Application of magnetic nanoparticles Fe_3O_4 in the field of orthopedics and medicine

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Abstract. Magnetic nanoparticle Fe_3O_4 have super paramagnetic, biological cell compatibility, low toxicity, antibiosis and bacteriostasis, drug loading, sustained release and thermal effect. Using magnetic nanoparticles Fe_3O_4 as magnetic source, magnetic mesoporous glass two-dimensional bone framework was synthesized under the action of external magnetic field, which provides growth space for bone repair, cell proliferation and metabolism, and contribute to mineralizing. The same time, The application of graphene, especially magnetic nanoparticles Fe_3O_4 , in bone materials, bone repair and related medical fields was discussed.

1 Introduction

The lead-in note the ultrapolat material grapheme is divided into power and film [1,2]. When the external magnetic field exists [3], the Fe_3O_4 is drawn into the glass to prepare powdery individual with a high magnetic dimensional hexagonal mesopore [4].

Figure 1 : Due to the large surface area , rapid magnetization and super paramagnetic the stability of the particles is improved. The same time it's observed that the sustained release of antibiotics has a long period, which provide a good drug [5] sustained release system for anti-infection treatment after bone repair. It has stable and effective antibiosis and bacteriostatic effects. [6,7]

To further improve particle stability and expand its application in the medical field, such as nuclear magnetic resonance [8] .gene therapy [9] .immunity [10] bone repair , tumor targeted therapy hyperthermia.

Fig 1. Please give the Caption of the Figure 1.

2 Data and methods

162 articles related to magnetic nanoparticles Fe_3O_4 are published from 2006-2020; including china full-text database and pubmed database. The argument is reliable figure 2 (analysis and collation)

162 related articles were retrieved, 130 articles were included, 32 articles were excluded, 39 Key related documents were included.

Fig 2. Please give the Caption of the Figure 2.

3 Results

3.1 Preparation fo magnetic nanoparticles Fe_3O_4

Preparation of magnetic nanoparticles Fe_3O_4 is divided into physical method [11,12] and chemical method the particles prepared by the physical method have low purity uneven large particles and less use. The chemical method is formulated with small and uniform particles , high purity and ultra-magnetic compliance is widely used.

3.2 Frequently used chemical methods

Frequently used chemical methods: co-precipitation hydrothermal gel micro-emulsion, etc. [12] Magnetic nanoparticles Fe_3O_4 was obtained by coprecipitation method, [13,14] hydrothermal method is divided into oil-in-water type, and water-in-oil type, which prevents

particle aggregation and obtains dispersed nanoparticles. Hydrothermal method obtained at high temperature and high pressure.

3.3 Surface modification

Commonly used modified materials are inorganic material, organic small molecules, macromolecules, SiO_2 modification etc. According to different requirements polymer forces are combined to the surface of magnetic nanoparticles Fe_3O_4 [15, 16]. Double bonds are introduced to make its surface potential sufficient. Commonly used coprecipitation method to extract nanoparticles Fe_3O_4 . Used heat treatment method to obtain sodium oxide water particles. Used gel latex method to obtain polymerized latex in three-dimensional space. Used microemulsion method to form oil-in-water, water-in-oil for preventing particles from aggregating together. Inorganic materials are coated to form a shell-core structure such as a large number of hydroxyl groups on the surface of hydroxyl groups on the surface of SiO_2 [15, 16], which has good biological activity, stabilizes the properties of nanoparticles Fe_3O_4 and is low in toxicity and acid resistant [17]. $\text{Fe}_3\text{O}_4/\text{Ag}$ composite material has antibacterial properties. [18-20] the cytotoxicity of graphene oxide dilute by modification, change the hydrophobic effect, change the surface charge, and improve fine brain uptake [30] Reduce toxicity, which is the cytocompatibility of graphene dilute

4 Application of magnetic nanoparticles Fe_3O_4 in orthopedics and some medical fields. Shell-core structure.

The antibacterial and bacteriostatic effects of graphene oxide have attracted people's attention. [31, 32] Graphene oxide has paid more attention to the antibacterial properties of *Staphylococcus aureus*, *Salmonella*, *Escherichia coli*, *Pseudomonas aeruginosa*, etc. [33]

Intraosseous implants are easy to infect, and it is very difficult for bacteria to form biofilm after infection. It has been reported [34, 35] that the use of graphene oxide at a certain concentration of silver ions can inhibit the formation of biologic

The magnetic nanoparticles Fe_3O_4 are spinel ferrite models of *Staphylococcus aureus* and soft magnetic material. In the light sensing, photoconductive function, coatings, biomedical aspects have penetration [25] The most common method is chemical coprecipitation

At the same time, silver was reduced to its surface with Fe_3O_4 nanoparticles in the core, and the shell core powder was produced at a certain temperature without ascorbic acid. The catalyst can be recycled.

At the same time, silver was reduced to its surface with Fe_3O_4 nanoparticles in the core, and the shell core powder was produced at a certain temperature without ascorbic acid. The catalyst can be recycled [26, 27]

The effect of silane coupling agent on magnetic Fe_3O_4

particles were surface modified [28], introducing hydrophobic groups to improve their dispersion ability at the interface and reduce aggregation.

The shape and physical and chemical properties of graphene nanomaterials play an important role in cells, tissues and tubes the smaller the size, the easier it is to degrade. Graphene oxide is rich in oxygen groups, and organic macromolecules modify its function. Including: polyethylene alcohol, polyethylene imine, bovine serum protein and other organic macromolecules. Reduce

Escherichia coli, reduce the infection of intraosseous implants, and improve the cure rate after infection. [36]

It has also been reported that metallic peptides coated on graphene oxide have destructive and inhibitory effects on the biological model of *Staphylococcus aureus*. [37] Thus, graphene oxide has a killing effect on free bacteria and bacteria forming biofilms [38, 39]

4.1 Special shell structure

Introducing magnetic nanoparticles Fe_3O_4 into common glass. [21] Under the action of external magnetic field, a specific graphene powder is developed. Used magnetic nanoparticles Fe_3O_4 to obtain [22] Super paramagnetic, expand the surface area, and provide three growth spaces for cell metabolism in bone repair. The results showed that Fe_3O_4 nanoparticles had better biocompatibility and activity in vitro. The inorganic material SiO_2 [15, 16] has the advantages of acid resistance, low toxicity, and magnetic nanoparticles Fe_3O_4 form a core-shell structure to stabilize its performance.

4.2 magnetic nanoparticles Fe_3O_4 form a core shell structure to stabilize its performance.

Application in the field of biomedicine.

Therapeutic amount of drugs and non-toxic magnetic nanoparticles Fe_3O_4 under the action of an external magnetic field, [8, 9] so that the concentration of drugs in the lesion site is increased, azithromycin and magnetic nanoparticles Fe_3O_4 are used to make microspheres, and the sustained release of drugs is increased for a long time.

Graphene can be combined with related drugs by using drug-loaded sustained release. Under a certain pH value [6], it is placed into the joint cavity the medullary cavity, coupled with the antibacterial properties of graphene itself to achieve the therapeutic purpose. Coated twice with sodium oleate and dextran, it shows super paramagnetic, and the specific binding force of tumor cells is improved. At the same time, dextran is used to modify its surface.

The obtained contrast agent is hydrophilic, stable and has good biocompatibility which increases the imaging effect. Using the thermal effect of magnetic nano-water particles Fe_3O_4 in the magnetic field, it is used for tumor hyperthermia and magnetic hyperthermia.

5 Conclusion

Graphene Magnetic Nanoparticles Fe_3O_4 has become a hot

spot due to its unique characteristics: [11] super paramagnetic, antimicrobial properties, drug-loaded sustained release properties, and shell and core structure. It has a good potential application in orthopedics and other medical fields. For example: antimicrobial properties for bone and joint surgery is used to reduce postoperative infection. Drug-loaded sustained-release properties is used for antimicrobial and bacteriostatic Hyperthermia, gene therapy, etc. Magnetic nanocomposites have good magnetic properties,[22]

which will be widely used in tumor targeted drug delivery, magnetic resonance imaging,[13] antiinfection, anti-tumor, promoting the proliferation of bone marrow mesenchymal stem cells, bone [23] implantation and other fields.

Due to Fe₀,nanoparticles are cheap and have good magnetic response,and their combination with biomedicine makes them have a broad application prospect in the field of biomedicine. Although great achievements have been made in the single

properties of FeO. nanoparticles,such as magnetic responsiveness and biocompatibility, how to optimize the comprehensive

properties to obtain different particle sizes and different magnetic response intensities,so that the biocompatibility can be more extensive and applicable to more organisms,and improve the relevant theoretical mechanisms for clinical application

Lt is believed that in the near future,with the continuous cooperation .cooperation an innovation of Biomedical workers and nanomaterials workers, FEO,nanotechnology will make a greater contribution to the benefit of mankind.

References

1. NOVOSELOVKS , GEIM AK , Electric field effect in atomically thin carbon films [J]. Science , 2004 , 306[5696] : 666-669
2. PORWALH, GRASSO S, REECEM, et al. Review of graphene-ceramic matrix composites[J]. Advances in Applied Ceramics,2013,112[8]:443- 454.
3. Institute of Metals, Chinese Academy of Sciences, Southeast University, Taizhou Graphene Research and Testing Platform, Institute of Semiconductors, Chinese Academy of Sciences, Taizhou Juna New Energy Co., Ltd., Q/LMOICGSOOI_2013
4. SELOVKS , GEIM AK , Electric field effect in atomically thin carbon films [J]. Science , 2004 , 306[5696] : 666-669
5. Zhang Jie, Yang Jing, Zhen Weijun, preparation of poly (lactic acid)/Fe₃O₄ loaded azithromycin microspheres and their invitro release characteristics[J]. Progress in fine petrochemical industry,2012.13(1):51-54
6. Tan Lisha, Sun Mingyang, Hu Yunjun, etc. Preparation of functionalized nanoparticles Fe₃O₄ magnetic materials and their removal of metal ions in water[J]Chemical Progress.2013.25[12]:2147- 2158
7. Kiani M, Hendijani M, et al. Design, Preparation and Characterization of MoO₃H-functionalized Fe₃O₄@SiO₂Magnetic Nanocatalyst and Application for the One-pot Multicomponent Reactions. Acta Chim Slov.2017;64(3):707-713.
8. Yazdani F, Fattahi B, Azizi N. Synthesis of functionalized magnetite nanoparticles to use as live targeting MRI contrast agent. J Magn magn Mater.2016;406:207-211.
9. LiuX, LiL, LiuYQ, etal. Ultrasensitive detection of deltamethrin by immune magnetic nanoparticles separation coupled with surface plasmon resonance sensor. Biosens Bioelectron.2014;59:328-334.
10. Xuequnji. Xu Kang, Nanochemistry [J]. Progress in chemistry.2000.12(4):431-442
11. Xu Ruren. Pang Wenqin. Inorganic synthesis and preparative chemistry[M]. Beijing: Higher Education Press, 2001:523-542
12. LiLi. LiLi. Preparation and characterization of Fe₃O₄ magnetic particles[J]. Chinese Tissue Engineering Research and Clinical Rehabilitation, 2011.15(34):6385-6387.
13. Rezayan AH, Mosavi M, Kheirjou S, et al. Monodisperse magnetite (Fe₃O₄) nanoparticles modified with water soluble polymers for the diagnosis of breast cancer by MRI method, J Magn Magn Mater.2016;420:210-217.
14. Yu L, Hao G. Gu J.et al. Fe₃O₄/PS magnetic nanoparticles: Synthesis, characterization and their application as sorbents of oil form waste water, J Magn Mater.2015;394(15):14-21.
15. Bagwe RP, Hilliard LR , Tan W. Surface modification of silica nanoparticles to reduce aggregation and nonspecific binding. Langmuir 2006;22(9):4357- 4362.
16. Peng X, Liu WS, Shi HC. Functionalized magnetic core-shell Fe₃O₄@sio2 nanoparticles as selectivity-enhanced chemosensor for Hg(II)Dyes Pigments.2019;91(1):26-32.
17. Kubo T, Sugita T, Shimose S, et al. Targeted delivery of anticancer drugs with intravenously administered magnetic liposomes in osteosarcoma-bearing hamsters. Int J Oncol.2000;17(2):309-315.
18. LiYazhai and Wang Hong. Research progress on the preparation of Fe₃O₄_Ag magnetic composite nanoparticles and their biomedical applications [J] New Chemical Materials.2015.43(4):229-231.
19. DuJJ, Jing CY. Preparation of Thio Modified Fe₃O₄Ag Magnetic SERS Probe for PAHs Detection and Identification. J Phys Chem C.2011;115(36):17829- 17835.
20. Chudasame B, Vala AK, Andhariya N, et al. Enhanced antibacterial activity of Bifunctional Fe₃O₄-Agcore- shell nanostructures. NanoRes.2009;2(12):955-965.
21. Dong X. Zheng Y. Huang Y, et al. Synthesis and characterization of multifunctional poly (glycisl methacrylate) microspheres and their use in cell

- separation. *Anal Biochem.*2010;405(2):207-212.
22. Yuan Zilong, Zhang Wei, Zhao Weiren, Study on thermomagnetic stability of magnetic fluid for hyperthermia [J]. *Journal of Guangdong University of technology.*2011.28(3):62-65
23. Ma Xifeng, Tang Chunni, Li Bin. Preparation and properties of sodium Polylactide/nano-Fe₃O₄ loaded azithromycin sustained release agent[J]. *Chemical and bioengineering.*2014(2):35-37.
24. JUSTINR, CHEN Biqiong. Characterisation and drug re-lease performance of biodegradable chitosan-graphene oxide nanocomposites [J]. *CarbohydrPolym.*2014,103:70-80.
25. Schwartzberg A M,Grant C D,Wolcott A,et al.Unique gold nanoparticle aggregates as a highly active surface-enhanced Raman scattering substrate[J].*J Phys Chem:B*,2004,108(50):19 191-19 197.
Kuo C W,Lai J J,Wei H K,et al.Studies of surface-modified gold nanowires inside living cells[J].*Adv Funct Mater*,2007,17(18):3 707-3 714.
26. Cai Guangxu, Jiangchangzhong, Ren Feng, etc, Ag@Agi Study on the light absorption and transmission electron microscopy of composite nanoparticles [j] *Journal of Wuhan University: Science Edition*, 2007.53 (5): 589-592
27. MaLellan J M,Xiong Yuejie,Hu Min,et al. Surface-enhanced Raman scattering of 4- mercaptopyridine on thin films of nanoscale Pd cubes,boxes,and cages[J].*Chem Phys Lett*,2006,417(3):230-234.
28. Shi Weixian, Yang Jun, Wang Tingjie, et al. Surface organic modification of magnetic Fe₃O₄ particles [J]. *Acta physicochemical Sinica*, 2001. (17): 507-510
29. Zhang Y,Alif, Dervishi E,et al.Cytotoxicity effects of graphene and single-wall carbon nanotubes in neural pheochromocytoma- derived PC12 cells[J].*ACS Nano*,2010,4(6):318-3186.
30. Zhang Y,Nayak TR,Hong H,Cai W.Graphene:a versatile nanop-latform for biomedical applications[J].*Nanoscale*,2012,4(13):3833- 3842.
31. KrishnamocmChy K,Veerapandian M,Zhang LH,et al.Antibac-terial efficiency of graphene nanosheets against pathogenic bac-teria via lipid peroxidation[J]. *J Phys Chen C*,2012,116[32]:17280-17287.
32. Akhavan O,Ghaderi E.Toxicity of graphene and graphene oxide nanowalls against bacteria[J].*ACS Nano*,2010,4(10):5731-5736.
33. Lim HN,Huang NM,Loo CH.Facile preparation of graphene-bas-ed chitosan films:Enhanced thermal,mechanical and antibacterial properties[J].*J Non-cryst Solids*,2012,358(3):525-530.
34. Zhu Chen, Shang Xifu, Kong Rong, et al. Study on the mechanism of antibacterial effect of MRSA in human air defense [J] *biological orthopedic materials and clinical research.* 2017. (1404) : 1.5.
35. Zhu Chen, Kong Rong, Fang Shiyuan, et al., Differential analysis of the expression of human kan-defensin 3 in artificial joint periprosthetic infection and aseptic loose boundary membrane tissue, *Biological Orthopedic Materials and Clinical Research*, 2016.13. (02:12-16)
36. Kulshrestha S,Qayyum S,Khan AU.Antibiofilm efficacy of gre-en synthesized graphene oxide-silver nanocomposite Lager-stroemia speciosa floral extract:A comparative strdy on inhibition of gram-positive and gram- negative biofilms[J].*Microb Pathog*,2017,103:167-177.
37. Jia Z,Shi Y,Xiong P,et al.From Solution to Biointerface:Graph-ene Self-Assemblies of Varying Lateral Sizes and Surface Proper- ties for Biofilm Control and Osteodifferentiation[J].*ACS Appl Mater Interfaces*,2016,8(27):17151-17165.
38. Leenaerts O,Partoens B,Peeters FM.Water on graphene:hydro-phobicity and dipole moment using density functional theory[J].*Phys Rev B*,2009,79:235440- 235445.
39. Valentina Palmieri, Massimiliano Papi Cladio Conti, et al The future development of bacteria fighting medical devices: the role of graphene oxide). *Exper Review of Medical Devices*, 2016,13(11):1013-1019.