NANOCOMPOSITES AND THEIR APPLICATIONS

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What are Nanocomposites?

" A Nanocomposite is a composite material, in which one of the components has at least one dimension that is around 10^{-9} m.

or

" A Nanocomposite is a multiphase solid material where one of the phases has one, two or three dimensions of less than 100 nm, or structure having nano-scale repeat distance between the different phases that make up the material.

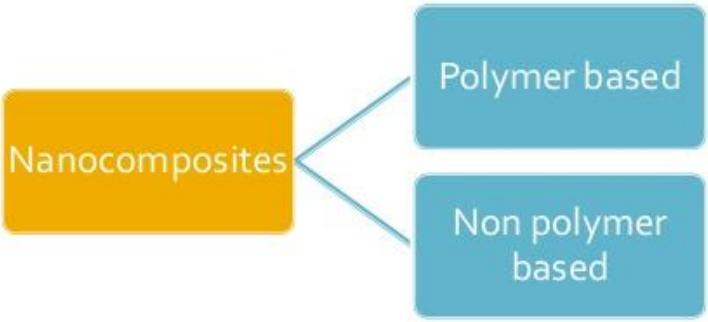
difference

- Mechanically the term nanocomposites are differ from conventional composites due to the exceptionally high surface to volume ratio of the reinforcing and/or its exceptionally high aspect ratio.

GENERAL CHARACTEISTICS

- consist of one or more discontinuous phases of distributed in one continuous phase.
- continuous phase is called “matrix”, whereas discontinuous phase is called “reinforcement" or “reinforcing material”

Classification of nanocomposites



Non-polymer based nanocomposites

- **Metal/Metal nanocomposites**

  (either in the form of alloy or core-shell structure)

  Eg. Pt-Ru

- **Metal/Ceramic nanocomposites**

  (either in the form of nanotube or complicated nanostructure)

  Eg. Polysilazane/polysiloxane

- **Ceramic/Ceramic nanocomposites**

  (alloy or ceramic)

  Eg. Zirconia-toughened alumina

Polymer based nanocomposites

- **Polymer/Ceramic Nanocomposites**

  (Layer structure) **Eg. Barium-titanate with polymers**

- **Inorganic/Organic Polymer nanocomposites**

  (clusters) **Eg. Polymer nanofiber with zero valent nanoparticles.**

- **Inorganic/Organic Hybrid Nanocomposites**

  (Nanocrystal) **Eg. CdS nanocrystals, Poly N- vinyl carbozole- photorefractivity.**

- **Polymer/ layered silicate nanocomposites**

  Eg. Nylon-6 (N6)/ montmorillonite(MMT) with silicate

- **Polymer/Polymer nanocomposites**

  (fillers) **Eg. Poly(*p*- phinylene oxide)- plastic scrap recycling**

- **Biocomposites**

  Eg. Elastin- collagen

Why polymer nanocomposites are unique???

- Increase in electrical break down strength of polymers.
- Melting temperature, color ,magnetization and charge capacity is more.
- interacting Zone is increasing such that we can get our expected property.

Applications

- electro catalyst in batteries for energy saving
- light weight materials for less fuel consumption.
- in artificial joints, economically beneficial
- carbon nanotubes most widely speaking nanomaterial which can be made as nanocomposite fibers.
- Abrasion and wear Applications
- Marine Application

- Food packaging
- Fuel tanks
- Films
- Environmental protection
- Flame ability reaction
- Erosion and corrosion Applications

conclusion

- ***Nanocomposites are upcoming materials which shows the great changes in all the industrial fields and it is also going to be a economical barrier for developing countries as a tool of Nanotechnology.***

General features of nanocomposites

Nanocomposites differ from traditional composites in the smaller size of the particles in the matrix materials.

Small size may cause
a) Physical sensivity of bulk materials to physical or mechanical energy
b) Higher chemical reactivity of grain boundaries

Physical sensitivity

- ❑ Small size effect
- ❑ Quantum confinement effect

Chemical reactivity

- ❑ Higher gas absorption
- ❑ Increased nonstoichiometry
- ❑ Regrowth
- ❑ Rotation and orientation
- ❑ Sub graining
- ❑ Assembly

Physical sensitivity

Small size effect:

When the particle sizes in composite materials approach lengths of physical interaction with energy, such as light wave, electromagnetic waves, the periodic boundry conditions of coupling interaction with energy would behave different from its microscopic counterparts, which results in unusual properties

Quantum confinement effect:

When electrons are confined to a small domain, such as a nanoparticles, the electrons behave like "particles in a box" and their resulting new energy levels are determined by quantum confinement effect. These new energy levels give rise to the modification of optoelectronic properties such as "blue shift" light emitting diode

Chemical reactivity

Higher gas absorption:
large specific area of nanopartilces can easily absorb gaseous species

Increased nonstoichiometry phases:
Nanomaterials easily form chemically unsaturated bonds and nonstoichiometry compounds

Regrowth:
Nanomaterials are probably easier to recrystallise and regrow in processing and service conditions than traditional materials

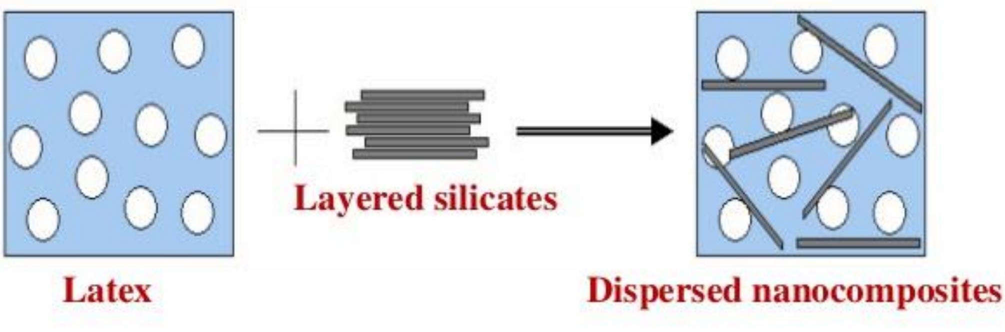
Rotation and orientation:
Crystallographic rotation and orientation of nanoparticles have been found in processing of nanocomposites

Sub-grain:
Nanoparticles enveloped into larger particles act as dispersed pinholes to divide the large particles into several parts.

Assembly
Nanoparticles are easy to aggregate and assemble in liquid or gaseous media

Nanocomposites materials

Nanocomposites can be formed by blending inorganic nanoclusters, fullerenes, clays, metals, oxides or semiconductors with numerous organic polymers or organic and organometallic compounds, biological molecules, enzymes, and sol-gel derived polymers



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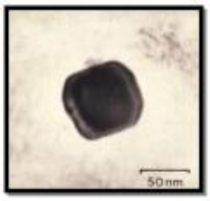
- Resulting nanocomposite may exhibit drastically different (often ***enhanced***) properties than the individual components
  - Electrical, magnetic, electrochemical, catalytic, optical, structural, and mechanical properties



Lycurgus Cup

Lycurgus Cup is made of glass. Roman ~400 AD, *Myth of King Lycurgus*

Appears green in reflected light and red in transmitted light

Classification of nanocomposites

Ceramic based nanocomposites

- Increase in the strength, hardness, and abression by refining particle size
- Enhance ductility, touchness, formability, superplasticity by nanophase
- Change electrical conduction and magnetic properties by increasing the disordered grain boundry interface

Metallic based nanocomposites

- Increased hardness, strength and superplasticity;
- Lowered melting point;
- Increased electrical resistivity due to increased disordered grain surfaces;
- Increased miscibility of the non-equilibrium components in alloying and solid solution;
- Improved magnetic properties such as coercivity, superparamagnetsation, saturation magnetization and magnetocolatic properties

Polymer based nanocomposites.

- electrical, optical, magnetic and catalytic properties arising from the inorganic materials, and enhanced thermal and mechanical stability originating from the polymeric matrix

Advantages and limitations of ceramic nanocomposite processing methods.

Methods	Advantages	Limitations
Powder process	Simple	Low formation rate, high temperature, agglomeration, poor phase dispersion, formation of secondary phases in the product.
Sol-Gel Process	Simple, low processing temperature; versatile; high chemical homogeneity; rigorous stoichiometry control; high purity products; formation of three dimensional polymers containing metal-oxygen bonds. Single or multiple matrices. Applicable specifically for the production of composite materials with liquids or with viscous fluids that are derived from alkoxides.	Greater shrinkage and lower amount of voids, compared to the mixing method
Polymer Precursor Process	Possibility of preparing finer particles; better reinforcement dispersion	Inhomogeneous and phase-segregated materials due to agglomeration and dispersion of ultra-fine particles

Advantages and limitations of processing methods for metal-based nanocomposites.

Methods	Advantages	Limitations
Spray Pyrolysis	Effective preparation of ultra fine, spherical and homogeneous powders in multicomponent systems, reproductive size and quality.	High cost associated with producing large quantities of uniform, nanosized particles.
Liquid Infiltration	Short contact times between matrix and reinforcements; moulding into different and near net shapes of different stiffness and enhanced wear resistance; rapid solidification; both lab scale and industrial scale production.	Use of high temperature; segregation of reinforcements; formation of undesired products during processing.
Rapid Solidification Process (RSP)	Simple; effective.	Only metal-metal nanocomposites; induced agglomeration and non-homogeneous distribution of fine particles.
RSP with ultrasonics	Good distribution without agglomeration, even with fine particles.	
High Energy Ball Milling	Homogeneous mixing and uniform distribution.	
Chemical Processes (Sol-Gel, Colloidal)	Simple; low processing temperature; versatile; high chemical homogeneity; rigorous stoichiometry control; high purity products.	Weak bonding, low wear-resistance, high permeability and difficult control of porosity.
CVD/PVD	Capability to produce highly dense and pure materials; uniform thick films; adhesion at high deposition rates; good reproducibility	Optimization of many parameters; cost; relative complexity.

Advantages and limitations of polymer-based nanocomposite processing methods

Methods	Advantages	Limitations
Intercalation / Prepolymer from Solution	Synthesis of intercalated nanocomposites based on polymers with low or even no polarity. Preparation of homogeneous dispersions of the filler.	Industrial use of large amounts of solvents.
In-situ Intercalative Polymerization	Easy procedure, based on the dispersion of the filler in the polymer precursors.	Difficult control of intragallery polymerization. Limited applications.
Melt Intercalation	Environmentally benign; use of polymers not suited for other processes; compatible with industrial polymer processes.	Limited applications to polyolefins, who represent the majority of used polymers.
Template Synthesis	Large scale production; easy procedure.	Limited applications; based mainly in water soluble polymers, contaminated by side products
Sol-Gel Process	Simple, low processing temperature; versatile; high chemical homogeneity; rigorous stoichiometry control; high purity products; formation of three dimensional polymers containing metal-oxygen bonds. Single or multiple matrices. Applicable specifically for the production of composite materials with liquids or with viscous fluids that are derived from alkoxides.	Greater shrinkage and lower amount of voids, compared to the mixing method