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It's A **Nano** World After All: *using nanotech consumer products to engage student learning*



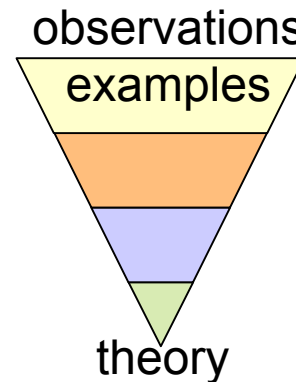
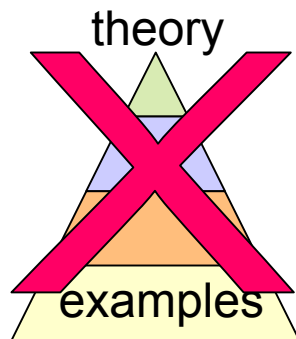
Teaching Nanotechnology



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!



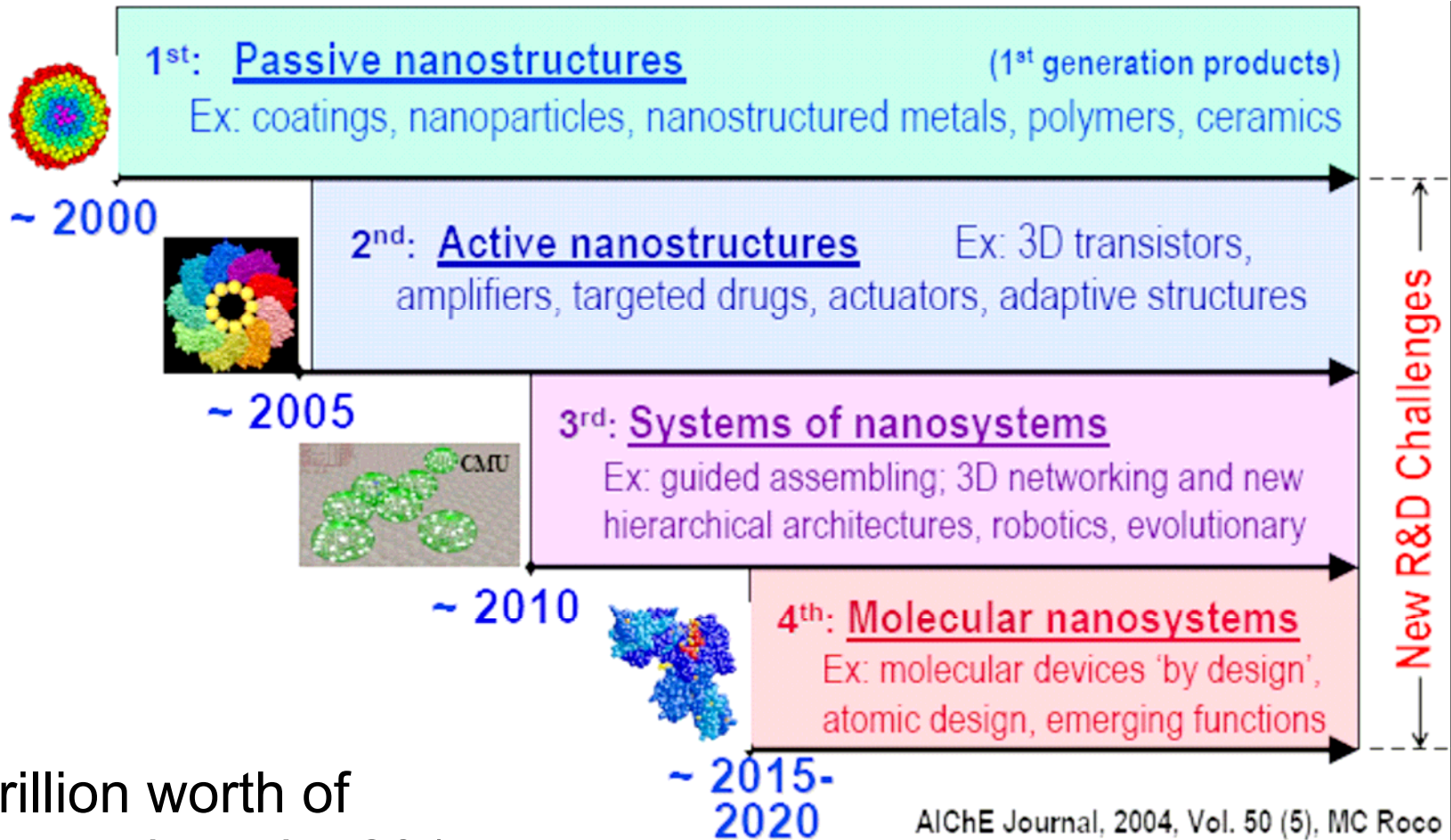
Nanotechnology Products

- 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

Nanotechnology Applications

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



Clothing, Fabrics



Cosmetics,
Sunscreen



Sports



Cleaning products

Coatings





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



Mercedes-Benz Clearcoat

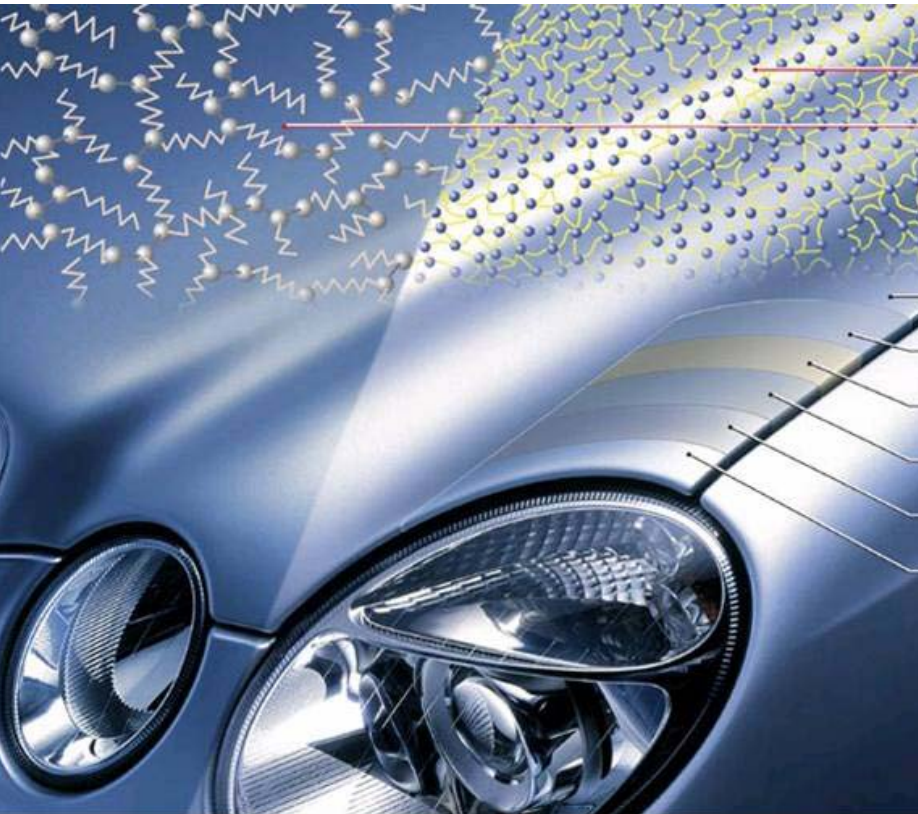


- scratch resistant
protects against mechanical washes
- enhanced, long-lasting gloss
- weatherproof barrier

Lackoberflächen unter dem Mikroskop: Höherer Glanz und weniger Kratzer durch neuartigen Nano-Klarlack
Paint surfaces under the microscope: Higher gloss and less scratches due to new nano-particle clearcoat

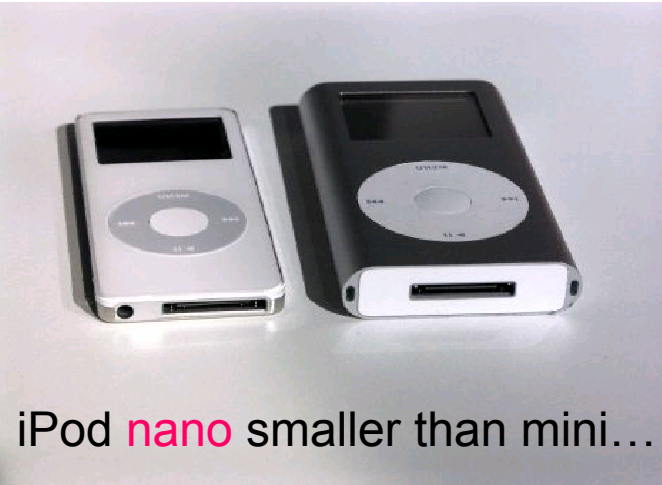
Herkömmlicher Klarlack
Conventional clearcoat

Neuer kratzfesterer Nano-Klarlack
New scratch-resistant nano-particle clearcoat

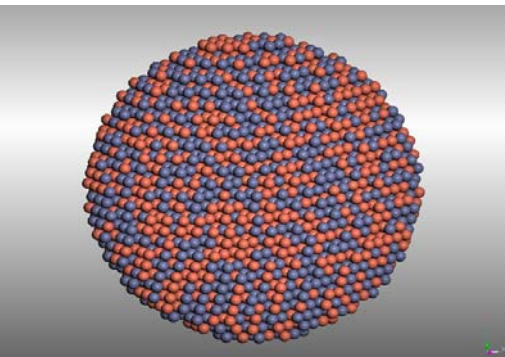
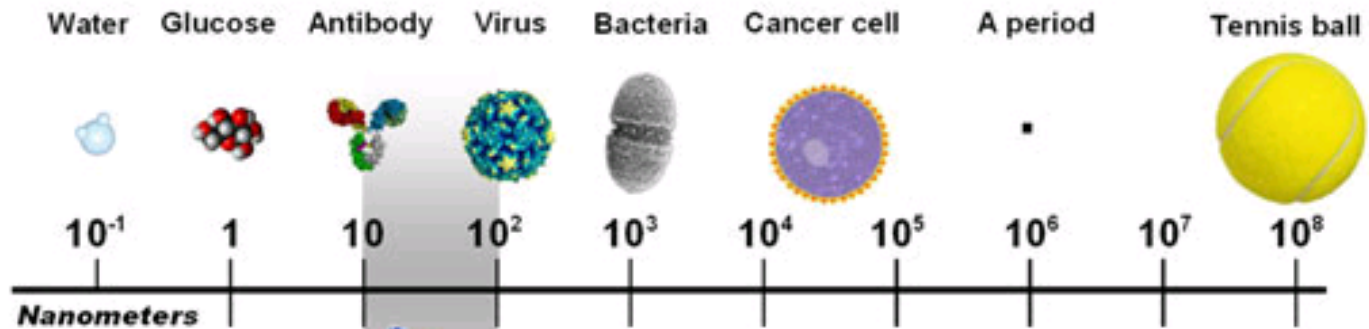
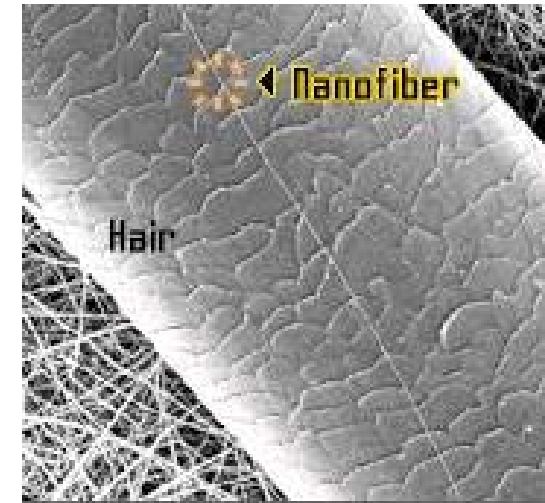


Ceramic **nanoparticles**
harden in paintshop oven
to form an extensive
cross-linked network

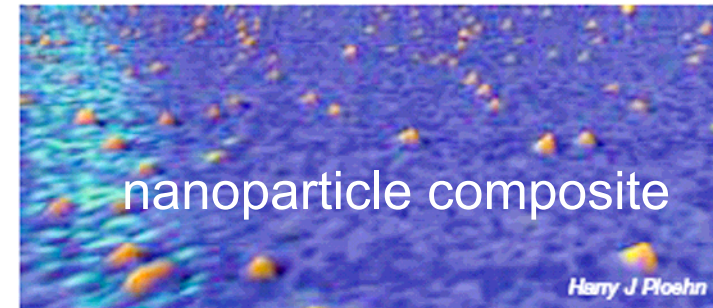
Size and Scale



$$1 \text{ nm} = 10^{-9} \text{ m}$$



nanoparticle:
aggregate of atoms





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



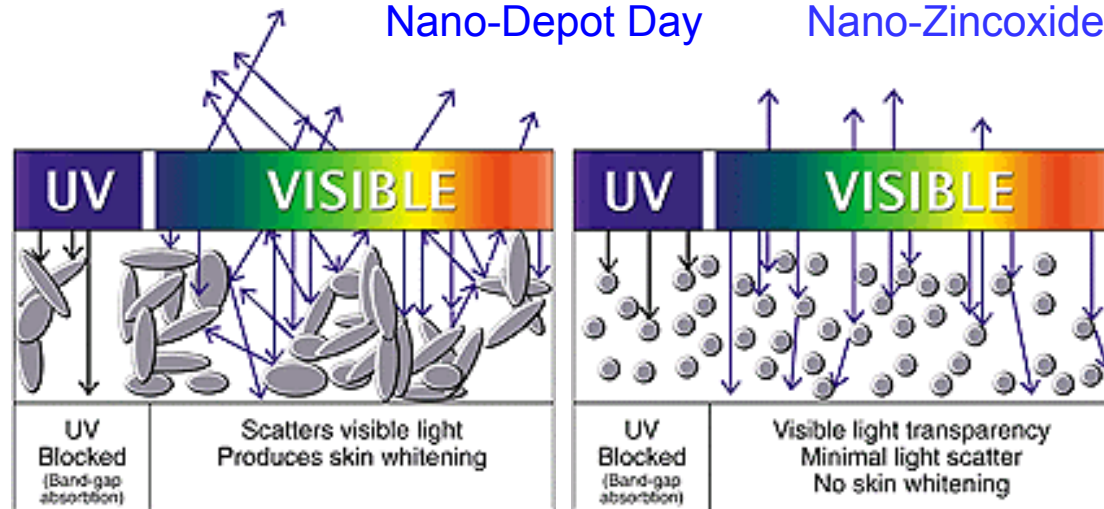
Grandel PR Vitamin Nano-Depot Day



Keys Solar Rx Nano-Zinc Oxide

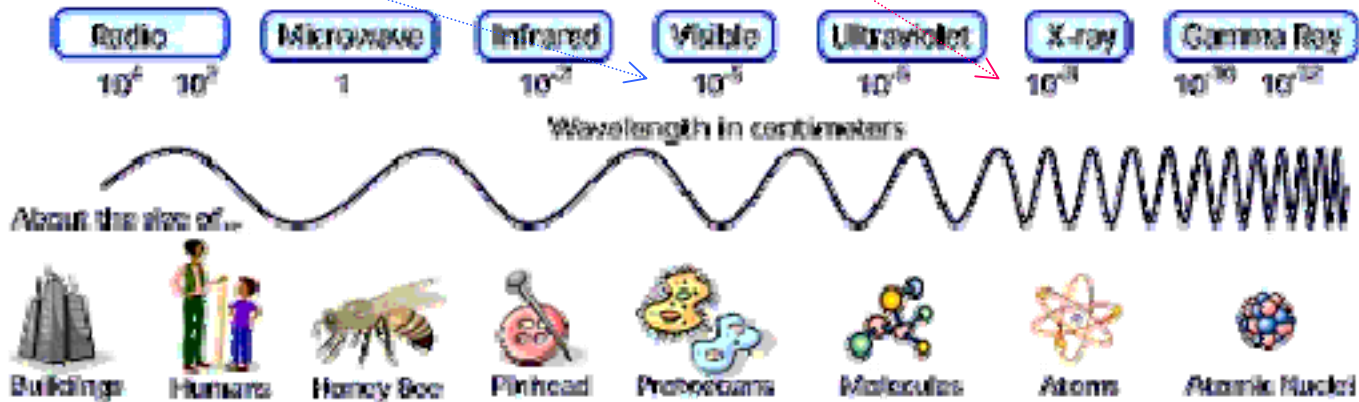


Wet Dreams sunscreen with ZinClear ZnO

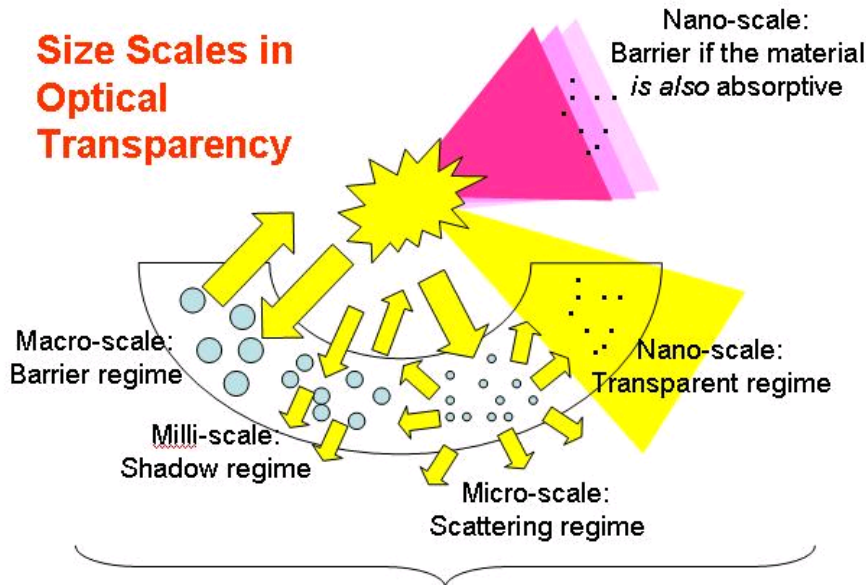


Optical Properties of Nanoparticles

particles on the **nanoscale** are too small to scatter **visible light** and appear *transparent* to the naked eye



Size Scales in Optical Transparency



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”



BIONOVA
NANO SKIN TECH



L'ORÉAL
PARIS

zinc oxide nanoparticles
for UV protection in
Olay Complete

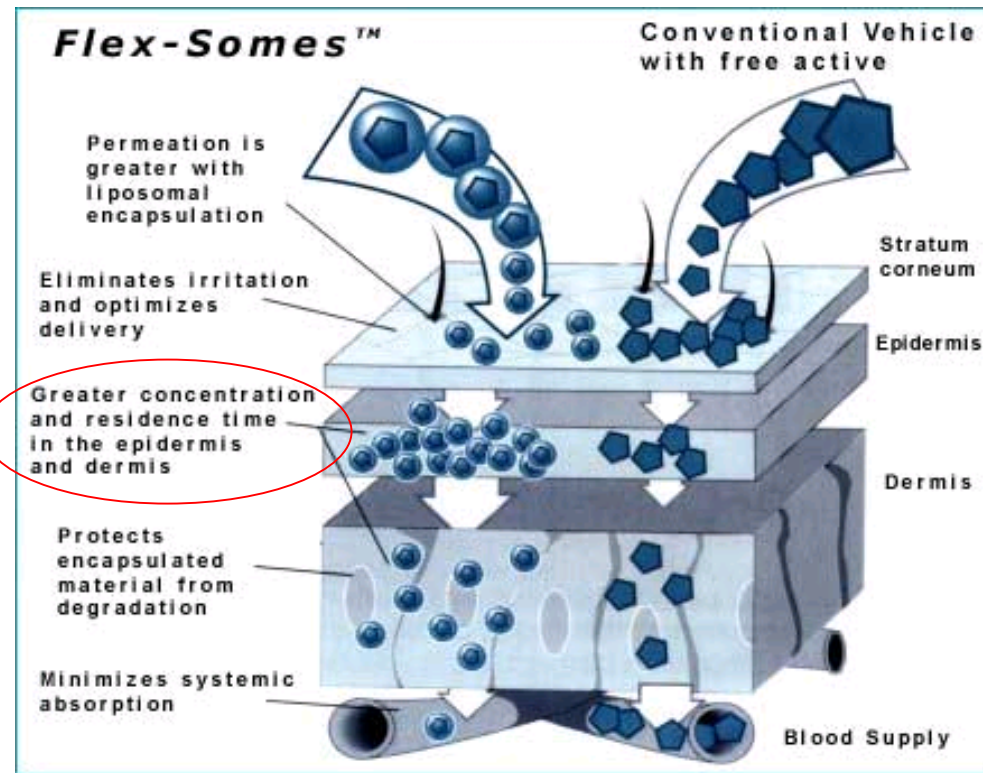
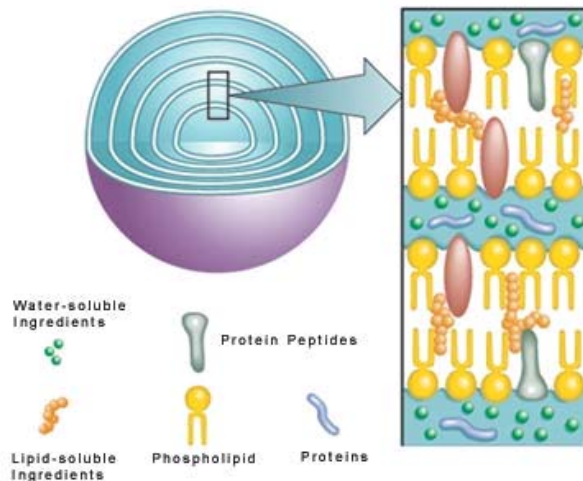
nanosomes (small liposomes)
in L'Oréal Revitalift



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.



NANotex™
Fabric to the Next™



Levi's Dockers Go Khaki with Stain Defender
Eddie Bauer's Nano-Care chinos



Bedding



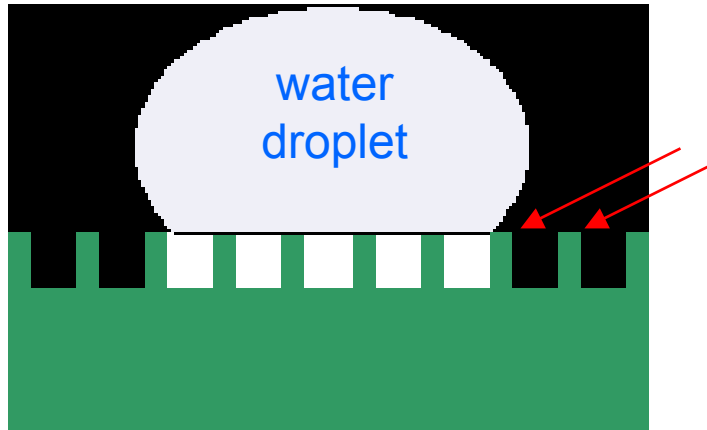
Nano-Tex™ **nanowhiskers** create a semi-impervious layer that traps fluids and particles so they can be removed and washed away



Simmons HealthSmart
Bed Mattresses



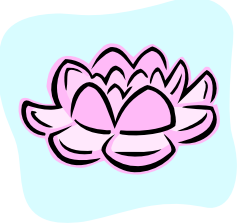
Water repellent surfaces in Nature



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

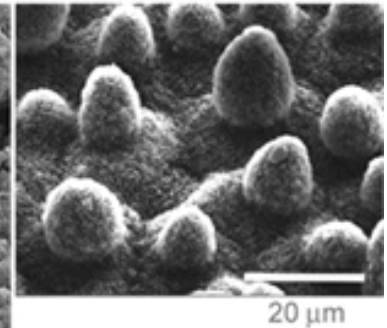
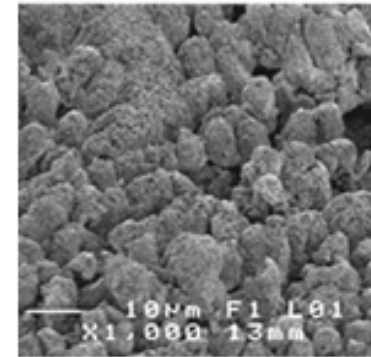
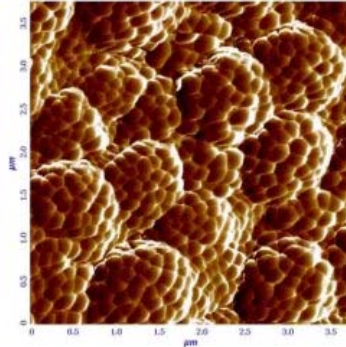
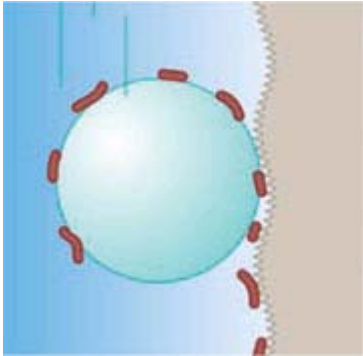
- reduces contact area between water and surface to a minimum
- decreases the forces of adhesion; water droplets assume globular form
- dirt particles rinsed away
- surfaces stay clean for a long time



BASF Mincor™
superhydrophobic coating

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)



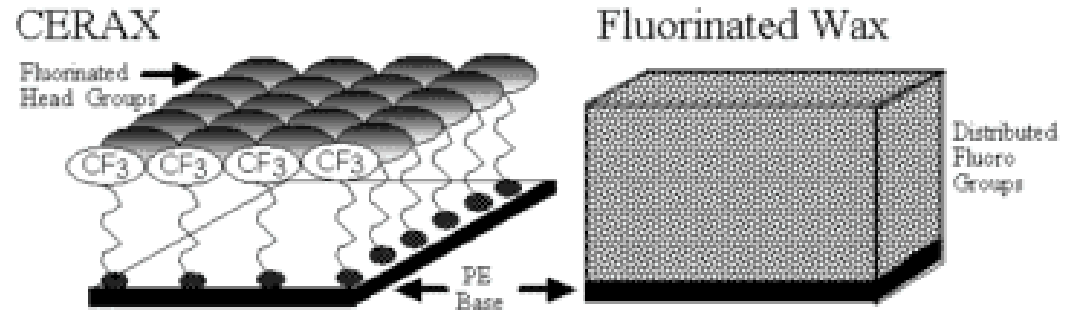


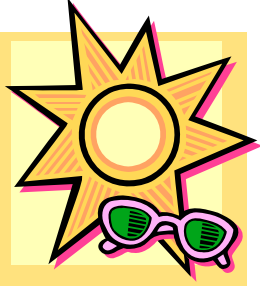
Ski Polymer (“Nanowax”)



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





Sunglasses



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

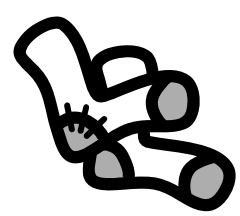


Hard and strong coating:

- excellent scratch, chip resistance
- resistant to dirt and moisture
- anti-reflective

Native Eyewear Nano Sunglasses
With Nanofilm coating

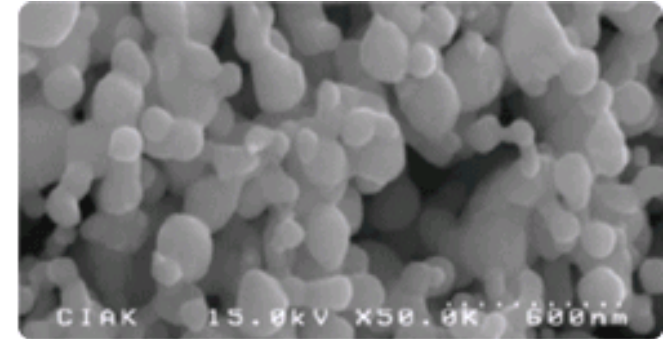
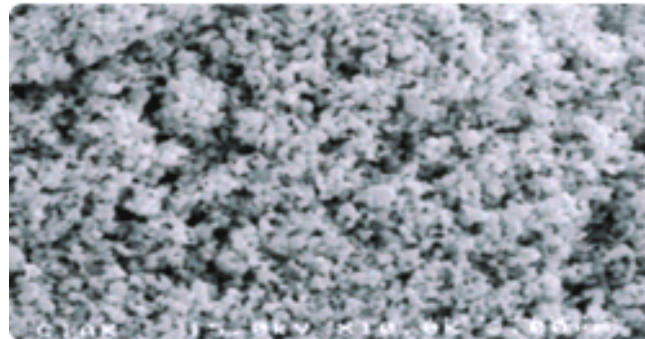




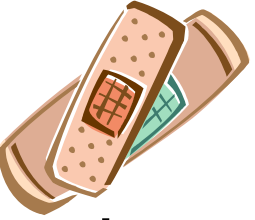
Odor-Free Socks

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

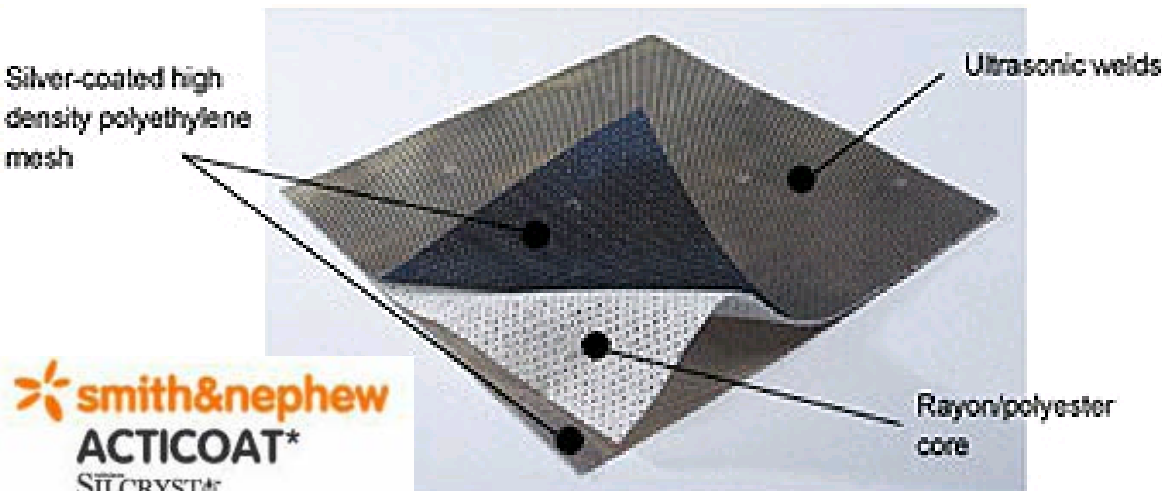


Wound Dressing

Large surface area of **nanosized silver particles** improves anti-bacterial effectiveness

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

Nucryst Acticoat dressing for burns



Curad silver bandages

Appliances

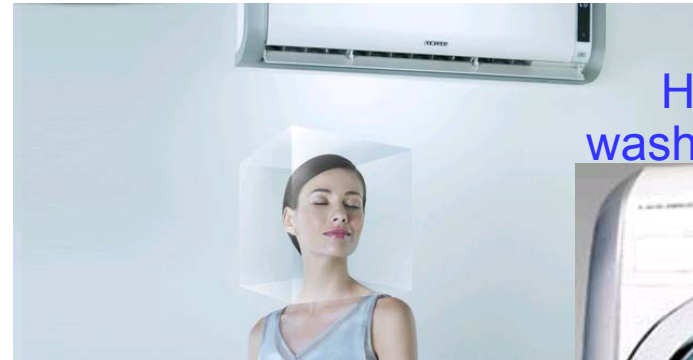


Nano-sized silver particles (1-100 nm) coat the interior of refrigerators, washing machines, and filters of air conditions, air purifiers and vacuum cleaners

RS-21DLMR
refrigerator



AS-24S6GB air conditioner



HA-1435A
washing machine



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

Air Purifier

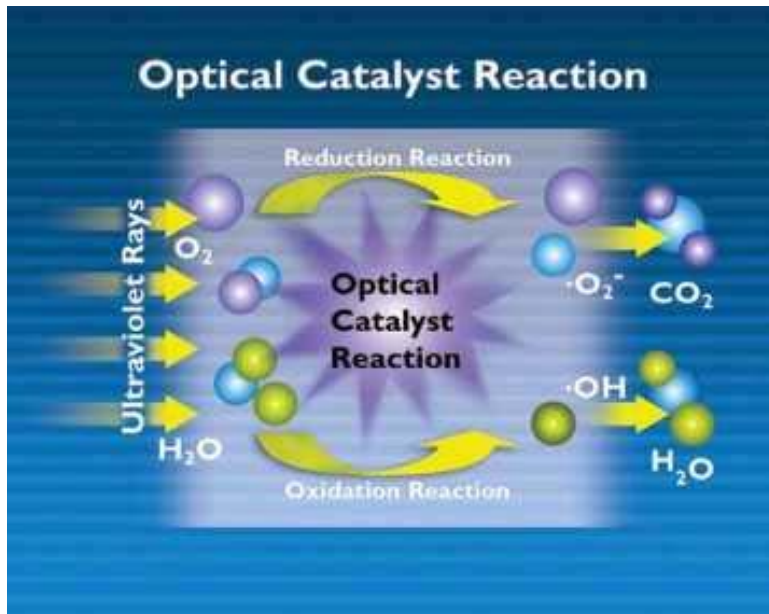
TiO₂ nanoparticles (40 nm) convert organic pollutants to CO₂ and H₂O through oxidation by photocatalysis



NanoBreeze
Room Air Purifier



NanoBreeze
Car Air Purifier



- 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

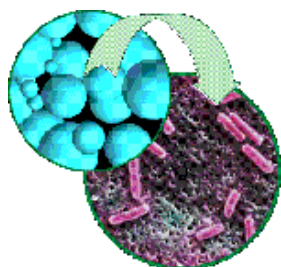


Disinfectant



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

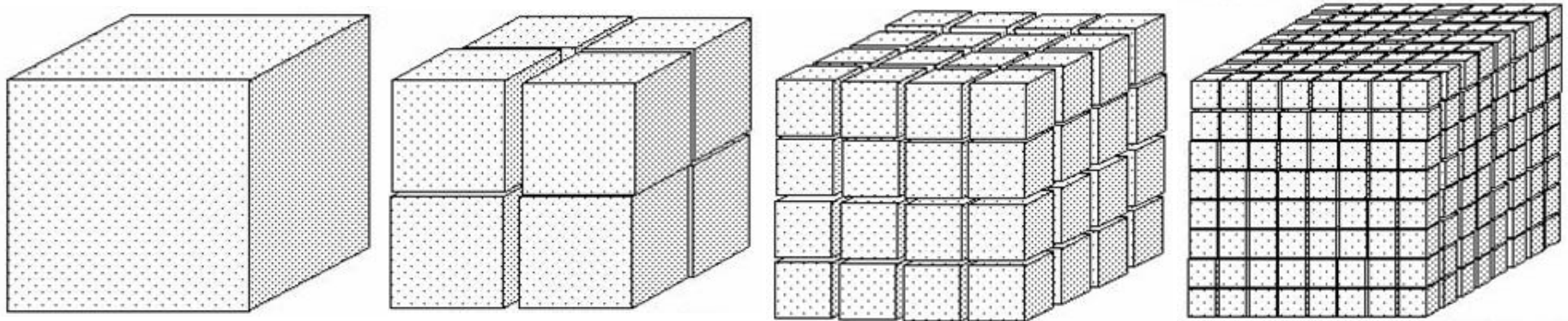


EnviroSystem EcoTru
nanoemulsion disinfectant



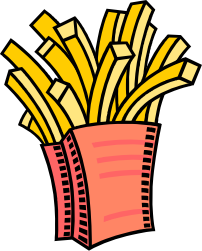
Surface Area/Volume: size effects

Nanoparticles offer HUGE amounts of surface area!



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 costs!*



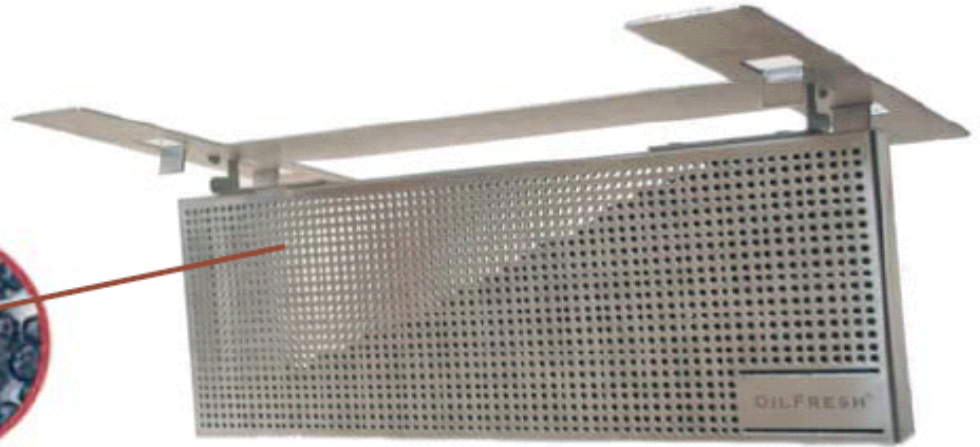
Catalytic Device

antioxidation of deep-frying oil

Porous **nanoceramic** catalytic pellets contain silver

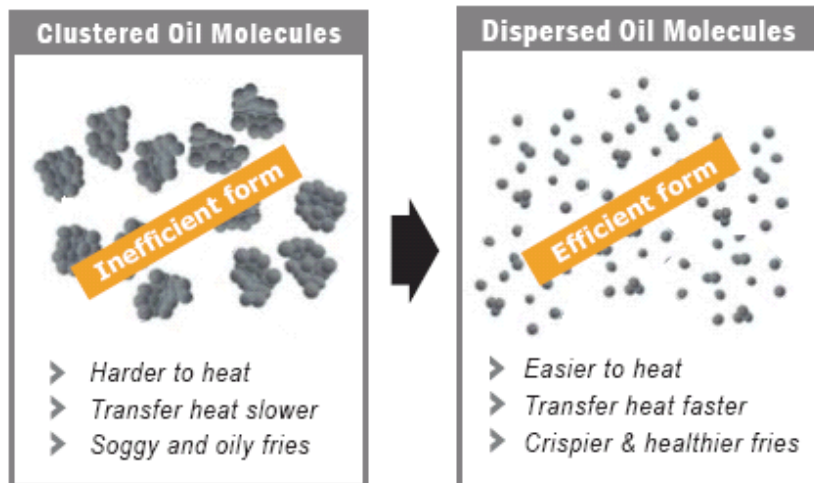


Nanoceramic pellets



OilFresh Antioxidation Device

large surface area prevents oil from oxidizing and clumping:



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

Footwarmers



Nanoporous lattice structure
for low weight insulation

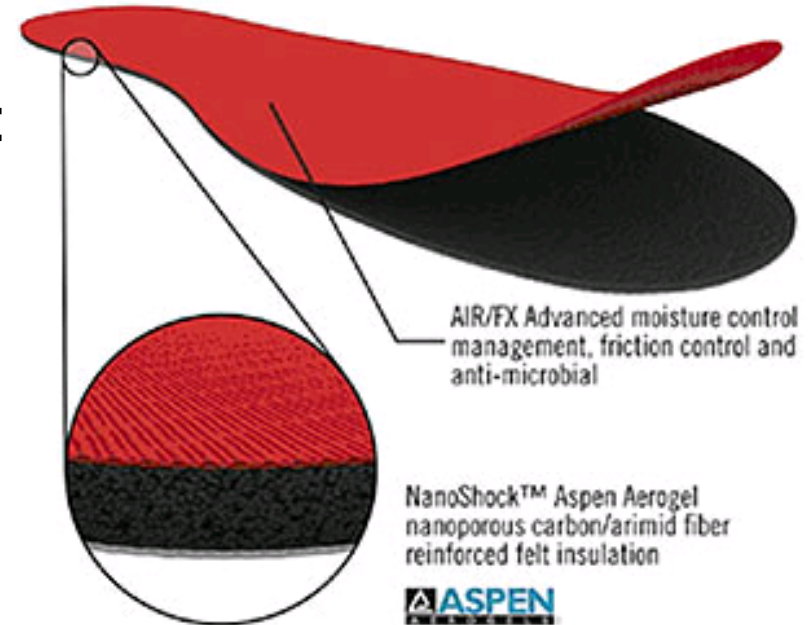


open-celled structure with very high surface area and billions of irregularly shaped pores (2-50 nm):

- high insulation efficiency
- very light weight

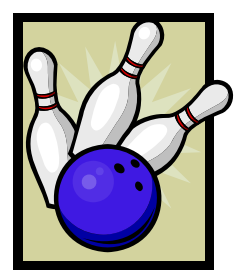


HotBed Aerogel Super Insulating Inserts



Aspen Aerogel (Pyrogel AR5401)
Shock Doctor HotBeds



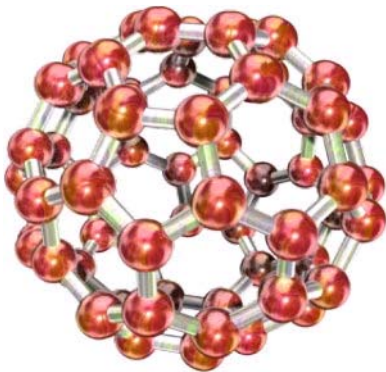


Bowling Balls



Fullerenes or **Buckyballs**
in super-hard coating

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



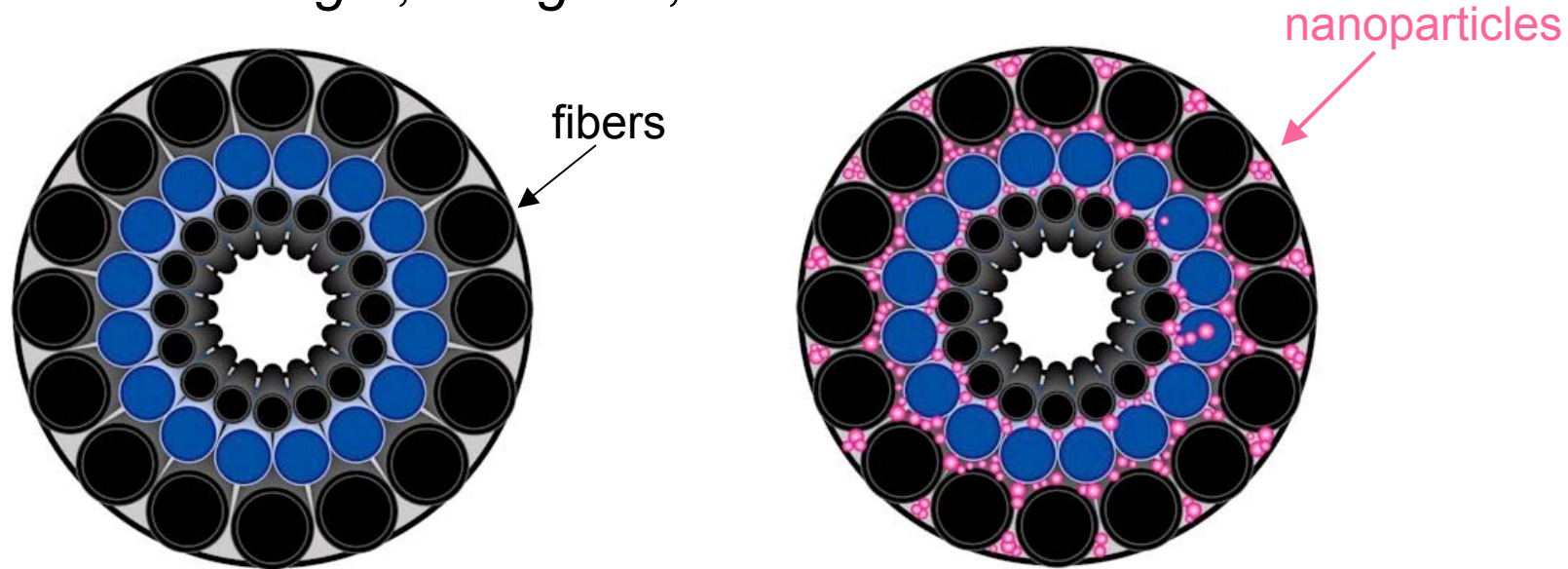
Japanese company Nanodesu
"It's nano!" bowling balls



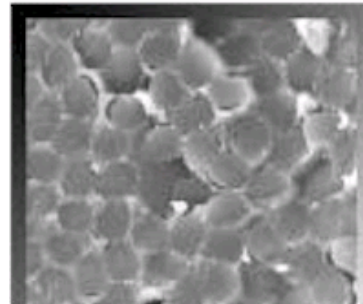
Golf Club Shafts

Nanoparticles within fiber reinforced composites

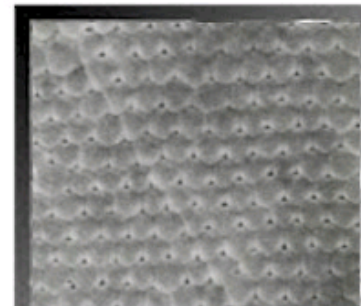
AccuFLEX shafts: *"longer, straighter, more consistent"*



Example of the "tighter" structure of the NANO vs Other, under Magnification



Standard
"high density"
Graphite



Nano Technology



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

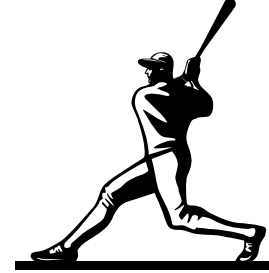
Wilson Clubs Dd5 Pd5 FwC:

- reduced weight (thus faster club head speed)





Baseball Bats

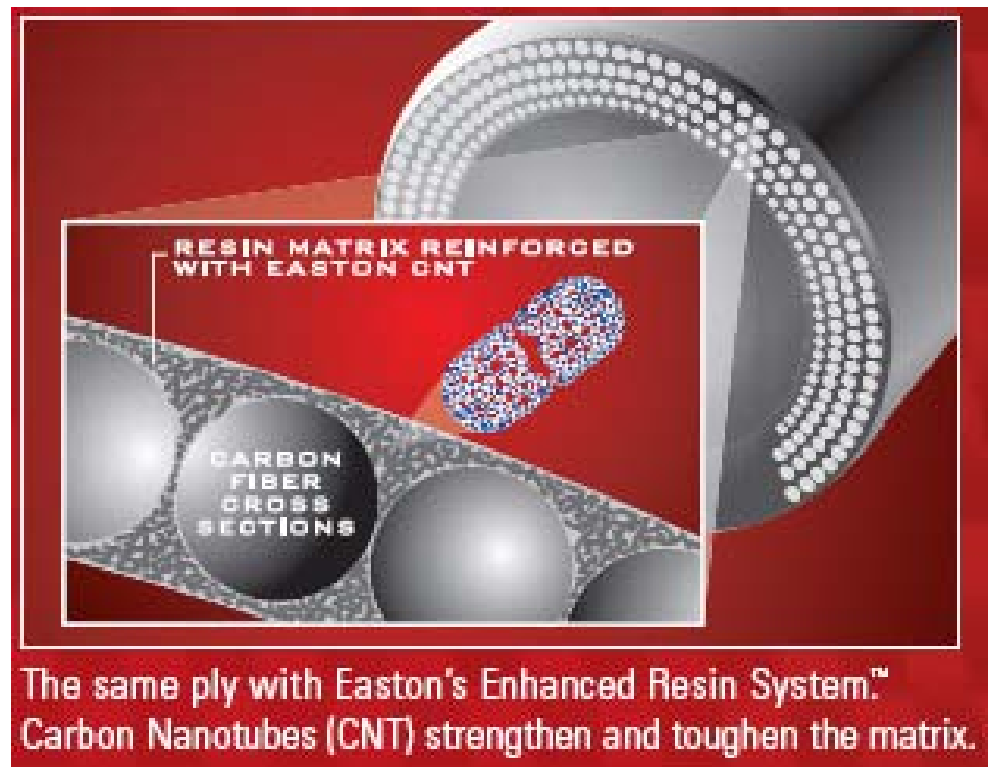


Carbon **nanotubes** within carbon fiber composites

Easton Stealth CNT bats



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



The same ply with Easton's Enhanced Resin System™. Carbon Nanotubes (CNT) strengthen and toughen the matrix.

Tennis Racquets

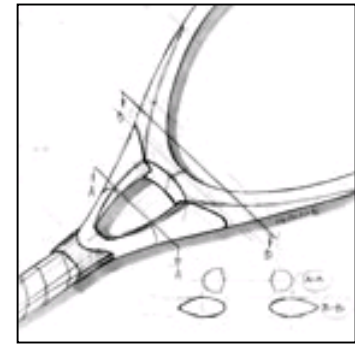
Nanosized SiO_2 within voids of carbon fibers



Wilson nSix-One Tour racquet:

- greater strength, stability, power

Roger Federer 2004 Wimbledon

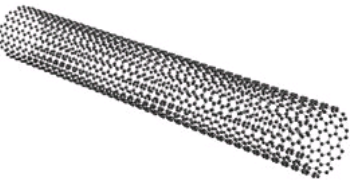


Carbon **nanotubes** around racquet head

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:

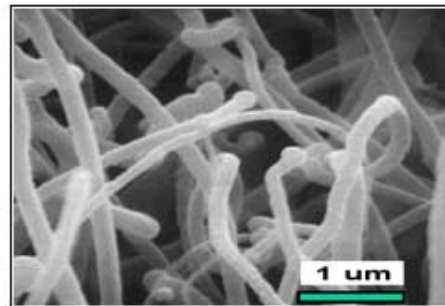
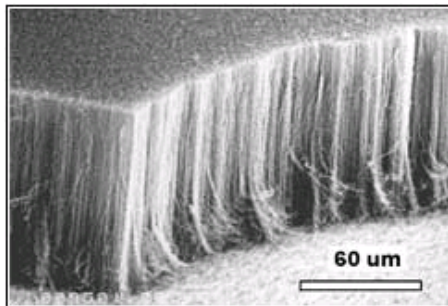
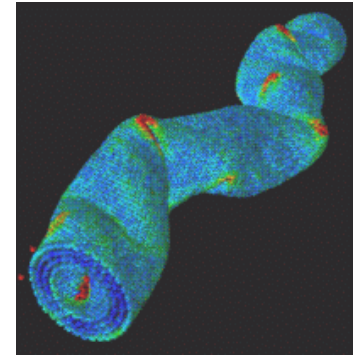
Tensile strength = 63 GPa (16X stronger than steel)

Young's modulus = 1 TPa (theoretical)

highly flexible

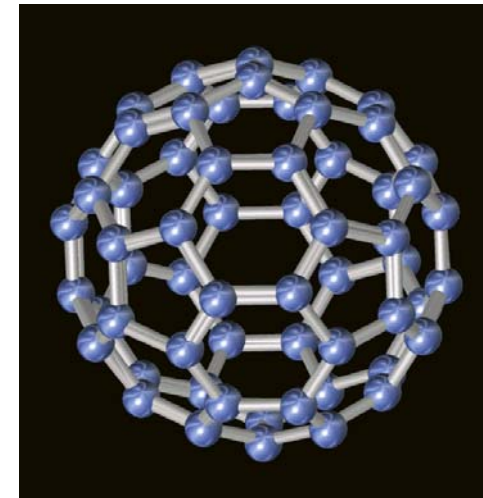
good thermal and electrical conductors

can increase toughness and lower density in composites



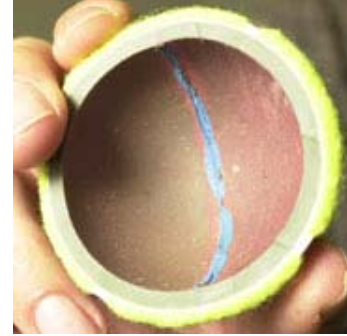
Buckyballs or Fullerenes

C₆₀ sphere, diameter ~0.4 nm





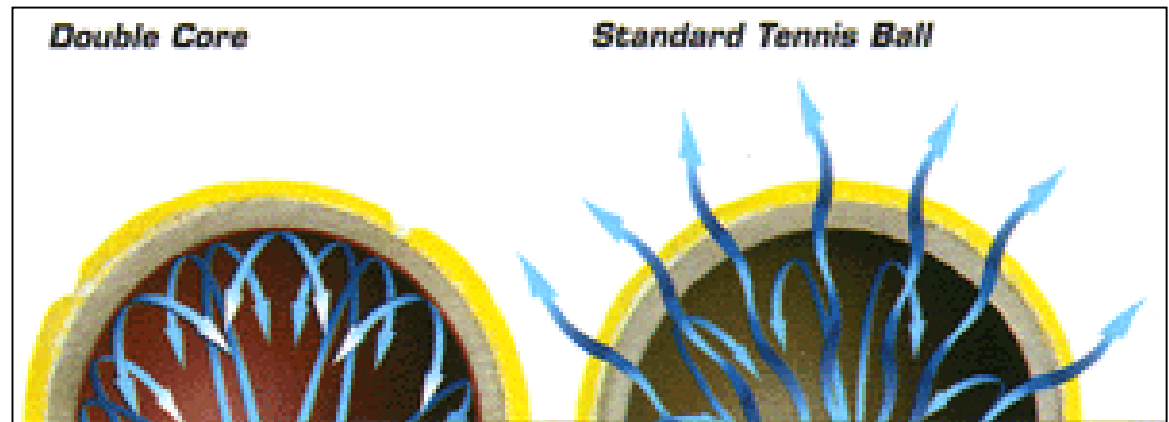
Tennis Balls



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

contaminated water goes in, but only pure water seeps through self-hydrating membrane pouch by osmotic pressure

Hydration Technologies X-Pack

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



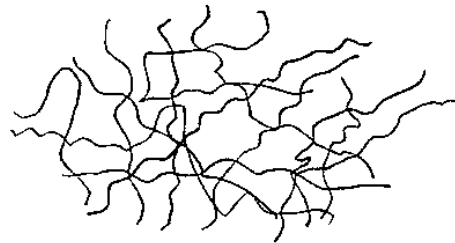
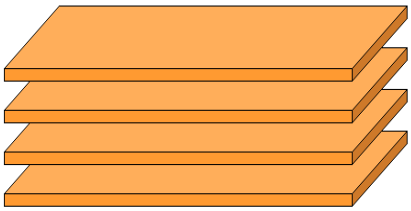
Hydration Technologies' Life-Sustaining Water Filtration Bags Deployed To Hurricane Katrina Victims



Nano-clay Composites

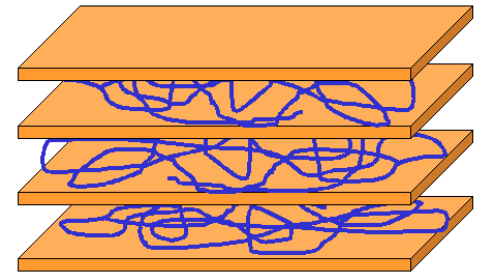
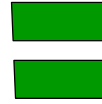
Clay platelets

10 Angstroms thick, but
over 200 times that in width



Polymer

molecular chains bind
clay platelets together



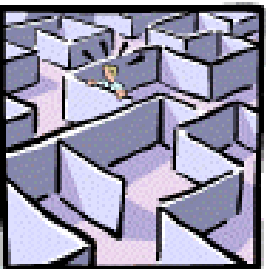
Intercalated Material



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



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

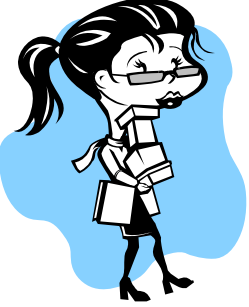


very low loadings of filler (< 5 wt%) needed:

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



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

