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MICROSTRUCTURAL STUDIES OF THE SUPERPARAMAGNETIC IRON OXIDE NANOPARTICLE MEDIATED ANTICANCER DRUG DELIVERY SYSTEM

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ABSTRACT

In this study, magnetite (Fe3O4) nanoparticles(MNPs) prepared by the modified controlled chemical co-precipitation method from the solution of ferrous/ferric mixed salt-solution in alkaline medium were analysed for its crystalline structure, size and shape. The crystalline structure of magnetite nanoparticles was determined by X-ray powder diffraction (XRD) analysis and was found to be matched with the data base for magnetite. The size and shape of nanoparticles were determined by Transmission microscopy. The particles were found to be in the range of 9-30 nm which is ideal for its usage as drug delivery vehicle in cancer therapy.

KEYWORDS : Superparamagnetic iron oxide nanoparticles (SPIONs), X-ray diffraction (XRD) analysis, Transmission electron microscopy.

INTRODUCTION

The dimensions of these nanoparticles (NPs) make them ideal candidates for nano-engineering of surfaces and the production of functional nanostructures. Hydrodynamic size, (1) helps govern the NP concentration profile in the blood vessel (Decuzzi and Ferrari, 2006), (2) affects the mechanism of NP clearance, and (3) dictates the permeability of NPs out of the vasculature (Chavanpatil et al., 2006). In the case of the former, Decuzzi et al produced models suggesting that smaller sized, spherical NPs observed higher diffusion rates, increasing the NP concentration at the center of a blood vessel, thus limiting interactions with endothelial cells and prolonging the NP blood circulation time. Hydrodynamic size also affects NP clearance from circulation (Longmire et al., 2008). Particles of size 10–100 nm believed to be optimal for i.v. administration (Gupta and Gupta, 2005). A vast majority of developed NPs have been unable to breach the BBB. Consequently, this has become an area of intense research, with broad ramifications in the development of treatment strategies for brain tumors, Parkinson's, Alzheimer's, and Huntington's diseases. However, additional studies will be required to confirm and better elucidate the mechanisms of this paradox.

In investigating the effects of NP shape on biodistribution, a limited number of comparative studies have been performed evaluating the biodistribution of non-spherical and rod shaped NPs (Gratton et al., 2007; Liu et al., 2007). It has been suggested that anisotropically shaped NPs can avoid bio elimination better than spherical NPs (Liu et al., 2007).

1- MATERIALS AND METHODS

1-1. XRD ANALYSIS

To determine the crystalline structure of the particles, x-ray Diffraction (XRD) analysis was conducted on a (D8 FOCUS 2.2 kW, Bruker, Germany) X-ray diffractometer The x-ray diffraction patterns were taken from 20 to 80˚ (2θ value) using CuKα radiation.

1-2.TEM ANALYSIS

Morphology and size of the bare and conjugated SPIONs were determined by Transmission electron microscopy (TEM), for which a drop of diluted solution of the MNPs was placed on a carbon coated copper TEM grid and was allowed to dry. The samples were imaged at 80 kV using a Transmission Electron Microscope (JEOL, JEM-1400).

2-RESULTS AND DISCUSSION

2.(1). Microstructural study

Powder x-ray diffraction (XRD) analysis exhibited information about the crystallographic structure, chemical properties and physical properties of the materials. Fig.1 shows the XRD pattern of MNPs, which indicates that the particles are crystalline with specific diffraction peaks to respective 2Θ positions. The broadening of XRD peaks was observed in 2Θ : 30.348, 35.746, 43.400, 57.473 and 62.945° positions. Peaks matching with reference inorganic crystal structure data base ICSD files confirms that the particle to be primarily cubic face centered magnetite(Liu et al.,2006). No peaks were detected which could be assigned to impurities.

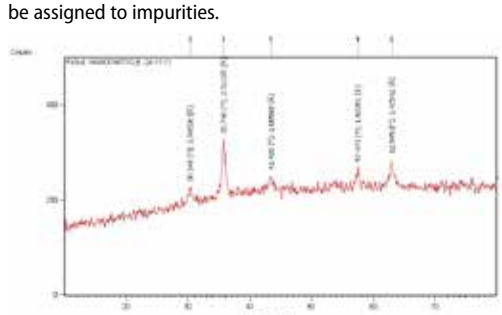

Fig.1: XRD pattern of SPIONs synthesised by modified co-precipitation method showing the peak broadening at 2Θ positions which are specific for the spinel face centered magnetite.

2-(2). Morphology and size

Transmission Electron Microscopy (TEM) is a well established technique for micro- and nano-imaging of material features: morphology, particle size and aggregation. The TEM images in Fig.2a, shows that most of the particles synthesized have increased length to width aspect ratio in comparison to purely spherical particles. High aspect ratio shaped MNPs evaluated in vivo have shown enhanced blood circulation times over the spherical counterparts (Par et al.,2008).

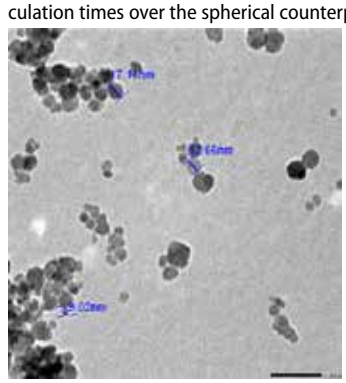

Fig.2a: Transmission electron micrographs of MNPs without any surface functionalization, showing the spherical to elliptical variation in their shape, and sizes within 9-20nm range.

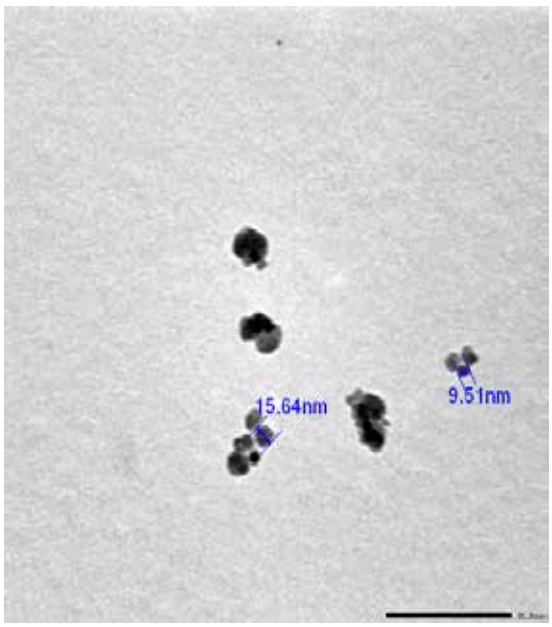

Fig.2b: Transmission electron micrographs of organic silane (ϒ-APTES) modified MNPs where the aggregating tendency of the particles found to be reduced.

The size of the surface modified MNPs were found to be increased in comparison to the unmodified particles, but all were fallen within a range of 9-30nm. The particles with the sizes between 10 and 100nm are most effective for drug delivery purposes as they evade the RES (Gupta and Gupta., 2005). At the same time, surface modified MNPs have shown lesser tendency to get aggregated which in turn helps to reduce the chance to get eliminated in the biological system.

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