanning tip to 'mark' surfaces with narrow lines. These hold promise of writing fine structures. It has been estimated that the line width as written with the STM can be an order of magnitude smaller than is possible with the SEM. If true, this represents a large advance in our effort to shrink the size of microstructures as fabricated using these techniques.