Notes for Nanotechnology Products and Career Presentation

Slide 1 – Pennsylvania State University Copyright

Slide 2 – Intro

Slide 3 – Outline of presentation

Slide 4 - You can either have students write this down or have a class discussion on this. Ask them what is the smallest thing they can think of. Depending on the age of the students they may say atoms and electrons. Respond that this is where nanotechnology happens – at the level of atoms and molecules. Younger students may respond with a grain of sand, a flea, etc. Tell them nanotechnology happens even smaller than this. Then go to the next slide for a discussion of the definition.

Slide 5 - It is an exciting area of science and engineering that occurs at the atomic, molecular level. This interdisciplinary field occurs at the 1-100 nanometer range. Nanotechnology is the science and technology of small things – in particular things that are less than 100nm in size. One nanometer is 10-9 meters or about 3 atoms long. Scientists have discovered that materials at small dimensions—small particles, thin films, etc- can have significantly different properties than the same materials at larger scale. There are thus endless possibilities for improved devices, structures, and materials if we can understand these differences, and learn how to control the assembly of small structures.
There are many different views of precisely what is included in nanotechnology. In general , however, most agree that three things are important:

- Small size, measured in 100s of nanometers or less
- Unique properties because of the small size
- Control the structure and composition on the nm scale in order to control the properties.

What is new about nanotechnology is that we can now, at least partially, understand and control these structures and properties to make new functional materials and devices. We have entered the era of engineered nanomaterials and devices.

Slide 6 - Nanotechnology is not new. Medieval artists ground down gold and silver into fine particles to make the salts used in stain glass. They did not know why fine particles of gold gave them the wonderful colors we see in the stained glass windows they created but they knew how to get those colors. As we will learn later, gold behaves differently at the nanoscale.

Slide 7 - Nanoscale research is possible because of the development of tools that allow us to see and manipulate matter at the nanoscale. These tools allow us to understand what occurs at the nanoscale and to control materials in ways not possible before.

Slide 8 - This slide introduces one of the tools used in nanotechnology. A description of how the tool works is included and you can use as much detail as you want to describe how the AFM works. The simplest explanation is that this tool allows us to "see" things at the atomic scale as well as move individual atoms. We

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do not actually see the atoms but use the force to determine what is at the nanoscale. The far right picture represents IBM spelled out by moving and placing individual atoms of xenon.

The Atomic Force Microscope (AFM) is a relatively new type of scanning probe instrument. These instruments see things by "feeling" the surface with a very tiny tip on the end of cantilever (see middle picture on slide). The tiny tip is only a few atoms wide (sometimes even 1 atom). It acts similar to moving your finger across a surface – a rough surface like dirt in your yard moves your finger up and down as you travel across it. A smooth surface, like the fabric of running shorts, lets your finger glide over it easily. As the tip moves across the surface it is pushed up and down (by the atomic forces), which move the cantilever, and a laser inside the AFM measures this movement. Essentially the tip is measuring the forces between atoms. The AFM use computers to convert the information from the tip's trip across the surface of the sample to make a three-dimensional view of the object, kind of like a topographic map in 3-D.

With an atomic force microscope we can "see" things as small as individual atoms and even manipulate atoms.

Slide 9 - An overview slide of where nanometer fits on the scale of measurement. It is 10-9 or one billionth of a meter.

Slide 10 - Ask the students to predict the size of these items. They can do this as a class discussion or as an actual measurement exercise.

Student height 4' = 1.22m; 4'6" = 1.37m; 5' = 1.52m; 5'6" = 1.68m; 6' = 1.82m
Pencil diameter is approximately 0.7 cm
A dime is 1.35mm in thickness
Hair diameter is about 70 microns (range is 50-100)
DNA is 2-3 nm (2.5 for the average width and)
Atoms are about 1-4 angstroms in diameter (100-400 picometers 10-12)

Slide 11 - How do we see and measure things? At the meter and centimeter level we can use our eyes, a ruler, or a caliper. At the millimeter scale we begin to need to use an optical microscope like the ones in school. We can see a leaf with our eyes but to see what the surface looks like we need something more powerful like a microscope. At the micrometer level we begin to need to use electron microscopes and the AFM for things at the atomic level

Slide 12 - Ask the students to provide some guesses before clicking on the question to reveal the answer. Answer is 21.1 years.

Slide 13 - The Powers of Ten is a wonderful exploration of the concept of scale developed by Charles and Ray Eames using images from space down to the angstrom level – a wide range of scale is presented in a series of images You may want to use the links to explore size further during the presentation or direct students to do so on their own.

Slide 14 - Ask the students what are the forms of carbon. They should say graphite (softest) and diamond (hardest). These are the two most commonly known allotropes of carbon. A recently discovered allotrope is Carbon 60 also known as buckyball. This form of carbon was discovered by Richard Smalley and Bob Curl of Rice University and by Harry Kroto then at the University Sussex in England (not at Florida State University). They were actually using Smalley's equipment (a laser that vaporized materials into atomic clusters) to reproduce a material found in deep space that was carbon based. These researchers won the Nobel Prize in

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Chemistry in 1996 for this discovery. C-60 is called a buckyball (short for buckminsterfullererne) because it resembles the geodesic dome designed by Buckminster Fuller. When buckballs are formed another version is created called the carbon nanotube (CNT) (a lattice of carbon atoms formed as a cylinder. They are essentially buckyballs that never close to form a sphere.

We all know that graphite is soft (think of a pencil) and diamond is very hard so what about C 60? CNTs are about 100 times stronger than steel and 6 times lighter in weight. They can be metallic or a semiconductor, depending on the form of the CNT. Researchers are now trying to make these into longer particles (currently the longest is measured in mm).

Slide 15 - As noted, materials behavior differently at the nanoscale and gold is an excellent example. Earlier we noted that gold salts gave stained glass its different colors. Gold at the nanoscale has different optical absorption properties which differ with size of the gold particle. This variation in optical property with size gives gold a wide range of colors as noted in the picture on the right.

Slide 16 - The field of nanotechnology is wide open for discovery as we have the entire periodic table to explore with our new tools and capabilities.

Slide 17 - We are now moving from the world of microelectronics to the world of nanoelectronics. Computers are getting smaller and there capabilities are increasing. In 20 years we have gone from the bulky car cell phone to the portable cell phone that is often smaller than the palm of your hand. These cell phones can schedule an appointment, surf the web, play video clips, play music, and also make phone calls!

Slides 18 - Who likes to get a shot at the doctor's office? The needle on the left is a needle used for injections. The one on the right shows the new version within the "normal" needle. Researchers are creating arrays of these micro-needles that will fit on a patch which will be placed on your skin to inject the medicine into your body without the pain you typically experience with a shot.

Buckyballs are being explored for use in drug delivery. Drugs are centered inside the buckyball and based on the pH of the infected cells, the buckyball will attach to the cell and the drug will be delivered directly to the infected cell. Several pharmaceutical companies and university researchers are exploring buckyball use for targeted drug delivery.

Slide 19 - Nature has been "doing" nano for a very long time. Biomimetics is how we can mimic nature in developing new materials and products. Velcro is an excellent of a product developed on the hook and loop method of attachment for cockleburs. Don't you wish you had looked a little more closely on how they stick to your clothes?

The gecko's foot has been the center of much research. Geckos can run vertically or even upside down on smooth surfaces such as glass. It was assumed that the foot had a sticky substance that allowed for such movement. But how could they make it stick and un-stick to walk across the glass so quickly? In fact, it is not an adhesive but numerous tiny hairs on the gecko's foot which are subdivided into even tinier hairs at the nanoscale which create a very rough surface. These interact with the atoms of the surface on which the gecko is standing by a force called "van Der Waals" which is a weak force of attraction. But when you add up all the millions of hairs and therefore points of contact, the force becomes strong enough to support the gecko's walking habits. Researchers are now making tape based on this property. Will we soon be able to walk walls like Spiderman?

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Slide 20 - At this point in the presentation you will hand out to students the student activity sheet. Tell them that they will now explore products that are currently available to consumers. Go to the next slide and indicate the directions which are also on their sheets.

Slide 21 - Leave this slide up during the nanoproducts exploration.

Slide 22 - The next few slides show products influenced by nanoscience research.

As mentioned before, the electronics industry is getting smaller and faster all the time. Computer chips pictured above contain millions of transistors to run a variety of electronic devices including computers, digital cameras, memory sticks, and traffic lights. Light Emitting Diodes (LEDs) found in traffic lights and display boards are the product of micro and nano-electronics research.

Slide 23 - Medical and pharmaceutical products are important areas where nanoscience is being used to create new methods, resources, and products.

Top left to bottom right: Textured surfaces used to grow mono-layers of epithelial cells for burn victim patients; The second picture represents the field of MEMs; silver bandages to prevent infection, calcium phosphate coated titanium structures for broken bones and implants; Mass spectrometry plates for use in the pharmaceutical industry and drug development; diabetic biocapule that houses insulin producing cells used to regulate sugar levels in blood stream; Radiation therapy capsule that combines silver and iodine 125 to produce a radioisotope and inhibit the growth of tumor cells; smart catheters that use ultrasound to locate narrowed arteries for stent deployment; humidity sensor used to monitor the breathing status of patients and may be used in home sleep apnea kits, stents that are coated with thin films of time releasing drug molecules; and microneedles.

Slide 24 - As we saw in the nanoproducts activity, there are several consumer products on the market that use nanotechnology.
Top row – Nano tennis racket with either titanium nanoparticles or carbon nanotubes to provide strength; magnetic thin films on money and some inks display interference properties for anti-counterfeiting properties ; Nanoparticles added to paint for a stronger finish or a finish that cleans easily; clothing with coated fibers to resist spills and wrinkles.

Bottom row – tennis balls with a double coating of nano-sized particles to prevent air loss, sunscreen with nano-sized particles of zinc oxide that are translucent; car tires can use the same air defense coating as the tennis balls; pregnancy testing that contains gold nanoparticles that aggregate with exposed to hormones present when pregnant…is a "lab on a chip"; sunglasses with shape memory alloys that maintain there shape due to the bodies temperature; car wax with nanoparticles that penetrate scratches; and facial cream with nanoparticles that deeply penetrate the skin.

Slide 25 - Have a discussion with the students how shrinking electronics with increased capabilities have changed the communications industry, television, computers, and video games.

Slide 26 - This begins a section on encouraging students to consider education that leads to careers in science, math, engineering, and nanotechnology

Slide 27 - An overview slide of why they should consider this area.

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Slide 28 - The amount invested by the U.S. government on nanotechnology in 2006 was approximately $1.3 billion. For current funding levels go to http://www.nano.gov. In 2009 it was >1.4 billion.

Slide 29 - That is nearly 1 million new jobs in the US by 2015 for one area of technology. It is expected to be a > 2.0 trillion part of our economy by 2015. (source Lux Research)

Slide 30 - Industry – large and small companies; universities – not just the big research universities; national labs like Brookhaven, Sandia, Oak Ridge

Slide 31 - Homeland security and military applications are also big areas for applying nano to real world problems. MIT has the Institute for Soldier Nanotechnologies (http://web.mit.edu/isn/).

Slide 32- Not all careers in nanotechnology are focused on nano research. Many ancillary industries and companies will be involved.

Slide 33 - A cleanroom is a laboratory where the air is filtered to create a super clean environment. The picture shows a hair placed on top of a chip being made in a cleanroom. Such contaminants would destroy the nanoscale work because of their relatively large size. It is very important to keep particles from the body and clothing off of the materials being processed in the cleanroom as well as any other particulates that might be in the air.

To see real time video of a cleanroom go to http://grover.mirc.gatech.edu/cameras

Slide 34 - Parts of a cleanroom suit that is required of all who work with the facility.

Slide 35 - Nanotechnology is an interdisciplinary field. It is where biology, chemistry, physics, and engineering interconnect. Engineers will need to know the basic sciences and scientists and medical researchers will need to have an understanding of engineering.

It is evident that we will need to develop a trained workforce to meet the more than 1 million employment opportunities that will occur over the next decade. The need for a skilled workforce to meet this challenge has been highlighted in two recent reports; *Innovate America* (Council on Competitiveness, 2004) and *Assessing the Capacity of the U.S. Engineering Research Enterprise* (National Academy of Engineering, 2005). The economic importance of nanoscience and nanotechnology has not yet been fully realized. The two reports noted here stressed the critical importance of technological innovation in U.S. competitiveness, productivity, and economic growth. Nanotechnology is seen as one of these technologically important fields and as noted in the *Innovate America Report,* "nanotechnology could impact the production of virtually every human-made object." It is important that students be aware of the educational and career opportunities awaiting them.

Slide 36 - Explain to students that they can enter this field with training at several different levels and that you do not need to be a research scientist with a doctorate to work in nano. The state of Pennsylvania is an excellent example of a statewide program that encourages students to gain two year degrees to work in nanotechnology research labs and industries.

Slide 37 - Additional areas are homeland security and military research and development. You can refer students to MIT's Institute of Soldier Nanotechnology as noted in an earlier slide.

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Slide 38 - Ask students if they had even heard of nano education or thought about working in this field? Did they think you had to have a Ph.D. to work in nano?

These are just some of the sites that provide information on programs. An extension to this unit is to have students explore career and educational opportunities at the additional sites listed in the extension and in the next slide.

Slide 39 - Additional resources focused on workforce issues.

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