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A 90-Degree-Tilt Rotary Adapter for SEM

Continued from page 24

4. The fit between components should be tight enough so that traction provided by the O-ring turns the drive wheel, but not so tight as to produce binding. Mating surfaces should be polished smooth and lubricated with a small amount of vacuum grease.

5. The bottom of the base plate should be machined so that it attaches to the stage in a similar fashion as standard specimen holders.

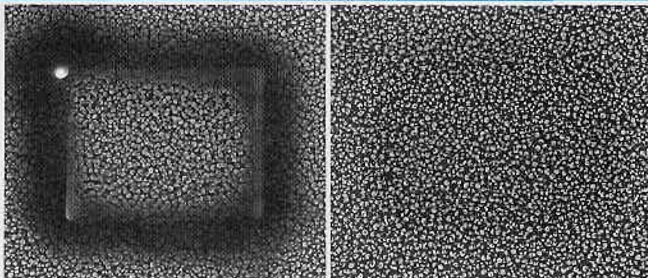
6. Components below the specimen (machine screw and washer) should be masked with a foil shield coated with carbon paint to provide a uniformly dark background.

7. As with any large specimen and/or holder, the rotary adapter should be used with caution. Care should be taken especially with manipulation of stage height and tilt controls, to prevent collision damage with other components in the column.

Acknowledgments

We are routinely grateful for the patience and skill of Al MacDonald, the machinist wizard who crafted this device and many others in our lab. This adapter was modeled after a less elaborate device designed by James M. Ehrman and J.R. Scott at the Texas A&M University Electron Microscopy Center in 1981. The Natural Sciences and Engineering Research Council of Canada (NSERC), the Canada Foundation for Innovation (CFI), and Mount Allison University have provided major funding for the Digital Microscopy Facility. ■

"The Evactron device can significantly reduce contamination in the SEM."



A silicon "grass" sample irradiated for 10 minutes before (left) and after (right) the use of Evactron SEM-CLEAN device. 50kX - From *Active Monitoring and Control of Electron Beam Induced Contamination* by A. Vladar, M. Postek, & R. Vane., SPIE Microlithography Conference. Feb. 2001.

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Measuring Conductivity With Scanning Probe Microscopes

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There are two kinds of conductivity measurements possible with scanning probe microscopy (SPM). In the first case, the specific resistance of material directly below the tip is probed. In the second case, SPM probes local potential induced by the lateral current applied through macroscopic contacts, thus providing the information on the mesoscopic transport properties of the sample.

The first set of techniques is invariably based on measuring tip-surface current in contact or intermittent tapping mode. If the tip-surface contact resistance is small (good contact), the current will be limited by the spreading resistance of the sample from which specific resistance can be calculated, assuming that the contact area is known. In practice, good tip-surface contact requires high indentation forces and extremely clean surfaces, especially for semiconducting oxides. On semiconductor surfaces, space charge layers and Schottky regions below the tip will also affect the measurements. An interesting development of this approach is thin-film measurements, in which case regions with high current density (*e.g.*, defects) can be detected.

The second type of conductivity measurement are based on using potential-sensitive SPM techniques such as scanning surface potential microscopy (SSPM, or Kelvin Probe Force Microscopy, KPFM) on laterally biased surfaces. This setup is very similar to the usual four point resistivity measurements, but instead of two fixed voltage electrodes, the SPM tip acts as a single moving voltage electrode.

For quasi-one dimensional systems such as a metal-semiconductor interface or a grain boundary in a bicrystal, the subsequent analysis is straightforward. Assuming that the sample is connected in series with current limiting resistors of total resistance R, the current is $I = V_{lat}/(R+R_d)$, where V_{lat} is lateral bias applied by an external voltage source and R_d is voltage dependent interface resistance. The current voltage characteristic of the interface is then $I_d(V_d)=(V_{lat}-V_d)/R$, where V_d is potential drop at the interface measured directly by SSPM. The presence of stray resistances in the circuit *(e.g.*, due to the bulk of the sample) can be determined and quantified by varying the current limiting resistor R. Alternatively, the current in the circuit can be measured directly. Such measurements can be conveniently done by applying a slow (approximately milliHz range) triangular voltage ramp across the interface with the slow scan disengaged. The first image is then the SSPM image in which each line corresponds to different lateral bias conditions (*i.e.*, potential profile across the interface, from which $V_d(V_{lat})$ is obtained). The second image stores the actual lateral bias (V_{lat}) and the third image is current in the circuit measured by an I - V converter ($I = I_d$). A similar approach can be extended to systems with multiple interfaces, such as *p-i-n* diodes, *etc*.. In all cases, the potential we are interested in is the difference between the potential under bias and the potential of the grounded surface, which takes care of the contact potential difference (CPD) variations across the surface.

Analysis of conductivity in laterally inhomogeneous systems is less straightforward. Qualitatively, detection of resistive barriers (*e.g.*, grain boundaries) is still straightforward. On applying the lateral bias, potential drops develop on electroactive interfaces and can be readily visualized by SSPM. However, the quantitative image analysis in this case is difficult.

One of the factors that has to be taken into account in SSPM

measurements is the cantilever effect. Under optimal conditions, the potential drop measured at the interface (*i.e.*, ± 500 nm from the interface) is approximately 90% of it's true value. The rest decays at distances on the order of approximately 10 micrometers, for example, comparable to the cantilever length. Therefore, by measuring potential distribution in ceramics with grain sizes of approximately 10 to 20 micrometers, grain boundary conductivity can be determined reliably, whereas grain bulk conductivity cannot. Similar problems exist for carbon nanotube circuits. Due to the fact that interaction area of SSPM (30 to 100 nm) is much larger than the diameter of a nanotube, the measured potential is a weighted average of nanotube potential and back gate potential.

Some of these problems can be taken care of by using other SPM techniques, such as EFM. The tip-surface interactions in these cases are more localized, therefore, cantilever effects are negligible. However, interpretation of the signal (which is now quadratic in voltage) is less straightforward. Another possibility is the application of AC bias across the sample and use of a static (DC biased) tip as in Scanning Impedance Microscopy. In this case, detection of amplitude and phase of the first harmonic of cantilever oscillations across the surface yields not only interface resistances and an I-V characteristic, but also interface capacitance and a C-V curve.

The primary limitation of SPM techniques discussed above arise from the force (SSPM, SIM) or force-gradient (EFM) detection scheme, in which the first or second derivative of tip-surface capacitance limits the resolution. A number of potential sensitive SPM techniques were developed utilizing current detection. In conductive AFM and nanopotentiometry, the lateral resolution is limited by contact area (approximately 10 nm). In Scanning Tunneling Microscopy (STM) based techniques atomic resolution can potentially be achieved. ■

Further details on SPM measurements on laterally biased devices can be found in:

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Or on the Bonnell group web-site: www.seas.upenn.edu/~bonnell

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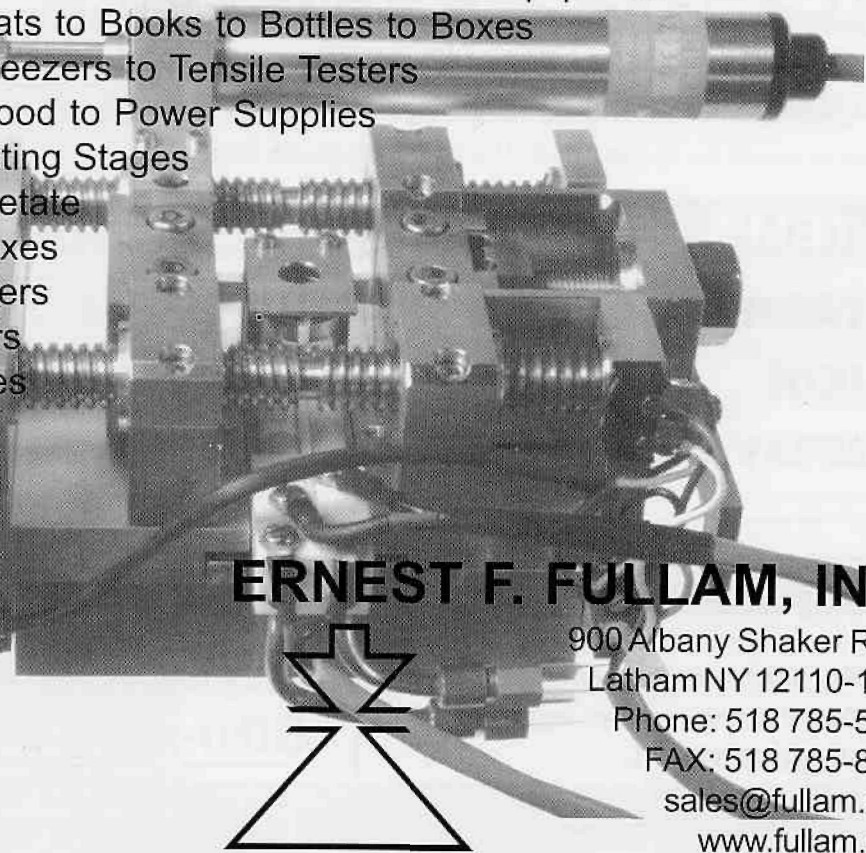
Glass Bottles to Grid Boxes
Razor Blades to Ruby Mica
Ferritin to Films to Forceps
Acetone to Apertures

What can you imagine?



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