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A NOVEL APPROACH OF SUPERMAGNETIC IRON OXIDE NANOPARTICLES IN MEDICAL FIELD

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ABSTRACT

Superparamagnetic iron oxide nanoparticles (SPION) with proper surface chemistry have been widely used experimentally for numerous applications such as magnetic resonance imaging contrast enhancement, detoxification of biological fluids, hyperthermia, drug delivery and in cell separation, etc. All these biomedical demand have high magnetization values and size less than 100nm with overall narrow particle size distribution, so that the particles have homogeneous physical and chemical characteristics. But the body is a very complicated system that imposes many physiological and cellular barriers to outside items. There are many problems happen for the nanoparticles in the body. In this review initially we address the all obstacles that we are going to confront or face by iron oxide nanoparticles in cancer therapy and how we may overcome these challenges by surface coating. Everything is going to talk here. Superparamagnetic iron oxide nanoparticles has been taken into consideration due to their many applications one application among these is in biomedical field. It is used in the treatment of cancer therapy. Magnetic hyperthermia, a process is possible only with super paramagnetic iron oxide nanoparticles (SPION). SPION has unique properties to acts as a heat mediator to destroy cancer cells in the presence of magnetic field. In this review, we discuss the heating efficiency of the SPION. In other words, how SPION is so effective in the cancer therapy, we will discuss here. The heating efficiency of SPION depends upon many factors like, magnetic anisotropy of iron oxide nanoparticles that affects the SAR (specific absorption rate). Upon changing the shape & size of SPION also leads to change in their heating efficiency.

Keywords: *Superparamagnetism, Iron Oxide Nanoparticles, Surface Modification, Hyperthermia, Surface Coating, Biomedical Application.*

Introduction

IONP (Iron oxide nanoparticles) have many applications in the medical field. They are used in separation & purification of biological components such as proteins & DNA. One of the most important applications of IONs is in magnetic hyperthermia. To make IONPs able to work better in the human body, we have to overcome barriers that we face or confront during insertion of magnetic nanoparticles in the body. Alone iron oxide nanoparticles cannot perform functions. We should have to do coating on it and also attach appropriate ligands to minimize distractions with biological body. And SPIONs will not take part in the biological functions. To overcome these barriers, first we have to know what these barriers we should have overcome. First is Physiological barriers & second one is cellular barriers.

Physiological Barriers

These barriers are imposed by liver, kidney and spleen & these barriers arises due to inappropriate size iron oxide nanoparticles. And hence, can overcome by modifying size & surface chemistry of the SPION

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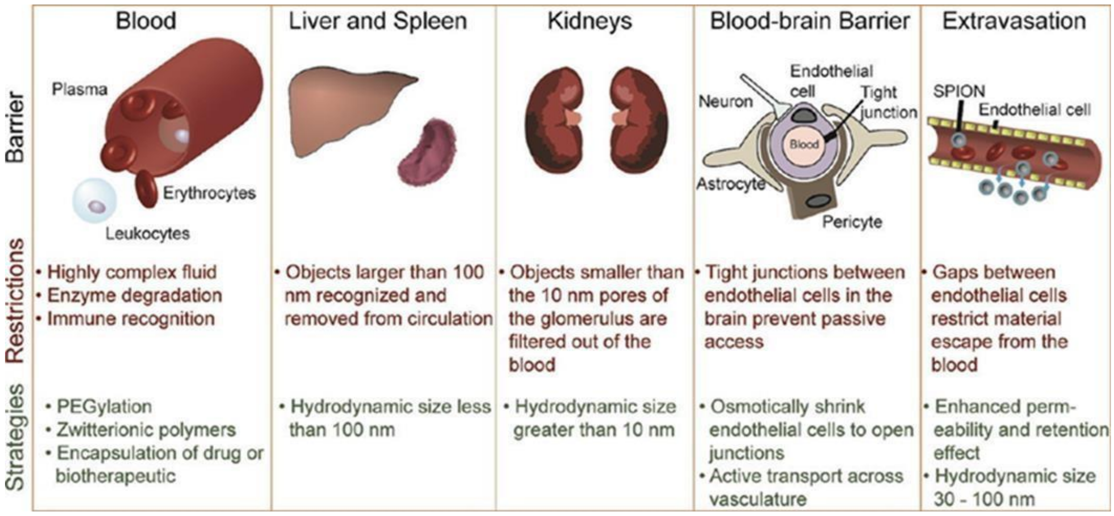


Fig. Physiological constraints

Source: *Acc. Chem. Res.* 2011, 44, 10, 853–862

Cellular Barriers

This barrier can be overcome by using targeting agents to increase absorption of the SPION by cancer cells.

Superparamagnetic Iron Oxide (SPION) Coating

- **SPION Coating:** As we have discussed that SPION must be cross physiological barriers and cellular barriers so that SPION can do better work in Cancer therapy. Circulating SPIONs must extravaste from the blood vessels to reach the target cells. Two approaches can be taken for coating the the SPIONs : one is ligand addition and other is ligand exchange.
- **Polymer Coating for Enhancing Stability:** When hydrophobic SPION particles are injected into the bloodstream they are surrounded by plasma proteins (hydrophobic surface), result in aggregation due to hydrophobic - hydrophobic interactions. If hydrophobic SPIONs are coated with hydrophilic polymers, the interaction of the SPIONs with the plasma proteins can largely be avoided. A hydrophilic coating will also give stability and functionalization to which drug, gene or imaging agents can be conjugated. The commonly used biocompatible polymers including chitosan, PEG, dextran, PVA and PVP.

Chitosan

Chitosan a natural polymer, chitosan biocompatible, hydrophilic, biodegradable, non- antigenic and non toxic. The monomer unit hexosaminide residues consisting of one amino group and two hydroxyl groups. The hydroxyl and amino functional group present on the chitosan rapidly form complexes with iron oxide surfaces, making the SPIONs hydrophilic, biocompatible and stable. Chitosan coated ferrite nanoparticles (CFNs). The amino group of Chitosan were bonded to the particles, the hydroxyl group remains unbonded. The strong bonding of Chitosan molecules to the surfaces of the nanoparticles confirmed by Fourier Transform IR measurements. Kievit et al. Used PEI – PEG – grafted.

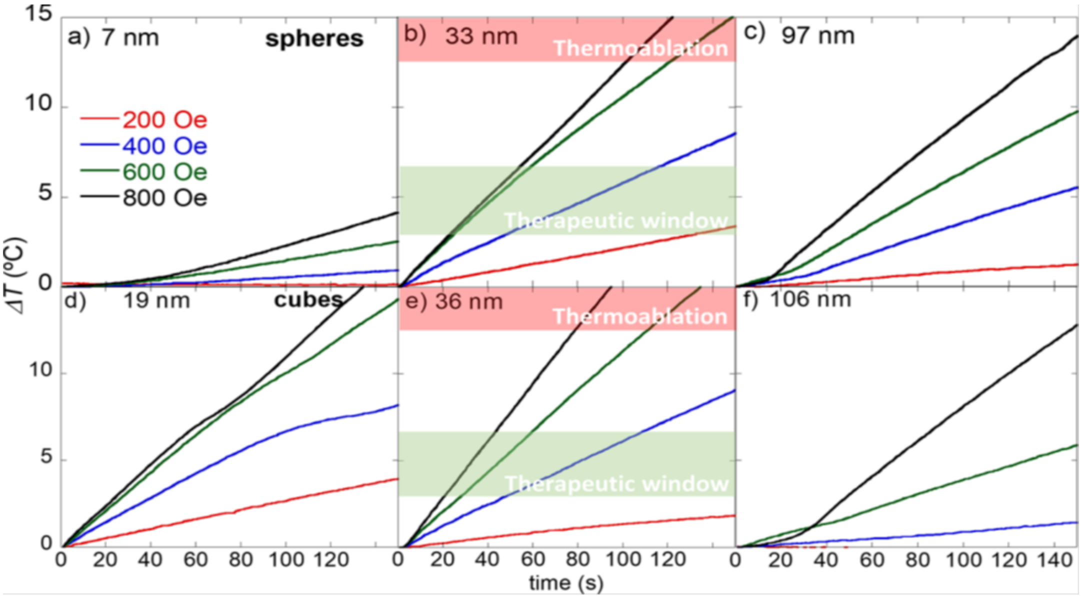
Firstly, to increase the transfection. As PEI has positive charge due to this, (1) it can helps materials to escape the endosomes through Proton sponge effect and (2) it can disturb the cell membrane, resulting in toxicity to the cells. The author grafted PEG to PEI to reduce the toxicity which provides colloidal stability. The PEI – PEG grafted chitosan coated SPIONs bound to DNA and helped in transaction, while the PEG protected the cells from the adverse effects of PEI.

Dextran

Dextran coated are SPIONs commercially available contrast agents for MR imaging and have been shown to possess cancer nodal staging capabilities. The dextran coating has been improved by introducing a carboxy methyl group for enhanced stability and functionality a strong attachment was still required since this polymer was susceptible to detachment. Consequently, the dextran was cross linked with epichlorohydrin to form cross.

The CLIOs had better stability than previous nanoparticles, even in harsh conditions, without any changes in their sizes and their halt lives in the blood circulation.

Iron oxide nanoparticles contain super paramagnetism. So, they show magnetism in the presence of external magnetic field. This characteristics has been used in biomedical field. By heating the SPION inside the body where cancer cells are present, we can destroy the cancer cells efficiently. This is depends upon heating efficiency of a material. And SPION is a good choice for this. Along with the heating efficiency of a material, SPION can pass through the barrier inside the body effectively with the help of SPION coating & attaching ligand with it. Now, to determine heating efficiency of a SPION, we have to discuss factors on which heating efficiency depends. MION heating efficiency is influenced by factors such as rate of magnetic relaxation, anisotropy energy & saturation magnetization. And the mostly factors of heating efficiency depends on the size & shape of nanospheres & nanocubes. The nanospheres of higher diameters aggregates & make polyhedric structure like octahedron cube. Tiniest nanosphere & largest nanospheres has size 7-13nm and 107nm as determined by XRD. At around blocking temperature 55K, SPIONs show their magnetic behavior. As size increases, higher temperature required and SPM behavior is no longer seen. The coercive field and remanence determine heating efficiency by analyzing hysteresis loss. The interaction between magnetic nanoparticles is also called dipolar interaction. These dipolar interaction decides magnetic behavior of SPIONs.



The differences in HC values are largely due to variations in magnetic anisotropy. As a result, magnetic anisotropy is predicted to play an important role in the heating efficiency of these nanospheres and nanocubes. We used a combination of calorimetric and AC magnetometry studies to examine the heating efficacy of the MNPs.

Environmental challenges, such as air and water pollution, soil contamination, and waste management, have become increasingly critical concerns in the modern world. These challenges pose significant threats to ecosystems, human health, and sustainable development. As traditional approaches struggle to cope with the scale and complexity of these issues, the emergence of nanotechnology as a powerful and innovative tool in environmental management has garnered attention. Nanotechnology involves the manipulation and utilization of materials at the nanoscale, typically between 1 to 100 nanometers. At this scale, materials exhibit unique and enhanced properties that differ from their bulk counterparts. The remarkable characteristics of nanomaterials, such as high surface area, reactivity, and unique optical and magnetic properties, have paved the way for a wide range of applications in various sectors, including medicine, electronics, and energy.

In recent years, nanotechnology has also emerged as a promising field for environmental management due to its ability to offer novel and efficient solutions to pressing environmental challenges. Nanomaterials possess a high potential for pollution control, remediation, and monitoring, making them invaluable in efforts to achieve sustainable environmental preservation.

This research paper aims to delve into the diverse applications of nanotechnology in environmental management and shed light on its potential to revolutionize the way we approach environmental problems. By exploring the key nanomaterials used in environmental applications and analyzing case studies and ongoing research, this paper seeks to highlight the advantages and potential risks of nanotechnology implementation.

The paper will focus on various areas where nanotechnology plays a pivotal role, such as air quality improvement, water purification, soil remediation, and waste management. Each section will examine specific nanotechnology applications, showcasing how nanomaterials can be tailored to address unique challenges in each environmental domain. However, while the potential benefits of nanotechnology in environmental management are promising, it is essential to consider the potential environmental implications and risks associated with the use of nanomaterials. As nanomaterials interact with the environment and organisms, their fate, transport, and potential ecotoxicological effects need careful examination.

To ensure the responsible and sustainable implementation of nanotechnology, a robust regulatory framework and guidelines must be established. Understanding the risks and addressing potential limitations is crucial in maximizing the benefits of nanotechnology while minimizing any adverse effects.

Through this research paper, we seek to contribute to the growing body of knowledge on nanotechnology applications in environmental management. By providing insights into the cutting-edge advancements, successful case studies, and potential challenges, we hope to foster greater awareness and appreciation for the transformative potential of nanotechnology in safeguarding our environment and fostering a cleaner, healthier, and more sustainable planet for future generations.

Nanomaterials in Environmental Management

Nanomaterials are engineered substances with unique properties at the nanoscale, enabling innovative applications in environmental management. These materials play a vital role in pollution control, remediation, and monitoring, offering promising solutions to pressing environmental challenges. Some key points regarding nanomaterials in environmental management are:

- Unique Properties: Nanomaterials possess distinct properties, such as high surface area and reactivity, making them effective for pollutant adsorption, catalysis, and sensing.
- Nanoparticles for Monitoring: Nanoparticles-based sensors enable real-time monitoring of pollutants, helping in early detection and response to environmental threats.
- Nanocomposites for Pollution Control: Nanocomposites can be designed with enhanced pollutant removal efficiency for air and water treatment, reducing environmental contamination.
- Nanocatalysts for Remediation: Nanocatalysts facilitate the degradation of harmful pollutants, transforming them into harmless compounds, aiding in soil and water remediation.
- Potential Risks: The release and behavior of nanomaterials in the environment raise concerns about their potential ecological and health risks, necessitating careful study and regulation.
- Scalability and Cost: Ensuring the scalability and cost-effectiveness of nanomaterials for large-scale environmental applications is a crucial consideration for practical implementation.
- Sustainable Solutions: Nanomaterials offer sustainable and efficient solutions, contributing to cleaner air, water, and soil, while promoting overall environmental health.

Conclusion

The SPIONs can be coated by various biocompatible polymers for stability, enhanced contrast imaging, and tissue targeting. When the coating materials consist of targeting moieties, the imaging becomes more specific by reducing the non-specific interaction and increasing the availability in the targeted region. Biocompatible polymers such as chitosan, PEG, dextran, PVA, and PVP for enhancing stability which target hepatocytes, immune cells, and cancer cells, were discussed in this review.

Due to dipolar interactions, both nanospheres and nanocubes tend to form clusters in this size range (10100 nm), and this effect is more noticeable for nanocubes, whose physical rotation is very limited even in water.

The magnetic anisotropy of the MNPs directly controls the shape of the hysteresis loops and thus the heating efficacy of the MNPs; below 35 nm, the nanocubes have lower magnetic anisotropy and heat more effectively than the nanospheres; however, as size increases, the magnetic anisotropy of the nanocubes rises more rapidly due to the greater effect of dipolar interactions, making the nanospheres better heating agents than the nanocubes are more demanding and require higher fields than nanospheres to enhance the SAR, although having higher heating values than nanospheres.

In order to improve heating effectiveness while working under conditions of agglomeration and mobility constraint, as seen in in vivo testing, we need to increase both the size of the MNPs and the size of the AC field. We can boost the heating capability of these MNPs by changing their form and configuration.

In conclusion, nanotechnology applications hold immense promise in environmental management. The research paper highlights the potential of nanomaterials in pollution remediation, water treatment, air purification, and soil remediation. The use of nanotechnology can lead to more efficient and effective environmental solutions, contributing to a cleaner and healthier planet. However, further research and responsible implementation are necessary to address potential risks and ensure the safe and sustainable integration of nanotechnology in environmental management practices.

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