Introduction to nanocomposites

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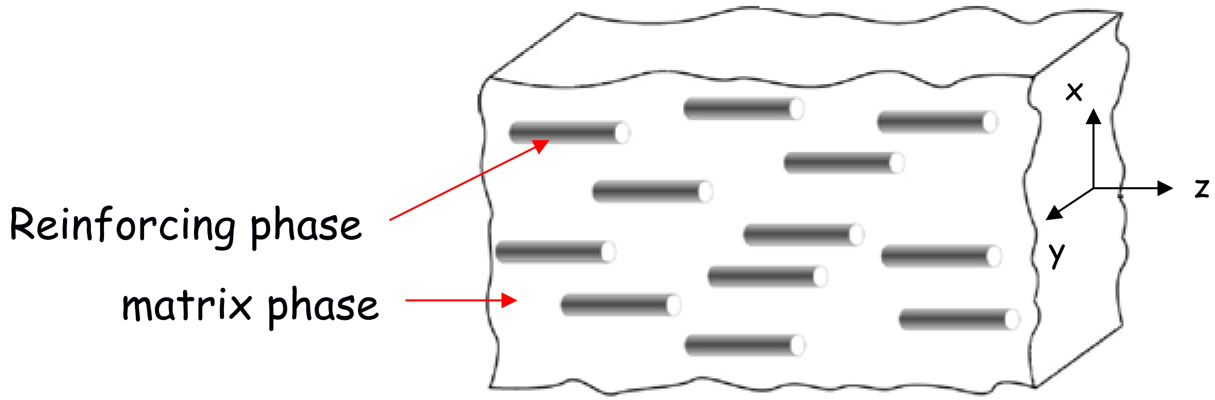
What are composites ?

Composites are combinations of two materials in which one of the material is called the **reinforcing phase**, is in the form of fibers, sheets, or particles, and is embedded in the other material called the **matrix phase**.

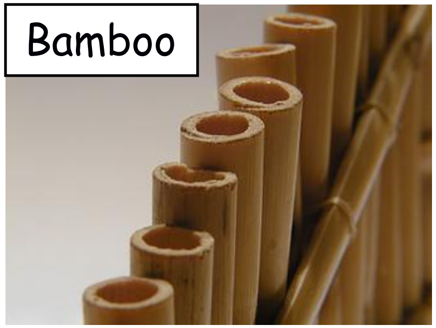
Typically, reinforcing materials are strong with low densities while the matrix is usually a ductile or tough material. If the composite is designed and fabricated correctly, it combines the strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties not available in any single conventional material.



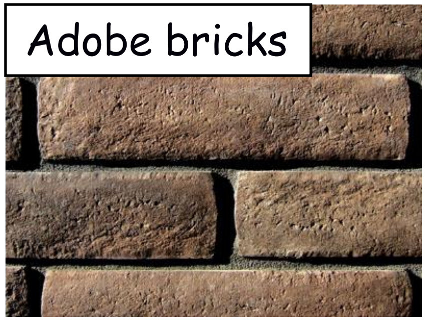
Natural composite materials in the world

- **Wood** is a good example of a natural composite, combination of cellulose fiber and lignin. The cellulose fiber provides strength and the lignin is the "glue" that bonds and stabilizes the fiber.

- **Bamboo** is a very efficient wood composite structure. The components are cellulose and lignin, as in all other wood, however bamboo is hollow. This results in a very light yet stiff structure. Composite fishing poles and golf club shafts copy this natural design.



- The ancient Egyptians manufactured composites! **Adobe bricks** are a good example. The combination of mud and straw forms a composite that is stronger than either the mud or the straw by itself.



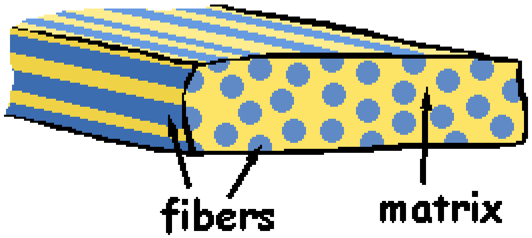
Fiber-reinforced composites

Fiber Phase

Requirements for the fiber

- The small diameter fiber must be much stronger than the bulk material
- High tensile strength

(whiskers, fibers, wires)



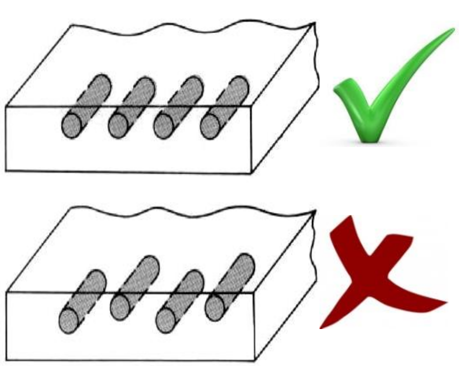
Matrix Phase

Function

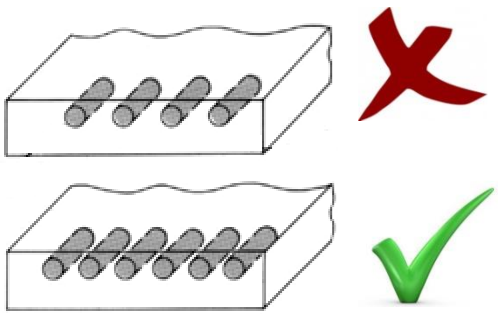
- <u>Binds</u> fibers together
- Acts as a <u>medium</u> through which externally applied stress is transmitted and distributed to the fibers
- <u>Protects</u> fiber from surface damage
- <u>Separates</u> fibers and prevents a crack from one fiber propagating through another

Properties of composites

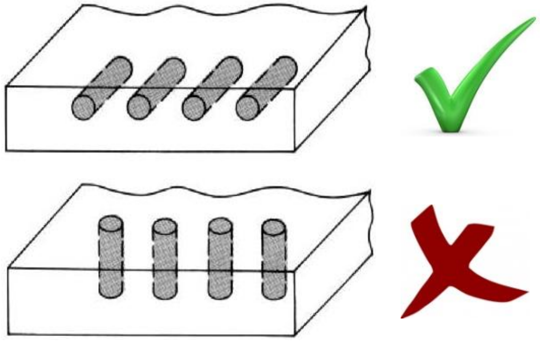
For a given fiber/matrix system:



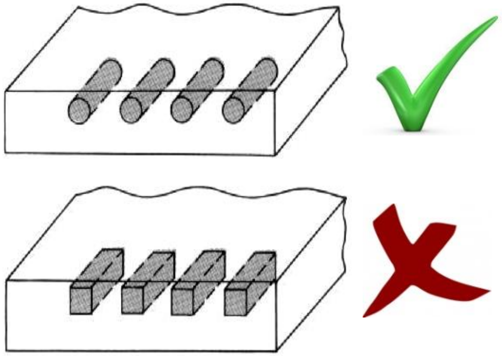
Distribution



Concentration



Orientation



Shape

Engineering applications

Composite materials have been used in aerospace, automobile, and marine applications (see Figs. 1-3). Recently, composite materials have been increasingly considered in civil engineering structures. The latter applications include seismic retrofit of bridge columns (Fig. 4), replacements of deteriorated bridge decks (Fig. 5), and new bridge structures (Fig. 6).

Figure 1

Figure 2

Figure 3

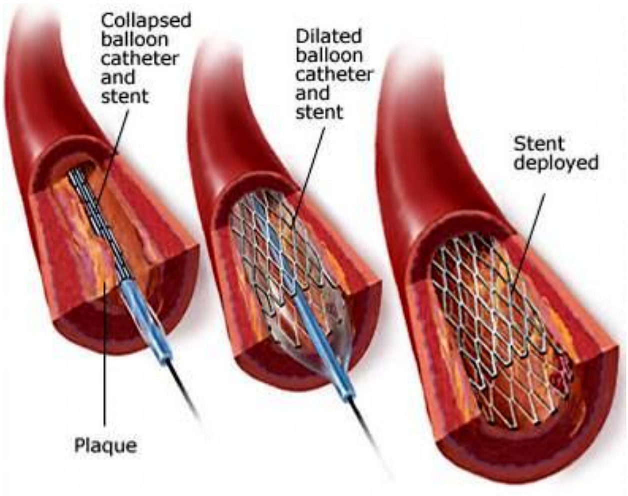
Figure 4

Figure 5

Figure 6

Medical applications

- Stents are made with steel and more recently with composite polymers with shape memory effects.
- The material is deformed within a temperature range of glass transition temperature (T_g) of amorphous phase and melting temperature (T_m) of crystalline phase, then was cooled below T_g. After the material was reheated between T_g and T_m, the original structural shape was recovered. High dosage (up to 35% by weight) and at a high rate of release of medication were noted in this study.

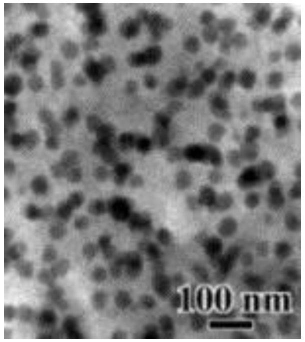


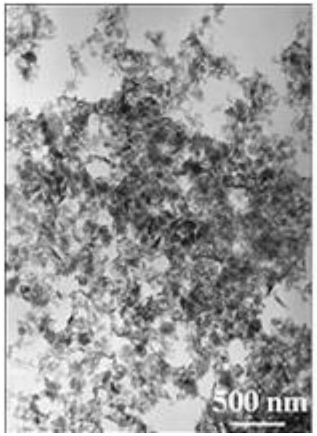
Limitations of composites

- Properties of material are highly anisotropic due to the orientation of fibers
- Strength perpendicular to the direction of alignment is considerably less (the fibers do not contribute)
- Loss optical/electrical/chemical (barrier) properties

Welcome to the world of nanocomposites !

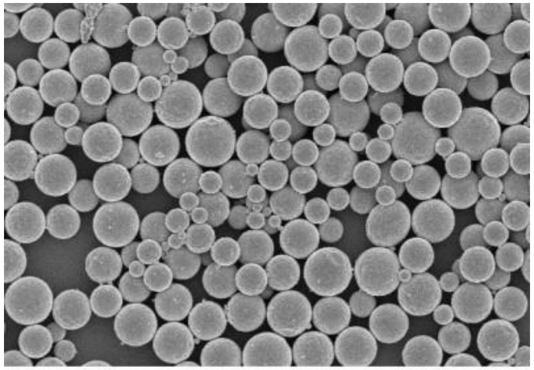
- A broad class of materials, with microstructures modulated in zero to three dimensions on length scales less than 100 nm.
- Materials with atoms arranged in nanosized clusters, which become the constituent grains or building blocks of the material.
- Any material with at least one dimension in the 1-100 nm range.



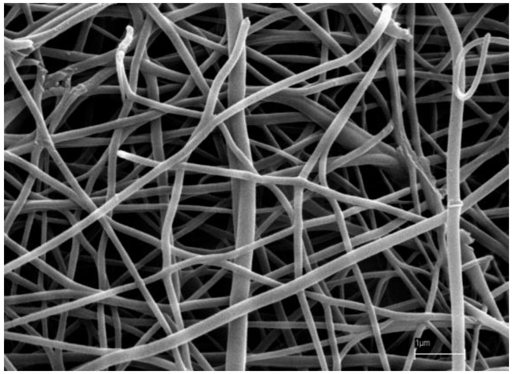


What are nanocomposites ?

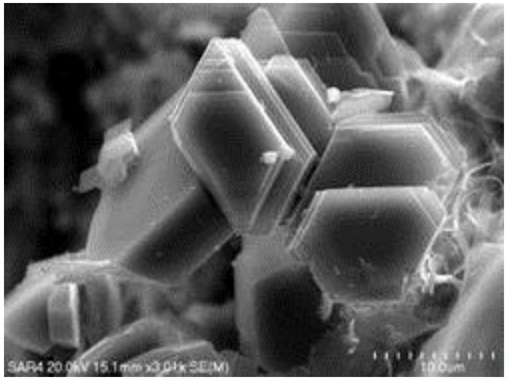
- Constituents have at least one dimension in the nanometer scale.
  - Nanoparticles (Three nano-scale dimensions)
  - Nanofibers (Two nano-scale dimensions)
  - Nanoclays (One nano-scale dimension)



Nanoparticles



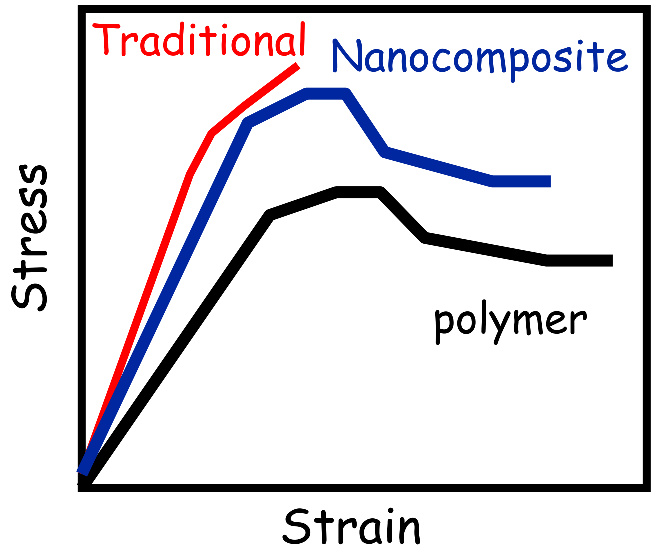
Nanofibers

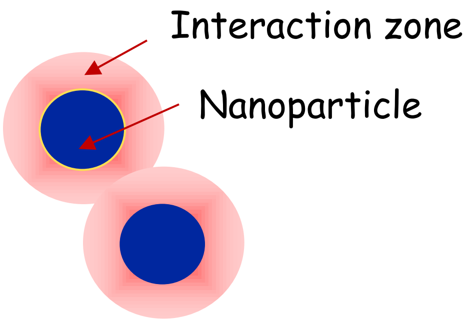


Nanoclays

Why nanocomposites ? → Multifunctionality

- Small filler size and distance between fillers
  - high surface to volume ratio
- Mechanical Properties :
  - Increased ductility with no decrease of strength,
  - Scratching resistance
- Optical properties:
  - Light transmission characteristics particle size dependent

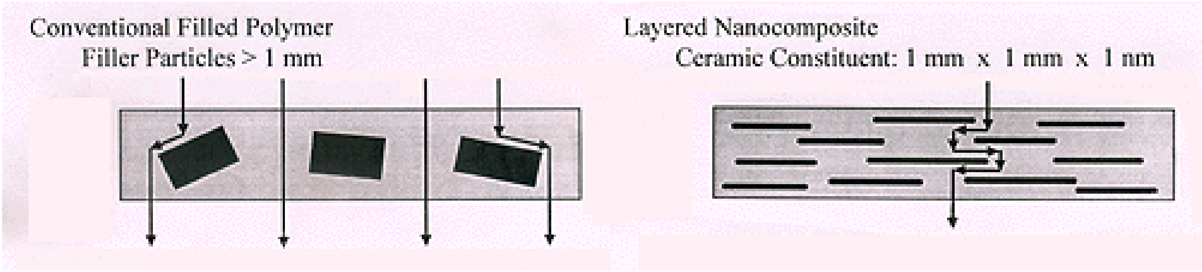




Application: barrier properties

- Imagine a drop of water trying to get through the film made with nanocomposites. Compared to a film made with conventional composites, the water drop would face more barrier going through the film made with nanocomposites because the distance between fillers is much smaller.
- Uses:

  Packaging in food, medical and pharmaceutical industry.



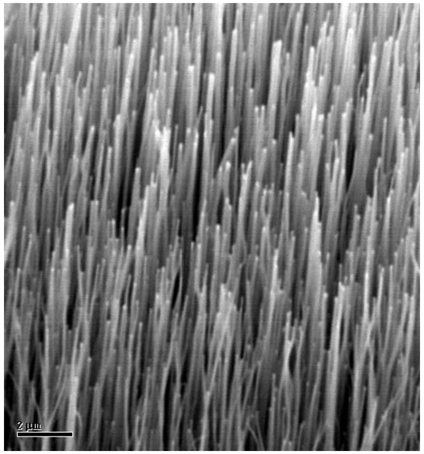
Thermal barrier coatings for Hubble Space Telescope (HST)

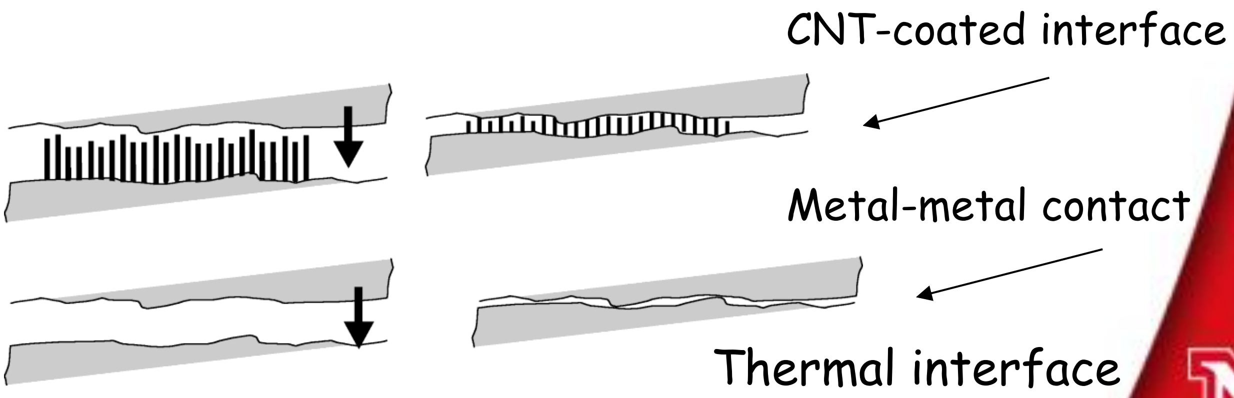
Current Problem:

Hubble Space Telescope Imaging Spectrograph overheats, causing data degradation.

Proposed Solution:

Carbon Nanotube (CNT) may greatly improve HST's ability to dissipate excess heat. (2X is the goal)

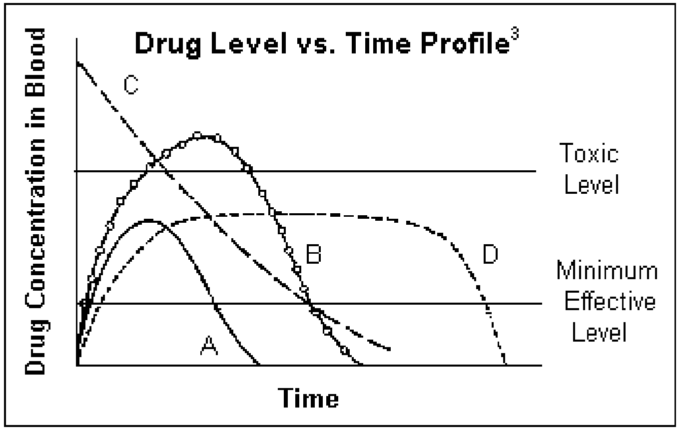




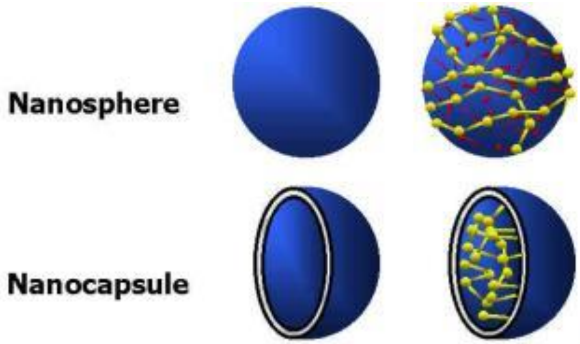
Drug delivery

Attributes of nanoparticulate systems:

1. provide a better penetration of the particles inside the body.
2. can be used for intramuscular or subcutaneous applications
3. minimizes the irritant reactions at the injection site.
4. exhibit greater stability, in both longer shelf storage lives and uptake times.
5. and can be designed to elicit the desired kinetics, uptake, and response from the body (i.e. biocompatibility).



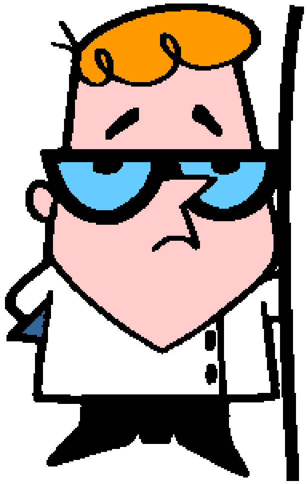
A: Oral Dose B: Oral Overdose C: IV Injection
D: Ideal Controlled Release



Limitations !

- To date one of the few disadvantages associated with nanoparticle incorporation has concerned toughness and impact performance. Nanoclay modification of polymers such as polyamides, could reduce impact performance.
- Research will be necessary to develop a better understanding of formulation/structure/property relationships, better routes to particle exfoliation and dispersion etc.
- Economically feasible.

Thank you for attention!



Questions?

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