Applications of Nanomaterials

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Abstract— Now-a-days nanotechnology is one of the most exciting topic in the scientific research. The role of nanotechnology was given its due recognition by prominent academicians from all over the world & the industry as well recognized its potential for a plethora of applications because size of nanomaterials. As nanomaterials have exclusive, advantageous physical, chemical & mechanical properties, they can be applied in various important applications. This paper covers classification & various applications of nanomaterials in various field like material science, medicine, water treatment, electronics, composite, environment etc. Beside these, nanomaterials applications may include construction materials, military goods, space science, agricultural science etc.

Keywords: Nanomaterials, Nanomedicine, Energy Storage, Sensors

I. INTRODUCTION

Nanotechnology is the art and science of design, characterization, production & application of materials, devices & systems through control of matter on the nanometer length scale (1-100 nm), and have its unique phenomena and properties (physical, chemical, biological, mechanical, electrical etc.) at that length scale. Because of ultra-small particles with exceptional properties nanoparticles are used in medical technology where direct medicines enter straight to the place where the human body needs them. Also they can material stronger and they can convert solar energy more efficiently. Nanomaterials & nanoparticles already gained importance in research & technological importance due to their adjustable important characteristics such as very high reactivity, light weight, super sensing, enhance electronic property etc. By controlling the size, shape and internal order of nanostructures properties (colour, chemical reactivity, electrical conductivity etc.) can be modified [1]. Now-a-days China is the fastest growing country for using of nanotechnology in different fields. Generally nanomaterials classified as their based on different applications. Here based on the construction, nanomaterials classified as (a) carbon- based, (b) metal-based, (c) dendrimers & (d) composites [2]. Normally, in carbon-based nanomaterials have carbon & it found in carbon nanotube, graphene etc. Metal based nanomaterials are commonly known as quantum dots, nanosilver, nanogold & oxides with metal bases. Titanium dioxide (TiO_2) is one such example. Dendrimers are in between moleculer chemistry & polymer chemistry [3]. They used as a catalysis in biomedicine industry. A composite is a material made from combination of nanoparticles & other materials. Nanoparticles, such as nanosized clays, are already being added to products ranging from auto parts to packaging materials, to enhance mechanical, thermal, barrier, and flame-retardant properties [4]. In recent days most widely used & researched nanomaterials are Ag, Zinc oxide (ZnO), Copper oxide (CuO), Cerrium oxide (CeO_2), Titanium dioxide (TiO_2), Iron oxide (FeO), fullerenes, carbon nanotubes ($CNTs$) & a small number of others. Figure 1 shows classification & wide range of applications of nanomaterials.

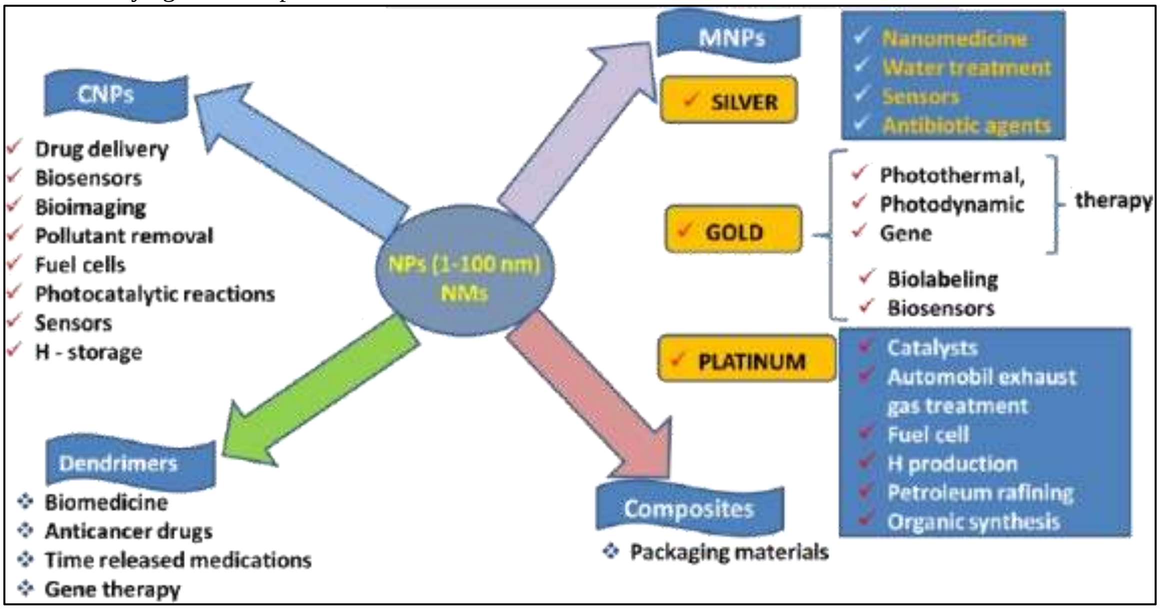

Fig. 1: Classification & wide range of applications of nanomaterials

II. APPLICATIONS OF NANOMATERIALS

Specifically, gold(Au), silver(Ag), titanium(Ti), zinc(Zn) nanomaterials have novel physicochemical properties which gain a great deal of attention in biomedical applications, titanium in waste water applications, platinum in energy storage. Having optical properties of silver nanoparticle, it is use as the functional component in various products and sensor. Because of small grain size, nanomaterial application use in making aerospace components. Nanocomposite use in weapon making industry because of it's properties. Beside these applications, nanomaterials application use in various field. Here we discuss some important applications of nanomaterials.

A. Medical field

Cancer has been one of the most serious threats to human health in the past few centuries. Cancer patients have a sort survival expectation & poor life quality [4]. Significant progress in medical technology for cancer therapies made but the mortality from cancers is still higher than expected. There are some cancer therapies mainly photodynamic cancer therapy, surgery etc. while surgery is unable to completely remove all cancer cells in human body, photodynamic cancer therapy have severe toxic side effects on normal cells & poor specificities for cancer cells. Photodynamic cancer therapy mainly work for destroy of the cancer cells by laser generated atomic oxygen, which is cytotoxic. For generated atomic oxygen, a larger quantity of special dye used which is taken in by the cancer cells when compared with a healthy tissue. In this technique all die molecules are not used for destroy cancer cells. So, remaining unusable dye molecules roam to the skin & eyes & make the patient very sensitive to the daylight exposure. This effect can stay for up to six weeks. To avoid this side effect, inside a porous nanoparticle the hydrophobic version of the dye molecule was enclosed [5]. The dye did not spread to the other parts of the body because of it stayed inside the ormosil nanoparticle.

Material	Type	Size	Main component	Main applications
Organic	Polymeric micelles	20-200 nm	Polymer	Therapeutic & imaging agent
	Liposomes	10-100 nm	Lipid	Therapeutic & imaging agent carrier
	Polymer drug congucates	5-50 nm	Polymer	Drug carrier
Inorganic	Silica NPs	20-100 nm	Silica	Therapeutic & imaging agent carrier
	Carbon nanotubes	1.4-100 nm	Carbon	Photodythermal Therapy

Table 1: Example of nanomaterials for cancer therapy & imaging

B. Water Treatment

Important challenges in the global water situation, mainly resulting from worldwide population growth and climate change. So for developing the global water situation adapt innovative water technology which is nanotechnology. For water & waste water treatment, the applications of nanomaterials has drawn broad attention. Nanomaterials have strong reaction & adsorption capacities due to their tinny size & wide surface areas. By different types of nanomaterials [6], water impurities like organic pollutants [7], bacteria [8], heavy metals [9], inorganic anions [10] have been successfully removed. Now-a-days metal oxide nanoparticles such as Titanium dioxide (TiO_2) has been successfully applied in water & waste water for contaminant degradation of water. In such case TiO_2 use because it have photocatalytic degradation quality. Also in recent years, TiO_2 is a highly research material because of its unique properties like chemical stability, non-toxicity, high photoactivity, commercial availability, etc. [11; 12; 13]. Water contaminants can be gradually oxidized into intermediate products which have low molecular weight & eventually changed into H_2O, CO_2 & anions like Cl^- etc.[14]. Except TiO_2, there are some most promising nanomaterials applied for water & waste water treatment which are highlighted in following table 2.

Nanomaterials	Properties	Applications
Nanometals & nanometal oxides	+short intraparticle diffusion distance compressible, +photocatalytic, -less reusable	Removal of heavy metals, slurry reactors, media filters etc.
Nanoadsorbents	+high specific surface, high adsorption rate, -high production cost	Removal of organic, bacteria, Heavy metals
Membranes & membrane processes	+reliable, largely automated process, -relative high energy demand	All fields of water & waste water treatment processes

Table 2: Overview of type of nanomaterials applied for water treatment

III. ENERGY STORAGE

The success of nanomaterials in energy storage applications has manifold aspects. Platinum based nanomaterials have promising potential in the fields of energy storage application. Platinum (Pt), have rich electronic structure & also have excellent catalytic activities in a series of catalytic processes including fuel cell, petroleum refining, automobile exhaust gas treatment & hydrogen production [15]. The Pt-based NMs significantly increase specific surface area and number of exposed active sites, thus, the utilization of Pt atoms greatly increase [16; 17; 18]. Energy production needs clean, less expensive sources. It can be brought about by novel nanomaterials with high efficiency. Solid sate lighting is beneficial in the sense that it reduces total electricity consumption (white light emitting diodes-LEDs) & helps sustain the green environment.

IV. SENSORS

The development of nanomaterials has covered the way for their applicability in the design of high performance electrochemical sensing devices for medical diagnostics, food safety & environment. Different types of nanomaterials for the electrochemical determination of some common contaminants & additives, like ascorbic acid (AA), caffeine, hydrazine (N_2H_4), bisphenol A (BPA), sulfite & nitrite, which are mostly found in food & beverages have been synthesized [19]. Nanomaterials has mostly impacted the area of biosensors, specifically through their high sensitivity & selectivity, as well as the miniaturization of sensor devices. Fluorescent nanomaterials have been used to make new nanostructured biosensors for glucose sensing. The electrochemical technique for glucose sensing is mainly used for measure glucose percentage in blood among diabetes patients [20]. Now-a-days nanotechnology based techniques exists for detecting trace explosives using different methods [21]. Various explosive detection methods to function as nanosensors for chemical & biological compounds including explosives have been experimentally illustrated by various R&D studies in the area of nanomaterials as listed in table 3.

Type of detection method	Principle	Nanoplatform	Explosive detected
Electrochemical	Variations in environment through changes in current, when chemicals interact with the sensor electrodes.	Nanoparticles, Nanowires, Nanotubes	TNT
Fiber optic based	Fiber optical sensors rely on changes on frequency or electromagnetic radiation	Nanoparticles, Nanowires Quantum dots	DNT, DNB
Photoluminescence	Change in the photoluminescence of sensor element in response to an explosives	Nanoparticles Quantum dots	TNT, RDX Amonium nitrate
Bio-sensors	Devices that integrate a biological element on a solid state surface, enabling interaction with an explosive & signal transduction	Nanoparticles, Nanowires Quantum dots Nanotubes	TNT, RDX, PETN

Table 3: Various techniques for the detection of various explosives using Nanotechnology

V. DEFENSE FIELD

Recent days nanotechnology grasps powerful promises for use in the defence industry. Current thinking is that nanotechnology can be used by soldiers for two main ways [22]. First one is miniaturization of existing weapons to allow it to be not only lighter, but smaller also, use less energy & be more readily hideable. As an example we can say about electromagnetic launchers or railguns, which are utilize electrical energy, as well as magnetic energy for propelling the projectiles at velocities of up to 10 km/sec. The amount of energy is directly proportional to the damage of the target. Railguns mainly made of copper because copper have excellent conductors of electricity. But problem is railguns made of copper break out faster because of the erosion of the rails by the hypervelocity projectiles & also lack of high temperature strength. To solve these problems, a nanocrystalline composite material made of copper, tungsten & titanium diboride is used for make railguns [23]. This nanocomposites exhibits the essential electrical conductivity, thermal conductivity, erosion resistance, hardness, high strength etc. This results in erosion resistant & wear resistant railguns that last longer & can be fired more often than traditional equipments. Except this application nanotechnology used in different field of defence like that nuclear detection, clothing, vehicles etc. which are listed in figure 2.

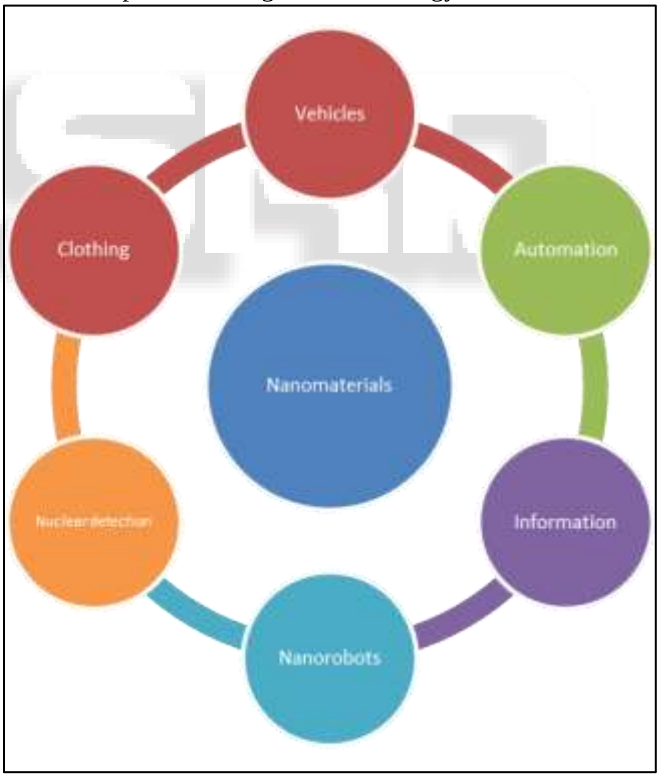

Fig 2: Various application of nanomaterials in the defence field

VI. IMPACT OF NANOMATERIALS ON THE ENVIRONMENT

Engineered nanomaterials have both positive & negative impact on the environment. We discussed earlier the positive impact of nanomaterials on the environment by discussion of various applications of nanomaterials. Nanomaterials may react with cells, organs, organisms in a new & unpredicted way. Hence exposure of humans & the environment to nanomaterials may result with possible negative impact [24]. Some nanomaterials are extremely wonderful at a specific task but are disagreeable due to their impact on environment [25]. By the particle size, compound, or aggregation of these nanoparticles, toxicological function is affected. Recently, some research papers pointed the negative impact upon the aquatic system of the environment [26]. The negative impact of nanomaterials also effects on biological systems, & the environment caused by nanoparticles, like chemical threats on edible plants after treatment with high concentration Ag nanoparticle, also, in some aspects, nanomaterial produced free radicals in living tissue leading to DNA damage. Hence nanotechnology should be carefully analyzed before increasing the use of nanoagromaterials [27]. Beside these, there are lot of negative impact of nanomaterials on the environment. Some positive & negative impact of nanomaterial on the environment are presented in figure 3.

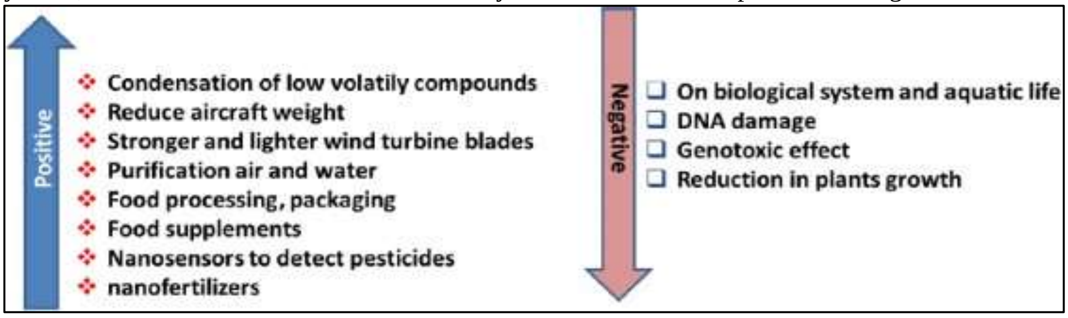

Fig. 3: Positive & negative impact on the environment

VII. Conclusion

This review has specially focused on the advancement & progression of new nanomaterials. From this review, it is also concluded that nanomaterials have positive & negative impacts both on the environment & on human beings. Subsequently, for having both desired & undesirable effects, nanomaterials can be compared as drugs. Till now, nanomaterials have been analysed for many different applications in various sectors along with sensing, photovoltaic, catalysis, energy, biomedical & environment. But, due to the level of nanomaterials in the environment is continuously increasing, the hazards of nanomaterials to animal, plants & microbes has had an indirect effect on our human. Since, the size, composition & shape of nanomaterials can have both remarkable effects on their function & achievable risks to human health, further deep investigation & research is also needed not only to fully understand their characterization, synthesis & toxicity but also to expand the application possibilities & methodologies in various field.

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