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Atomic Resolution Microscopy

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Although it has been possible for many years to determine the average position of atoms by using diffraction techniques, finding the positions of specific atoms has been an elusive target. This latter goal is now in sight. Individual atoms on surfaces were first seen in the seventies by the Chicago Group using the then newly invented Scanning Transmission Electron Microscope (STEM). More recently atoms on surfaces have also been seen by Scanning Tunneling Microscopy (STM) and associated variants (e.g. Atomic Force Microscopy). Atomic structures in the interior of a material have been imaged in recent years through atomic resolution transmission electron microscopy of thin film specimens. Progress in these developments is following an acceleration path and the Materials Research Division of the NSF recently commissioned a panel to review the area and provide advice on an appropriate response. This panel, co-chaired by Dr. Morris Cohen of MIT, Dr. John Poate of ATT-Bell Labs and myself have submitted a report in April to the NSF where it is currently under consideration.

At an international workshop held in May, 1992 in Harbour Towne, MD, the panel learned of progress in a number of approaches to atomic resolution microscopy. Those based on scanned tips can provide surface atomic resolution and are already being used in imaging and in altering surface structures at the atomic level. Surface electronic structure studies and the creation and alteration of specific atomic structures on the surface with associated electronic structure changes are examples of the level of command over nature that is now emerging. At present, the time scales for such studies are lengthy and the suitable systems are rather few. Nevertheless, the insight that is being generated and the inevitable extension of these limits make this area one of the most exciting in current microscopy research.

Studies of specific atomic structures inside a material (as opposed to the surface structures revealed by STM) are also becoming feasible through new developments in electron microscopy. *Atomic structure images of materials* have been possible for some time. Such pictures are projections of atomic columns (i.e., of atoms stacked up one upon another). Disturbances of the structure inside the specimen (often the features of importance) are difficult to determine. Indeed, this challenge is the one most often faced by the contemporary electron microscopist. Enhancement of the spatial resolution enables the scientist to respond more effectively. Current resolution levels of 1.6 to 2.0 Angstroms just about match atomic spacings in materials. At this resolution, typically only one crystal orientation can be found in which an atomic structure image is feasible and thus ambiguities of interpretation abound. Indeed, these images are just tantalizing glimpses of the interior of the sample. As the resolution is extended to 1.0 Angstrom, many more spacings and orientations open up and at 0.5 Angstroms most atomic configurations of interest to material scientists will appear. There is even hope that more complex materials (e.g., amorphous solids) might be successfully studied at such resolution levels. A much more comprehensive view of the interior world will emerge. Recent accomplishments support expectations that the necessary performance levels can be attained over the next decade.

Electron holography is one of the approaches undertaken towards these ends. Long standing programs in Europe and Japan are now bearing fruit in the form of workable schemes for generating phase information from electron micrographs. Key to the success of this thrust is the availability of substantial computer resources for digital image acquisition and analysis. Such schemes permit both the improvement of spatial resolution and the extraction of new images (e.g., both electron wavefunction amplitude and phase maps of the atom structure and maps of magnetic and electric fields within the sample - subject to traditional limitations due to specimen preparation and lens constraints). Development of 300 KeV STEM microscopes is approaching 1.3 Angstrom

The Light Side!!!

In attempt to make our days just a small bit more enjoyable, we are going to start a "humor" element in this newsletter - where readers are encouraged to make contributions. The contributions may be a short "jokes" or a longer articles - and must relate, in a very broad sense, to the science and/or business.

Jean-Paul Revel (Caltech), Bob Fisher (Univ. of Washington) and I will evaluate each contribution and judged it on humor value. Each accepted will generate an "entry" and from these entries we will draw a winner at next year's MSA Conference. The winner will receive an Apple Newton notebook computer. We must only reserve the right to cancel this program should we not receive appropriate participation.

Readers are encouraged to submit as many contributions as they wish. Each accepted will produce an entry. The more contributions, the more entries. The more entries, the better chance you will have to win the computer.

- - - Don Grimes, Editor

The Light Side

How many field service engineers does it take to change a light bulb?

It depends upon how many defective bulbs they brought with them.

--- Don Grimes, Microscopy Today

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