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An Overview On Nanomaterials, Nanoparticles And Its Various Applications

Gargi Debnath[1*], Kush Biswas[2], Ashit Dey[3], Chandrima Dutta[4], Tripti Pal[5], Abhijit Mukherjee[6], Sourav Kanti Ghosh[7]

[1,3,4,5] *Assistant Professor, M.R. College of Pharmaceutical Sciences and Research, Bira, Kolkata*
[2] *Associate Professor, M.R. College of Pharmaceutical Sciences and Research, Bira, Kolkata*
[6] *Assistant Professor, BCDA College of Pharmacy & Technology Campus – 2, Udairajpur, Kolkata*
[7] *Assistant Professor Mayurakshi College of Pharmacy, Sundarpur, West Bengal*

[*] ***Corresponding Author:*** *Gargi Debnath*
[*] *Assistant Professor, M.R. College of Pharmaceutical Sciences and Research, Bira, Kolkata*

ABSTRACT

Smart nanomaterials are distinguished in the current world for their exceptional thermal, electrical, optical, and mechanical properties. Smart materials are appealing options for pharmaceutical analysis because of their distinctive qualities, as analytical chemistry is employed to assess the quality of medicinal products. This research explores the detailed applications of intelligent nanomaterials in pharmaceutical analysis. Analysing the financial challenges, health and safety hazards related to nanomaterials, and conducting life cycle assessments in the pharmaceutical business is a systematic way for using smart nanomaterials on a large scale. Research on nanoparticles and their applications is essential in medicine and the healthcare system. Research on particulate delivery systems, such nanoparticles, has been increasingly active in recent decades. Enhancing public comprehension of the characteristics and applications of nanoparticles significantly aids the fields of biology and medicine.

KEYWORDS: *Nanoparticles, Uses in various fields, Nanotoxicity.*

1. INTRODUCTION

Nanotechnology involves researching and utilizing structures that are between 1 nm and 100 nm in size. Nanotechnology is the use of tools to study physical phenomena. The development of nanoparticles and the study of their size and properties are advantageous for both biological and medicinal fields. The various applications of nanoparticles in industrial and healthcare sectors should be disclosed to the public.[1,2]

1.1. NANOMATERIALS

In theory, materials with a single unit tiny size in the range of 1 to 100 nm are referred to as nanomaterials. The components of nanomaterials include:[3,4]

1.Nanofibres
2.Nanorods
3.Nanotubes
4.Nanoribbons

1.2 Smart nanomaterials

In order to develop smart materials, researchers are working very hard to understand and imitate the traits of biological microbes. For instance, cephalopods, which include octopuses, squid, and cuttlefish, may alter their colour by stretching out tiny sacs of black pigment using the little muscles in their skin. Additionally, it has been discovered that zebrafish can change their level of camouflage by pushing a black pigment fluid from beneath their skin to the surface.[5,6] Even if artificial materials are immutable, recent developments in materials science have allowed engineers to draw inspiration from natural principles to create intelligent nanoparticles that react to their surroundings or outside stimuli. Because they have the ability to alter their characteristics, smart nanomaterials are biomimetic and can be applied to self-healing materials and drug delivery. Among the examples are artificial muscles made of smart polymeric materials that can contract and revert to their initial configuration when cut short. These have potent visual effects and can mimic muscular movement.[7,8]

For the administration of drugs, the smart polymeric nanoparticles that are responsive to stimuli have been thoroughly studied. Different redox responsive polymeric micelles have been effectively produced because the intra- and extracellular spaces exhibit a redox potential gradient. A redox sensitive amphiphilic co-polyphosphate backbone has been utilised to create a nanoscale micellar drug delivery system that exhibits both Simultaneous smart redox responsiveness, excellent biocompatibility, and biodegradability.[9,10] The numerous terminal functional groups on the micelles connect to drug molecules, targeting, and imaging ligands. They are also sensitive to changes in their environment, releasing drugs—particularly anticancer drugs—into tumour cells' nuclei and preventing the growth of cancer cells. Therefore, it is possible to create efficient medication administration methods for medical conditions by utilising responsiveness to the redox conditions.[11,12]

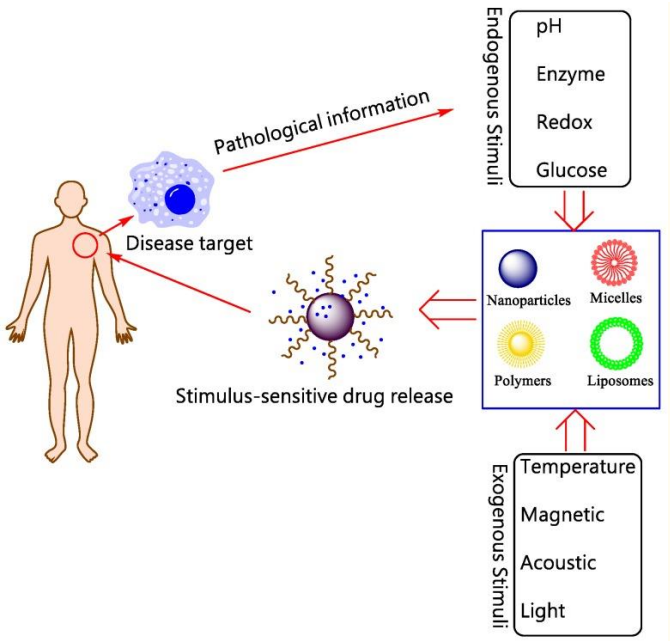

Figure 1. Diagram showing the stimuli-responsive medication delivery mechanism.

1.3 Polymeric nanoparticles

Smart or stimuli-responsive polymers are those that can react to an external physical or chemical stimulation. The earliest application of smart polymers was in controlling the release of biologically active cargos fifty years ago, and this was a significant advancement in the study and creation of nanomedicines. The rate at which the medicine is released can be controlled by the artificial carriers' level of stimulation.[13,14,15]

These smart polymer materials can be divided into two categories: single stimulus and dual/multi-stimulus responsive polymers. A single stimulus molecular conformational change; these stimuli can be classified as exogenous or endogenous. Owing to polymer chains that are turned on and off, external stimuli can cause conformational changes. Endogenous stimuli include variables. It demonstrates how to use polymeric nanoparticles with dual or multiple triggers to control the release of drugs in solid tumours. pH, redox, enzymes, light, and temperature are only a few of the many stimuli that have been used; these have emerged as potential triggering motifs for the development of smart polymeric DDSs.[16,17]

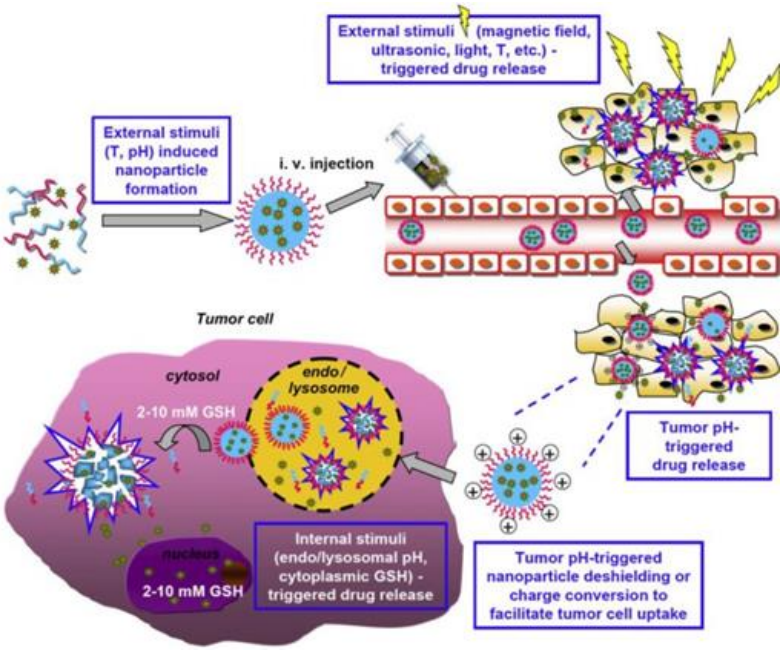

Figure 2. Smart polymeric materials with dual or multiple stimuli are employed to create smart medications for solid tumours.

Typically, a family of polyelectrolytes with ionizable groups is known as pH-responsive polymers. Smart polyelectrolytes are ionised and have the ability to significantly alter their conformation for drug release in response to changes in the pH or ionic composition of their surroundings. The reasoning behind the pH environment-triggered nanoparticle design for intelligent has been the subject of numerous studies. In general, there are two methods for managing the release of drugs from polymers near tumours.[18,19] These reversible transition processes are typically triggered by exposure to visible or ultraviolet light. Spiropyran, spirooxazine, and azobenzene are examples of photochromic chemicals that are frequently employed in polymeric systems. One type of minimally invasive treatment is called photodynamic therapy (PDT), which uses a photosensitizer (photoactive medication) and light at the right wavelengths to kill target cells by releasing extremely toxic ROS.[20,21] By combining plasmonic nanoparticles with palladium-photosensitizers, Zheng's group was able to create new photosensitizers. Another use for a long wavelength responsive polymer system is photothermal therapy (PTT).[22,23] Porphyrin bilayers produced a particular type of porphysome nanovesicles; the redshifted porphysomes were also capable of exhibiting reactivity at 760 nm. Furthermore, a great deal of research has been published on organic photosensitizers of up conversion nanoparticle for biological applications. Using triplet-triplet annihilation (TTA), Li and colleagues created the first highly effective up conversion nano capsules that could load both sensitizer and annihilator into BSA-dextran stabilised oil droplets. These findings demonstrated that the nano capsules may be used to successfully image living mice's lymph nodes in vivo.[24,25]

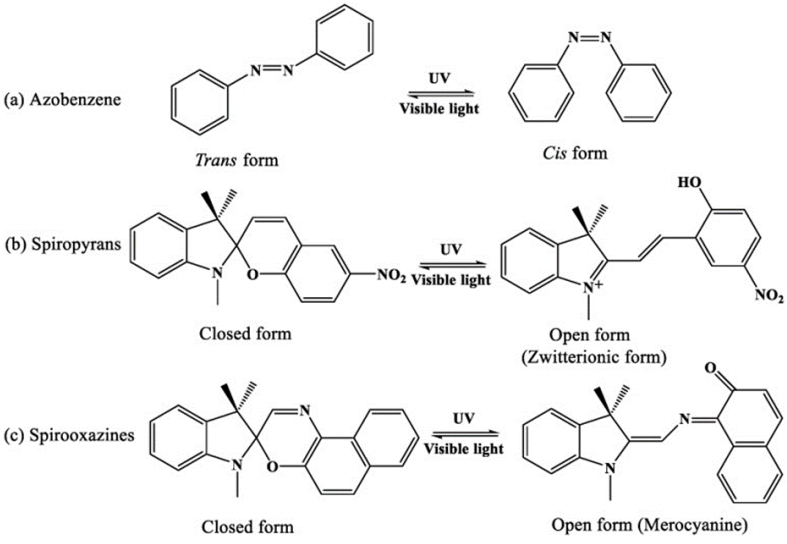

Figure 3. Common photochromic substances found in systems of photoresponsive polymers

1.4 Liposomes

Alec Bangham and associates published the first description of inflated phospholipid systems in 1965. Since then, "liposomes" have been used to refer to a wide range of enclosed phospholipid bilayer structures made up of single bilayers. Gregoria et al. employed liposomes as medication delivery devices for the first time in 1971.[26,27] Subsequently, extrusion of multilamellar vesicles via polycarbonate filters can yield enormous unilamellar liposomes (LUV) because to advancements in preparation technology. Particularly when the liposome's width is reduced to 100 nm or less, liposomes have been extensively employed as sophisticated drug delivery systems (DDSs) in various clinical studies, including those involving anti-fungal, anti-cancer, anti-inflammatory, and gene therapeutics. Commercial usage of some liposome formulations has been authorised. PEGylated liposomes are the foundation of Doxil, the first FDA-approved nanomedicine delivery system.[28,29] A variety of lipidic nanoparticles, excluding liposomes that are now marketed, are being developed from idea to clinical application, suggesting that liposomes utilised as drug carriers may be well-developed for acceptability in clinical settings. As a result of the intriguing therapeutic uses, the creation of smart liposomes—which are readily activated by a variety of stimuli, including changes in pH, temperature, enzyme concentrations, light, and ultrasound—is currently a popular issue in nanomedicine. These new, more intelligent liposome delivery methods might have greater clinical application potential in the future. Temperature stimuli may be a significant trigger from a safety and facility standpoint, even if other stimuli can also be employed to modulate the medication release of liposomes.[30,31] ThermoDox, temperature-sensitive DOX liposomes, a smart drug carrier system created by Celsion, might be the most clinically viable formulation to date. Domobacin can be liberated from ThermoDox at this temperature by taking use of the lipid crystallisation melting point of 41.5°C. Activating the release of DOX from ThermoDox was also accomplished using radiofrequency ablation, or RFA. Thermo Dox DDS, which targets liver cancer, demonstrated a better safety profile than free doxorubicin. Temperature-sensitive liposomes offer a promising clinical future for the smart DDS, even though the life span following treatment by ThermoDox did not meet the 33 percent criteria in Phase III clinical studies, which left the results somewhat unsatisfied. Temperature-sensitive polymeric liposomes were created by modifying liposomes with thermosensitive polymers to enhance the control of medication release in response to gentle heating.[32,33]

1.5 Organic-inorganic hybrid smart nanoparticles

After hybridization, materials possessing traits from Materials, both organic and inorganic, can respond to stimuli; these materials are referred to as organic-inorganic hybrid smart biomaterials. By joining molecules that are organic or polymeric and contain nano-metal or nano-oxide particles. Mesoporous silica materials have attracted a lot of attention as smart DDSs within the past 10 years.[34,35] Furthermore, a great deal of research has been done on the use of gold nanoparticles in photothermal treatment in the biological sector. Their distinct chemistry on the surface, which allows for easy functional modification, opens up new possibilities for hybridization.[36,37]

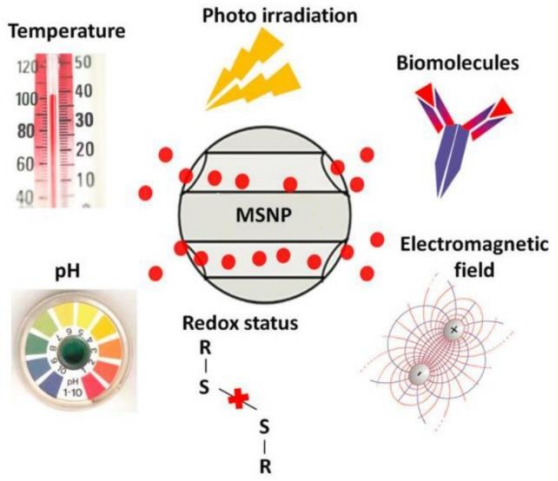

Figure 4. Organic-inorganic hybrid smart nanoparticles

1.6 GOLD NANOPARTICLES:

PTT agents have been created extensively using gold nanoparticles (AuNPs) in the form of nanoshells, nanocages, nanorods, or composite nanostructures. AuNPs, on the other hand, are inorganic nanoparticles that do not biodegrade and instead accumulate in the body over time following systemic delivery. The organic functional groups' surface modification may be the solution to this issue. Kojima and associates have

synthesised diverse liposome complexes containing AuNPs. The findings demonstrate that, in isotonic conditions, the liposomes facilitate the stable dispersions of AuNPs.[38,39] This approach offers a viable means of defeating multidrug resistance in cancer cells while simultaneously exploring the intracellular milieu to identify properties of controlled drug release.[40,41]

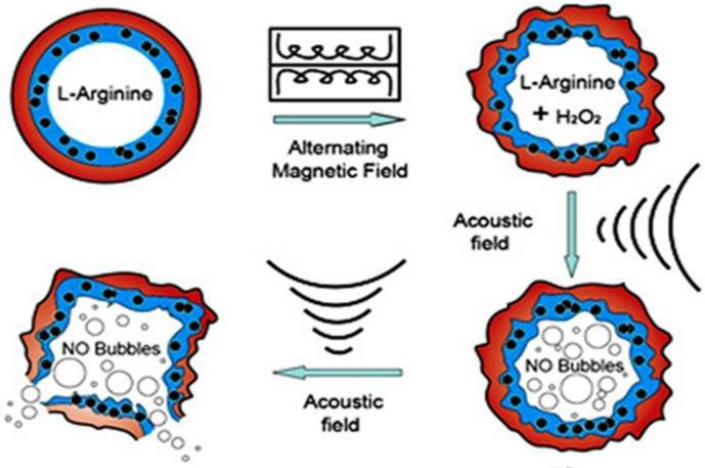

Figure 5. Stimuli-responsive drug-delivery systems in clinical trials.

2. CONCLUSION

The paper discussed nanomaterials, their classification based on various features, synthesis processes in connection to applications and properties, and the use of nanotechnology in numerous fields for manufacturing nanomaterials. Classification of nanomaterials is based on their origin, structural configuration, dimension, pore diameter, and potential toxicity. They can be categorized as natural or artificial, organic or inorganic, carbon-based or composite materials. They can also be classified based on their pore diameter as microporous, mesoporous, or mesoporous materials. Additionally, nanomaterials can be categorized as fiber-like nanoparticles, persistent granular nanoparticles, or CMAR nanoparticles. Nanomaterials are created by bottom-up and top-down synthesis processes. Nanometer-scale materials exhibit distinct properties compared to atoms and bulk materials due to factors.

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