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Review Article
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An Overview of Recent Advances in Application of Some Inorganic Materials-Biological and Technological Perspectives

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Abstract

Inorganic compounds which include metals, minerals, and organometallic compounds are used as catalysts, pigments, coatings, surfactants, medicines, fuels and more. They often have high melting points and specific high or low electrical conductivity properties, which make them useful for specific purposes. The scope of the review focusses on the application of a few inorganic materials with special emphasis on their biological and biomaterials perspectives.

Keywords: Inorganic materials; Organic-inorganic hybrid; Biomedical applications; Biomaterial; Drug delivery system

Introduction

Natural materials often consist of inorganic and organic hybrid distributed on the (macro) molecular or nano scale where the inorganic part provides mechanical strength and an overall structure while the organic part delivers bonding between the inorganic building blocks and/or the soft tissue [1]. The most accepted definition of biomaterials is employed by the American National Institute of Health that describes it as "any substance or combination of substances, other than drugs, synthetic or natural in origin, which can be used for any period of time, which augments or replaces partially or totally any tissue, organ or function of the body, in order to maintain or improve the quality of life of the individual". The Williams Dictionary of Biomaterials defined biocompatibility as "ability of a material to perform with an appropriate host response in a specific situation". The first biomaterials used by Egyptians and Roman where gold and ivory were employed for replacements of cranial defects. Based on the reaction of the tissue to the biomaterial, these are classified into three distinct categories: biotolerant, bioactive and bioinert materials [2].

Clay Materials

Clay minerals are members of the phyllosilicate or sheet silicates family (chlorite, serpentine, talc and the clay minerals) which form parallel sheets of silicates consisting of hydrated alumina–silicates. The basic building blocks of clay minerals are tetrahedral silicates and octahedral hydroxide sheets. The arrangement sheets give rise to various classes of clay minerals such as 1: 1 (e.g. kaolinite and serpentine) and 2: 1 (e.g. smectite, chlorite and vermiculite) clay.

Clay minerals are one of the oldest earth materials used for healing purposes in traditional medicine. Indigenous people around the world have been using clay minerals for curative and protective purposes. Clay minerals are usually either positively charged or negatively charged, which the main reason for their ion exchange capacity is. Layered double hydroxides (LDHs), also known as "anionic clays", composed of an anion located in the interlayer space that compensates for the deficit of negative charge in the brucite-like layers [3,4].

Layered silicates belonging to the clay smectite family (montmorillonites, saponites, etc.) or microfibrous clays (sepiolite and palygorskite) are currently being investigated to develop hybrid advanced materials useful for diverse purposes including environmental and biomedical applications [5-14] (Table 1).

Application	References
Pharmaceuticals (Antacids, Gastrointestinal protectors, Antidihhoreatics, Antidiarrhoeaics, Osmotic oral laxatives)	[15-18]
Cosmetics (Cosmetic creams, powders and emulsions, Bathroom salts, Deodorants)	[4,15,19]
Biomaterial	[3,20-22]
Biosensor	[23-25]
Medical Devices	[26]

Table 1: Application of clay materials.

Titanium

Titanium is the 9th most abundant element in the earth's crust; only oxygen, silicon, aluminum, iron, magnesium, calcium, sodium and potassium. The most common titanium-bearing minerals are ilmenite ($FeTiO_2$), rutile (TiO_2), anatase (TiO_2), arizonite (Fe_2TiO_5), perovskite ($CaTiO_2$), leucoxene (altered ilmenite) and sphene ($CaTiSiO_3$) or titanite of these, only ilmenite, leucoxene, and rutile have significant commercial importance. About 65% of titanium is used in aerospace applications while rest 35% is divided among armour, automotive, consumer, industrial, medical and other applications [27]. The application of Titania nanotubes for energy and fuel applications is reported by many researchers [28-32]. Application of Titanium Dioxide nanoparticle as Environmental Sanitizing Agent was reported by Sujata and Jack [33].

The natural selection of titanium-based materials for implantation is due to the combination of its outstanding characteristics such as high strength, low density, high immunity to corrosion, enhanced biocompatibility, low modulus and high capacity to join with bone and other tissues. Titanium and its alloys received extensive attention in dental applications. Commercially pure Ti is the dominant material for dental implants and is used as an alternative to Ag-Pd-Au-Cu alloy not only because of its excellent properties but also due to the increasing

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cost of palladium. Few other reported representative dental titanium alloys are Ti–6Al–7Nb, Ti–6Al–4V, Ti–13Cu–4.5Ni, etc. [34]. For hard tissue replacement, the low Young´s modulus of titanium and its alloys is an advantage because the low elastic modulus can result in smaller stress shielding compared to other implant materials, faster bone regeneration. Artificial bones, joint replacements and dental implants, titanium and titanium alloys are often used in cardiovascular implants [35,36]. The corrosion behavior of the uncoated and hydroxyapatite (HA) coated titanium (Ti) corrosion behavior in simulated body fluid was studied by [37]. Ovissipour et al. discussed about the possible impact of titania and other nanoparticles on aquatic organisms [38]. Nia et al. reported about the method validation and application for the determination of Ti from TiO_2 Nanoparticles in Biological Materials by ICP-MS [39].

Mediaswanti et al. discussed about the bioactive porous titanium and porous titanium alloys with a variety of alloy components development as the solution to overcome stress shielding problems on dense titanium and for the improvement of biomechanical properties [40]. The synthesis, bio-characterization and antibacterial property of mesoporous silica nanospheres modified by titanium dioxide was studied by Cendrowski et al. The light activated antibacterial activity of the composite was studied on *E. coli*. The toxicity of the nanomaterial was further studied by quantifying the amount of lactate dehydrogenase released from mouse fibroblast cells L929 with LDH assay [41]. Murr et al. discussed about the a wide range of biocompatible, antibacterial and biofunctional implant devices with stress compatibility, cement less fixation by bone cell ingrowth with special emphasis on Ti-6Al-4V [42]. Sollazzo et al. synthesized highly porous titanium biomaterial induces osteoblastic bone marrow Stem Cells differentiation [43].

Silica

In nature, silica raw material is occurring in extensive range of mineral and includes unconsolidated sand and consolidated rock. Recently extraction of high purity silica from Amazonian sponges was reported by Barros et al. [44]. Ghosh and Bhattacherjee reported the extraction of nanosilica from rice husk [45]. Silica sand is most primary ingredient material in all glass industry. The range of chemical product silica is extended to reach food processing, soap and cleaners industries, photovoltaic, catalysis, etc. [46-50]. Further applications of silica includes materials for controlled release (Fragrances and Aromas, active pharmaceutical ingredients (APIs), Biocides), Inks and Coatings, Catalysis for Fine and Specialty Chemicals, etc. filler of rubber reinforcement [51,52]. Elemental silicon also finds many applications in different forms such as nanowires as photovoltaics and as light emitting devices, in energy and electronic field, photocatalysis, etc. [48,53].

Silica nanoparticles (MSNs) have been extensive investigated as a drug delivery system as it possess excellent properties such high specific area, high pore volume, tunable pore structures and physicochemical stability. Earlier MSNs were used for controlled delivery of various hydrophilic or hydrophobic active agents. Later advances in the MSN surface properties such as surface functionalization and PEGylation rendered them as a promising drug delivery vehicle for cancer treatment [54]. Encapsulation of Water Insoluble Drugs in Mesoporous Silica Nanoparticles using Supercritical Carbon Dioxide was reported by [55]. The biomedical application of silica includes the application of Silica-Gold Core Shell Structured Nanoparticles for targeted delivery system [50]. A facile and novel approach for the synthesis of Fe_3O_4/SiO_2 core/shell nanocubes in which magnetite nanocubes can be functionalized with uniform silica shell for various bio-sensing applications were reported by [56]. Nivorozhkin reviewed the developments in using silica materials in drug delivery applications to bring it in the realm of commercial applications compatible with FDA to enter clinical trial [57]. Zeolite Y in the sodium form (NaY) was synthesized using amorphous silica ash derived from waste rice husks for use as an antimicrobial agent for controlling implant-related infections was developed by Salama et al. [58]. The Application of silica as 3D biosensor was reviewed by Wu [59]. López et al. reported the application of SiO_2 Nanostructured Materials for Local Delivery of anticancer drug Methotrexate [60]. Functionalized Dendritic Mesoporous Silica Nanoparticles for the pH controlled release of curcumin was reported by AbouAitah et al. [61]. Hsiao et al. synthesized core-shell fluorescently labeled SiO_2 NP of 15, 60 and 200 nm diameter and analyzed their cytotoxicity in THP-1 derived macrophages, A549 epithelial cells, HaCaT keratinocytes and NRK-52E kidney cells for studying the cellular uptake of Silica nanoparticles [62].

Bioglass

In 1969, Hench et al. termed certain silicate-based glass compositions as “bioactive” for their ability to bond chemically to rat bone. This oldest bioglass(BG) composition, consists of a silicate network (45 wt% SiO_2) incorporated with 24.5 wt% Na_2O, 24.5 wt% CaO and 6 wt% P_2O_5 as network modifier. Bioactive glass compositions developed over the years are sodium free or have additional elements such as such as fluorine, magnesium, strontium, iron, silver, boron, potassium or zinc incorporated in the network [63].

The use of Bioactive Glass S53P4 in Reconstructive Surgery in the Upper Extremity Showing Bone remodeling followed by its vascularization, cartilage repair and antibacterial properties was shown by Lindfors [64]. Tripathi et al. prepared bioactive glass containing SiO_2-Na_2O- CaO-P_2O_5-MgO was fabricated by sol-gel process. Bioactivity of the glass was explored by immersion in stimulated biological fluid (SBF) for different time periods. The formation of hydroxyl carbonate apatite (HCA) layer was identified by FTIR spectrometry, scanning electron microscope (SEM) and XRD which showed the presence of HCA as the main phase in all tested bioglass samples [65]. Rendón et al. reported the synthesis of bioactive sol-gel coatings and deposited on stainless steel AISI 316L using a pneumatic spray. The corrosion resistance of the coatings was tested with potentiodynamic curves after immersion of the coatings in SBF for 7 and 40 days. Wollastonite dispersed in the sol matrix is compatible with the physiological environment and the composition of SiO and CaO helps to accelerate the osteointegration forming an apatite layer in a short period. This fast bioactive response allows to the implant to have a good fixation to the bond [66]. Vasconcelos et al. evaluated the antimicrobial activity of a new formulation containing red and green propolis. The propolis loaded bioglass did not lose the antimicrobial activity. Results suggest that propolis in this sustained release formulation should be further tested as an alternative therapy against infectious agents of the oral cavity [67]. In vitro biocompatibility of bioglass synthesized in hydrothermal chemical route by the use of microwave energy irradiation was reported by Sarkar and Lee [68]. Haach et al. fabricated PMMA+HA and PMMA+45S5 scaffold and compared their mechanical properties and *in vivo* test. The histological analysis and mechanical properties suggest that both materials are suitable to bone replacement of small size areas [69]. Chitosan-based bioactive glass (BG-CH) with 17 wt% chitosan was fabricated by a freeze-drying process. BG-CH was implanted in the muscle and in the femoral condyles of ovariectomised rats. Grafted tissues were carefully removed for physico-chemical and histological analysis. Results suggests that antiosteoporotic ability makes of BG-CH a useful material for preventing bone loss associated with postmenopausal osteoporosis [70].

Mabrouk et al. prepared Nanobioactive quaternary glass system 46S6 by modified sol-gel process at 600°C with particle size ranging between 40-60 nm and a decrease in the gelation time. The *in vitro* biocompatibility of the sol-gel prepared glass was faster compared to the melting bioglass. Cell viability assay confirmed the effectiveness of the prepared bioactive glass as a bone replacement material. Composite scaffolds of polyvinyl alcohol (PVA) and/or quaternary bioactive glass (46S6 system) loaded ciprofloxacin were prepared by lyophilisation technique. The scaffold was characterized by Porosity SEM, XRD and FTIR. Biodegradation rate and prolonged drug release assay suggests that the scaffold offers a distinguish treatment for osteomylitis as well as local antibacterial effect [71]. Bioactive glasses, doped with traces of copper (Cu) and zinc (Zn) were synthesized by fusion method. Cu and Zn present interesting functions for the biological metabolism through their antibacterial, anti-inflammatory and antifungal properties. The material was non-cytotoxic to osteoblast cells SaOS and endothelial cells while exhibiting invivo biocompatibility as shown by the formation of hydroxyapatite. These biomaterials offer an alternative for the orthopaedic or maxillo-facial surgery [72]. Bioavailability of strontium ions from bioactive glasses *in vivo* was studied by Lao et al. [73]. Waselau et al. studied the *in vivo* effects of bioactive glass S53P4 or beta tricalcium phosphate on osteogenic differentiation of human adipose stem cells after incubation with (bone morphogenic protein 2) BMP-2 protein [74]. Glass reinforced hydroxyapatite composite and highly crystalline and still resorbable HAP by additions of alpha or beta tricalcium phosphate, $Ca_3(PO4)_2$, (TCP) was presented by Hannickel and Prado [75]. The role of TiO_2+ZrO_2 in the system of 45S5 bioactive glass for improving the bioactivity as well as other physical and mechanical properties of 45S5 bioactive glass was evaluated by XRD, FTIR, SEM, Density and compressive strength analysis by Himanshu et al. [76]. Structural, magnetic and *in vitro* bioactivity of Co-Cu ferrite and bioglass composite for hyperthermia in bone tissue engineering was studied by Sampath [77]. Implantation of nano bioglass scaffold enhanced with mesenchymal stem cell in rat calvaria was studied by Amiri [78].

Calcium Phosphate

Calcium phosphate (CaP) biomaterials are of special interest because they are bioactive and can form intimate and functional interfaces with neighbouring bone. Some commonly used CaPs include monocalcium phosphate monohydrate, monocalcium phosphate anhydrous, dicalcium phosphate dihydrate, dicalcium phosphate anhydrous, octacalcium phosphate, α- and β-tricalcium phosphate (TCP), amorphous CaP (ACP), calcium-deficient hydroxyapatite(HA) and HA [79]. CaP biomaterials are commonly used in orthopedic and dental surgery as bone void fillers or as a coating material on metallic implants [80]. The application of CaP ranges from hard tissue regeneration to the delivery of small molecules, oligonucleotides, and proteins. CaP also holds promise as a vaccine Adjuvant where nanoscale formulations have been shown to be more effective than micrometer-sized particles at targeting lymph node dendritic cells for enhancing immunity [81]. Calcium Phosphate Cement (CPC) is another calcium phosphate biomaterial, is a self-setting synthetic bone graft materials. CPC was approved in 1996 by the Food and Drug Administration (FDA) for repairing craniofacial defects. When mixed with an aqueous solution to form a paste, CPC can self-harden to form HA in situ. Moreover CPC has good biocompatibility and injectability, enabling minimally invasive [79].

Development of resorbable calcium phosphate cement with load bearing capacity was reported by Unosson and Engqvist [82]. Bioceramics based on α-alumina and calcium phosphate was synthesized and physical property was determined for application as dental implant [83]. Kumar et al. fabricated self-setting bone cement formulations based on egg shell derived tetracalcium phosphate bioCeramics that can immensely improve the material and biological properties of the self-setting bone cement [84]. Setting mechanisms of acidic premixed Calcium Phosphate cement was investigated by Jonas et al. [85]. Toyama et al. synthesized sulfate-ion-substituted hydroxyapatite from amorphous calcium phosphate [86]. Tensile Stress in bone cement is influenced by cement mantle thickness, acetabular size, bone quality, and body mass Index in case of total hip replacement was investigated by Lamvohee et al. [87]. Kato et al. developed ultrathin amorphous calcium phosphate freestanding sheet for dentin tubule sealing [88]. Padilla et al. developed Novel Nanostructured Zn-substituted Monetite as a biomaterial fore bone regeneration [89]. Nano-hydroxyapatite (nHA) coated with the biodegradable co-polymer poly(glycolide)-poly(ethylene glycol) (PGA-PEG) was synthesized for the delivery of Statins to treat low bone density pathologies [90]. CNT reinforced hydroxyapatite was prepared exhibited improved fracture toughness with respect to that of pure HAp for potential application in bone tissue engineering [91]. Biocompatible HA/Mwcnts/BSA was modified with TiO_2 for Using as a Bone Replacement Materials [92]. Effects of surface roughness of hydroxyapatite on the attachment and proliferation of rat osteosarcoma cells was studied by Li et al. [93].

Zeolites

Zeolites are crystalline, hydrated aluminosilicates of alkali and alkaline earth cations, consisting of three dimensional frameworks of SiO_4^{4-} and AlO_5^{4-} tetrahedral linked through the shared oxygen atoms [94]. They are crystalline nanoporous inorganic materials with well-defined interconnected channels or cavities in the nanometre or subnanometer length scale, termed as micropores (0.5-2 nm) [95]. Zeolites are among the most important inorganic cation exchangers. The aluminosilicate structure is negatively charged and attracts cations that come to reside inside the pores and channels. Zeolites have large empty spaces, or cages, within their structures that can accommodate large cations, such as Na^+, K^+, Br^+ and Ca^{2+} and even relatively large molecules and cationic groups, such as water, ammonia, carbonate ions, and nitrate ions [96]. Zeolite finds its application as adsorbents, ion exchangers and catalysts in industry, veterinary medicine, agriculture, sanitation and environmental protection. In human medicine zeolites have been applied as antidiarrheal remedies, the removal of ammonia ions from kidney dialysates, external treatment of wound and athlete foot, etc. [94]. Guo et al. photoactivated the Zeolite framework by encapsulating with semiconductor oxides, thereby enhancing the efficiency and selectivity as photocatalyst [95].

The properties such as long-term chemical and biological stability, ability to reversibly bind small molecules, size and shape selectivity, possibility of metalloenzyme mimicry and immunomodulatory activity reasons for the use of zeolite for biomedical applications [94]. Pavelic et al. reported the use of finely ground clinoptilolite (a natural zeolite) as a potential adjuvant in anticancer therapy [97]. *In vitro* application of zeolite as biomaterial on Stimulated Biological Fluid (SBF) and two types of cells (chronic myelogeneous leukemia and swiss albino fibroblast culture cells) was observed by Ceyhan et al. [98]. The application of zeolite composite membranes and crystals as potential vectors for drug-delivering biomaterials was observed by Tavolaro et al. [99]. Electrospinning method was used to fabricate polyurethane nanofibers, enhanced by zeolite crystals showed the normal development and growth of cells and exhibits antimicrobial effect against bacterial strains. This nanocomposite structure is promising for their potential usage and value in biomedical engineering applications [100]. Class "F" fly ash was used to obtain new zeolite materials for advanced wastewater treatment for removal of heavy metals(Cd^{2+}, Cu^{2+} and Ni^{2+}) from synthetic wastewaters containing one, two and three pollutants [101]. Leggo evaluated the properties and benefits of using an organo-zeolitic fertilizer (biofertilizer) for the production of food crops and the vegetation of contaminated land [102]. Clinoptilolite sorbent KLS-10-MA was prepared as food additive in laboratory inbred ICR line mice and reduction in lead bioaccumulation was explored. The results shows a significant favourable effect and thus it appears as a reliable means for detoxification of human and animal organisms chronically poisoned by heavy metals, particularly lead [103]. Leggo reported the use of Organo-zeolitic biofertilizer was used as new strategy of soil amendment to greatly enhance the scope of plant growth on damaged and marginal soils [104]. Aluminium ion adsorption capacity of zeolite from polluted tap water was investigated by Abdullah [105]. The influence of zeolites as feed additives on the chemical, biochemical and histological profile of fish. Rainbow Trout was supplemented with normal diet and diet supplemented with 1-4% of natural zeolite. Pathomorphological and histological examinations of muscle tissues and internal organs of the rainbow trout was carried out along with lipid fatty acid and amino acid composition. The results of this study confirmed that zeolites had a positive effect on the chemical, amino acid and fatty acid composition without any pathological changes in the liver, muscles and other organs [106]. Zeolite Y in the sodium form (NaY) was synthesized using amorphous silica ash derived from waste rice husks and was modified ZnO and ZnS. The antimicrobial activity was tested NaY, ZnO/NaY and ZnS/NaY. The result show a superior antimicrobial activity of ZnS/NaY compared to the rest therefore making it a potential candidate as an antimicrobial agent for controlling implant-related infections [107]. Synthesis of porous gelatin/hyaluronic acid/zeolite composite scaffolds by lyophilisation technique was used for wound-healing applications by Grohens [108]. Aflatoxin and two adsorbents (Zeolite and Mycosorb) were added to diet to evaluate some blood biochemical and enzyme activities in broiler chickens. Results showed reduced adverse effects of AF which could be helpful in a solution of aflatoxicosis problem in poultry [109].

Magnetic Nanoparticles

Magnetic materials are those materials that show a response to an applied magnetic field. They are classified into five main types; ferromagnetic, paramagnetic, diamagnetic, antiferromagnetic and ferrimagnetic. Magnetic nanoparticles (MNPs) are those nanoparticles (NPs) that show some response to an applied magnetic field. MNPs are of great interest for a wide range of disciplines, such as magnetic fluids, catalysis, biomedicine, magnetic energy storage, information storage and spintronics, etc. [110]. Biomedical applications of magnetic nanoparticles can be classified according to their application inside or outside the body (*in vivo*, *in vitro*). For in vitro applications, the main use is in diagnostic separation, selection and magnetorelaxometry, while for *in vivo* applications, it could be further separated in therapeutic (hyperthermia and drug-targeting) and diagnostic applications (nuclear magnetic resonance [NMR] imaging) [111,112].

High efficacy in hyperthermia-associated with polyphosphate magnetic nanoparticles for oral cancer treatment was reported by Candido et al. [113]. Thermosensitive magnetic nanoparticles for self-controlled hyperthermia cancer treatment were reported by Martirosyan [114]. Israel et al. synthesized ultrasound-mediated surface engineering of theranostic magnetic nanoparticles synthesis using mixed polymers for siRNA delivery [115]. Hereba et al. studied the effect of magnetic microspheres on some biophysical parameters of human blood [116].

Zinc Oxide

Zinc Oxide (ZnO) films have become technologically important due to their range of high electrical (piezoelectric constant), optical properties (band gap), good chemical and mechanical stability, low toxicity and biodegradability [117-119]. This metal oxide finds its application in wide spectrum such as UV light emitters, spin functional devices, gas sensors, transparent electronics and surface acoustic wave devices, wireless fluorescence lamp, image recorder, rheostat, phosphor, cosmetics and sunscreens food industry, astringent for eczema, excoriation, wounds and haemorrhoids in human medicine as additives, packaging due to their antimicrobial properties [118,120]. They are also being explored for their potential use as fungicides in agriculture and as anticancer drugs and imaging in biomedical applications such as glucose, phenol H_2O_2, Urea, Cholesterol biosensors, etc. [121].

Recently application of ZnO nanoparticles in the perspective of opportunities and challenges in veterinary sciences was reviewed by Raguvaran et al. [120]. Guano et al. and Wallace et al. reported the synthesis of zinc oxide crystals with controlled size and morphology and ZnO nanowire respectively [121,122]. Nanocrystalline zinc oxide thin films were synthesized for application as ethanol vapour sensor by Bhasha et al. [118]. Mugwang et al. synthesized Aluminum Doped Zinc Oxide (Azo) thin films for solar cell apllications [123]. Zinc oxide nanomaterials for biomedical fluorescence detection were reviewed by Hahm [124]. Sub-acute oral toxicity of zinc oxide nanoparticles in male rats was reported by Ben-Slama et al. [118]. The author reported that oral exposure to moderate dose of ZnO-NPs has no significant main effect on the behavior of the rodents and causes subtle signs of toxicity. Kisan et al. investigated the effect of nano-Zinc Oxide on the leaf physical and nutritional quality of spinach. The reported that Nano-zinc oxide (1000 ppm) can be used as a biofortification agent to improve protein and dietary fibre contents of spinach leaves [125].

Apart from the above mentioned particle there are a number of metallic nanoparticles that offer a wide range of application. The applications of silver nanoparticles have attained the highest level of commercialization compared to other nanomaterials [126]. Silver nanoparticle is used as antimicrobial agent, magnetic and optical polarizability, catalysis, electrical conductivity, DNA sequencing, surface-enhanced Raman scattering and various other applications [127-129]. Copper and copper oxide nanoparticle finds its application in catalyst, electrical, optical, antidiabetic, antioxidant, antimicrobial activities [128,130]. Novel Selenium nanoparticles (SeNPs) are attracting increasing attention as potential drug carriers due to their excellent biological and chemopreventive activity [131-133].Gold nanoparticles, due to its biocompatibility and simple method of preparation, have wide range of application right from genomics, biosensor, immunoassay, clinical chemistry, detection and photothermolysis of microorganisms and cancer cells; targeted delivery of drugs, peptides, DNA and antigens, optical bioimaging and monitoring of cells and tissues, water purification, etc. [134,135].

Conclusion

The above review investigates the latest advances in inorganic materials for various applications with special emphasis on biological perspective. Inorganic materials have been used since antiquity and scientific research has further uplifted its potential for more delicate application by hybridizing with organic materials. The author hopes that the review gives more insight and help in the advancement of future research.

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