Lesson 5:
Applications of Nanoscience

Student Materials

Contents

What's New Nanocat? Poster Session: Student Directions

Overview

When scientists want to share their findings and proposals with other scientists, they often do it at a national meeting with scientists who have the same interests. They often share ideas at what is called a *poster session*. The scientists come to the meeting with a poster that explains in *text and graphics* what their findings or proposal is all about. The poster is usually either a rolled up paper about 4 feet long and 2.5 feet wide, or a set of 8-12 normal (letter size) printed pages that they tack up on a board. They stand near the poster and as others walk by, they discuss their work with the other scientists and answer questions.

Your Assignment

You will assume the role of a prominent nanoscientist working on a new nanotechnology application, and explain the proposed usage of the new technology to replace a current technology in a poster session. You will be given a list of nanotechnology applications (based on what we have discussed in class) from which you can choose, or you can prepare a poster on an application that is not on the list if your teacher approves it. The posters will be displayed in class and you will explain the technology by explaining the poster. Your classmates will assess your poster, and you will assess their posters, using the Poster Feedback Sheet.

Your poster must include the following:

1. A written description of the current technology and how it is used, and how it works.
2. At least one picture or diagram that helps illustrate how the current technology works.
3. A written description of the new, related nanotechnology, how it is proposed to be used, and how it works.
4. At least one picture or diagram that helps illustrate how the new nanotechnology works.
5. A written description of the implications of the new nanotechnology: how it will help improve understanding, solve a problem, and possible ethical or societal issues.

At the poster session, be prepared to discuss the applications and answer questions, so that someone visiting the poster will walk away with a good understanding of the science.

Grading

To receive full credit,

1. Your poster must include all of the elements mentioned above.
2. Your written descriptions and diagrams must have a sound scientific basis.
3. Your design should be neat and have an attractive layout.
4. All text and borrowed diagrams must have source citations.
5. Your oral explanation must be clear and understandable, all team members must participate, and you should be able to answer questions about the poster and how you created it.

What's New Nanocat? Poster Session: Student Topic List

Stain Resistant Clothes

Manufacturers are embedding fine-spun fibers into fabric to confer stain resistance on khaki pants and other products. These "nanowhiskers" act like peach fuzz and create a cushion of air around the fabric so that liquids bead up and roll off. Each nanowhisker is only ten nanometers long, made of a few atoms of carbon. To attach these whiskers to cotton, the cotton is immersed in a tank of water full of billions of nanowhiskers. Next, as the fabric is heated and water evaporates, the nanowhiskers form a chemical bond with cotton fibers, attaching themselves permanently. The whiskers are so tiny that if a cotton fiber were the size of a tree trunk, the whiskers would look like fuzz on its bark. Nano-resistant fabric created by NanoTex is already available in clothing available at stores like Eddie Bauer, The Gap, and Old Navy. This innovation will impact not only khaki wearers, but also dry cleaners who will find their business declining, and detergent makers who will find less of their project moving off the shelf. Nanoparticles (e.g., of silver) could also be introduced to destroy microbes and create odor-resistant cloths.

More information:

- Fancy pants: http://www.sciencentral.com/articles/view.php3?article_id=218391840&cat=3_5
- Nano fiber finishing: http://www.textileinfo.com/en/tech/nanotex/page02.html
- Odor-resistant products: http://www.physorg.com/news1373.html

Paint That Resists Chipping

On cars, special nanopaints that hold up better to weathering, are more resistant to chipping and have richer and brighter colors than traditional pigments. The paints contain tiny ceramic particles added to a liquid clearcoat. The particles link and create a very dense and smoothly structured network that provides a protective layer.

More information:

- Mercedes-Benz Nano Paint (3 page article on benefits, material, and paint process): http://www.auto123.com/en/info/news/news,view.spy?artid=21942&pg=1
- Nanotechnology improves paint gloss: http://www.canadiandriver.com/articles/jk/040407.htm
- Mercedes tougher, shinier nanopaint: http://www.supanet.com/motoring/testdrives/news/40923/

Paint That Cleans the Air

Chinese scientists have announced that they have even invented nanotech-based coating material that acts as a permanent air purifier. If the coating proves to be effective at air cleaning, it will be gradually used on buildings across Shanghai in order to improve the city's air quality. The core of the material is a titanic-oxide-based compound that comprises particles at nanoscale achieved by advanced nanotechnology. Exposed under

sunlight, the substance can automatically decompose the major ingredients that cause air pollution such as formaldehyde and nitride.

More information:

- Paint to help clean and purify the air: http://english.eastday.com/eastday/englishedition/metro/userobject1ai710823.html
- New pollution paint will clean the air: http://www.edie.net/news/news_story.asp?id=8025&channel=0
- Smog-busting paint: http://www.ananova.com/news/story/sm_862568.html?menu=news.latestheadlines

Painting On Solar Cells

Enough energy from the sun hits the earth every day to completely meet all energy needs on the planet, if only it could be harnessed. Doing so could wean us off of fossil fuels like oil and provide a clean energy alternative. But currently, solar-power technologies cost as much as 10 times the price of fossil fuel generation. Chemists at U.C. Berkeley are developing nanotechnology to produce a photovoltaic material that can be spread like plastic wrap or paint. These nano solar cells could be integrated with other building materials, and offer the promise of cheap production costs that could finally make solar power a widely used electricity alternative. Current approaches embed nanorods (bar-shaped semiconducting inorganic crystals) in a thin sheet (200 nanometers deep) of electrically conductive polymer. Thin layers of an electrode sandwich these nanorod-polymer composite sheets. When sunlight hits the sheets, they absorb photons, exciting electrons in the polymer and the nanorods, which make up 90 percent of the composite. The result is a useful current that is carried away by the electrodes. Eventually, nanorod solar cells could be rolled out, ink-jet printed, or even painted onto surfaces, so that even a billboard on a bus could be a solar collector.

More information:

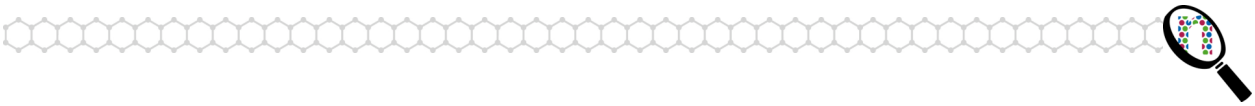
- Painting on solar cells: http://www.californiasolarcenter.org/solareclips/2003.01/20030128-6.html
- Cheap, plastic solar cells may be on the horizon: http://www.berkeley.edu/news/media/releases/2002/03/28_solar.html
- New nano solar cells to power portable electronics: http://www.californiasolarcenter.org/solareclips/2002.04/20020416-7.html
- Our energy challenge: http://smalley.rice.edu/

High Density Storage Media

New nanomedia could have a storage density that is a million times higher that current CDs and DVDs. Nano storage applications currently in development use a variety of methods, including self-assembly.

More information:

- Franz J. Himpsel's web site: http://uw.physics.wisc.edu/~himpsel/nano.html



- Nanoscale memory: http://uw.physics.wisc.edu/~himpsel/memory.html
- Nanoscale memory developed at ASU: http://www.asu.edu/feature/nanoscale.html
- IBM's Millipede project demonstrates trillion-bit data storage density: http://domino.research.ibm.com/comm/pr.nsf/pages/news.20020611_millipede.html
- IBM puts new spin on nano-storage: http://news.zdnet.com/2100-9584_22-934825.html
- Nanoscale memory builds itself: http://www.betterhumans.com/News/news.aspx?articleID=2003-12-09-5

Smaller Devices and Chips

A technique called nanolithography enables us to create much smaller devices than current approaches. For example, dip pen nanolithography is a 'direct write' technique that uses an AFM to create patterns and to duplicate images. "Ink" is laid down atom by atom on a surface, through a solvent—often water.

More information:

- AFM Oxidation nanolithography http://www.ntmdt.ru/SPM-Techniques/Principles/Lithographies/AFM_Oxidation_Lithography_mode37.html
- Dip pen nanolithography (DPN): http://www.chem.northwestern.edu/~mkngrp/dpn.htm
- Improved DPN through thermal dip pen nanolithography: http://www.voyle.net/Nano%20Research%20200/research00110%20.htm

Hybrid Neuro-Electronic Networks

Researchers are studying the electrical interfacing of semiconductors with living cells—in particular, neurons—to build hybrid neuro-electronic networks. Cellular processes are coupled to microelectronic devices through the direct contact of cell membranes and semiconductor chips. For example, electrical interfacing of individual nerve cells and semiconductor microstructures allow nerve tissue to directly communicate their impulses to computer chips. This research is directed (1) to reveal the structure and dynamics of the cell-semiconductor interface and (2) to build up hybrid neuro-electronic networks. Other researchers have built a cyborg, a half-living, half-robot creature that connects the brain of an eel-like fish to a computer and is capable of moving towards lights. Such research explores the new world at the interface of the electronics in inorganic solids and the ionics in living cells, providing the basis for future applications in medical prosthetics, biosensorics, brain research and neurocomputation. For example, neuro-electronic networks could lead implants that can restore sight.

More information:

- Nanopicture of the day from Peter Fromherz: http://www.nanopicoftheday.org/2003Pics/Neuroelectronic%20Interface.htm
- Max Planck research: http://www.biochem.mpg.de/mnphys/
- Lamprey cyborg: http://www.sciencenews.org/articles/20001111/fob4.asp

Detecting Disease with Quantum Dots

Quantum dots are small devices that contain a tiny droplet of free electrons, and emit photons when submitted to ultraviolet (UV) light. Quantum dots are considered to have greater flexibility than other fluorescent materials, which makes them suited for use in building nano-scale applications where light is used to process information. Quantum dots can, for example, be made from semiconductor crystals of cadmium selenide encased in a zinc sulfide shell as small as 1 nanometer (one-billionth of a meter). In UV light, each dot radiates a brilliant color.

Because exposure to cadmium could be hazardous, quantum dots have not found their way into clinical use. But they have been used as markers to tag particles of interest in the laboratory. Scientists at Georgia Institute of Technology have developed a new design that protects the body from exposure to the cadmium by sealing quantum dots in a polymer capsule. The surface of each capsule can attach to different molecules. In this case, they attached monoclonal antibodies directed against prostate-specific surface antigen, which is found on prostate cancer cells. The researchers injected these quantum dots into live mice that had human prostate cancers. The dots collected in the tumors in numbers large enough to be visible in ultraviolet light under a microscope. Because the dots are so small, they can be used to locate individual molecules, making them extremely sensitive as detectors. Quantum dots could improve tumor imaging sensitivity tenfold with the ability to locate as few as 10 to 100 cancer cells. Using this technology, we could detect cancer much earlier, which means more successful, easier treatment.

More information:

- Quantum dots introduction: http://vortex.tn.tudelft.nl/grkouwen/qdotsite.html
- Lawrence Livermore Labs work in quantum dots: http://www.llnl.gov/str/Lee.html
- Quantum dots light up prostate cancer: http://www.whitaker.org/news/nie2.html
- Quantum Dots. Cientifica White Paper. http://nanotechweb.org/dl/wp/quantum_dots_WP.pdf

Growing Tissue to Repair Hearts

Cardiac muscle tissue can be grown in the lab, but the fibers grow in random directions. Researchers at the University of Washington are investigating what type of spatial cues they might give heart-muscle cells so that they order themselves into something like the original heart-muscle tissue. Working with one type of heart muscle cell, they have been able build a two-dimensional structure that resembles native tissue. They use nanofibers to "instruct" muscle cells to orient themselves in a certain way. They have even able to build a tissue-like structure in which cells pulse or 'beat' similar to a living heart.

More information:

- University of Washington cardiac muscle work: http://www.washington.edu/admin/finmgmt/annrpt/mcdevitt.htm
- The heart of tissue engineering: http://www.coe.berkeley.edu/labnotes/1202/healy.html

Preventing Viruses from Infecting Us

If we could cover the proteins that exist on the influenza virus, we could prevent the virus from recognizing and binding to our body cells. We would never get the flu! A protein recognition system has already been developed. More generally, this work suggests that assembled virus particles can be treated as chemically reactive surfaces that are potentially available to a broad range of organic and inorganic modification.

More information:

- Virus nanoblocks http://pubs.acs.org/cen/topstory/8005/8005notw2.html
- Nanotechnology could block viruses from entering cells: http://www.betterhumans.com/Errors/index.aspx?aspxerrorpath=/Nanotechnology_Could_Block_Viruses_from_Entering_Cells.Article.2003-03-20-1.aspx

Nanobots Making Repairs to the Body

Nanobots are decades off, but if they are developed someday, they could be used to maintain and protect the human body against pathogens. For example, they could (1) be used to cure skin diseases (embedded in a cream, they could remove dead skin and excess oils, apply missing oils), (2) be added to mouthwash to destroy bacteria and lift plaque or tartar from the teeth to be rinsed away, (3) augment the immune system by finding and disabling unwanted bacteria and viruses, or (4) nibble away at plaque deposits in blood vessels, widening them to prevent heart attacks.

More information:

- Nanorobots: medicine of the future: http://www.ewh.ieee.org/r10/bombay/news3/page4.html
- Robots in the body: http://www.genomenewsnetwork.org/articles/2004/08/19/nanorobots.php
- Drexler and Smalley make the case for and against molecular assemblers http://pubs.acs.org/cen/coverstory/8148/8148counterpoint.html

Drug Delivery Systems

Nanotubes and buckyballs could serve as drug delivery systems. Researchers have attached florescent markers and proteins to nanotubes and mixed them with living cells. They can see (from the florescent marker) that the nanotubes enter the cell, and could "deliver" the protein inside the cell. The nanotubes don't seem toxic to the cell, so far, but lots more research to be done. Similarly, investigators anticipated that buckyball or fullerene-related structures could serve as "cages" for small drug molecules.

More information

- Tiny weapons with giant potential: http://www.mult-sclerosis.org/news/Jul2002/NanobombsDeliveringDrugs.html
- Amino groups link up with carbon nanotubes: http://nanotechweb.org/articles/news/2/3/1/1
- Buckymedicine: http://www.sciencenews.org/articles/20020713/bob10.asp

Self-Cleaning Surfaces

Self-cleaning surfaces (e.g., windows, mirrors, toilets) could be made with bioactive coatings. Researchers have already developed water-repellent surfaces that could lead to self-cleaning glass. This surface mimics the surface of the water lily, which is waxy and covered with tiny bumps, so water rolls off. There are spray coatings that currently exist that make glass self-cleaning, but these coatings wear off. Nanotechnology would build this new surface into the surface of the window, so it would work for the lifetime of the window.

More information:

- Bumpy glass could lead to self-cleaning windows: http://www.voyle.net/Future%20Technology%202005/Future%202005-0006.htm
- Yes, it's true: Windows that clean themselves: http://www.clarkpublicutilities.com/Residential/TheEnergyAdviser/Archives2004/04_10_17
- ABC News: Scientists develop self-cleaning windows: http://abcnews.go.com/Technology/DyeHard/story?id=440893&page=1

Food Storage and Manufacturing

Nanocomposites for plastic film coatings used in food packaging could detect or even prevent contamination in food or food packaging. This could enable wider distribution of food products to remote areas in less industrialized countries.

More information:

- Food manufacture: A mini revolution: http://www.foodmanufacture.co.uk/news/fullstory.php/aid/472/A_mini_revolution.html
- Coating process could revolutionize food packaging: http://www.bakeryandsnacks.com/news/news-NG.asp?id=50325
- Hungry for nano: The fruits of nanotechnology could transform the food industry: http://www.findarticles.com/p/articles/mi_m1200/is_13_166/ai_n6366589

Water Treatment

Nanotechnology could lead to advanced water-filtering membranes that could purify even the worst of wastewater. Only about 1 percent of the water in the world is usable (97 percent is saltwater, and two-thirds of the remaining fresh water rest is ice). With the world population expected to double in 40 years, over half the world population could face a very serious water shortage in that time. Even now, 10,000 to 60,000 people die every day because of diseases caused by bad water. Advanced nanomembranes could be used for water purification, desalination, and detoxification, nanosensors could detect contaminants and pathogens, and nanoparticles could degrade water pollutants and make salt water and even sewage water easily converted into usable, drinkable water.

More information:

- Nano world: Water, water everywhere nano: http://www.wpherald.com/storyview.php?StoryID=20050318-112217-1110r
- Nanowater: http://www.nanowater.org/nano.htm
- Wired News: Water filters rely on nanotech: http://www.wired.com/news/technology/0,1282,65287,00.html

Health Monitoring

Several nano-devices are being developed to keep track of daily changes in patients' glucose and cholesterol levels, aiding in the monitoring and management of diabetes and high cholesterol for better health. For example, some researchers have created coated nanotubes in a way that will fluoresce in the presence of glucose. Inserted into human tissue, these nanotubes can be excited with a laser pointer and provide real-time monitoring of blood glucose level. No more discomfort from needles, pricking, or drawing blood!

More information:

- Selective coatings create biological sensors from carbon nanotubes: http://www.voyle.net/Nano%20Research%20200/research00176.htm
- Nano-sensor to monitor glucose levels in diabetics: http://www.123bharath.com/health-india-news/index.php?action=fullnews&id=44390
- Encapsulated Carbon Nanotubes for Implantable Biological Sensors to Monitor Blood Glucose Levels: http://www.azonano.com/news.asp?newsID=439
- Glowing sensor may allow artificial pancreas: http://www.betterhumans.com/News/news.aspx?articleID=2004-03-17-3

Clean Energy

Cars of the future may use nonpolluting hydrogen fuel cells. Today, hydrogen fuel is expensive to make, but with catalysts made from nanoclusters, it may be possible to generate hydrogen from water by photocatalytic reactions. Novel hydrogen storage systems could be based on carbon nanotubes and other lightweight nanomaterials, nanocatalysts could be used for hydrogen generation, and nanotubes could be used for energy transport.

More information:

- Sun and hydrogen to fuel future: http://news.bbc.co.uk/2/hi/science/nature/3536156.stm
- Nanotechnology could promote hydrogen economy: http://www.eurekalert.org/pub_releases/2005-03/rtsu-ncp032805.php
- USF working hard to make alternative fuels a reality: http://www.voyle.net/Nano%20Research/research00092%20.htm
- Our energy challenge: http://smalley.rice.edu/

Name_____ Date_____ Period _____

What's New Nanocat? Poster Session: Peer Feedback Form

1. What is the topic of the poster you are evaluating?

2. What are the names of the students who developed the poster you are evaluating?

3. The poster contained the following items:

A text description of a current technology and how it works.	True	False
A picture that helps illustrate how the current technology works.	True	False
A text description of a new, related nanotechnology and how it works.	True	False
A picture that helps illustrate how the new nanotechnology works.	True	False
A text description of the implications of the nanotechnology: how it will help improve understanding, solve a problem, and any possible societal issues.	True	False

4. How strongly do you agree with the following statements?

	Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
The poster is visually appealing.	1	2	3	4	5
The poster has a solid scientific basis.	1	2	3	4	5
The poster presenters communicated clearly and answered questions effectively.	1	2	3	4	5
Borrowed text and pictures have citations.	1	2	3	4	5

5. What was your favorite part of the poster?

6. Any additional comments or suggestions for the poster or poster presenters?