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Impact of Magnetic Nanomaterials on Biotechnology and Biomedicine

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Abstract

This note describes certain salient features of magnetic nanoparticles and their applications in biotechnology and biomedicine.

Mini Review

Twenty first century is said to be the century of nanomaterials and nanotechnology. The word nano is derived from Greek word 'nano' means 'dwarf'. It is one billionth of 1 meter. A page of this journal is about 100,000 nanometers thick. Atomic diameter of gold is nearly one third of a nanometer. So a gold nanoparticle will have only 3-4 atoms .Like this any material at Nanoscale will have only few atoms. In larger particles there are very large numbers of atoms and application of quantum mechanics in multi body is extremely difficult, time consuming and results of classical mechanics and that derived from quantum mechanics are not significantly different. While at Nanoscale situation is different. Only few atoms are there and larger number resides on the surface of the particles as surface to volume ratio is high. Hence, quantum mechanics prevails at this scale. Quantum mechanics have explained several amazing properties of nanomaterials like mechanical strength, optical and magnetic properties etc.

Though the idea of nanotechnology was originated in 20th century while Richard Feynman delivered his famous lecture "There is plenty of room at the bottom: an invitation to enter a new field of physics" its impact on biotechnology and biomedicine etc is only felt in the present century. It is interesting to note that in that very same lecture Feynman also hinted possibility to use this technology in surgery. ('A friend of mine (Albert R. Hibbs) suggests a very interesting possibility for relatively small machines. He says that, although it is a very wild idea, it would be interesting in surgery if you could swallow the surgeon. You put the mechanical surgeon inside the blood vessel and it goes into the heart and "looks" around. (Of course the information has to be fed out.) It finds out which valve is the faulty one and takes a little knife and slices it out. Other small machines might be permanently incorporated in the body to assist some inadequately-functioning organ.") [1]. Foundation stone of nanotechnology was laid by Eric Dexter who published a book titled 'Engines of Creation: The Coming Era of Nanotechnology' in 1986 [2]. This work is often referred as Molecular Nanotechnology (MNT) as it mainly deals with development of capabilities for molecular manipulation. Experimental work on science and technology of Nanomaterials got a big boost by development of 'scanning tunnel microscope (STM) and 'atomic force microscope' (AFM). These devices led discovery of Fullerenes and structural assignment of carbon nanotubes (CNT). Rapid growths in fields of nanobiotechnology, nanomedicine, environment science, healthcare etc., are mainly due to above developments. A very large number of researchers papers in different journals devoted to these fields are published, new specialized journals are added frequently and several conferences are being organized almost every year. Amongst all this work, nanoparticles of a magnetic material are gradually occupying a prominent position due to following reasons:

a) Magnetic particles can be transported or held at a specific site by help of externally applied magnetic field. One can remotely control their motion.

b) At nanometer size each particle acts as a single domain and performs like a tiny magnet. Hence the requirement of magnitude of the field is modest.

c) The particles can be heated by applying oscillating magnetic field of proper frequency.

d) Like all other nanoparticles magnetic nanoparticles

(~10nm) have stronger physical properties like mechanical strength, are more chemical active and more corrosion resistant. Bioactivity of materials at the nanoscale can also be different from that of at the macro scale. For example, silver at nanosize becomes bactericide. Further their size is much less than biomolecules like cell, gene, virus etc. For example a typical cell size is between 10 to 100μm, virus size is between 20 to 400nm and size of a protein molecule is in the range of 20 to 50nm, while gene dimension lies between 2nm wide and 10 to 100nm long. This size range facilitates to coat or bound bio molecules on a nanoparticle. Such a coated biomolecules (say a protein) is referred as "tagged" or "labelled".

Criteria for selecting magnetic materials

a) The material should have low toxicity.

b) The particles should have the ability to bind biomolecules.

c) Usually, a collection of large number of particles is used together. These particles are dispersed in water or in a biocompatible fluid. Here too, to prevent agglomeration due to the van der Waals attraction and magnetic attraction, particles are stabilized either by steric repulsion or Coulomb repulsion of particles.

Based on the above considerations, extensive research work is being carried out by nanotechnologists as well as biotechnologist focussing in three aspects of nanomedicine.

These are

a) Diagnostic techniques

b) Drugs and

c) Prostheses and implants.

The first one has the advantage that it is applied outside the body and there is not much risk and a patent can be relatively granted in short time. Biosensors and Lab-on-a-Chip techniques are developed for analyzing blood and other samples and for inclusion in analytical instruments for R & D on new drugs. For defence 'wearable biosensor clothing' is being developed for soldiers so that he can detect anthrax or other deadly virus or bacteria in a short time. Sensors involving nanoparticles are also developed for; preparing ultra pure chemicals, pharmaceuticals environmental and medical monitoring. It is envisaged that in the near future, it will be possible to map genome code of a person almost instantaneously. Life span of human beings also can be extended by 50%.

For applications inside a body anticancer drugs and implant of insulin pump are being developed. It is not yet proved that efficiency of nanostructured drug is better than normal drugs, but it is shown that drug delivery systems involving nanostructured magnetic materials like carbon Bucky balls, nanotubes and magnetic nanoparticles can be more efficient and less harmful compared to normal drug delivery methods. For example, anti-cancer drug like doxorubicin or anaesthetic drug attached to nanomagnetic particles are convenient and less toxic compared to usual direct delivery system [3].

Method of synthesis and fictionalization of magnetic nanoparticles depends on the specific application of these particles. There are several methods like co-precipitation, thermal decomposition, micro emulsion etc. The first one is the simplest and inexpensive. But it has a limitation that one cannot control the shape of the particles. Further, compared to the thermal decomposition size distribution is broad. Still, this widely used to coat antibody and certain drugs. On the other hand, thermal decomposition method is complicated and requires inert atmosphere. Using one of the above techniques a large number of biomolecules are tagged to magnetic nanoparticles. A partial list is given in (Table 1).

Table 1: A partial list.

Sr. No.	Biomolecules	Applications
1	Proteins, DNA, anaesthetics drugs like lignocane, anti-bodies like Ig-G , enzymes	Separation, MRI, bio-sensor, smart drug delivery
2	Dextran	Blood circulation, stabilizer
3	Folic acid	Targeting tumour
4	Doxorubicin	Cancer treatment
5	Polyethylene Glycol (PEG)	Protein conjugation
6	Silica	Fabrication of multifunctional magnetic nanoparticles.

Detail discussion about the methods used for synthesis of above tagged particles and their applications are discussed elsewhere [4]. In the above paragraphs we have described the importance of nanotechnology based on magnetic nanoparticles and its impact on biotechnology and biomedicine. But like all other technologies nanotechnology is also not free from hazards and risk. Hazards refer to the inherent toxicity of a material while risk refers to potential threat to health which can be controlled. Certain nanomaterials pose health hazards while others may have potential threats. One of the main issues is an environmental health hazard and risk. During preparation of nanomaterials or while fabrication of nano devices nanomaterials may spread in the surrounding atmosphere .This may pose as an occupational hazard or may adversely affect microorganisms in soil. If waste treatment of nanomaterials is not proper then also particles may escape in the surrounding or enter into the soil. Secondly, when they are used in biotechnology or biomedicine individual risk is also required to be considered. Unfortunately, there is little or no control over production of magnetic nanoparticles. Efforts are being made in this direction.

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