A Perspective on the Need for Electrical Measurement Instrumentation, Methodologies, and Metrology Standards for Nanotechnology

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Abstract
Electrical measurements provide the underpinning for many nanotechnology discoveries. Instrumentation suppliers must continue to develop new equipment and measurement techniques to support cutting edge research. Sophisticated measurement equipment and/or tools used for nanoscale measurements must be supported by metrology standards and measurement protocols so that repeatable and verifiable measurements can be performed.

Historically, many scientific advances occur only after suitable investigative instruments become available. Atomic Force Microscopes (AFM), Scanning Electron Microscopes (SEM), and Semiconductor Characterization Systems (SCS) have helped nanotech researchers visualize, resolve, and perform electrical characterization of nanoscale objects and devices. The knowledge obtained with these tools allows researchers to further manipulate atoms and molecules to create new materials, structures, and electronics. But for electrical measurements, we need to ask ourselves whether or not Volts, Ohms, and Amps mean the same thing on the nanoscale as they do on the micro and macro scale. Assuming Ohms Law does not mean the same thing on the nanoscale, what references do we compare a measurement to?

In 2002, the National Nanotechnology Initiative in the United States expanded the list of Grand Challenges to include more sophisticated and standardized nanoscale instrumentation and metrology designed to provide higher performance and measurement efficiency at lower cost. The NNI committee outlined instruments and tools for measurement, manipulation, and analysis that will not only support current research activity, but could eventually be used in future production. But without metrology standards and accepted methodologies, how do instrumentation suppliers create the next generation of tools without a means to compare results and verify performance?

Today, researchers, from academia to major government and industrial research centers, are asking instrumentation companies how to make measurements on nanoscale materials and electronics. Everyone is using what tools that are available today. But are the tools, measurement techniques, and available standards being used correctly? How do we know that the measurement results are reflective of the characteristics of the device and have not been influenced by the instrumentation itself? Only now are we beginning to scratch the surface on the types of metrology standards and measurement protocols/methods needed to compare and verify data.

Many challenges lie ahead. Time is critical. The development of accepted instrumentation, metrology standards, methods, and testing structures that will allow for repeatable and verifiable data must be a globally cooperative effort between instrumentation suppliers, international standards organizations, industry, and academia. Once these are in place, startup companies and large corporations will be able to perform incoming inspection so they can be assured that the nanomaterials they purchase are exactly what they are purchasing. Next generation electronics can be manufactured and tested to meet the demands of consumer electronics. Standards will allow organizations, such as those that approve biomedical technologies and pharmaceuticals, to approve new drug delivery and diagnostic systems that Nanotechnology promises. Metrology must be considered an indispensable component of nanotechnology. But only until we have agreed upon metrology standards and methodologies can we then see the economic impact that nanotechnology promises.

This presentation will highlight various electrical measurement challenges associated with low level electrical measurements made on nanoscale devices and components. Examples of measurement errors and

challenges will be highlighted to demonstrate the need for agreed upon standards, methods, and testing fixtures.

Figure 1: Example Characterization Tool for Electrical Measurements and a Nanomanipulation Tool. Nanomanipulation Tool graphic courtesy of Zyvex Corporation.