MANUFACTURING INSIGHTS
Nanometrology

MUSIC AND UNDER:

NARRATION (VO):

MANUFACTURING INSIGHTS, MANUFACTURING ENGINEERING MAGAZINE’S VIDEO SERIES. THIS PROGRAM WILL EXPLORES NANOMETROLOGY.

1. WHAT IS NANOMETROLOGY?
2. WHY IS NANOMETROLOGY IMPORTANT?
3. WHY IS IT DIFFICULT?
4. HOW ARE MEASUREMENTS MADE AT THE NANOSCALE?

ONE NANOMETER IS A BILLIONTH OF A METER—ABOUT THE SIZE OF THREE ATOMS SIDE BY SIDE. MANUFACTURING HAS BEEN WORKING IN THE MICROSCALE WORLD, BETWEEN 1 AND HUNDRED MICRO METERS, ALSO CALLED MICRONS, FOR MANY DECADES NOW. STARTING ABOUT TWO DECADES AGO RESEARCHERS STARTED MOVING INTO THE NANOSCALE WORLD.

MIKE POSTEK:
Nanotechnology is the understanding and control of matter at the nanoscale, basically at the area of between 1 and 100 nanometers, where unique properties often take place. What we’d like to do is be able to measure, be able to image, and understand these materials in order to come up with better products for the future.

NARRATION (VO):

IF YOU CAN’T MEASURE IT, THEN YOU CAN’T BUILD IT. MORE EXACTLY, IF YOU CAN’T MEASURE IT QUICKLY, PRECISELY, AND CHEAPLY, YOU CAN’T SELL A PRODUCT AND STAY IN BUSINESS.

Mike Postek is head of the National Institute of Standards and Technology's Center for Nanometrology:

MIKE POSTEK:
Metrology is very important for nanotechnology. This is something that is obvious from the beginning, because here you're dealing with something that has a defined size range, 1 to 100 nanometers. So the first question is, does the material you're dealing with fit within that size range. If you're talking about something that is maybe 90 nanometers in size, is that nanotechnology? Yes, according to the definition. But what if your measurement uncertainty, or your inability to make a good, accurate measurement of this has an uncertainty of 10 or 20 nanometers. Then you're not real sure what the measurements are. We need to be able to be within 1 nanometer or less when it comes to the accuracy of these measurements in the future. Somewhere along the way we'll be looking at the changes in the properties, and where these properties actually occur within this material, and it may happen at 10 nanometers, or it may happen at 11 nanometers, and we need to know that information.

NARRATION (VO):

MAKING MEASUREMENTS AT THE NANOSCALE IS DIFFICULT FOR A NUMBER OF REASONS. HERE, FOR EXAMPLE, IS AN IMAGE MADE BY A SCANNING TUNNELING MICROSCOPE THAT SHOWS 35 XENON ATOMS THAT WERE IMAGED AFTER BEING PLACED ON FIELD OF NICKEL ATOMS.

NARRATION (VO):

FRED TERRY IS A PROFESSOR OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE AT THE UNIVERSITY OF MICHIGAN ANN ARBOR, AND PART OF THE UNIVERSITY'S NANOFABRICATION FACILITY.

FRED TERRY:

A standard difficulty in building very small structures. We're always trying to build the smallest thing we possibly can, very often using some sort of directed energy. Whether it's light or electron beams or other ways of causing a change in a small area, you're always working at the resolution limits of that instrumentation. Those are the same tools you're trying to use then to measure the structure. You've got an almost automatic problem that the smallest things you build are at a resolution that's very difficult to measure in the first place.

NARRATION (VO):

THE TWO MAJOR TYPES OF MICROSCOPES IN USE TODAY ARE BASED ON EITHER AN ENERGY BEAM MADE UP OF ELECTRONS OR IONS, OR A SCANNING PROBE WITH A SHARP TIP. THE ENERGY BEAM METHODS MAY USE ELECTRONS, SUCH AS IN AN S-E-M – SCANNING ELECTRON MICROSCOPE, AND THE T-E-M – TRANSMISSION ELECTRON MICROSCOPE, OR THEY MAY USE IONIZED ATOMS, SUCH AS IN THE F-I-B –FOCUSED ION BEAM. THE SCANNING PROBES INCLUDE THE S-T-M (SCANNING TUNNELING MICROSCOPY), AND THE A-F-M (ATOMIC FORCE MICROSCOPY). THEN THERE ARE HYBRID APPROACHES SUCH AS THE NSOM - NEAR-FIELD SCANNING OPTICAL MICROSCOPY, WHICH CAN COMBINE THE DIFFERENT METHODS USED BY THESE SCOPES, BASED ON WHAT FUNCTIONALITY THE USER NEEDS.

FRED TERRY:

The physical probes are very important. Without getting caught up too much in semantics, for the most part I would classify AFM's and similar tip-base approaches as excellent laboratory characterization tools. They might not be overtly destructive to the sample, but keeping contamination control at a minimum, they are not likely to ever be manufacturing tools, at least in the sense of sampling large amounts of a manufacturing line.

JOHN MANSFIELD:

SEM, scanning electron microscope. That's where you raster a tightly focused beam of electrons across the surface of the sample, and you look at the secondary electrons that are emitted by the sample as the beam interacts with the sample. The great thing about the scanning electron microscope is it is pretty surface-specific. You get very near surface information, particularly if you use very low voltages. You can do very nice near-surface imaging, so you see the true topography of the surface.

The focused ion beam, or FIB. That grew out of the clean room people wanting to actually do edit and repair of devices. So they have a chip they develop, and it doesn't quite work the way they would like. So they actually use these instruments, the ion beam, to cut into the device, and the gas ejection system to lead a small amount of organometallic into the chamber and write lines. Or some other kind of gas that, when it interacts with the ion beam, it will give them carbon or insulator on the surface. Basically they could write a track, remove a track, write an insulator patch, write a line across it and actually fabricate a little bit of the device, rather than having to start from scratch.

NARRATION (VO):

ANOTHER PROBLEM WITH MEASURING AT THE NANOSCALE IS CONTAMINATION.

FRED TERRY:

Things like vibration or environmental factors, depending on cost, those can be handled. The costs for some of those controls can be prohibitive. But the biggest headache is not getting particulate matter or chemical contaminants onto the object you're trying to measure. That's still something that even in the highly evolved semiconductor industry is a serious headache.

FRED TERRY:

The issue of forces at small scales, both affecting the measurement, those kinds of issues can be real problems. For instance in a tip based measurement a standard headache is how the shape of the tip affects the data you're getting. That unfortunately has, in terms of dimensional and topographic measurements for pattern structures, that has rendered that a very difficult area. Most companies that use that in their R&D laboratories have a devoted PhD expert whose pretty much his whole job is to make sure that the data that comes out of the AFM instruments is really accurately analyzed.

NARRATION (VO):

PROCESS CONTROL IN THE NANOMANUFACTURING ENVIRONMENT DEPENDS ON ACCURATE, PRECISE AND RELIABLE NANOMETROLOGY. ACCURACY IS THE CLOSENESS OF A MEASUREMENT TO AN OBJECTIVE, ABSOLUTE STANDARD. FOR EXAMPLE, THE DISTANCE TO A BULLS EYE. PRECISION, ON THE OTHER HAND, IS THE CLOSENESS THE MEASUREMENTS HAVE TO EACH OTHER. RELIABILITY CAN FURTHER BE SUBDIVIDED INTO REPEATABILITY AND REPRODUCIBILITY.

FRED TERRY:

When I started working in semiconductor process control, the manufacturers viewed that as being in some senses very silly. I'll use Intel as prototypical example. They have this "copy exact" philosophy. Once we get a process nailed down in the research lab, we're going to use the same tools, the same processes, no deviation, lockstep around the world in all our manufacturing. That worked for them extremely well for many years. Now Intel is one of the greatest proponents of more active process control, because at some levels just unavoidable variations get in the way. Almost all microelectronic manufacturers, and these are people working in the 45 nanometer and smaller regime these days, so really nanomanufacturing from a top down perspective. They all use some level of sample test and rework during the front end of the line manufacturing. It has become a problem in that industry that very slight variations in the focus exposure processes in photolithography will lead to line width and shape variations that are unacceptable. So it is standard now to do a high level of lot sampling, checking, and at that point they can strip, recoat, and re-expose. They can rework without damage there. Later in the process that is not achievable..

NARRATION (VO):

DOUG HAHN IS PRODUCT MANAGER OF THE FEI COMPANY'S FABRICATION PRODUCTS FOR METROLOGY.

DOUG HAHN:

The data storage business is an excellent example of where nano metrology is a requirement on a day to day basis. The devices on a write head of a hard disk drive, both the reader and the writer, are approaching 32 nanometers in dimension. These are true nano scale, nanotechnology devices, and they are being produced at huge volumes, measured in the millions. When you're manufacturing that many things, your yield becomes critical. You have to be able to rely on your processes, knowing they are going to produce exactly what you need to achieve the performance on your hard disk drive. What FEI has done is, we have recognized a need in that industry to make measurements that are statistically relevant, that are gage capable at that dimension. We produce tools, automated tools, from advanced technologies like scanning electron microscopes and transmission electron microscopes, that can be used to go measure those devices and produce, with a precision that can be relied upon in order to give you the measurement information, or metrology, you need to control those processes.

NARRATION (VO):

PROCESS CONTROL DEPENDS ON AUTOMATION- NOT ONLY THE ADVANCED INSTRUMENTS THAT MAKE THE MEASUREMENTS, BUT ALSO THE COMPUTERS THAT ARE PROGRAMMED TO CONTROL THEM.

DOUG HAHN:

Software is a critical component in terms of being able to control the metrology process when measuring things at the nano scale. It is almost impossible to make mechanical systems that in and of themselves can stay stable enough or track with things that are this tiny. Things that are tiny, very small movements can have a big impact on the measurements you're trying to make. So what you do, you utilize a combination of hardware and software that can then work together to allow you to keep track of what you're trying to measure, this very tiny, nano scale particle or device. Then that allows you to, in the end, make these measurements. You also need to be able to, if you're going to make measurements in a manufacturing environment, you can't rely on a PhD to sit in front of a tool all day and keep it running. It has to be a typical production engineer or production operator, who runs the tool. So you have to automate these processes. Furthermore, for metrology, people aren't necessarily the most precise. It's difficult for humans to do the same thing the same way all the time. When it comes to metrology, that's the foundation. You have to be able to do the same thing, the same way, all the time, that's precision. By employing software to automate your tools, to automate your systems, you can get the same result time after time, day after day. That gives you the precision you need to be able to rely on the measurements you make.

NARRATION (VO):

RICHARD YOUNG IS A TECHNOLOGIST IN FEI'S NANO ELECTRONICS GROUP

RICHARD YOUNG:

we're seeing the trend over the last few years of people, both within data storage and semiconductor and other areas, putting more of these manufacturing measurement technologies closer to the fab or even in line, so we have examples, particularly in data storage, where people are putting every sample, every wafer, through a metrology tool where they will make a cut and look with the SEM to really understand what they have done. So rather than finding out three weeks later when they are trying to test these samples in a real situation, they can get real time feedback to what the previous process in the manufacturing step did to the sample. Either they can choose to scrap it there and avoid all the expense, or you can rework it or just know that it's still in tolerance but you can make a small change upstream so the next wafers are closer to the sweet spot of your process.

NARRATION (VO):

A NUMBER OF PARAMETERS MUST BE CONSIDERED TO DETERMINE WHETHER THESE ADVANCED INSTRUMENTS ARE APPROPRIATE FOR ONLINE INSPECTION.

RICHARD YOUNG:

The economics have to work out right. For data storage it has worked out where it is worthwhile, given the vast number of devices on a single wafer, where they can go in and sacrifice some number of those samples and inspect them, and then carry on and they know that inspection has not compromised the rest of the sample, and it's valuable data. In other areas, like in semiconductor, they don't tend to do it in line on every wafer, but they tend to do it more as part of the development process of doing what they call short lived wafers, where you just do a few process steps, and inspect what you did, and get a lot of data from that. Then if you have a problem in manufacturing, you'll pull those samples out and make cross sections or TM samples to look at them, and use those electron microscopes to analyze the problem. But you are not doing it to that same level of marking every wafer that comes through.

NARRATION (VO):

THE PROBLEM OF NANOMETROLOGY GETS WORSE WHEN TRYING TO MEASURE LARGE AMOUNTS OF NANOMATERIAL, SUCH AS CARBON NANOTUBES.

FRED TERRY:

If we look at a really challenging problem like carbon nanotubes, where you get semiconducting tubes of different chirality and different band gaps, and some of them are metallic and some are multi-walled, and you can't, at least currently no one seems to have a way of growing them right in the spot where you want to use them. So you get into an issue of how do I measure, sort, and then at least in some context to make use of them in structured systems, how do I pick and place and assemble. Those are big problems.

NARRATION (VO):

NANOMETROLOGY IS VERY IMPORTANT TODAY IN THE SEMICONDUCTOR INDUSTRY. BUT AS OTHER INDUSTRIES BEGIN WORKING AT THE NANOSCALE, NANOMETROLOGY WILL START TO BECOME IMPORTANT IN UNEXPECTED PLACES.

MIKE POSTEK:

…recently cellulose nanocrystals has become a very interesting product. Cellulose nanocrystals are made from the forest products industry, and the forest products industry is a huge industry within the United States, as you might guess. But when it comes to the nano part of it, it's not that huge yet. They have a lot of biomass out there, a lot of leftover land mass from the trees. There's a lot of biomass in your yard, that all have cellulose nanocrystals in them. The cellulose nanocrystals are not as strong as the carbon nanotubes per se, but they can be as useful in other ways. A lot of research is going into that now, but the cellulose nanocrystal is easily obtained, it's easily renewable, it doesn't have any catalysts that have been proven to be carcinogenic in the environment. The cellulose nanocrystal is easily isolated from the material itself. They have processes today that can make it in kilogram quantities also. It has yet to hit the radar screen yet, but soon enough it will.

MIKE POSTEK:

Pharmaceuticals have always been doing nanotechnology if you think about it. They're dealing with chemicals, and chemicals, down at the basic levels, are nanotechnology. That isn't going to change to any great extent, but perhaps the medical aspects of the nanotechnology associated with this will change quite a bit. There will be deep pockets there if you think about it. If, for example, you have a material that somehow conjugated to a new particle that will go in and actually attack a cancer cell, which some early research has shown to be possible, then you're going to have a whole industry built up around that. If you are able to attach a nanoparticles to a magnetic material, which will resonate when you hit it with a certain wavelength of light, that will attach to a cancer cell, and that cancer cell will then be killed because it's heated up, for example. That's another whole area that's up and coming for nanotechnology applications in the medical field. So yes, the pharmaceutical and medical field is a great area as well for potential nanotechnology applications. If they are very successful in attacking some of the big problems associated with human life, there will be a great deal of research money put into those areas, which will then result in the instrumentation being developed.

JOHN MANSFIELD:

The automotive guys have been doing nanometrology for years, because they have been making better and better catalysts for their catalytic converters. So we have a lot of guys here in chemical engineering studying catalysts, and that's where you're in the sub-nano region. Most of those catalysts are in the ballpark of a few angstroms in diameter. An angstrom is a tenth of a nanometer, it's an old fashioned unit. I grew up with angstroms, and it's very difficult for me to actually get away from angstroms. But these days we start talking about the newest microscope we're going to buy will enable us to measure features in the tens of picometers.

NARRATION (VO):

ALL INSTRUMENTATION FOR NANOMETROLOGY OWES IT'S ORIGIN EITHER TO THE MICROSCOPE, WITH WHICH EVERYONE IS FAMILIAR--AND THE PROFILOMETER, WHICH IS NOT AS POPULAR.

PILAR HERRERA-FIERRO:

This is a four inch wafer, and it has some lithograph in it, you can see the patterns. We need to know how thick is the photoresist, which is what makes the pattern. For this we use the profilometer, which is a tool that has a stylus that goes over the surface. You can detect all the imperfections, all the heights and all the deep parts of the surface.

JOHN MANSFIELD:

We've moved from doing profilometry with a fairly crude tip, you could say it was actually like the end of a large toothpick, to doing profilometry on the atomic scale with a tapping mode scanning probe microscope or scanning tunneling microscope, or with a scanning electron beam, and moving from something that can measure resolutions of microns to things that can measure resolutions of nanometers and now sub-nanometers.

RICHARD YOUNG:

We have a series of different products. The first one is the scanning electron microscope, the SEM, and that's basically a system whereby we scan electron beam across the sample surface. We get different signals coming from the sample, and then form an image of the surface. So it's very similar to what you might think of as a CRT tube in your television tube. But rather than using that to form the image, we're actually using that to create different signals as we scan the beam from point to point. And it allows you to get a very highly magnified view of the sample, going from the millimeter scale all the way down to the submicron scale, with nanometer level of resolution.

NARRATION (VO):

THE MAIN DIFFICULTY OF THE BEAM INSTRUMENTS IS THAT THEY GENERALLY REQUIRE HIGH VACUUM ENVIRONMENTS AND SAMPLE PREPARATION.

RICHARD YOUNG:

With an electron microscope you're fundamentally dealing with a particle beam, so it needs to travel in a vacuum. Otherwise it's going to have scatter and it's not going to work very well. So that puts some constraints on the sample you can put in there, but in general they need to be samples that are not going to evaporate or have different materials coming off in that vacuum condition. But there is a lot of expertise built up over time of what samples are suitable. We do have some SEMs called environmental SEMs that allow you to image a sample when you're still using a partial pressure of the water vapor or the gas around the sample. Under those conditions you can deal with essentially hydrated samples, very valuable for biological research and people looking at all sorts of things from hair gel to toothpaste and even bakery goods and things like that. In the environmental SEM you have a lot more flexibility as to some of those kind of vacuum constraints.

RICHARD YOUNG:

Another type of system we have is what we call a transmission electron microscope. That's more like a slide projector, an optical system where you have an electron beam going through a thin sample, and by putting in a series of lenses you can form a very magnified view of the sample, all the way down to the atomic level of resolution. So that allows you to go further than you can in the SEM, but with the constraint that you have to make a thin sample, maybe 100 nanometers or thinner. So you have the issue of, well is my thin sample representative of the bulk. But that's something the TM people have worked about over many tens of years, and we're in a pretty good situation where you can look at a very thin sample and still get a lot of useful information about the bulk sample.

DAVID HORSPOOL:

The main mode in TEM is conventional imaging, what we call bright field TEM. So you get a grayscale image of your sample, but what you see in terms of contrast is highly dependent on the electron specimen interactions. So you can use these images for metrology purposes, making measurements of structures. You can also operate the TEM in other modes. We have a STEM, or Scanning Transmission Electron Microscopy, where you raster the beam, somewhat like a TV or SEM. That's great, because it gives you very accurate position of the beam for chemical analysis. That also gives you an image in a certain mode, it gives you an image based solely on Z contrast, or atomic number contrast. In that case, what you see in the image is easy to interpret. Bright things are heavier elements, darker things are lighter elements.

NARRATION (VO):

THIS ADDED CAPABILITY OF STEM MEANS THAT MANUFACTURING ENGINEERS CAN DO BOTH METROLOGY AND CHARACTERIZATION. IN OTHER WORDS, NOT ONLY CAN THEY MEASURE DISTANCES AND DETECT SHAPES AT THE NANOSCALE, BUT THEY CAN ALSO PRECISELY DETERMINE THE ELEMENTAL COMPOSITION OF THE SAMPLE.

DAVID HORSPOOL:

In terms of what we can measure, from an image perspective you can measure everything you would from a standard image. For semiconductor device structures you can measure critical dimensions, upside or nitride thickness, etc., and you can do this at the atomic level. If you think about other techniques, such as electron diffraction, if you have a crystalline sample, you can then take diffraction patterns of your crystalline material, and you can use those to measure accurate lattice parameters of the material. You can look at interfaces and determine orientation relationships. You can look at straining the materials. Strained silicon is very big in semiconductor. From the diffraction patterns you can get a measure of how strained the silicon is. Then that sets you up for chemical analysis. You can do chemical analysis two ways in TEM. You can do X-ray work, similar to what you would do on the SEM. EDS, or energy dispersive spectroscopy, is the main X-ray technique in the TEM, and that is very suited to heavier elements. The complementary technique is called EELS, electron energy loss spectroscopy, and that works very well for light elements, for example oxides or nitrides. With all these techniques combined, you can get a really good feel for what’s in your sample.

NARRATION (VO):

UNFORTUNATELY, TEM HAS SOME DISADVANTAGES.

DAVID HORSPOOL:

The principal difficulty with TEM is sample preparation. Probably for most work in TEM, 90 percent of it is sample prep, getting a good sample to start with. Historically this is very difficult, because the old ways of sample preparation involved either wedge polishing, where you take a large piece of material and polish it down until it’s electron transparent, and then float it off onto a grid, then to the microscope; or ion milling, and that can be laborious and can result in some sample damage. Both of those techniques are difficult to try to prepare a sample from a specific region. You’re not sure what you’ll get until you put it into the microscope. With modern techniques, like focused ion beam machining, you can see exactly where your sample is in the microscope prior to preparation. It’s also quicker, it’s more efficient, it’s low damage, and we can easily transfer into the TEM for analysis.

DAVID HORSPOOL:

STEM is scanning transmission electron microscopy. In this case you're using a very fine probe and rastering it across your sample, somewhat like using SEM. That gives you a great setup for chemical analysis, because you have a very fine probe that you can carefully position on a sample. And you can make use of the imaging technique in one particular mode, which is called Z contrast imaging. Then the image you see is heavily dependent on the atomic number of the sample.

DOUG HAHN:

In the data storage industry, again with hard disk drives, the write head, the way it's manufactured, its dimensions and its geometries, the angles and sizes, are critical to the way the end hard drive performs. The problem is, the way these devices are shaped, from the surface you can't just look directly at the device and make a measurement. You have to cut into the wafer and look at the devices at an angle in order to make the measurements of the various geometries. What we have at FEI is a combination of SEM, scanning electron microscope technology, and focused ion beam, or FIB technology. We use the FIB, where the ions have mass, to dig a hole in the wafer, and then look inside that wafer and take an image with the SEM. Then through automated software and machine vision we do automated measurements on the structures inside the wafer. I would say this pretty much revolutionized the write head production process, the wafer process, for producing that portion of the hard disk drive in the data storage industry, because it allowed them to take a process that had relatively poor yield, make measurements, go back and rework wafers, and then drive that yield up to an acceptable level to where their profitability was suitable to their business needs.

The CD STEM is the next generation of that same sort of process that we used for hard drive metrology. Instead of using a SEM, we now use a STEM or TEM tool. The STEM is capable of atomic resolution, so this will allow us to go from the 60 down to 30 nanometer range, which we can do with our dual beams, to 10, maybe even 5 nanometer structures, which really puts us out 5 and 10 years from now being able to remain gage capable on very small structures. What we have done is coupled our focused ion beam technology to create these samples that then get moved into the STEM tool and get automatically imaged and measured. It's the automation of the STEM which is really a historical achievement. STEMs and TEMs typically have been run by PhD's, and it is a very complex tool to be able to operate and understand. We have automated the entire process, so that it can be done extremely repeatedly ,and now we can approach reproducibilities at the 1 angstrom level, much smaller than the size of an atom.

DAVID HORSPOOL:

Tomography is a great technique for getting a 3D visualization of your sample. The way it works, you take multiple images from your sample, usually over a wide tilt range. You can tilt your sample in the holder. Usually you go from, say, +70 deg to -70 deg in a certain increments. Then you take all these images, or slices if you will, and then use offline software to reconstruct them into a volume. So then you have a volume of information. You can take that and visualize it, and then basically you have basically a simulation of your material. You can interact with it, you can drag it, and move it around, and really get an idea of how your sample exists in three dimensions. And of course from that you can make measurements of particles in three dimensions, layers, etc.

DAVID HORSPOOL:

I think it's hard sometimes to interpret the images. With TEM it can be difficult in some cases to know what you've got without complementary information. Say, for example, from a bright field TEM image, which is essentially a grayscale image formed from numerous contrast mechanisms. Unless you have a thorough understanding of your sample material and the contrast mechanisms that generated it, it's hard to definitively interpret it sometimes. So you need chemical analysis data to back up the fact that you think that particle is made of "X", say. Then information from other techniques, such as SEM, to really give you an idea of what the sample is like in bulk. So if you think of the TEM, the largest thing you can put in the TEM is a 3-millimeter diameter sample, and of that sample you're looking at a very tiny fraction that's electron transparent usually. So you really need complementary techniques such as SEM and X-ray analysis from other instruments to make a full analysis of your sample.

NARRATION (VO):

THE FUTURE OF NANOMETROLOGY IS UNKNOWN, BUT RESEARCHERS HOPE THAT THEY CAN

PREDICT IT IN THE BEST POSSIBLE WAY: BY MAKING IT HAPPEN.

FRED TERRY:

My research emphasis is very much on what's referred to these days as top-down nanofabrication, where we intentionally impose our will on nature, if you will. I'm perhaps too publicly on record of believing that the top-down processes are going to be the dominant ones that are used for highly structured systems. I may suffer serious foot in mouth disease, but I'm not a believer that self assembly based processes, in the short term, are going to produce very highly complicated structured systems. Certainly if you pick the absurd example of a microprocessor, programming that in a self assembled fashion seems to me like science fiction, or at least going very far out into the future. If somebody beats me on that, that's great, I'll be happy. I'll be red faced, but I'll be happy.

RICHARD YOUNG:

In SEMs and jewel beams, you can put in a tensile stage to actually test and pull a sample. You can break it in the system and see what happens there. You can do electrical probing in the system. You can also do a certain amount of chemistry in there. There is a new TM called the E-TM where you can do a sort of chemistry with the transmission electron microscope watching the reactions going on. So the fact that you can add more things to the tool is kind of how people have found ways of increasing the value of the tools in the past, and that will continue into the future. More different types of accessories, so you go from not just a jewel beam, but you have other accessories and widgets on the tool to allow you to do more investigation. One of the key things we have seen is the ability to get multiple data on a single point on the sample. Rather than plotting three different pieces of data, but they're all from wildly different areas of the sample, so you're not really sure how they're correlated. Having the ability to go in an collect analytical data and other measurement data out of the same area by multiple techniques, I think is very valuable and very powerful, to really understand what's going on. If you can really understand what's going on at this nanoscale, then you have a better chance of replicating and manufacturing.

DOUG HAHN:

It's actually hard to imagine what we will need to be able to measure repeatedly when it's much smaller than a quarter of the diameter of the atom. What physically will people be creating that will have to have reproducibilities that are approaching the size of almost an electron. One thing I'm certain of is that as the need arises for making measurements at smaller and smaller scales, those of us that deal in technologies that actually can see a quarter of an angstrom or smaller, that kind of physical dimension, will continue to develop whatever solutions necessary.

NARRATION (VO):

IN CONCLUSION, ANY SERIOUS MARKET PENETRATION BY NANO-ENABLED PRODUCTS, AND ANY FUTURISTIC VISIONS OF NANOTECHNOLOGY WILL NEED TO DEPEND ON ADVANCES IN INSTRUMENTS THAT CAN MEASURE FEATURES BETWEEN ONE AND A HUNDRED NANOMETERS, QUICKLY, PRECISELY, AND INEXPENSIVELY. AS NANOTECHNOLOGY EXPANDS FROM THE ELECTRONICS INDUSTRY INTO AEROSPACE, BIOMEDICINE, AUTOMOTIVE, PHARMACEUTICALS, AND FORESTRY, ENGINEERS MUST FAMILIARIZE THEMSELVES WITH THE MANY TECHNIQUES AND INSTRUMENTATION FOR MEASURING THE NANOSTRUCTURES THEY HAVE BUILT.

FADE TO BLACK

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For further information and discussion on this subject visit the SME website at www.sme.org/nano and join the Nanomanufacturing Group, which is part of SME’s Rapid Technologies Technical Community Network.