IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.57
Volume 4, Issue 1, July 2024

An Overview of Magnetic Nanoparticles: Physical and Chemical Traits in Modern Medicine

Mukesh Kumar Yadav[1] and Dr. Versha Gupta[2]
Research Scholar, Department of Chemistry[1]
Assistant Professor, Department of Chemistry[2]
Sunrise University, Alwar, Rajasthan, India

Abstract: *Medical applications have shown the immense potential of magnetic nanoparticles (MNPs). Technological developments in the synthesis and manipulation of nanoscale materials have accelerated the creation of many MNP medicinal applications. This study examines the primary physical and chemical characteristics of MNPs that are significant for medicinal applications. MNP pharmacokinetics and cellular adsorption are closely linked to their physicochemical properties. Superparamagnetic, high magnetic susceptibility, high coercivity, non-toxicity, biocompatibility, and low Curie temperature are some of the essential qualities of MNPs that make them suitable for a wide range of medical applications. Medical uses of magnetic nanoparticles (MNPs) may be broken down into three primary categories: targeted medication administration, magnetic hyperthermia, and contrast agent for applications in magnetic resonance imaging. Coercivity, non-toxicity, biocompatibility, high magnetic susceptibility, and morphology, hydrodynamic size, charge, and other surface features are among the most significant chemical and physical properties of MNPs. Other qualities include charges, hydrodynamic size, and high magnetic susceptibility.*

Keywords: Magnetic nanoparticles have garnered significant biomedical applications chemical composition, magnetic properties, capabilities

I. INTRODUCTION

Nanoparticles are submicron particles composed of either organic or inorganic materials that have dimensions between 1 and 100 nm. NPs are different from bulk materials in a number of ways Despite the fact that actual applications of NPs in the biological sciences are relatively uncommon, their excellent qualities suggest a bright future for this discipline.

One of the NP kinds that reacts somewhat to the application of a magnetic field is magnetic nanoparticles (MNPs). In this sense, MNPs possess a number of special magnetic characteristics, such as low Curie temperature, high magnetic susceptibility, and superparamagnetic nature. Furthermore, these materials have been used in a number of industrial, medical, and environmental fields, including data storage biomedicine magnetic fluids medical diagnostics and therapy catalysis and magnetic energy storage Non-toxicity, biocompatibility, and high-level aggregation in the target tissue are some of the key characteristics of MNPs that make them an excellent option for medical applications.

Furthermore, due to their inducible magnetization properties, MNPs may be moved to the desired place or heated by applying an external magnetic field. These features make them appealing for a variety of uses, such as drug delivery systems, magnetic hyperthermia, separation methods, and contrast-enhancing compounds for MRI However, selecting materials for the nanostructured materials with tunable chemical and physical properties is one of the most significant challenges for the use of MNPs.

In this context, many researchers proposed several types of MNPs with distinct chemical compositions for use in biomedical applications to improve magnetic moments and superparamagnetic properties, among other magnetic phenomena. Certain characteristics, including composition, size, morphology, and surface chemistry, may be adjusted to suit different processes in order to enhance the magnetic and physical behaviors of NPs.

Certain MNP properties are needed for various applications. To display bits of information, for example, particles in data storage applications need to be in a stable, switchable magnetic state that is unaffected by temperature changes

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.57
Volume 4, Issue 1, July 2024

MNPs must be stable in a physiological environment and in water with a pH of 7 in order to be used in biology, medicine, and treatment. Furthermore, the charge and surface chemistry that produce both Steric and Coulombic repulsions, as well as the particle size which should be so small to prevent precipitation due to gravity will all have a significant impact on the fluid's colloidal stability. In order to prevent biodegradation, modification from the original structure, and the production of massive accumulations when exposed to magnetic fields, MNPs must be enclosed in a biocompatible polymer before being used in biomedical applications. Through adsorption, trapping on the particles, or covalent attachment, the medications may adhere to the polymer-coated NPs .

MNPs' large effective surface areas and reduced sedimentation rates are their other key advantages Non-toxicity and non-immunogenicity are the two primary properties of MNPs that make them suitable for use in biomedical applications. These particles should also be tiny enough to pass through tissues' capillary networks and stay in the bloodstream. MNPs need to be highly magnetized in order to regulae their movement in blood arteries when exposed to an external magnetic field. The production process of nanoparticles (NPs) may describe their size distribution, shape, surface chemistry, and magnetic characteristics . In this context, bulk materials are ground to create ferri- and ferromagnetic nanoparticles, whereas spherical MNPs may be created by the use of plasma atomization and wet chemical processes. Furthermore, crystalline or amorphous spherical particles might develop, depending on the production procedure Additionally, novel properties of MNPs, including high saturation field, superparamagnetic, high field irreversibility, and additional anisotropy contributions, may be identified using the synthesis approach .

The physical and chemical characteristics of the primary MNPs used in medical applications are the major topic of this research. There is discussion of the connections between these traits and how well they work in various applications.

Magnetic properties of nanoparticles

Two factors permeability and susceptibility determine how a material behaves when
exposed to an external magnetic field. When an external magnetic field (H) is present, a material's magnetization level (M) is described by its susceptibility (χ):

$$M = \chi H \quad (1)$$

The permeability shows the change in magnetic induction (B) brought on by an external magnetic field (H): these materials produce a weak magnetic moment that is antiparallel to the external field when an external magnetic field is present. As a result, their susceptibility is low and negative. The spins return to their starting positions and lose their magnetic characteristics when the external field is eliminated. Examples of diamagnetic materials include water, wood, quartz (SiO2), copper, silver, and the majority of organic molecules. All of these materials have the characteristic of having filled electronic subshells .

Paramagnetic

When an external field is applied, paramagnetic materials exhibit a faint magnetic field in parallel. These have a positive susceptibility that falls from (to). Their magnetic moment vanishes when the external field is removed. Magnesium, lithium, oxygen, and aluminum are all paramagnetic .

Ferromagnetic

Magnets, another name for ferromagnetic materials, have a high and positive susceptibility.Temperature, atomic structure, and external field all affect a ferromagnetic substance's susceptibilities. Their magnetic characteristics endure even after the magnetic field is removed, in contrast to two other types. In fact, once a strong magnetic field is applied, the substance's spins align with the field. The maximum magnetization, known as saturation magnetization, is attained during this period. Because spins return to their initial trajectories when the field strength is reduced, the overall magnetization decreases. Nevertheless, even under a zero field, these materials' magnetic moment remains constant . Furthermore, a single strong magnetic moment is present in tiny ferromagnetic materials that vary in size from tens of nanometers. Particles may freely spin at the blocking temperature. Consequently, net magnetization decreases to zero once the external field is eliminated . They do exhibit superparamagnetic characteristics under these circumstances. Compared to paramagnetic materials, their magnetic susceptibilities are greater. They can maintain their colloidal stability and be beneficial for biological applications because to these characteristics.As previously stated, tiny particles

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.57
Volume 4, Issue 1, July 2024

exhibit superparamagnetic characteristics; nonetheless, a decrease in size is linked to a number of significant problems. As the surface-to-volume ratios increase after size reduction, the surface effects become visible .

Properties for Medical Applications

Biocompatibility and Toxicity

For use in vivo, MNPs must be stable, nontoxic, and biocompatible. By altering the nanoparticles' size and coating characteristics, these characteristics may be managed Because of their oxidation and acid erosion, metallic magnetic materials (iron, nickel, and cobalt) have been shown to be hazardous. For these reasons, it is crucial to encapsulate magnetic nanoparticles to prevent Magnetic nanoparticles should be able to go beyond the reticuloendothelial system in order to reach their target in a biological application. The opsonization process takes place when nanoparticles are administered into the bloodstream. This mechanism coats NPs with plasma proteins, which phagocytic cells then remove, preventing them from reaching their target cells NPs are covered with either inorganic species like carbon and silica or organic layers like polymers and surfactants to prevent this occurrence. MNPs' colloidal stability and circulation duration may be extended by this extra layer .

Size of Nanoparticles

The ideal choice for in vivo applications are tiny nanoparticles that vary in size from 10 to 50 nm; these nanoparticles provide a number of advantages :

By decreasing the magnetic interaction of nanoparticles, colloidal stability may be increased and aggregation can be prevented. In order to do this, NPs' sizes must possess superparamagnetic characteristics. Therefore, in order to acquire superparamagnetic characteristics, size reduction is required.

The sixth power of the particle radius determines the dipole-dipole interaction. As a result, dipolar interactions become smaller and particle aggregation is reduced as size decreases.

The precipitation may be avoided by small NPs.

For a given volume, small NPs have a greater surface area. It may increase coating and targeting process efficiency.

At pH 7, small NPs may remain stable in water.

Saturation magnetization of magnetic nanoparticles:

NPs possess two capabilities due to their high saturation magnetization :

The velocity of blood particles may be controlled by an external magnetic field.

It is possible to transport the particles in close proximity to the diseased tissue of interest.

II. CONCLUSION

The physical and chemical properties of MNPs that are essential for medicinal applications were evaluated in this work. New particles for diagnostic uses, including magnetic drug administration, gene delivery, magnetic resonance imaging, and hyperthermia, have been made possible by advancements in MNP synthesis that allow for property control. To benefit from these uses, it is necessary to understand the characteristics of MNPs and how they behave in different scenarios. MNPs' physicochemical characteristics, including their size, shape, and surface chemistry, may influence their success by defining their pharmacokinetics, biodistribution, and biocompatibility. We need to understand the synthesis and coating procedures in order to describe and regulate the physicochemical characteristics of MNPs. There have been many reported structural models for MNPs, each with unique benefits. More sophisticated technologies must be developed and used in order to synthesis novel MNPs and determine how they behave in the body.

REFERENCES

[1]. LaConte, L., N. Nitin, and G. Bao, Magnetic nanoparticle probes. *Materials Today*, 2005. *8(5):* 32-38.

[2]. Davaran, S. and A.A. Entezami, Synthesis and hydrolysis of modified poly vinyl alcohols containing Ibuprofen pendent groups. *Iran Polym J*, 1996, *5(3):* 188-191.

[3]. Spanhel, L., *et al*., Photochemistry of colloidal semiconductors. 20. Surface modification and stability of strong luminescing CdS particles. *Journal of the American Chemical Society*, 1987,*109(19):* 5649-5655.

[4]. Steigerwald, M.L. and L.E. Brus, Synthesis, stabilization, and electronic structure of quantum semiconductor nanoclusters. *Annual Review of Materials Science,* 1989, *19(1)* ,. 471-495.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.57
Volume 4, Issue 1, July 2024

[5]. Ali, Y., *et al*., Applications of Upconversion Nanoparticles in Molecular Imaging: A Review of Recent Advances and Future Opportunities. *Biosci., Biotech. Res. Asia,* 2015, *12(Spl.Edn.1*): p. 131-140.

[6]. Ali, Y., *et al*., Dye-Doped Fluorescent Nanoparticles in Molecular Imaging: A Review of Recent Advances and Future Opportunities. *Material Science Research India*, 2014, 11(2).

[7]. Jordan, A., *et al*., Magnetic fluid hyperthermia (MFH): Cancer treatment with AC magnetic field induced excitation of biocompatible superparamagnetic nanoparticles. *Journal of Magnetism and Magnetic Materials*, 1999, *201(1):* p. 413-419.

[8]. Kolhatkar, A.G., *et al*., Tuning the magnetic properties of nanoparticles. *International journal of molecular sciences,* 2013, *14(8):* 15977-16009.

[9]. Vallejo-Fernandez, G., *et al*., Mechanisms of hyperthermia in magnetic nanoparticles. *Journal of Physics D: Applied Physics*, 2013, *46(31):* p. 312001.

[10]. Lu, A.H., E.e.L. Salabas, and F. Schüth, Magnetic nanoparticles: synthesis, protection, functionalization, and application. *Angewandte Chemie International Edition,* 2007, *46(8):* p. 1222-1244.

[11]. Frey, N.A., *et al*., Magnetic nanoparticles: synthesis, functionalization, and applications in bioimaging and magnetic energy storage. *Chemical Society Reviews,* 2009, *38(9):* 2532-2542.

[12]. Singamaneni, S., *et al*., Magnetic nanoparticles: recent advances in synthesis, self-assembly and applications. *Journal of Materials Chemistry,* 2011, *21(42):* p. 16819-16845.

[13]. Horák, D., *et al*., Magnetic microparticulate carriers with immobilized selective ligands in DNA diagnostics. *Polymer*, 2005. *46(4):* p. 1245-1255.

[14]. Neuberger, T., *et al*., Superparamagnetic nanoparticles for biomedical applications: possibilities and limitations of a new drug delivery system. *Journal of Magnetism and Magnetic Materials*, 2005. *293(1):* p. 483-496.

[15]. Jordan, A., *et al*., Presentation of a new magnetic field therapy system for the treatment of human solid tumors with magnetic fluid hyperthermia. *Journal of Magnetism and Magnetic Materials*, 2001. *225(1):* p. 118-126.

[16]. Tartaj, P., *et al*., The preparation of magnetic nanoparticles for applications in biomedicine. *Journal of Physics D: Applied Physics,* 2003. *36(13):* p. R182.

[17]. Gupta, A.K. and M. Gupta, Synthesis and surface engineering of iron oxide nanoparticles for biomedical applications. *Biomaterials*, 2005. *26(18):* p. 3995-4021.

[18]. Ersoy, H. and F.J. Rybicki, Biochemical safety profiles of gadolinium based extracellular contrast agents and nephrogenic systemic fibrosis. *Journal of Magnetic Resonance Imaging*, 2007. *26(5):* p. 1190-1197.

[19]. Morcos, S., Nephrogenic systemic fibrosis following the administration of extracellular gadolinium based contrast agents: is the stability of the contrast agent molecule an important factor in the pathogenesis of this condition? 2014.

[20]. Thakral, C., J. Alhariri, and J.L. Abraham, Long term retention of gadolinium in tissues from nephrogenic systemic fibrosis patient after multiple gadolinium enhanced MRI scans: case report and implications. *Contrast media & molecular imaging*, 2007. *2(4):* p. 199-205.

[21]. Sosnovik, D.E., M. Nahrendorf, and R. Weissleder, Molecular magnetic resonance imaging in cardiovascular medicine. *Circulation,* 2007. *115(15): p.* 2076-2086.

[22]. Moghimi, S.M., A.C. Hunter, and J.C. Murray, Long-circulating and target-specific nanoparticles: theory to practice. Pharmacological reviews, 2001. *53(2):* p. 283-318.

[23]. Park, J., *et al*., One nanometer scale size controlled synthesis of monodisperse magnetic Iron oxide nanoparticles. *Angewandte Chemie*, 2005. *117(19):* p. 2932-2937.

[24]. Nitin, N., *et al*., Functionalization and peptide-based delivery of magnetic nanoparticles as an intracellular MRI contrast agent. *JBIC Journal of Biological Inorganic Chemistry*, 2004. *9(6):* p. 706-712.

[25]. Puntes, V.F., K.M. Krishnan, and A.P. Alivisatos, Colloidal nanocrystal shape and size control: the case of cobalt. *Science*, 2001. *291(5511):* p. 2115-2117.

[26]. López-Quintela, M.A., *et al*., Microemulsion dynamics and reactions in microemulsions. Current opinion in colloid & interface science, 2004. *9(3):* p. 264-278.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.57
Volume 4, Issue 1, July 2024

[27]. Thorek, D.L., *et al*., Superparamagnetic iron oxide nanoparticle probes for molecular imaging. *Annals of biomedical engineering,* 2006. *34(1):* p. 23-38.

[28]. Sjögren, C.E., *et al*., Crystal size and properties of superparamagnetic iron oxide (SPIO) particles. *Magnetic resonance imaging*, 1997. *15(1):* p. 55-67.

[29]. Lee, Y., *et al*., Large scale synthesis of uniform and crystalline magnetite nanoparticles using reverse micelles as nanoreactors under reflux conditions. *Advanced Functional Materials*, 2005, *15(3):* p. 503-509.

[30]. Chung, S., *et al*., Biological sensors based on Brownian relaxation of magnetic nanoparticles. *Applied physics letters*, 2004, *85(14):* p. 2971-2973.

[31]. Grossman, H., *et al*., Detection of bacteria in suspension by using a superconducting quantum interference device. *Proceedings of the National Academy of Sciences*, 2004, *101(1)*: p. 129-134.

[32]. Grancharov, S.G., *et al*., Bio-functionalization of monodisperse magnetic nanoparticles and their use as biomolecular labels in a magnetic tunnel junction based sensor. *The Journal of Physical Chemistry B*, 2005, *109(26):* 13030-13035.

[33]. Marinin, A., Synthesis and characterization of superparamagnetic iron oxide nanoparticles coated with silica. 2012.

Hyeon, T., *et al*., Synthesis of highly crystalline and monodisperse maghemite nanocrystallites without a size-selection process. *Journal of the American Chemical Society*, 2001, *123(51):* p. 12798-12801.

[34]. Sun, S., *et al*., Monodisperse FePt nanoparticles and ferromagnetic FePt nanocrystal superlattices. *Science,* 2000, *287(5460):* p. 1989-1992.

[35]. Sun, S., *et al*., Monodisperse MFe2O4 (M= Fe, Co, Mn) nanoparticles. *Journal of the American Chemical Society*, 2004, *126(1):* p. 273-279.

[36]. Weissleder, R. and U. Mahmood, Molecular Imaging 1. *Radiology*, 2001, *219(2):* 316-333.

[37]. Gu, H., *et al*., Facile one-pot synthesis of bifunctional heterodimers of nanoparticles: a conjugate of quantum dot and magnetic nanoparticles. *Journal of the American Chemical Society*, 2004, *126(18):* p. 5664-5665.

[38]. Bulte, J.W. and D.L. Kraitchman, Iron oxide MR contrast agents for molecular and cellular imaging. *NMR in Biomedicine,* 2004, *17(7):* p. 484-499.

[39]. Fischer, D., *et al*., In vitro cytotoxicity testing of polycations: influence of polymer structure on cell viability and hemolysis. *Biomaterials,* 2003, *24(7): p.* 1121-1131.

[40]. Shenoy, D.B. and M.M. Amiji, Poly (ethylene oxide)-modified poly ([-caprolactone) nanoparticles for targeted delivery of tamoxifen in breast cancer. *International journal of pharmaceutics*, 2005, *293(1):* p. 261-270.

[41]. Briley-Saebo, K., *et al*., Hepatic cellular distribution and degradation of iron oxide nanoparticles following single intravenous injection in rats: implications for magnetic resonance imaging. *Cell and tissue research*, 2004, *316(3):* p. 315-323.

[42]. Owens III, D.E. and N.A. Peppas, Opsonization, biodistribution, and pharmacokinetics of polymeric nanoparticles. *International journal of pharmaceutics*, 2006, *307(1):* p. 93-102.

[43]. Roberts, M., M. Bentley, and J. Harris, Chemistry for peptide and protein PEGylation. *Advanced drug delivery reviews,* 2002, *54(4):* p. 459-476.

[44]. Issa, B., *et al*., Magnetic nanoparticles: surface effects and properties related to biomedicine applications. *International journal of molecular sciences,* 2013, *14(11):* p. 21266-21305