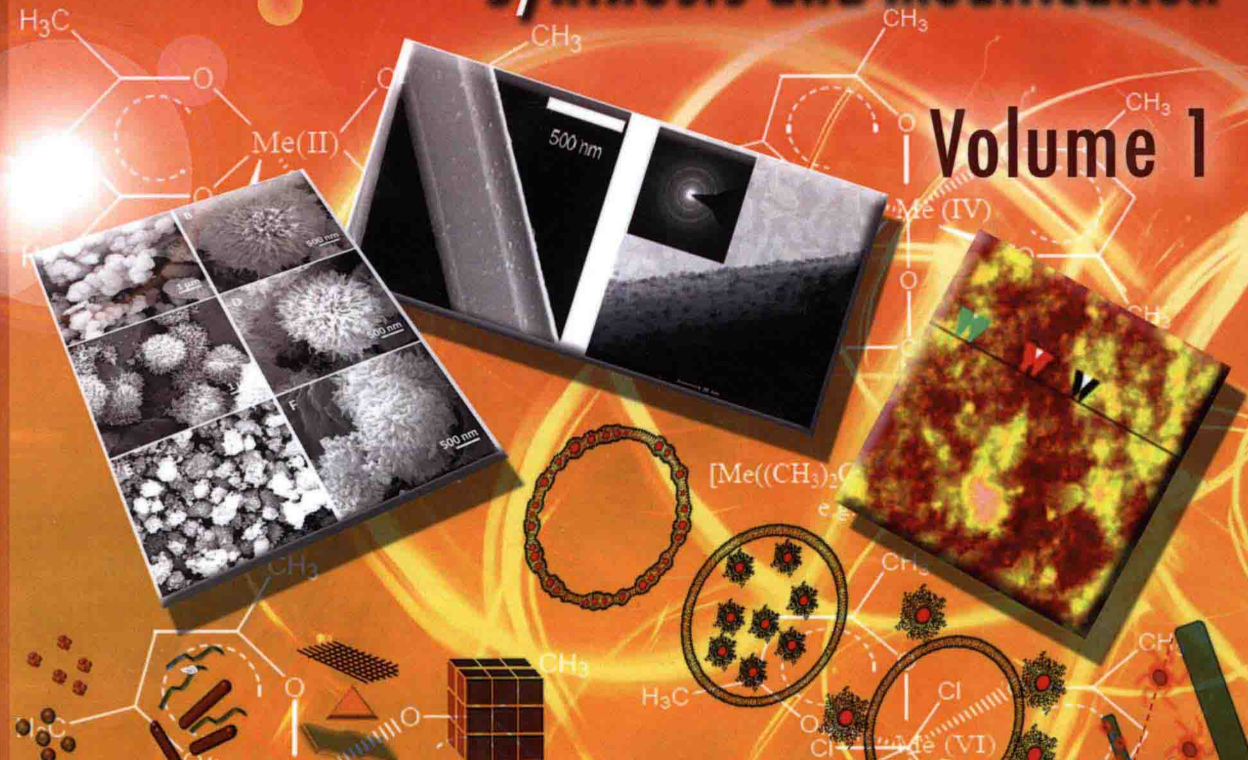
Nanotechnology Science and Technology

Handbook of Functional Nanomaterials

Synthesis and Modification

Volume 1



Mahmood Aliofkhazraei
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NANOTECHNOLOGY SCIENCE AND TECHNOLOGY

HANDBOOK OF FUNCTIONAL NANOMATERIALS

VOLUME 1

SYNTHESIS AND MODIFICATION

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PREFACE

This is the first volume of the handbook of functional nanomaterials (4 volume set). Functional nanomaterials appear in our daily lives. These materials mainly include nanocomposites, nanopowders, nanoparticles and nanocoatings. Nanotechnology enables the creation of structures that do not exist in nature, those which cannot be produced by conventional chemistry. Some advantages of this technology are the synthesis of stronger, more adjustable materials as well as lower costs. Nanotechnology is scientific and research development at the atomic, molecular, or macromolecular levels in a dimension range of 1 to 100 nm; the fabrication and application of the structures, equipment, and systems which involve unique characteristics and new applications because of their small or medium dimensions; and the potential for (materials and processes) the control and management of atomic scales. Therefore, nanotechnology involves industrial research and development at atomic, molecular, and macromolecular levels. This research aims to create and exploit the structures and systems which involve unique applications due to their small dimensions. The main difference between nanotechnology and other technologies is found within the dimensions and properties of the materials and structures applied to this technology. As a matter of fact, the main difference between these two types of technologies is the presence of base elements, which are indeed the same nanoscale elements with different properties in their nanoscale and larger states. Due to the developed properties of the very fine powders including surface chemistry, compressive properties, optical characteristics, and synthetic reactions, as well as an increasing demand for fine powders in industries, a very fine fragmentation is applied in many materials such as: minerals, ceramics, dyes, chemicals, microorganisms, pharmaceuticals and paper manufacturing. This volume mainly discusses the synthesis and modification of functional nanomaterials. Some of the functional nanomaterials discussed in this volume are zinc oxide nanoparticles, iron oxide, cadmium chalcogenide nanoparticles, chitosan-based nanocomposites, mesoporous materials, gallium nitride nanowires, titania nanoparticles, plasmonic nanofilms, polyaniline nanocomposites and nano silver. There are 19 chapters in this volume; each one includes examples of these interesting materials, supported by appropriate figures for better clarification.

Chapter 1 - This chapter is an introduction to the role of functional nanomaterials in our life. Nanotechnology allows creation of structures which do not exist in the nature and the conventional chemistry is not able to produce them. It also involves industrial researches and developments in atomic, molecular, and macromolecular levels. Functional nanomaterials will open their way in our life day after day. These materials mainly include nanocomposites, nanopowders and nanoparticles and nanocoatings. Some initial examples of these interesting materials have been mentioned in this chapter.

Chapter 2 - Owing to diverse applications in the field of electronics, optoelectronics and sensors, zinc oxide (ZnO) nanoparticles are attracting considerable attention in recent years. A few sol-gel processes for lab scale synthesis of ZnO nanoparticles have been reported so far. Increasing environmental concerns over chemical synthesis routes have culminated in efforts to develop biologically inspired synthesis processes. In case of ZnO nanoparticles the biological processes are yet to be explored. This chapter deals with sol-gel route to prepare zinc oxide nanoparticles using a biological agent (aqueous extract of *Azadirachta indica* (Neem) leaf) and provides an insight into its possible applications.

Chapter 3 - By manipulating the nanostructures, it is possible to impart new functionalities to material systems. In this chapter we try to combine the advantages of 1D and 3D nanostructures, to achieve superior electron transport along with high surface area. Intrigued by the unique properties of Fe_2O_3 at nanoscale and its abundance in nature, we demonstrate facile template-free solution based synthesis of hybrid α-Fe_2O_3 comprising of 1D nanorods nucleating radially from 3D core. We carry out studies on dye sensitized solar cell (DSSC) device characterization so as to gain understanding of how surface area and transport properties are affected by variation in morphology.

Chapter 4 - Ultra-small, 1.8–2.3 nm, CdS quantum dots (QDs) stabilized by polyethyleneimine (PEI) in water and guanidine dendrimers in dimethylformamide were prepared. CdS-PEI QDs have narrow size distribution of around 10% and photoluminescence emitted in a broad range of 400–600 nm with the quantum yields of 10–20%. Photoluminescence decay kinetics of CdS-PEI QDs is very non-exponential with an average radiative life time growing from ~15 to ~80 ns with the light quantum energy varying from ~3.2 to ~1.8 eV. Vibrational Raman spectra of CdS-PEI QDs exhibit a main peak at 250–300 cm^{-1} which is a superposition of longitudinal, transverse and surface-related vibrational modes, broadened due to spatial phonon confinement and structural reconstruction of QDs. Dendrimer-stabilized CdS QDs emit electroluminescence in the range of 450–700 nm under applied voltage higher than 6 V. Unusually strong temperature dependences of photoluminescence intensity and spectral maximum energy of CdS-PEI QDs in aqueous solutions and PEI films in the range of 280–353 K were found and interpreted in terms of reversible dissociation of a PEI complex with under-coordinated Cd(II) atoms on the QD surface.

Chapter 5 - Hybrid, semiconductor nanowire - metal nanoparticle assemblies have been investigated extensively in the context of nanotechnology for the development of novel sensors, solar cells, memory, energy storage and catalysis applications. In most cases silicon and metal - oxide semiconductor nanowires have been functionalized with noble metal nanoparticles. The large surface to volume ratio and high aspect ratio of semiconductor nanowires combined with the size dependent physical and chemical properties of noble metal nanoparticles make semiconductor nanowire - metal nanoparticle assemblies very attractive since one may achieve high device performances. Critical issues include control and modification of the surface properties of semiconductor nanowires for anchoring of noble metal nanoparticles but also the realization of ordered assemblies rather than random aggregates. Here we review the *state of the art* on the synthesis but also on the physical and chemical properties of semiconductor nanowires functionalized with noble metal nanoparticles such as Ag, Au, Pt and Pd with particular emphasis on their application for gas sensors, surface enhanced raman scaterring sensors, resistance switching memories, supercapacitors and batteries but also for their application in photocatalysis and electrocatalysis.

Chapter 6 - Chitosan, the only alkaline polysaccharide in nature, which has cationic polyelectrolytical and chemical reactive activities, has been applied widely in medicine, food, functional materials, cosmetics, environment, agriculture areas and so on. To expand the applications of chitosan, the composites based on chitosan or chitosan derivates have been the topic for many researchers. In recent years, chitosan-based layered silicate nanocomposites have attracted considerable interest since they combine the structural, physical and chemical properties of both layered silicate and chitosan. They are organic-inorganic hybrid nanocomposites with chitosan intercalated into the interlayers of layered silicate via simple solution intercalation method. Compared with ordinary composites, they excel in structure, property and applications. Intercalation of chitosan into layered silicate can identify characteristics of chitosan by layered silicate and construct novel chitosan-based nanocomposites from molecular level, which opens up the new development directions for chitosan. This chapter introduced the properties and applications of chitosan and layered silicate, and summarized the intercalation method, mechanism and applications of chitosan-based layered silicate nanocomposites.

Chapter 7 - Nanotechnology has been used in dentistry in several forms with the development of nanostructured materials as a useful tool. Nanomaterials are attractive to researchers both from practical and theoretical point of view because of their special properties. Many efforts have been made in the last two decades using novel nanotechnology and nanoscience knowledge in order to get nanostructured materials with determined functionality. There has been enormous interest in the evaluation of properties of nanosized materials for a variety of dental applications. The aim of this chapter is to study the methods of making, properties and applications of nanomaterials used in dentistry.

Chapter 8 - The Siliceous Mesoporous Molecular Sieve Si-MCM-41 was synthesized by the hydrothermal method at $100^{o}C$ for 2-10 days. Results show that eight days duration is the optimum duration for the synthesis of Si-MCM-41 with highly ordered uniform hexagonal mesopores with Type IV isotherm and *HI* type hysteresis loop. The Si-MCM-41 was then functionalized with 10-50wt% of Monoethanolamine (MEA), Tetraethylenpentamine (TEPA) and Polyethylenimine (PEI). All the functionalized samples were characterized by XRD, FTIR, FESEM, HRTEM, N_2 adsorption-desorption, TGA and elemental analysis. The physicochemical changes have been observed with a reduction in peak intensity in XRD diffractograms. Functional groups responsible for amine functionalization were observed in FTIR spectra. Agglomerated.particles were observed in FESEM micrographs. Hexagonal pores remained intact as observed in HRTEM images The adsorption-desorption isotherms changed from Type IV to Type III by N_2 adsorption-desorption. Each group showed different thermal stability observed by TGA and elemental analysis confirmed the presence of C and N in functionalized samples. Overall, results showed that Si-MCM-41 was successfully modified with Monoethanolamine, Tetraethylenpentamine and Polyethylenimine.

Chapter 9 - Crystalline wide bandgap semiconductors can be tailored for opto-electronic applications using solar radiation, ranging from photovoltaics up to photocatalysis, covering electrochromic windows and hydrogen production in photoelectrochemical cells. For each application, the main output property/properties might be different but it is strongly influenced by the crystalline structure and morphology of the components and assembly; when developing semiconductor associates, tandem materials or diode structures, the output properties are also significantly influenced by the interface. In optoelectronic applications, the real band structure of the components and assemblies can be tuned in the nano-range, with deviation from the bulk values, allowing the obtaining of novel or improved properties. The chapter focuses on controlling the optoelectronic properties of wide bandgap semiconductors (comparative analysis for TiO_2, WO_3, SnO_2 and ZnO), by investigating the surfactant assisted spray pyrolysis deposition of thin films; the interaction mechanisms of the surfactants with the cation precursors and the influence of various types of surfactant templates on the morphology and crystallinity are investigated. Band energy models are developed and applied to assemblies containing wide bandgap semiconductors, allowing drawing conclusions on the need for fine tuning in semiconductor associates. To prove the concept, selected data from photocatalysis applications are presented.

Chapter 10 - In this work, we give a review of recent analytical results of reference character related to the fluctuation-electromagnetic interactions in the systems particle-surface, surface-surface, and particle-particle. The applications of these results are important in atomic and molecular physics, quantum field theory and nanotechnology.

Chapter 11 - Solar control windows, which shield considerable amount of near-infrared (NIR) light yet transmit visible light, are realized with conductive nanoparticles dispersed in binder resins. Those windows using nanoparticles have advantages over conventional technologies in low solar energy gain, transparency to radio-wave frequencies, high stabilities and low cost, while keeping visible transmittance high. Especially nanoparticles of lanthanum hexaboride (LaB_6) and Cs-doped tungsten oxide (CWO) have excellent NIR-blocking properties at significantly little amount used. The origin of NIR absorption by dispersed nanoparticles was investigated by measuring dielectric functions and using electron energy-loss spectroscopy, and the localized surface plasmon resonance was found as responsible for such a strong absorption. A numerical approach to calculate optical extinctions using Mie theory suggests that the numerous-particle effect and dielectric modification of nanoparticles due to surface oxidation should be taken into account for the observed broad-banded NIR absorption profiles, in addition to the effects of variations of particle shape and diameter. These NIR-absorbing nanoparticles are applied to solar control films in automotive and architectural windows, laminated glasses for automotive windshield, plastic glazing for arcade roofs and domes, on-site solar control coatings for existing windows, among others.

Chapter 12 - Vesicles are aqueous capsules dispersed in an aqueous media; their shells consist of supramolecular assemblies of amphiphilic molecules. The possibility to load hydrophobic encapsulants into the shell and hydrophilic encapsulants into the core of vesicles renders them attractive, versatile delivery vehicles. Vesicles must retain encapsulants while being stored; however, once in use, these encapsulants should be controllably released. One possibility to gain control over the timing of release is by functionalizing thermo-responsive vesicles with actuators that locally generate heat such as plasmonic nanoparticles when subjected to light, or magnetic nanoparticles when exposed to alternating magnetic fields. In this book chapter, we discuss possibilities to assemble, characterize and apply different types of nanoparticle functionalized vesicles.

Chapter 13 - The third order nonlinear optical properties of self-assembled films formed from ZnO colloidal spheres are investigated and are compared with those of ZnO thin films deposited by the sol-gel process as well as pulsed laser ablation. ZnO thin films clearly exhibit a negative nonlinear index of refraction at 532 nm and the observed nonlinear refraction. The colloids and films developed by dip coating as well as pulsed laser ablation exhibit induced absorption whereas the self-assembled film exhibits saturable absorption. These different nonlinear characteristics can be mainly attributed to the saturation of linear absorption of the ZnO defect states and electronic effects when the colloidal solution is transformed into self-assembled films. ZnO colloids and self-assembled films show two emission bands. The presence of pronounced visible fluorescence in the self-assembled film confirms the presence of surface defect sates. We also report our investigations on the intensity, wavelength and size dependence of saturable and induced absorption of ZnO self-assembled films and colloids. Values of the imaginary part of third order susceptibility are calculated for particles of size in the range 20-300 nm at different intensity levels ranging from 40 to 325 MW/cm^2 within the wavelength range of 450–650 nm. The wavelength dependence of figure of merit, which specifies the magnitude of nonlinear absorption for unit value of linear absorption, is calculated and this helps in comparing the absorptive nonlinearities at various excitation wavelengths. From the saturation property of self-assembled films of ZnO, it can be used to construct an optic diode which passes light only in one direction. In conclusion, a passive all-optical diode using nanoZnO can be realized.

Chapter 14 - Chemical sensing using nanoscale materials and devices is gaining increasing interest in recent years, due to unique properties of low-dimensional structures. Owing to their high surface-to-volume ratio, the one-dimensional semiconducting nanowires act as efficient electrical transducers with high sensitivity to the environment, while the zero-dimensional metal oxide nanoclusters can further enhance the device functionality by acting as highly selective receptors. By functionalizing the nanowires with metal/metal-oxide nanoclusters, the nanoclusters not only act as nanocatalysts increasing the sensitivity of the device and reducing the detection time but also enable us to tailor selectivity of such hybrid sensors by changing the adsorption behavior of the analytes. By incorporating different nanoclusters on the nanowire surface, multi-analyte sensing on a single chip can easily be realized. This chapter focuses on highly sensitive, selective and room temperature operable gallium nitride nanowire chemical/gas sensors functionalized with metal/metal oxide nanoclusters.

Chapter 15 - Trivalent silver nanocomposites stabilized by polydiguanide ligand are synthesized through the oxidation of monovalent silver using a reverse microemulsion technique. These nanocomposites showed superior antibacterial activity toward Gram-positive and Gram-negative bacteria compared to silver sulfadiazine, which has been used as standard burn wound therapeutic agent. The synthesized trivalent silver nanocomposite was monodisperse and it exhibited excellent photostability under ambient conditions. Based on highly antibacterial activity and its moisturizing effect on human skin, these nanoparticles are expected to be used as active therapeutic agents in the host matrices of antibacterial cream or in wound dressings.

Chapter 16 - Titanium dioxide is one of the most widely used metal oxide semi-conductors for photoinduced processes because of its comparatively low cost, low toxicity and its ability to resist photocorrosion. Nanoparticulate TiO_2 has proven as efficient light-harvesting material for potential use in photocatalytic removal of hazardous industrial byproducts, in nanocrystalline solar cells, photovoltaics and sensors. Manipulating shape and size of TiO_2 nanoparticles has gained considerable attention primarily in order to control surface chemistry at nanoscale. Although uniform morphologies and well-defined structures have been studied, there is still lack of full understanding of the interconnection between surface, bulk and electronic properties of nano-TiO_2. Herein, we will discuss how size, shape and crystallinity of TiO_2 nanoparticles affect their electronic properties, and how interplay between these properties affect tailoring of nano-TiO_2 in order to create efficient functional systems.

Chapter 17 - Highly uniform silver thin films were realized on glass and various plastics via wet chemistry route. These solution deposited silver thin films were used as inexpensive substrates for surface plasmon-coupled fluorescence emission (SPCE) studies. Their use as real time plasmonic optical filters for photon sorting of fluorescence emission from molecular multiplexes under ambient conditions have been demonstrated. These substrates were also used in ethanol sensing. Our research opens doors to a broad spectrum of next generation ratiometric SPCE sensors based on high-resolution spectral determination of nano-environments in a multi-species system. SPCE measurements are made possible even in water medium which was not possible till now because of large exit angles.

Chapter 18 - Among conducting polymers, polyaniline (PANI) because of its high electrical conductivity, environmental stability, ease of preparation and relatively low cost, has been studied extensively for various applications. One of the most important applications of PANI is in protection of metals against corrosion. PANI has both barrier and electrochemical protection effects. However, to enhance the anticorrosion efficiency of PANI coatings, various nanoparticles like nanoclays, zeolites, graphene, metals and metal oxides have been used. This chapter deals with introduction of anticorrosive property of polyaniline and also application of polyaniline nanocomposites as anticorrosive coating on various metal substrates. Finally this chapter will focus on the mechanism of corrosion protection by these materials.

Chapter 19 - This chapter explains the significance of obtaining an antibacterial property for the textile materials and supports the choice of silver nano particles in attaining it, by citing some of its advantages. After discussing the present understanding prevailing among the researchers about the mechanism of nanosilver in imparting antibacterial property, it outlines various methods of synthesizing and incorporating the nanosilver on the textile materials with varying substrate geometry such as fibers, yarns and fabrics of woven, knitted and nonwoven types made up of a variety of fibers. Some of the methods outlined in this chapter include nanosilver synthesis and deposition on the textile materials by Layer-by-Layer technique using polyelectrolytes as reducing and stabilizing agent, photo induced reduction, sonochemical application, graft co-polymerization, sol-gel techniques, electro spinning, etc. It cites the wide application of different chemicals as reductants to get nanosilver particles and at the end describes a few methods of green synthesis of nanosilver for application on the textiles. Incorporation of nanosilver on fibers like cotton, wool, silk, poly (L-Lactide), cellulose acetate, and their blends, etc. to obtain antibacterial products for day to day applications and also in the medical field has also been reviewed along with the author's research in this field.

CONTENTS

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Chapter 1

FUNCTIONAL NANOSTRUCTURED MATERIALS

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ABSTRACT

This chapter is an introduction to the role of functional nanomaterials in our life. Nanotechnology allows creation of structures which do not exist in the nature and the conventional chemistry is not able to produce them. It also involves industrial researches and developments in atomic, molecular, and macromolecular levels. Functional nanomaterials will open their way in our life day after day. These materials mainly include nanocomposites, nanopowders and nanoparticles and nanocoatings. Some initial examples of these interesting materials have been mentioned in this chapter.

1. INTRODUCTION

Todays, nanotechnology is considered among the main scientific and industrial challenges of the world. Over the past years, dimensions of product used in advance materials have been dramatically reduced and even reached to nano scales. Thus, using the nanotechnology will be very useful and efficient in these purposes.

Nanotechnology allows creation of structures which do not exist in the nature and the conventional chemistry is not able to produce them. Some advantages of this technology are synthesis of more adjustable and stronger materials as well as lower costs. Nanotechnology is scientific and research development down to the atomic, molecular, or macromolecular levels in dimension range of 1 to 100 nm, fabrication and application of the structures, equipment, and systems which involve unique characteristics and new applications because of their small or medium dimensions; and the potentials for (materials and processes) control and management in atomic scales. Therefore, nanotechnology involves industrial researches and developments in atomic, molecular, and macromolecular levels. These researches aimed to create and exploit the structures and systems which involve unique applications due to their small dimensions.

The main difference between nanotechnology and other technologies is in the dimension and properties of the materials and structures applied in this technology. As a matter of fact, the main difference between these two types of technologies is presence of base elements, which are indeed the same nanoscale elements with different properties in their nanoscale and larger states. Owing to the developed properties of the very fine powders including surface chemistry, compressive properties, optical characteristics, and synthetic reactions as well as an increasing demand for fine powders in industries, very finer fragmentation is applied in many materials such as minerals, ceramics, dyes, chemicals, microorganisms, pharmacy, and paper manufacturing.

For instance, limestone powder is used as filler in the plastics to improve their thermal resistance, hardness, dye durability, and material stability. This material is also used as paper factories as coating and filler to produce bright papers with appropriate resistance to staining and aging. In addition, limestone has various uses in printability, ink absorption, as well as smoothness of the produced paper. Thus, very fine fragmentation of limestone powder is widely applied as filling material in painting, dyes, food, plastics, and pharmaceutical industries.

Nanotechnology science is mainly based on the physical objects. In engineering view, materials are divided into the polymers, ceramics, and metals. The most important member of polymers family is the plastics which have more carbon structures or genetic materials. One of the most important materials in ceramics group are oxides such as aluminum oxide. Since the electrons are not stable in one spot in the ceramics, they involve electrical charge. They are mostly hard and brittle. Todays, nanotechnology has enabled their use instead of bone.

Health of domestic animals is among the problem closely associated with economy of the husbandries. Nanotechnology science will introduce potential capabilities and opportunities to the future strategies of the veterinary medicine and treating the domestic animals. Food supply for the domestic animals is constantly accompanied with an increase in cost and the need for specific veterinary cares as well as drug and vaccine prescription. In this regard, nanotechnology offers efficient solutions to deal with such problems.

Todays, the synthetic drug releaser systems work based on use of antibiotics, vaccines, and probiotics while the drugs are mainly used through adding them to the water or food of the animals or muscle injection. One-step release of drugs against a microorganism, despite its therapeutic effects and disease prohibitive properties, typically accompanies with relapse of illness symptoms and mitigation of the taken drug effects.

The available techniques in nano domain are capable of recognizing and treating the infection, as well as nutritional and metabolic disorders. The synthetic drug release systems can have multi-aspect properties to deal with biological obstacles in promotion of the treatment efficiency of the taken drug and reaching to the target tissue. Among these properties, one can name:

1. Appropriate time setting for drug release;
2. Self-regulation capability; and
3. Ability of pre-planning.

Hence, in the near future the following technological advances are expected:

1. Development of synthetic drug, probiotic, and nutrient release systems;
2. An increase in the diagnosis time of the illness symptoms and applying the fast therapeutic techniques; and
3. Development of release system of nucleic acids and DNA.

Using nano-molecules in synthesis of animal vaccines, illness diagnosis, and animals treatment, as well as envisaging injection of nanoparticles to the animals and gradual activation of the effective material attached to these nanoparticle in animals body for destroying and elimination of the cancer cells have opened new horizons for the researchers.

Researchers evaluated the introductory steps of nano-shells application for their injection to the blood circulation. These nanoparticles attach to the membrane of cancer cells and by emission of infrared light increase cell temperature up to 55°C and result in its popup and tumor destruction. Besides, nanoparticles composed of ferric oxides leads to destruction of these cells through the emission of magnetic waves.

One the most essential subjects of the current researches is development of inanimate DNA release systems with appropriate efficiency and minimum cost, side effects, and toxic material used in gene therapy. Livestock breeding and appropriate intercross time are among the factors requiring high costs and time in lactating cow ranches. Among the solutions recently applied to deal with this problem, one can name using specific nanotubes in the skin which indicates the real estrogen hormone peak and estrus time in the animal. This system relays some signals to the sensors attached to the monitor device and shows the exact and real insemination time to the rancher.

2. Functional Nanomaterials

2.1. Nanocomposites

Generally, composites consist of a material as matrix and another material as the reinforcing phase. This creates diversity in these materials. Some nanocomposites are composed of strong carbon nanofibres and strong fibers or even plastics resistant to corrosion which are extremely better than steel and aluminum. The advance nanocomposites are used in a wide range of everyday objects such as boat body, fishing lines, and tennis pedals, as well as the new bullet proof vests.

Using iron materials, since they involve high costs, weight, and liability to atmospheric conditions, is not economically justified. Rather, applying the composites and nano-composites not only provides good strength and involves low costs, also offers low weights and enhances effective life of the parts. Replacing the ceramic and plastic nanocomposites in mechanical parts and military machines body can guarantee fuel consumption decrease and effective life increase. By further advancing of mass production of long CNTs, this material can be produced with a weight and tensile strength 20% and 50 times greater than those of steel. It replaces this old metal and leads to an overall change in human life environment. However, now, rather than an upcoming future, these nanotubes are used in combination with plastics to obtain light, very strong, and electrically strong composites. However, these materials can be used for military purposes (where quality overpasses the price) prior to the commercial purposes. Self-healing textiles and permanent magnets with magnetization energy several times greater than that of ordinary magnets (for the electrical engines) are among the other applications of these materials. Fiberglass with its scaffold structure involves high strength. In these materials glass fibers are produced in very thin mode under specific conditions and woven together in various forms. Among the most common woven fibers one can name straw and needle fibers.

Nanotechnology creates very light strong fiber-glasses by applying warp and woof structure between the molecules which are superior compared to many contemporary fiberglasses. These materials have many applications in military submersibles and submarines.

2.2. Monolayer Coatings

Monomolecular nanostructured coatings are considered as another research fields in nanomaterial area. It is possible to deposit a thin layer of these materials on metallic or plastic surfaces and enhance their impact and attrition resistance. Among the interesting military applications in this area one can name:

- Fabrication and design of bullet proof, fire-retardant, and impact proof clothing; using the nanoplatings in fibers of military and security guard clothing offers lightness, portability, and strength to them.
- Using metallic nanooxide plating for repair of worn and stained parts
- Fabrication of military hats with high thermal resistance using the nanoplates

2.3. Nanopowders and Nanoparticles

Some applications of the nanopowders are as follows: due to their uniformed size of some nanopowders with visible wavelength, they radiate wavelengths in a very brilliant manner. For instance, fluorescence phenomenon in metallic gold in its nano state is 10 times to that of its ordinary state. Thus, the metallic nanopowders such as gold can be used in illuminators or materials which require the strong diffraction of a particular visible or infrared spectrum. Moreover, it is possible to used nanoparticle based dyes instead of organic dyes and paint aircrafts which suffer from erosion in harsh coldness at high altitudes.

Once reacting with oxygen, aluminum produce the energy content 4 times to that of hydrazine, but thermic reaction of the powder does not involve severe combustion due to the limited effective surface. But, the new aluminum nanopowders completely burn and release their high energy and can be used in both solid and liquid fuel missiles. Considering rate of combustion reaction, it seems that there is required a lower content of oxidizer. Moreover, the metallic nanopowders can be mentioned as the next generation of the detonative materials.

The base nanomaterials in defend industry are the most susceptible materials in this field of technology. Indeed, the most important effect of nanotechnology in this industry is the