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Stable Properties and Applications Innanotechnology

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ABSTRACT

In different sources, the basic elements are classified based on the structure type or their dimensions. In this article, the basis of classification is the type of desired basic element. According to chemical composition and morphology, the basic elements are divided into other nanostructures. The second generation basic elements are a subset of basic elements from which they are formed. In the present paper, all basic elements of the definition, properties and applications are given.

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Massive nan ocrystalline materials:

Massive nanocrystalline materials are made of crystals that contain several hundred to several thousand atoms and are placed next to each other. Nanocrystalline structure due to atoms compaction next to each other has the lowest surface free energy.

When the crystal size in the material is going toward nanoscale, the ratio of atoms on the grains boundaries to the total number of atoms increases. Boundary atoms behavior is quite different from the atoms inside the particles and affects the behavior of whole the material. Often these phenomena in metals increase strength, hardness, electrical resistivity, specific heat capacity, improve thermal expansion, magnetic properties and reduce thermal conductivity and in ceramics, they increase the malleability, and improve mechanical and thermal properties.

There are several ways to create massive nanocrystalline materials including

- Powder Compression
- Method of crystallizing primary amorphous material
- Severe plastic deformation processing

In powder compression, nanoscale particles are produced initially, which will be subsequently compressed by static or dynamic methods.

Crystallization of amorphous material can produce finest scale of nanostructures, but it is limited to material that can reach the amorphous state.

Severe plastic deformation processing methods are only applicable to metals. Reducing the crystal size in nearly every metal dramatically increases the strength and in many materials, malleability can be increased. Because such methods can be implemented on a large scale, they are much more considered than the other methods for commercialization.

Nanocrystalline ceramics develop more malleability properties, meaning that these compositesare less fragile than similar non-crystalline materials. This has allowed them to become wire and based on superconducting properties of some ceramic, it will have applications.

Most practical massive nanocrystalline materials are nanocrystalline metals that are applied in industries such as automotive, aerospace and construction. Nanocrystalline metals can be used instead of structural metals and alloys.

One area in which nanocrystalline metals are used is manufacturing firm pieces used in the automotive industry. In such cases, their tremendous response in high temperatures, means less expansion due to temperature rise are considered as itsadvantages. Although ceramics can compete in this area, but they are usually very fragile.

However nanocrystalline ceramics are more flexible and may be applicable in pieces requiring strength, high wear resistance and resistance to high temperatures [1].

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Nanoparticles:

A nanoparticle is a particle which size is about 1 to 100 nm. Nanoparticles, in addition to the type of metal, include insulators, semiconductors and composite nanoparticles, such as core - layer structures. Nanoparticles in small sizes are considered as nanoclusters. Also,nanospheres, nanorods, and nano-cups are only considered as forms of nanoparticles.

Nanocrystals and semiconductor quantum dots are subsets of nanoparticles. Such nanoparticles are applied in various electronic and electrical and bio-pharmaceutical fields as drug carriers and imaging agents.

Characterization of nanoparticles is essential to control their synthesis, properties and applications. Characteristics of these compounds with X-ray, photoelectron spectroscopy, AFM, FT-IR are evaluated using various methods such as electron microscopy analysis.

Nanoparticles have many application areas, the most important of which are:

There are various methods to produce nanoparticles. These methods are divided basically into three categories:

Vapor condensation, chemical synthesis and solid-state processes such as milling

Methods of vapor condensation include evaporation of solid metal followed by its rapid condensation to form nanoscale clusters and Electro-exploding Wirethat is deposited as powder.

Basic elements, properties and applications are considered as 3components of vapor condensation methods.

The chemical synthesis method includes nanoparticles development in liquid media containing a variety of reagents. Sol-gel method is a sample ofsuch method, in chemical methods; the final particle size can be controlled throughstopping the process when the desired size is obtained or by selecting the chemical materials formingstable particles and stoppinggrowth at a certain size.

Solid processing method (grinding or milling) can be used to create nanoparticles. The method can be used to produce nanoparticles from materials that are not readily produced in two previous methods.Nanoparticles are currently made of a wide range of materials which most common one is ceramic, metal, polymer and semiconductor nanoparticles [2].

Semiconductor nanoparticle of quantum dots:

Quantum dot is an area of semiconductor crystal that consists of electrons, holes, and both of them callededeg zistonin three dimensions. This area includesa few nanometers to several hundred nanometers.

In quantum dots, electronsexactly likethe status of an atom occupy different energy levels, which is why they are also called artificial atoms. Compared with quantum wires that are in two dimensions and quantum layers that are in one dimension of Nano,nanostructures quantum dots are three-dimensional.

Due to the high quantum output, these composites are widely used in the optical fields.

There are three main methods to fabricate quantum dots; one of which includes quantum dots developmentin the reaction flask. In other two methods, quantum dots are produced on or near the surface of a semiconductor crystal. In the second method, the lithography process is used to create a two-dimensional nanostructure that is Nano in two dimensions, then to separate the quantum dots, nanostructures are engraved.

In the third method, with the deposition of a semiconductor material having larger lattice constant, the lattice constant represents the regularity of atoms intervals in a crystalline structure. These particles can also reflect, refract or absorb light by applied voltage. This property makes these composites applicable in electrochromic and photochromic materials and solar panels that change their color by applying light or electricity.

Basic elements, properties and applications: furthermore, the spin of an electron in a quantum dot can be used to represent a quantum bits - or qubits in a quantum computer.

Potential applications for quantum dots include:

- lasers with a very precise wavelengths
- Quantum computers
- Biomarkers

Ceramic nanoparticles:

The most common nanoparticles are ceramic nanoparticles that are divided into metal oxide ceramics, such as titanium oxides, zinc, aluminum, iron and silicate nanoparticles (silica or silicon dioxides are also ceramic) which are generally like clay nanoscale particles. Metal oxide nanoparticles have the same size in all three dimensions that are two or three nm to 100 nm and are attached to each other by electrostatic and are deposited as very fine powder. Ceramic nanoparticles are obtained through chemical synthesis and solid state processes. Silicate nanoparticles are particleswith a diameter of approximately 1 nm andwidth of 100 and 1000 nm. The most common types of silicate nanoparticles areMontmorillonite and layered Alumino-silicate. These types of nanoparticles are combined by polymerization or by melt mixing (mixing with a molten plastic) with the polymers and obtain interesting properties [5].

When the nanoparticle size decreases, the effective area ratio to the particle size increases, the surface impacts is dominated and catalytic property increases. Therefore, nanoparticles are applicable as catalyst in areas such as batteries, fuel cells, and a variety of industrial process. Greater proportion of atoms on the nanoparticle surface changes their physical properties, for example, ceramics which are normally fragile become softer. Finally, increasing the effective area increases the solubility.

Chemical modification of nanoparticles has significant effect on their efficiency and application. Hydrophilicity and hydrophobicity are among nanoparticles chemical modification methods. To obtain additional hydrophobicity, silicate nanoparticles must be chemically modified [4].

Ceramic nanoparticle nanocomposites:

In ceramic nanoparticle nanocomposites, ceramic nanoparticlesare distributed in a polymer network. The use of nanoparticles in composite materials can increase their thermal and chemical resistance and reduce their weight; and adds new features such as electrical conductivity to them and changes their interplay with light or other radiations.

One of the properties of ceramic nanoparticle nanocompositesin packaging industry is decreasing the permeability to gases. This feature is due to shape of nanoparticles grain that makes molecules to move in the maze of material. Silicate fillers can also change the feature a polymer from one-dimensional hardening to two-dimensional polymer.

When the silicatenanoparticles (clay) are used as filler in plastics, they create extraordinary strength with the dispersion of stress. Also, shrinkage, warping of the composite with a lower coefficient of thermal expansion and gas permeability is reduced; resistance to fire and chemicals increases, recycling of these materials is easier. Clay fillers with much less filler than conventional fillers increase resistance [3].

Metal nanoparticles:

Metal nanoparticles are generated using vapor condensation and exploding wire methods. The nanoparticles can be mixed in a solid without being melted (under a process called sintering) at temperatures below the metal melting temperature, leading to facilitating the process ofproducing coating, and improving their quality, particularly in electronic applications such as capacitors. Also, metal nanoparticles at lower temperatures than their greater non-nanoscale metal particles to the surfaces and become massive materials and reduce manufacturing costs [6].

Metal nanoparticle nanocomposites:

Metal nanoparticle nanocomposites are obtained through mixing metal nanoparticles with polymers. The nanocomposites due to their good blockage against electromagnetic interference can be used in computers and electronic equipment [7].

Aerogels:

Aerogels are a class of materials with very high special surface and very low density (sometimes they are only four times heavier than air).

These compounds are produced by sol-gel processes. When the sol (solution) is poured into a mold, a wet gel is formed. By drying and thermal processing, the resulting gel turns intocompact glass or ceramic particles. If in supercritical conditions, the liquid in wet gel is extracted, aerogel is obtained.

The use of aerogels as a membrane in separation and filtration processes is investigated. The aerogels are also applied in spacecraft to collect interstellar dust. These compounds were examined to use in double glazingas a filling layer instead of the air [8].

Nano coating and nano-layers:

Nanocoatingsare single or multi-layered surfaces with a thickness of 1 to 100 nm. Coatings based on nanoparticles exert different properties. Strength and wear resistance are among properties that have greatest advantages in nanocoatings and transparency is also important to them; especially in the case where increased hardness without surface clouding is required. The use of coatings on the ceramic surfaces causes the surface to be scratch-resistant and their easier cleaning. Scratch-resistant and hard nanocoatings can be used to coat glasses used. Type of solar cells has been released that are produced to increase their strength of nanoparticles. Thermal spray coatings based on metal oxide nanoparticles are used in repairing worn or corroded metal parts.

Today, metal nanoparticles are used in the electronics industry to cover the surface of capacitors. Also surfaces can be made on windows to be clean with minimal random rain. Coating can be antistatic, anti-damage, and anti-reflection while allowing visible light to pass through them, and blockpassing light wavelengths, such as ultraviolet radiation. Some ceramic coatings containing nanoparticles have created a composite which has many applications due to its properties such as wear and chemical resistance, and thermal insulation. Similarly coatings based on molybdenum sulfide containing nanoclusters have shown more resistance to friction, abrasion and chemical corrosion resulting from friction under wet conditions. Sol-gel and self-assembly methods are also used to produce coatingsthat are very promising for the future.

Coatings will have inevitably many applications such as protection of spaceships electronics equipment against radiation and thermal protection to re-enter the atmosphere.

Nanoparticles ceramic coatings result in thermal stability and corrosion resistance in the engine parts.

Coating containing metal nanoparticles that have specific applications in computers and electronic equipment show good prevention to electromagnetic interference [10].

Nanoshells:

By coating thenanoparticles, structures are created that are called nanoshells. To dissolve or degrade nanoparticles, hollow spheres are formed that are applicable in drug delivery and treatment of diseases. The chemical structure of nanoshells can be organic or inorganic [11].

Nanoporous materials:

The size and regularity of hollows is controlling the properties of nanoporous materials. In recent years, itis tried to produce specific pores byhigh control and precision of nanoporous materials. Nanoporous materials are divided into two broad categories: massive nanoporous and nanoporous membranes.

1. Massive nanoporous materials: By increasing the surface of these materials, catalytic properties, absorption and adsorption will be improved. Zeolites are considered as massive nanoporous material. Surface of this material is about hundreds of square meters per gram.
2. Nanoporous membranes: an application of these materials is their use as molecular sieve. Controlling the pores of these composites is one of the challenges determining the effectiveness of these materials.

There are many ways to produce a nanoporous material, in one of the methods, some materials are selectively removedfrom a solid, as a result of which pores in the nanoscale are created, in the other method, a mixture of polymers are transformed by heating nanoporous solid, in the process,one of the polymers is degraded and removed [12].

Conventional zeolites:

Zeolites are a range of natural and synthetic minerals with nanoscale and largerpores, which have been used as catalysts in the chemical industryfor years. Specific levels of these compounds are usually in the range of several hundred square meters per gram which has led to increase their absorptive properties tremendously [13].

Schwarzites:

Schwarzites like fullerenes and carbon nanotubes have a carbon structure. When carbon atoms form larger rings of six members, schwarzitesare createdwith a regular and stable structure and curves with negative slope similar to Zeolites. The calculations show that schwarzites are more stable than fullerene that seven and octet rings have a very small tensile stress. Schwarzitesare applicable in semiconductor systems and molecular sieves. These composites have been used as new catalysts [14].

Regular organic nanostructures:

Regular organic nanostructures include regular molecular arrangement that are repeated in nanostructures. Some of these composites are as following elements:

1. Dendrimers
2. Self-assembled monolayers
3. Metal organic nanocages
4. Diamoindoids
5. Langmuir Blodgett films – spirals
6. Organometallic compounds

Dendrimers:

Dendrimers are large and complex molecules, which have a clearly defined chemical structure. In terms of chemistry, dendrimers are relatively complete and uniform(in both size and shape) macromolecules which have a regular and highly branched three-dimensional architecture. They are formed of three main sections: core, branches, and terminating groups.

In synthesis of dendrimers, monomers are turned into polymerswith molecular weights almost identical. Dendrimers are prepared by the two following methods:

A- Divergent methods: In this method, molecules are formed from the core to the environment (outer branches).

B- Convergent methods: In this method,molecules are formed from the environment to the core.

Dendrimers are arranged as certain complex three-dimensional shapes. The creation of dendrimers that is a repetitive process is the most complex controlled continuity self-assembly functions bybuilding its multi-layers with designed chemical reactions.

The unique properties of dendrimers havecaused thesecomposites to be used in drug delivery systems [15].

Organic dendrimers:

In organic dendrimers, exterior and interior chemical structure are organic compounds.

Organic-inorganic dendrimers:

Inorganic - inorganic dendrimers, each ofexterior and interior structures and terminal groups can be of organic or inorganic compounds [16].

Organometallic compounds:

Organometallic nanostructures are composed of organic ligands and metal atoms, metal atoms form complexes centers and ligands are placed in metal coordinancelayer.

Organometallic nanocages:

Organometallic nanocages are formed by interaction oforganic and metal compounds, resulting in cage-shaped nanostructures, which confined certain areas and led to trapping atoms and small molecules. These spaces do not exist in organometallic compounds [17].

Diamondoids:

Diamondoids are considered as carbon cages that the structure of these compounds is exceptionally strong and tough. The most famous of these compounds areAdamantane with the formula $C_{10}H_{16}$ [18].

Spirals:

The structure of these compounds is somewhat similar to organometallic compounds, but their complexity is greater than the above compounds.

Nanofibers:

Nanofibers are relatively short fibers that their two dimensionswere in nanometer scale and their aspect ratio is larger. Variety of nanofibers can be obtained throughelectrospinning methods.

Polymer nanofibres:

Polymer nanofibers are produced by electrospinning with nanometer diameter. In this method, charged fluid are drawn into an electric field as small flows, then they are polymerizes as fibers [19].

Polymer nanofibers nanocomposites:

In polymernanofibers nanocomposites, we can benefit from polymer nanofibres strength. Also polymer nanofibres can be made with additives such as nanoparticles or nanotubes to offer many potential features of nanofibers nanocomposites.

Fibrils and carbon nanofibers:

Solid 15 carbons and hollow "Fibrils" are created with a few microns length and 2 to more than 100 nm diameter to be used in composite materials and coatings, resulting in increased strength andpotential conductivity of material.

To obtain similar properties, smaller "fibrils" than conventional carbon fibers (that have usuallymore than 0/1 mm diameter), fewer levelsof "fibrils" are consumed. Fibrils than conventional carbon fibers create a smoother surface oncoatings. The nanofibers are now produced on a large scale [20].

Carbon nanofibers nanocomposites:

Due to the unique properties of carbon nanofibers, these nanostructures are used in composite materials, surface coating and conductive plastics in automotive paint electrostatic and also dissipation of residing loads in electronic equipment.

Ceramic nanofibers:

Ceramic nanofibers have various applications that one of their applications (alumina nanofibers) is in filtration of viruses and bacteria from the air or water resources and biological fluids. The properties of this nanofiber can be improved by enhancing additives like nanoparticles [13].

Nanocapsules:

Nanocapsules are a nanoparticle that has a shell and a space to put the material inside it. The main processes for the manufacture of capsules have the same general form: an oil-in-water or water-in-oil emulsions are used to create oil and water nanocapsules respectively. The application of capsules depends on the type of emulsion used, for example, intravenous injection requires water nanocapsules, so to build the mentioned capsules,water-in-oil emulsion is used. However, the nature of the encapsulated materials –their hydrophilicity or hydrophobicity- dictates the type of nanocapsul required, which may not be consistent with the intended application. Capsuls coating with other layers may resolve this discrepancy. For coating, proteins, polymers and other natural and artificialmaterials can be used, They can be selected based on various properties besides the hydrophilicity or hydrophobicity, such as adhesion, resistance to different environments and so. In addition, temporary capsules may be used as the foundation for other layers and then destroy them. Production of nanocapsules is not acute or critical, so in the biological perspective, it has an attraction for the conductance of sensitive biological substances [12].

Polymeric nanocapsules:

Recently, polymers have been used to fabricate nanocapsules. The main process for building the nanocapsules is emulsion polymerization. Now polymeric nanocapsules can be produced in different sizes and shapes and in appropriate amounts. Then by attaching or accommodating a particular molecule in the wall of the nanocapsules, they will be functional.

These nanocapsules can act as a trigger for a targeted drug delivery system and release the content of the nanocapsulesin response to a particular biological molecule. Unlike nano-emulsions, polymeric capsulesare stick to each other with strong covalent bonding and so they have a special strength. Many nanocapsules are stable in both dry and liquid form.

For pharmacy instead of trigger mechanism, the consignment –if molecules are tiny-can be released withsimple mechanism of penetration;or to open it either by natural destruction or with the help of ultrasonic waves. Nanocapsules are considered some kind of self-assembly [10].

Nano-emulsions:

Nano-emulsions are consisted of surfactant molecules, such as phospholipids that are the hydrophobic and hydrophilic. When the molecules are placed in an aqueous environment, they form capsules that hydrophobic parts of the molecules will be set within them and thus they are protected from contact with water. Liposomes are structures made of lipids that are placed in this category. These compounds are widely used in the cosmetic industry [3].

Conclusions:

Analysts believe that nanotechnology, biotechnology and information technology (IT) form the three kingdoms of the Third Industrial Revolution. Nanotechnology can be seen as the continuation of current knowledge to Nano dimensions or planning current knowledge on newer and more modern bases.

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