

Biomedical Approach of Nanomaterials for Drug Delivery

Rachana R. Dalbhanjan¹ and Snehal D Bomble²

*^{1,2}Department of Chemical Engineering, AISSMS College of Engineering,
Kennedy Road, Near RTO, Pune-411001, India.*

Abstract

The objective of this paper is to highlight the diversity of nanomaterials, their advance applications and current demand for technology. Nanomaterials manifest extremely fascinating and useful properties which can be exploited for a variety of structural and non-structural applications. Since some techniques have disadvantages such as low bio-availability, rapid clearance, and less efficiency. Thus, there is a significant need for the development of more efficient methods. Nanomaterials has exploited biological pathway to achieve payload delivery of drug. Gold nanoparticles and biodegradable nanoparticles have attracted considerable attention as imaging agents, drug-delivery vehicles and theranostic agents due to their unique physical, chemical properties, ease of synthesis and surface modification. With advances in the syntheses of a variety of nanomaterials, including superparamagnetic iron oxide nanoparticles, quantum dots and gold nanoparticles, has come a surge of interest in the use of nanoparticles in biomedical applications. An illustrative example of their utility, the evaluation of targeted nanoparticles in the treatment of wet macular degeneration of eye, is discussed. This review focuses on the biomedical applications of nanoparticles based on recent research.

Keywords: Gold Nanomaterials; Drug delivery; Wet Macular degeneration;

1. Introduction

Nanotechnology and use of nanomaterials is a rapidly expanding field, it encompasses the development of man-made materials in the nanometer size range or molecular scale. The practical applications of nanotechnology can be traced to advances in

communications, engineering, physics, chemistry, biology, robotics, and medicine. Nanomaterials are been utilized in medicine as therapeutic drug delivery vehicle and for the development of treatments for a variety of diseases and disorders. These nanomaterials have risen as an excellent alternative for drug delivery. Their physiochemical properties have attracted most of the researchers. There are three main components to an effective drug delivery nanoparticle [1]: the core material of the nanoparticle, the therapeutic payload, and surface modifiers. (Figure 1.) Although a generalized structure does not accurately portray all nanomedicines, one may be used to aid in understanding the objective of each portion of a nanomedicine carrier. Nanomedicine carriers generally have the ability to load either hydrophobic or hydrophilic therapeutics. Thus, suitable carrier materials have to be thoughtfully selected for every therapeutic. However, some carrier materials have both hydrophobic and hydrophilic regions [2]. These materials could be effectively used to design nanocarriers for delivery of multiple drugs. Additionally, the nanoparticle core material must be non-toxic and non-immunogenic and should be easily eliminated from the body to avoid toxic accumulation and side effects.

The core material must also possess a release mechanism for the therapeutic payload after the carrier has reached its destination. Surface modifiers include both targeting moieties which aid in accumulation of the carrier in a specific location and biocompatibility modifiers which are needed to increase circulation at a specific location.

2. Nanomaterials for Drug Delivery

Drug delivery can be done by most of the conventional ways like oral administration, intravenous, injections or per-rectum. The only drawback of these methods is the time span required and the reactivity of the drug. Use of nanomaterials increased the circulation and maintained the required reactivity of the drug, it even reduced the time span required for the treatment. Some of the nanomaterials like carbon nanomaterials , gold nanomaterials, polymeric nanomaterials, biodegradable nanomaterials are effectively used as the drug delivery vehicle and nanocarriers. These nanocarriers (Figure 1.) are Structure composed of a core material containing both a hydrophobic and hydrophilic region, surface modifiers (biocompatibility modifiers and targeting moieties), and a therapeutic payload. Amongst these nanomaterials gold nanomaterial and biodegradable nanomaterial were proved to be the most efficient nanomaterials due to their properties.

Gold nanoparticles (AuNps) have emerged as an attractive drug delivery vehicle. Some of the properties of AuNps makes it viable for the use of drug delivery. AuNps has stable atomic core, high surface activity, non-toxic, electrical and thermal conductivity, Strength and elasticity. Number of Gold nanoparticles in 1 gram of nanomaterial is 2.929×10^{16} .

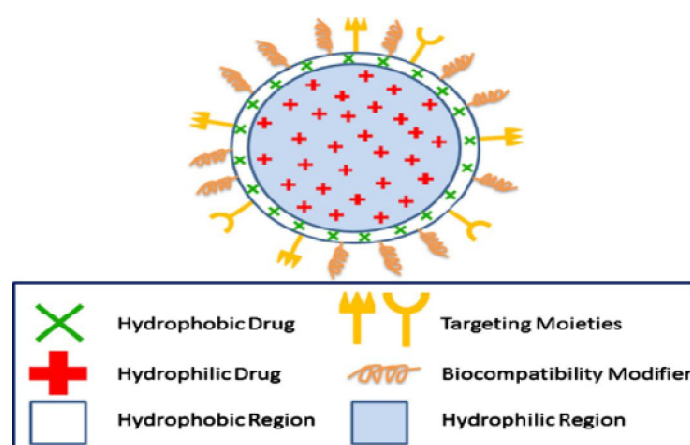


Figure 1: Generalized nanomedicine carriers.

2.1 Gold Nanomaterial for Drug Delivery

Several synthetic strategies exist, such as the two phase liquid–liquid method initially described to create metal colloidal suspensions by Faraday in 1857.[3] Faraday reduced an aqueous gold salt with phosphorous in carbon disulfide to obtain a ruby-colored aqueous suspension of colloidal gold particles. The Brust–Schiffrin method further optimized this two phase liquid–liquid system with gold salts being transferred from water to toluene using tetraoctylammonium bromide as the phase transfer reagent, with reduction by aqueous sodium borohydride in the presence of dodecanethiol [4].

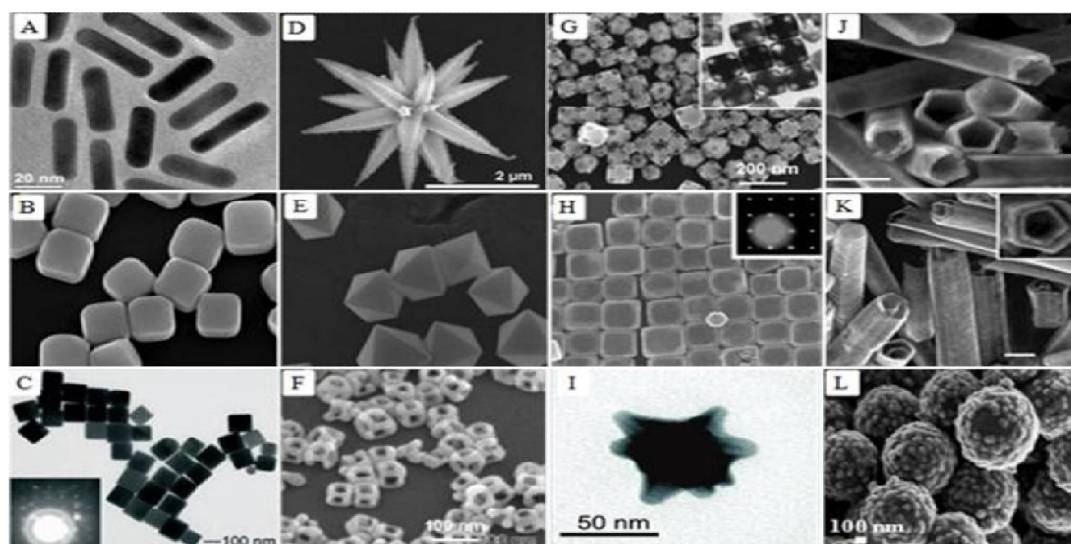


Figure 2: Various plasmonic nanostructures with absorption in the NIR region. (A) Au nanorods, (B and C) Ag nanocubes, (D) Au mesoflowers, (E) Au nanoctahedra, (F) Au nanoframes, (G) Au nanocages, (H) Au–Ag nanoboxes, (I) Au nanostars, (J, K) Ag/Au nanotubes, (L) silica–Au core–shell NP. [9]

Using modifications of this method, gold nanoparticles have been synthesized with numerous biomolecular coatings which possess biological applications. [5,6]. Drug to be delivered is conjugated with AuNps with ionic, covalent bond or physical adsorption. The surface of the nanoparticle can be modified with various conjugates. One such example is attachment of PEG which leads in improving the stability and increases the circulation time of gold nanoparticle. The cellular uptake of drug and toxicity of the nanoparticle depends upon the diameter of the nanoparticle, it also depends on the cell type, incubation time, and most important is the density if the conjugate. The researchers hypothesized that with the increase in conjugate density, the ability to bind more protein increases and thereby the cellular uptake increases [7].

Gold nanoparticles are used for the treatment of cancer. AuNps have unique optical and electrical properties, they are biocompatible and less toxic. They are even used as biosensor, CT contrast agent, optical imaging agent.

2.2 Biodegradable Nanomaterial for Drug Delivery

Other materials that are getting attention in the field of nanomedicine are polymeric and biodegradable nanoparticles. Most of the polymeric nanomaterials are preferred for drug delivery due to their potential for surface modification, biodegradable and biocompatible nature. The US Food and Drug Administration (FDA) has approved biodegradable polymeric nanoparticles, such as PLA polylactic acid and PLGA poly(lactic-co-glycolic acid), for human use. The surface properties of these polymeric nanoparticles are also a vital component of their targeting characteristics. Since nanoparticles come into direct contact with cellular membranes, their surface properties may determine the mechanism of internalization and intracellular localization [8].

Moreover, polymeric nanoparticles have been applied in gene therapy to breast cancer cells and wet macular degeneration of eye. Practically, large-scale production and manufacturing remains an issue with polymeric and biodegradable nanoparticles.

3. Recent Clinical Trials

Gold and biodegradable nanoparticles have immense applications among all nanoparticles. One of the clinical trial for the treatment of wet macular degeneration has been carried out with the help of biodegradable nanomaterials. Wet macular degeneration (WMD) of eye is caused due to the presence of a group of proteins in the body, called vascular endothelial growth factor (VEGF), which plays a significant role in the formation of the abnormal blood vessels that damages the retina in wet macular degeneration. Anti – VEGF drugs like lucentis, avastin are used for the treatment of WMD. In conventional method the drug is directly injected into the eye and allowed to diffuse. The disadvantage of conventional method is, the patient has to inject the drug every month for two years. This is because the reactivity of the drugs goes on decreasing with respect to time. Use of biodegradable nanomaterials allows the drug to maintain its reactivity level and reduce frequent injection into eye. The drug that is to be injected is enclosed in a biodegradable nanomaterial. Thin sheet of

biodegradable nanomaterial of 4x4 micrometer is used as a drug carrier. The patient has to inject the drug enclosed in a biodegradable material after every six months. Once the drug is injected in the eye, the medication diffuses throughout the retina and choroid. It binds strongly to the abnormal VEGF proteins, preventing the proteins from stimulating further unwanted blood vessel growth. Nanomaterials are emerged as a good alternative for effective drug delivery. They can be used further with better combinations and for better efficacy.

4. Conclusion

Drug delivery through nanomaterial leads to the solution for major medical problems that will significantly enhance the quality of life. In this review a medical trial is discussed with the help of nanomaterials. Research of these nanocarriers is active and leading to more efficacious therapeutic delivery through advances in material design, structural design and cellular targeting. It is clear from the above discussion that the convergence of many streams of science, material and engineering is leading to a new era of medicine, one where medicines will have substantially increased efficacy and administration convenience with high bioavailability and less toxicity.

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