The 21st-century advances in biomedical nanoparticles

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***Abstract*: Nanoparticles have unique physicochemical properties such as a very high volume to surface ratio, crystallinity, chemical stability, reactivity, etc. Especially, the use of magnetic nanoparticles in biomedical applications has grown rapidly during the past decade. This achievement has been facilitated by the advent of a range of specialized synthesis techniques. This study has been focusing on the recent advances of magnetic nanoparticles in different biomedical applications such as drug delivery, diagnosis of critical illness, tissue engineering, genetic engineering, hyperthermia, antibacterial treatments, surgical implants, sterilization techniques, etc. Finally, the opportunities and challenges of magnetic biomedical nanoparticles inbiomedical applications have been discussed herein.**

***Keywords*: Nanoparticles; Magnetic nanoparticles; Synthesis techniques; biomedical nanoparticles**

1. Introduction

Magnetic nanoparticles have received increased attention for their biomedical application and therelated areas such as targeted drug delivery [1], multiple imaging methods [2], pharmaceutical [3], the spatial and temporal resolution of diagnostic techniques [4], antibacterial [5], surgical implants [6], genetic engineering [7], surgery [8], treatments and therapies [9], medical appliances [10] particularly in the sterilization process [11], thus have a significant potential for applications in the field of biomedicine [12, 13]. Major studies have been carried out to evaluate the effects of these nanoparticles for predictable results. The controlled activity with minimum influences of the impurities are desised in this concern. Besides this maintaining a hygine and sustaining the life enhancing properties with minimum cytotoxicity is aimed for all the times. The main challenge in this category of study is to meet the accuracy and carefulness in tailoring the ligand shells, which allows the stabilization, target-oriented working of the material ordevice, and the correct recognition of the biochemical species [14]. So far the importance and thebiomedical need, this review has been focused upon a work reported by many researchers discussing the synthesis, characterization, and bio-functionalization of the inorganic metals, semiconductor materials and magnetic nanoparticles for the various biomedical applications [15]. In the past few decades, it has been seen that the magnetic materials like "spinel ferrite nanoparticles" have attracted the science working and loving people [16]. This attraction is valuable and do possess strong reason due to their excellent structural, magnetic, optical, morphological, properties. These nanoparticle have commercial biomedical applications in antibacterial activities, imaging, biocompatibility, biosensors, Magnetic Resonance Imaging (MRI), Magnetic Hyperthermia and drug delivery and many more [17, 18].

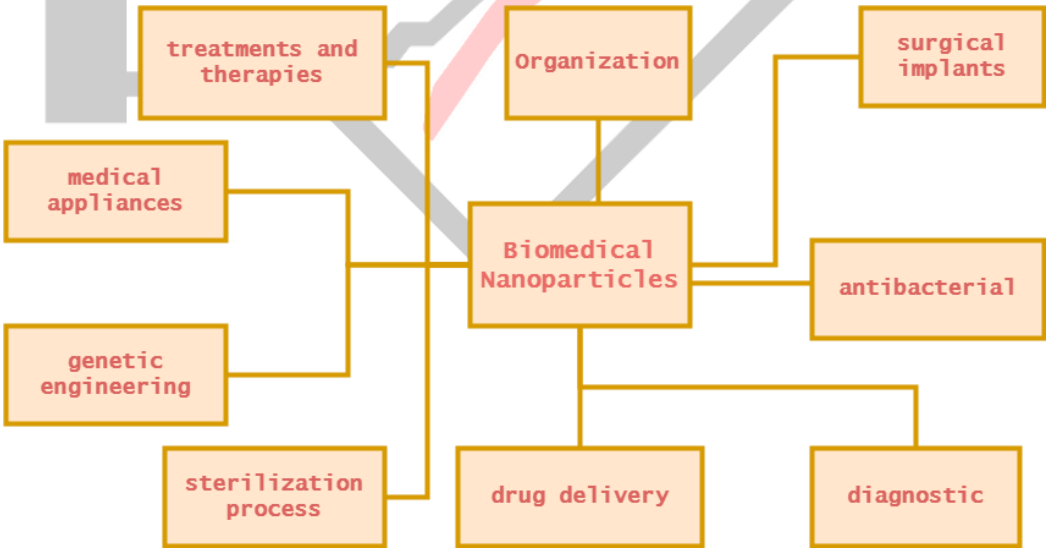

Figure 1. The uses of biomedical nanoparticles.

From the research point of view and technological approach, the field of biomedical engineering has been standing up as important for the doctors, engineers, scientists, and researchers associated with the clinical field.

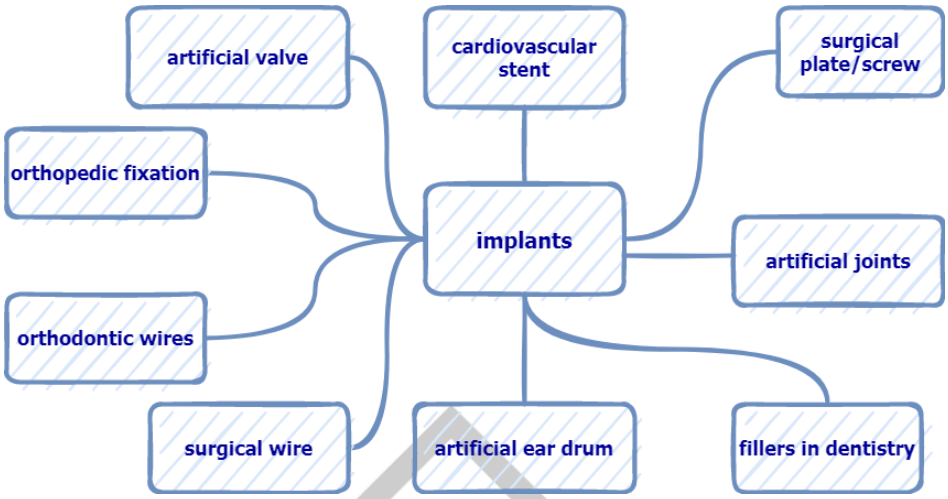

Figure 2. Various surgical implants of biomedical nanoparticles.

The core of the nanoparticles composed of inorganic materials like noble materials, new materials, functional materials, multi-functional materials, magnetic materials, metals, their alloys and oxides, and semiconductors have been of great interest to the scientific community studying in different areas of biomedicine, diagnosis tools, treatments, and therapies of diseases [19, 20]. Cancer is assumed to be a major public health issue all over the world that causes death and contributing the mortality in many cases. The popular treatments used for the control of these diseases are surgery, radiotherapy, and chemotherapy [21, 22]. Besides the playground, there are certain limitations of biomedical nanoparticles involving the high toxicity, minimum aqueous solubility, and unfavorable pharmacokinetics. To encounter the issue of side effects, magnetic nanomaterial provides various options in tumor diagnosis such as magnetic resonance imaging (MRI), positron emission computed tomography imaging (PET-CT), bio-fluorescence imaging and hybrid imaging model, etc. G. N. Rajivgandhi et. al have reported that Cu doped $Nife_2O_4$ NPs prepared via sol-gel method exhibited the single-phase cubic spinel structure with a spherical morphology shows enhanced antibacterial activity in comparison [23].

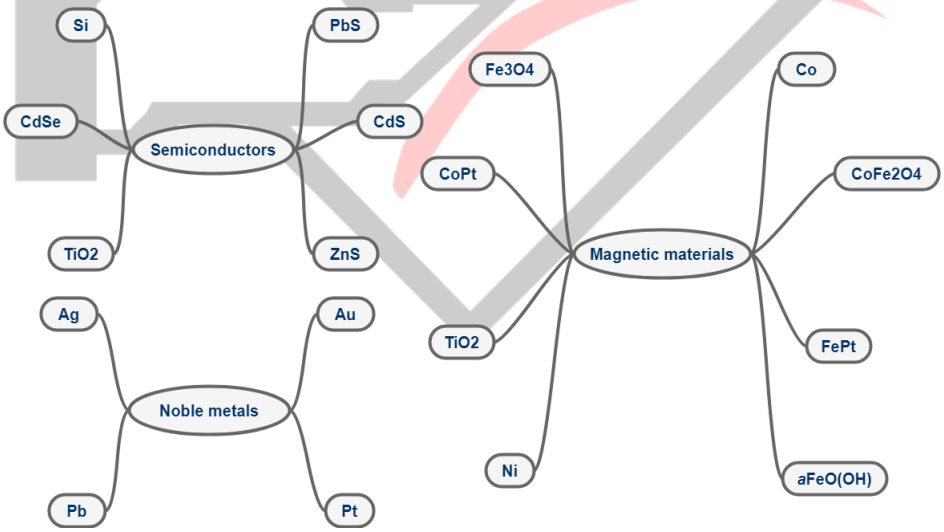

Figure 3. Various categories of nanoparticles are used in different biomedical usage.

B. G. Manju et. al have prepared Ni-Cu spinel ferrite nanoparticles by combustion method using Aloe barbadensis extract‟ as a „green reducing agent‟ and studied its antibacterial activity of prepared nanoparticles against Escherichia coli, Klebsiella pneumonia, Staphylococcus aureus, and Bacillus subtilis [24]. S. A. Hassanzadeh-Tabrizi et .al have designed a uniform core-shell combination of cobalt ferrite/hydroxyapatite nanocomposite. In their studies they have reported the controlled drug release up to 50 h; of the samples with a good drug loading capability. Further, the possibilities were predicted to be a promising candidate for various kinds of magnetic hyperthermia-based treatment [25]. Shadie Hatamie et. al have reported theapplications of graphene oxide (GO)/cobalt ferrite nanoparticles for the heat treatment on the breast cancer cell [26]. Kiruthiga Kaliyamoorthi et. al have reported the superparamagnetic nanoparticles coated with cyclodextrin-polyethylene glycol conjugate of the size range suitable for

effective drug delivery. In this study, they have loaded the anticancer drug namely camptothecin on the magnetic nanocarrier having adsorption percentage 92% to enhance the efficacy of the drug [27]. Sona Gandhi has studied the magnetic hyperthermia (MH) effect of synthesized cobalt ferrite nanoparticles (CFNPs) and found a suitable mode for biomedical applications [28]. Tuyet Nhung Pham, Tran Quang Huy, and Anh-Tuan Le have reported the uses of spinel ferrite-based hybrid architectures for biomedical applications [29]. Sumithra Y Srinivasan et.al have discussed some of the important applications of $CoFe_2O_4$ nanoparticles in biomedical nanotechnology, biotechnology, and bioengineering [30]. Meenakshi Dhiman et.al have reported about the use of $Mg_{0.9}Mn_{0.1}Sc_xFe_{(2-x)}O_4$ and studied the magnetic properties applicable for biomedical applications [31]. The researchers have invented several synthesis methods for the production of nanoparticles like the wet-chemical method [32], the ceramic method [33], micro-emulsion method [34], a hydrothermal method [35], spray pyrolysis technique, a salt-melt technique [36], auto-clave method [37], etc.

2. Summary

In this discussion, several major aspects of the superparamagnetic magnetic biomedical nanoparticle dealing with the superior structural, morphological, magnetic, and physicochemical properties possessing excellent chemical stability, biocompatibility, photothermal ability along with negligible magnetic susceptibility will be found to be most reliable for numerous medical applications. The importance of spinel ferrite nanoparticles was being noticed for biomedical applications, medical diagnosis, antibacterial activity-related study, and so on. Thus the future scope and the need for spinel ferrite nanoparticles are kept in front and need to be studied in detail.

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