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# Nanomaterials: An overview with respect to biological applications

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*Abstract--* Nanotechnology embraces the research and technological advancement in a novel category of materials at the macromolecular, molecular and atomic level that is rapidly attaining considerable recognition worldwide. It involves the study of devices and structures ranging from 1- to 100- nanometers in length scale known as nanomaterials that take up specific novel properties. Due to their unique small size, enhanced solubility, surface tailor ability, multi-functionality, shape dependent inherent physicochemical properties, many new biological advances in various fields are opened including medicine, biology, engineering and electronics. The ability of nanomaterial to interact with elaborate biological functions in innovative ways permits cross-disciplinary researchers the chance to plan and develop multifunctional nanoparticles that can target, diagnose, and treat diseases such as cancer. Nanomaterials have vital role in diagnostics, detection to therapeutic and treatment level. Hybrid nanomaterials exhibit higher efficiency as they are the combination of organic and inorganic nanomaterials and their both therapeutics and diagnostics functions can be directed in a single dose. They are specialized form having specific properties and give incredible biomedical, therapeutics and treatment applications. However, there might be health implications associated with it. This review article aims to present an overview of nanomaterials and discuss their biological applications in different areas.

Keywords- Nanotechnology; Characterization; Biomedical; Therapeutic

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# I. INTRODUCTION

In the last few decades, scientists have not only discovered the novel properties of atomic and molecular structures built at nanometer scale called nanomaterials but also employed them for multiple uses. As a result, Nanotechnology became quite successful in attaining the status of one of the best research accomplishments of early 21<sup>st</sup> century [1]. The ability to manipulate the properties of these particles enables researchers to logically plan and utilize nanoparticles as image contrast managers, for drug delivery and other investigative purpose.

# **II. APPLICATION OF NANOMATERIALS**

Nanoparticles are being utilized for different purposes starting from medical usages, industrial production of solar and oxide fuel batteries for energy storing to extensive integration into varied materials of daily practice like apparels and cosmetic products [2]. Currently, various metallic nanomaterials are being produced using zinc, magnesium, copper, titanium, alginate, gold and silver etc. While biology nowadays is gaining advantage from number of technological expansions, few may have the paradigm shift on simple research, drug development, and clinical medicine as nanotechnology. Prominent biological applications of nanomaterial are pointed out in Figure 1. Seeing the applications, nanomaterials are now the chief component of many products such as electronic gadgets, sports products as well as in biomedical area [1, 3]. With the passage of time, new technologies are being introduced in the markets on daily basis resulting in the formation of new products. Similarly, nanomaterials are being modified for more precise functions and applications [4]. 2D and 3D nanomaterials are the evolving products of this development [5, 6]. Considering the shape of nanomaterials, these are broadly differentiated into two categories i.e. nanoparticles and nanofibers. The nature of nanoparticles is not limited to inorganic material, and organic based nanoparticles are in demand for its miscellaneous properties [7, 8].

### **III. BIOMEDICAL USES OF NANOMATERIALS**

Nanomaterials are gaining tremendous attention as they are extensively being used for biomedical purposes including bioimaging, biosensing, diagnostics, cell engineering, tissue engineering, gene therapy, cell encapsulation, wound healing, and drug delivery [3]. Applications include drug-delivery platforms [9], improved image contrast managers [10], chip-based nano-labs proficient at monitoring [11], manipulating specific cells [12], and nanoscale probes capable of tracking movements of cells [13] and individual molecules [14] as they move around in their setting. It's an unparalleled capability to detect and impact complex structures in vivo and in real time offers comprehensive information about the central mechanisms and signaling pathways involved in the development of disease. This review will give some insight to researchers and students for better understanding of biomedical applications of nanomaterials.



Figure 1. Biological applications of nanomaterials

# IV. HYBRID NANOMATERIALS: USING NUMEROUS FUNCTIONS INTO SINGLE PRECISE NANOSYSTEM

Hybrid nanomaterials are the modified and combined form of inorganic and organic nanomaterials in which they fuse together in specialized form and specific nature to do targeted tasks with accurate performance [15]. These systems work on the idea of a theranostic device in which both therapeutics and diagnostics functions can be directed in a single dose [16]. Furthermore, the properties of both organic and inorganic components make an amalgam with a unique property based on their composition [17]. To achieve the targets in diagnosis and therapeutics, diagnostics components such as organic compounds can be attached to the surface of inorganic ones to make them hybrid and deliver in combined way to the target site for its function. Similarly, the way to make hybrid can also be achieved by attaching biomolecules with the external surface of inorganic nanoparticles for which biomolecules i.e. carbohydrates, lipids, proteins are extensively being used. Just as receptors in cell, nanomaterials can take the aid of these receptors and ligands for the proper functioning and delivery of the drug at the specific site. Several micro molecules and macromolecules are involved in making the nanomaterials hybrid for precise functioning [18]. The ideal diagram of hybrid nanomaterial is shown in Fig. 2.

#### A. Hybrid Silica Based Nanoparticles

Some nanoparticles demonstrate the ideal property due to which any type of desired modification can be done in them such as silica-based nanoparticles. However, silica-based nanoparticles are further categorized into solid silica nanoparticles (SNPs) and mesoporous silica nanoparticles (MSNs), both display different but ideal conditions for making them hybrid. In comparison with other inorganic nanoparticles, solid silica nanoparticles have many defined properties such as size, shells, shape, and surfaces. These properties in solid silica nanoparticles make them more ideal and efficient for making them hybrid. Any type of engineering can be easily done in SNPs for achieving desired functions and activities. Every kind of organic and inorganic molecules can be attached to SNPs for biomedical purposes. MSNs also have magnificent properties like large pore size and volume with wide surface areas which make them an ideal [19-22]. Attachment of targeting element or component at the exterior surface of nanoparticles makes the therapeutic approaches and applications more specified [18].



Figure 2. Hybrid Nanomaterials

# V. NANOPARTICLES WITH UNIQUE PROPERTIES

Many nanomaterials are in use and show remarkable achievements in number of fields. Quantum dots, gold nanoparticle, Iron oxide nanoparticles and silica-based nanoparticles are the most noticeable ones with diverse properties. Quantum dots (QDs) are inorganic nanoparticles with semiconductor property having approximately 200-10,000 atoms. QDs are known for their luminescent ability and based on their sizes, their wavelength varies [23]. On the other hand, gold nanoparticles (AuNPs) show the surface plasmon resonance (SPR) property which makes them able to engineer with strong absorption in the near infrared region. Whereas property of magnetite nanomaterials (Fe3O4), as the name suggests, relies on the magnetization. These nanomaterials are highly paramagnetic and are dependent on the magnetic field which are externally available for its magnetization property [24-27]. On the other hand, considering the nanomaterials on the basis of their structures, 2D nanomaterials are highly flexible in case of physical properties as they show variations in physical property based on the axis positions. 2D nanomaterial are well known for their thinnest nature. In case of diversity, nanomaterials vary in case of size, shape, mechanical, chemical and optical properties [28, 29].

#### VI. THERAPEUTIC APPLICATIONS

With the advancement in technology and time, world is progressing towards betterment though the field of biological processes needs an undivided attention. Advancement and updated in diagnostics, detection, therapies, and treatments are also required. Outdated approaches have some imperfections which are one of the main hurdles in the treatments and detections. Off target delivery of drugs in case of therapeutics is one of the main examples resulting in side effects. Clinical imaging and therapeutics need modifications to avoid flaws [30]. Nanomaterials have covered most of their side effects and they can easily be delivered to the target site by following the quiet simple approach of conjugation. In case of tumor target site, nanomaterials can easily bind to the biomolecule ligand or inorganic ligand, which makes the direction of nanomaterial specific. Binding of ligand with the nanomaterial enhance the activity and accumulation of nanomaterial to the target site. To perform the real time monitoring and for uptake of other therapeutic materials, nanomaterials can easily be engineered. However, due to sensitivity of their performance, proper approval for clinical trials and clinical use are mandatory [31-33].

# **VII. DRUG DELIVERY BY NANOPARTICLES**

Delivery of drug to the specific site depends on the shape, size, morphology and chemical composition of the nanoparticles [34]. Nanoparticles are used as encapsulated material having the ability to coat the drugs in nano capsules for the delivery at specific locations. Nanoparticles ensure the stability and nature of drug for proper delivery. Targeted and specified delivery is the distinctive quality of nanoparticles. The nano size is one of the important features which make them capable to diffuse through various membranes. Permeability feature with the targeted delivery to the tumor site include the enhanced effect of retention are the important features of the nanoparticles [35-38]. 2D nanomaterials have the ability of best adsorption due to which they can easily adsorb the drug molecules for the drug delivery [29].

#### VIII. BIOMOLECULES USED FOR BIOSENSING

Various biomolecules are used for biosensing applications. Three specific properties i.e. large size surfaces with edge concentration high and distinctive electronic properties enable the nanomaterials to serve as biosensors. Along with this, noble metals also have the capability to serve as biosensors and the main feature of noble metal nanoparticles are the localized surface plasmon resonance (LSPR) which enable them to perform biosensing activity more accurately [39, 40]. Gold based nanomaterials are also being used as biosensors for many years. The biosensing ability of gold nanoparticles range from low levels i.e. to detect the ions and elements to upper level i.e. involve the detection of large biomolecules nucleotides, antibodies, proteins and also microorganisms are involved including bacteria and viruses. Specificity, sensitivity of biosensors and early stage disease detection is the more attractive and challenging one [41]. Due to the stability in physical and chemical nature, nanomaterials have the capacity to be used for bioimaging. Fluorescent imaging ability of nanomaterials can extensively be used. For non-toxicity towards drugs or other materials favorable for functioning environment, nanomaterials are being used as promising agents. The most common agent of nanomaterials in bioimaging is Fluorescent dyedoped silica nanoparticles [3, 42]. Quantum dots have the ability to be used in bioimaging due to the photophysical property [43].

## IX. HYBRID NANOMATERIALS AS THERAPEUTIC AGENTS

Hybrid nanomaterials are widely in used as therapeutic agents. Hybrid silica-based nanomaterials are one of the land-

mark hybrid materials which are being used for drug delivery purpose and therapies. Photodynamic therapy of various diseases is being aided by hybrid silica-based nanomaterials for more accuracy. This is achieved by encapsulating the photosensitizer and photon providing materials encapsulated into the silica-based nanoparticle which further process the therapeutic activity [44]. Similarly, other diseases are also being treated by various nanomaterials. Gold nanoparticles (AuNPs) have the ability of thermal therapy. AuNPs produce heat energy in response to the absorption of light, that heat energy can be used for decreasing cellular proliferation. Magnetite (Fe<sub>3</sub>O<sub>4</sub>) based nanomaterials also have biological applications such as magnetic resonance imaging (MRI) [24-26]. Nanomaterials are not limited to biomedical applications but also involved in various other profitable activities. Lots of research is being carried by the researchers and scientists in this regard to improve the ability and functionality of the nanomaterials. The comparative biological applications of nanomaterials are summarized in Table 1.

#### X. CONCLUSION

Even though nanotechnology is a comparatively new field, it is emerging fast, appreciations to a robust establishment of material science field. Scientists are using this pioneering technology to reach beyond the boundaries shared by clinical medicine and cell biology and developing cross-disciplinary associations with engineers, biologists, physicists, and material scientists. Together with the future prospects of nanotechnology that it possesses for the biological innovation, there comes a limitation of potential risks and hazards. No doubt, nanomaterials in the form of nanofibers and nanoparticles have done some amazing interventions due to its specific diverse features ideal for many fields including biomedical science, diagnosis, delivery of drugs, therapeutics, treatments. At the same time, there might be health implications associated with nanoparticles. Either actual or professed, the prospective health risks related to the production, delivery, and use of nanoparticles must be done stabilized by the overall value that nanotechnology offers.

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#### XII. CONFLICT OF INTEREST

Authors declared no conflict of interest.

Table 1. Hybrid Nanomaterials as Therapeutic agents

Serial	Types of Na-	<b>Biological Appli-</b>	References
No.	nomaterials	cations	
1.	Dox-loaded Iron	Active inhibition	[45]
	oxide nanoparti-	of cancerous cells	
	cles		
2.	Gold Nanoparti-	Radiosensitizer	[46, 47]
	cles	application	

3.	Platinum nano- particles	Toxicity evalua- tion in cancer cell	[48, 49]	
4.	Gold/Silicon nanoparticles	Anti-HER2 anti- body-targeted Breast cancer therapy	[50]	[3
5.	Carbon nano- tubes	Electronic bio- sensors	[51]	[4
6.	Au nanoparti- cles	Anticancer thera- peutic agents	[52]	
7.	Silicon-built nanowires	Chip-based bio- sensors, Real- time recognition, titration of anti- bodies	[53, 54]	[5
8.	Silver-Sulfide quantum dots	Analysis and real- time bio-imaging for advanced treatment of can- cer cells	[55]	[7
9.	Zinc sulfide nanoparticle	Antifungal and anti-microbial activity	[56, 57]	
10.	Copper Sulfide Nanoparticles	Diagnostic appli- cation photo- acoustic tomog- raphy	[58]	[8
11.	Molybdenum disulfide nano- particles	Chemotherapy for cancerous cells	[59]	[9
12.	Silver nanopar- ticles	Antimicrobial assessment, tox- icity and thera- peutic evaluation	[60, 61]	
13.	Magnetic nano- particles	Biosensors, chemotherapy, nano-coating, gene transfer, nanocomposites, food packing	[62, 63]	[]
14.	Dendrimers- Bismuth Sulfide Nanoparticles	Bioimaging, Tar- geting cancer cells, drug deliv- ery	[64]	[]
15.	Silica-gold nanoshells	Photo-thermal based therapy in tumor & cancer	[65]	

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