It’s A **Nano** World After All:

*using nanotech consumer products to engage student learning*

Disclaimer: Products and companies mentioned in this presentation are not endorsed by the author, CP or NCLT.
Teaching Nanotechnology

Opportunities for learning science

“Hook” (relevant applications) to engage learning
- give examples **upfront** rather than at end
- pique interests and questions

**Be a more informed consumer with critical thinking!**
- Is there a true materials performance advantage or is it just marketing hype?

- Is the advantage just a performance enhancement or a *unique* product trait?

- Could the same technology be used for other applications?

- How much would you pay for a product of *nano*?

*Caveat Emptor!*
Nanotechnology Applications

Has anything “useful” come out of nano research?

$1 trillion worth of nano products by 2015
- NSF estimate, Lux Research

1st: Passive nanostructures
   Ex: coatings, nanoparticles, nanostructured metals, polymers, ceramics
   (1st generation products)
   ~ 2000

2nd: Active nanostructures
   Ex: 3D transistors, amplifiers, targeted drugs, actuators, adaptive structures
   ~ 2005

3rd: Systems of nanosystems
   Ex: guided assembling; 3D networking and new hierarchical architectures, robotics, evolutionary
   ~ 2010

4th: Molecular nanosystems
   Ex: molecular devices ‘by design’, atomic design, emerging functions
   ~ 2015-2020

What **nano** products are out there right now?

**Nanotechnology Applications**

- **Clothing, Fabrics**
- **Cosmetics, Sunscreen**
- **Sports**
- **Coatings**
- **Cleaning products**
Car Wax

Microemulsion of tiny particles of Carnauba wax and proprietary polishing nanoparticles

Eagle One Nanowax

• smoother coating minimizes smearing, allows light to reflect more evenly to give deep, glossy shine

• easy to remove, no white residue

• nanoparticles fill fine scratches and conceal swirl marks to create a more even surface
Ceramic nanoparticles harden in paintshop oven to form an extensive cross-linked network.

Mercedes-Benz Clearcoat

- scratch resistant
- protects against mechanical washes
- enhanced, long-lasting gloss
- weatherproof barrier
Size and Scale

1 nm = 10^{-9} m

iPod nano smaller than mini…
Sunscreen

**Nano-dispersed zinc oxide** (30 nm) provides protection against UVA and UVB rays and is transparent

- cosmetic clarity (no pasty white look)
- higher SPF ratings
- nongreasy, easy application

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Wet Dreams sunscreen with ZinClear ZnO

Grandel PR Vitamin Nano-Depot Day

Keys Solar Rx Nano-Zincoxide
Optical Properties of Nanoparticles

Particles on the nanoscale are too small to scatter visible light and appear transparent to the naked eye.

Size Scales in Optical Transparency

- Macro-scale: Barrier regime
- Milli-scale: Shadow regime
- Micro-scale: Scattering regime
- Nano-scale: Transparent regime
- Nano-scale: Barrier if the material is also absorptive

Materials that reflect light can become transparent at the nanoscale.
Cosmetics

Nano-capsules (200 nm) contain active ingredients and can easily penetrate skin

• delivers Vitamins A, C, & E, or pro-retinol A
• more effective means of delivery than emulsions
• goes on light and sheer; no residue
• affects skin at the “molecular level”

zinc oxide nanoparticles for UV protection in Olay Complete

nanosomes (small liposomes) in L’Oréal Revitalift
Muscle & Joint Pain Cream

Flex-Somes™, nano-liposomes (90 nm) to deliver medication

- encapsulates nutrients and pharmaceutical ingredients
- delivers active ingredients to the lower layers of the skin (topical rather than oral delivery)
- provides deep and quick delivery for faster recovery
Fabrics

- spill proof
- stain resistant
- wrinkle free

Billions of **nanowhiskers** (10 nm long) create a thin cushion of air above the cotton fabric, smoothing out wrinkles and allowing liquids to bead up and roll off without a trace.
Nano-Tex™ nanowhiskers create a semi-impervious layer that traps fluids and particles so they can be removed and washed away.
Water repellent surfaces in Nature

many small tubes or whiskers keep water and solid at minimal contact for superhydrophobia (extreme water repellency)

peach fuzz and the lotus leaf as inspiration
Surface Coatings

Nanoparticulate coatings make surfaces superhydrophobic (extremely water-repellent) and self-cleaning

• reduces contact area between water and surface to a minimum
• decreases the forces of adhesion; water droplets assume globular form
• dirt particles rinsed away
• surfaces stay clean for a long time
Self-cleaning Surfaces

- water droplets form spherical globules
- rough nanoscale surface picks up dirt
- water and dirt roll off
- biomimicry

Left: SEM image of surface produced within the project.
Right: SEM image of the surface of a Lotus leaf.
(D. Chakarov, P. Holgerson)
Ski Polymer (“Nanowax”)

Self-assembling fluoride (CF$_3$) polymers and multifunctional nanoparticles create lamellar (thin layer) structure on skis and snowboards

- superior adhesive behaviour more resistant to aggressive types of snow and minimally responsive to temperature
- hard, highly fluorinated surface gives excellent gliding ability
Native Eyewear Nano Sunglasses

Nanocoating on eyeglass lenses: antireflective polymer coating (3-10 nm) self assembles

Hard and strong coating:
- excellent scratch, chip resistance
- resistant to dirt and moisture
- anti-reflective
Odor-Free Socks

Silver nanoparticles embedded in the fibers of socks

- odor-free, antibacterial
- silver naturally antibacterial and antifungal
- large surface area achieved with nanoparticles

JR Nanotech SoleFresh Socks
Wound Dressing

Large surface area of **nanosized silver particles** improves antibacterial effectiveness

- faster recovery times
- bacteria killed quicker with nanoparticles than with other silver forms

Nucryst Acticoat dressing for burns

Curad silver bandages
**Appliances**

**Nano-sized silver particles** (1-100 nm) coat the interior of refrigerators, washing machines, and filters of air conditions, air purifiers and vacuum cleaners

- stops growth of fungi and bacteria
- resistant to odor-causing bacteria
- keeps food fresh longer

**HA-1435A washing machine**

**RS-21DLMR refrigerator**

**AS-24S6GB air conditioner**
Air Purifier

**NanoBreeze**

**Room Air Purifier**

**NanoBreeze**

**Car Air Purifier**

**TiO₂ nanoparticles (40 nm)**

convert organic pollutants to CO₂ and H₂O through oxidation by photocatalysis

- no filters or collection plates
- does not produce ozone
- decomposes airborne contaminants, VOCs (volatile organic chemicals): allergens, odors, germ, gases, smoke, fumes, etc.
- destroys microbes and bioaerosols (dust mites, mold spores) by disintegrating their DNA
Disinfectant

Nanoemulsion of oil droplets **nanospheres** (~170 nm) in water adhere to bacterial cells and kill microorganisms

- nanospheres carry surface charges that efficiently penetrate the surface charges on microorganisms’ membranes
- large surface area of nanospheres requires only miniscule amounts of the biocidal compound PCMX (0.2% vs. 3-5%)
- targets tiny bacteria and viruses, but not larger human cells
- effective and **non-toxic** (gloves & mask not needed)
- used on cruise ships and airplanes
As the object size gets smaller, the surface area to volume ratio becomes larger.

- nanoparticle surfaces act as excellent catalyst sites
- less amount of material needed for same effect

→ high efficiency, less toxicity, less weight, and/or less cost!
Catalytic Device
antioxidation of deep-frying oil

Porous **nanoceramic**
catalytic pellets
contain silver

large surface area prevents oil from oxidizing and clumping:

- enhanced heat conduction
- eliminates foul smells (ionized Ag)
- eliminates redundant fatty remnants (healthier fries!)

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**OilFresh Antioxidation Device**

Nanoceramic pellets

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Clustered Oil Molecules

- Inefficient form
- Harder to heat
- Transfer heat slower
- Soggy and oily fries

Dispersed Oil Molecules

- Efficient form
- Easier to heat
- Transfer heat faster
- Clusters of healthier fries
Footwarmers

**Nanoporous** lattice structure for low weight insulation

open-celled structure with very high surface area and billions of irregularly shaped pores (2-50 nm):

- high insulation efficiency
- very light weight

Aspen Aerogel (Pyrogel AR5401) Shock Doctor HotBeds
Bowling Balls

Fullerenes or Buckyballs in super-hard coating

- prevents chipping and cracking
- resists surface nicks
- straighter ball performance

Japanese company Nanodesu "It's nano!" bowling balls
Golf Club Shafts

**Nanoparticles** within fiber reinforced composites

**AccuFLEX shafts:** “longer, straighter, more consistent”

Example of the "tighter" structure of the NANO vs Other, under Magnification
Golf Club Shafts and Heads

Nanoparticles reinforces carbon (graphite) composite material

Wilson Nano-Technology Crown:
• high strength and low density
• improved torsion stability (longer, straighter shots)

Carbon nanotubes in club heads

Wilson Clubs Dd5  Pd5 FwC:
• reduced weight (thus faster club head speed)
Baseball Bats

Carbon **nanotubes** within carbon fiber composites

Easton Stealth CNT bats

- improved strength in resin area with **Zyvex nanotubes**
- greater strength/density
Tennis Racquets

Nanosized SiO$_2$ within voids of carbon fibers

Wilson nSix-One Tour racquet:
• greater strength, stability, power

Roger Federer 2004 Wimbledon

Carbon nanotubes around racquet head

Babolat’s VS NCT (Nano Carbon Technology):
• greater stiffness, flex resistance, rigidity
• lightweight, responsive
• larger sweet spot
Carbon Nanotubes

cylindrical carbon tube, diameter ~1 nm

high stiffness and strength:
  Tensile strength = 63 GPa (16X stronger than steel)
  Young’s modulus = 1 TPa (theoretical)

highly flexible

good thermal and electrical conductors

can increase toughness and lower density in composites

Buckyballs or Fullerenes

$C_{60}$ sphere, diameter ~0.4 nm
Tennis Balls

Nano-clay platelets (1 nm thick) within rubber polymer matrix

Wilson Double Core tennis balls with InMat Air D-Fense:
• better air retention (tortuous path for air to escape)
• more consistent bounce
• longer life
Plastic Bottles Gas Barrier

Nanoclay composites in multi-layer PET bottles

less CO₂ escape and less O₂ absorption:
• increases shelf life, efficiently preserves flavor
• greater light and fire resistance
• stronger mechanical and thermal performance

Honeywell’s Aegis nylon 6 nanocomposites optically clear if individual clay thickness < λ of visible light
Portable Water Filtration System

Porous plastic bag coated with nanoclays to filter water

Hydration Technologies X-Pack

- filters at 50 nm level (virus, bacteria, parasites)
- light weight
- military and recreational applications
Nano-clay Composites

Clay platelets
10 Angstroms thick, but over 200 times that in width

Polymer
molecular chains bind clay platelets together

Intercalated Material

Exfoliated Material

very large surface areas of contact between dispersed nano-platelets (1 nm thick) & polymer matrix result in:

- tortuous path for gases to travel through → barrier
- high strength, good toughness, low density → composites
Step Assists & Car Parts

**Nanocomposites** of clay platelets in polymer matrix

very low loadings of filler (< 5 wt%) needed:

- high strength and stiffness
- less brittle in cold
- low weight
- more recyclable
- wider processing window

Chevrolet Impala body side molding, 2004
Hummer H2 SUT cargo bed, 2005

Chevrolet Astro & GMC Safari vans step assists, 2002
Nanotech shopping is educational!

Concepts covered:
Length scales
Surface area/volume ratio as a function of size
Self assembly
Buckyballs, Nanotubes, Nanoparticles
Biomimicry
Photocatalysis, chemical reactions, hydrophobicity
Optical properties, em spectrum
Mechanical properties