Chapter 60
Recent Advances in Synthesis and Biomedical Applications of Magnetic Nanoparticles:
Magnetic Nanoparticles for Biomedical Applications

Irshad Ahmad Wani
Department of School Education, J&K, India

ABSTRACT

Magnetic nanoparticles due to their unique magnetic phenomenon, are gaining immense interest due to the utilization of these properties for a wide variety of applications in various arena especially in biomedical field. This book chapter, therefore, summarizes the synthesis of various types of magnetic nanoparticles using different approaches depending of their ability to generate either single core of multcore magnetic nanoparticles. The various biomedical applications of magnetic nanoparticles like Magnetic Resonance Imaging (MRI), drug delivery etc. along with possible limitations and challenges for their extended applications in medicine are also discussed.

INTRODUCTION

Nanotechnology is now a days working at the cellular and molecular levels to produce major progress in the life sciences and healthcare. Although real applications of nanomaterials in life sciences are still uncommon but the excellent properties of these materials provide a very promising future for their use in this field (Grainger & Okano, 2003; Hood et al., 2002; Niemeyer, 2001). Nanoclusters located at the transition region between molecules and micron size particles are ultrafine particles of nanometer dimensions. When viewed from the molecular perspective, their particle size is so large that they provide access to realms of quantum behaviour which are not otherwise accessible and from the materials perspective, their particle size is so small that they exhibit characteristics not observed in the larger structures (>100 nm). Recent advances in biology, physics and chemistry has been mainly made in this size regime (Roco,

DOI: 10.4018/978-1-5225-3158-6.ch060

Williams, & Alivisatos, 2000). For example, the band gap of semiconductor material increases when the particle dimension of semiconductor materials become comparable to, or smaller than the Bohr radius (El-Sayed, 2001; Heath, 1995). In noble metals, intense absorption is observed in the visible to near UV region as the particle size decreases below the electron mean free path (Bohren & Huffman, 1983). Other fascinating mechanical behaviors such as superplasticity is also observed in metal nanoparticles in this size range (Kung & Foecke, 1999). Powder ceramic materials with particle size in nanorange are also receiving attention due to significant enhancement in the sintering rates or lowering of sintering temperatures (Hahn, Logas, & Averback, 1990; J. Tartaj, Zärate, Tartaj, & Lachowski, 2002; P Tartaj & Tartaj, 2002). Ceramic matrix composites with dispersed nanoparticles have better mechanical properties (Kung & Foecke, 1999; Niihara, 1991; a G. Roca et al., 2009).

Nanotechnology has made major contribution in medicine and pharmaceutical industries, like controlled drug delivery, as biosensors, in disease detection, in tissue engineering etc. However, nanoparticles designed for drug delivery should be biocompatible and biodegradable (Gupta & Gupta, 2005a; Xie et al., 2006). Among many other nanosystems, special interest is focused on magnetic nanoparticles (MNPs), which have a potential to revolutionize current clinical diagnostic and therapeutic techniques (Mailander & Landfester, 2009; Mishra, Patel, & Tiwari, 2010; Suh, Suslick, Stucky, & Suh, 2009). Many applications of MNPs have been widely studied including magnetically induced hyperthermia, magnetically enhanced transfection, magnetically assisted gene therapy and magnetic-force-based tissue engineering (Chomoucka et al., 2010; Corchero & Villaverde, 2009).

However, the development of highly effective medicine requires continuous and timely monitoring of the medical treatment process. This monitoring in combination with therapeutics commonly referred to as "theranostics" allows a large degree of control on the treatment efficacy in different individuals (Sambasivarao, 2013). Magnetic nanoparticles (MNPs) containing ferromagnetic iron (Fe) and cobalt (Co) as well as their alloys and oxides has proved to be the most promising probes for theranostics with therapeutic efficacy and desired imaging sensitivity (J. Kim, Piao, & Hyeon, 2009; Lacroix, Ho, & Sun, 2010; Sambasivarao, 2013).

Magnetic nanoparticles show a wide range of applications such as magnetic fluids (Chikazumi et al., 1987), catalysis, (A. Lu et al., 2004; S. C. Tsang, Caps, Paraskevas, Chadwick, & Thompsett, 2004), data storage (Hyeon, 2003) and environmental remediation (Elliott & Zhang, 2001; Takafuji, Ide, Ihara, & Xu, 2004). However, Magnetic nanoparticles (MNPs) owing to their unique magnetic properties and size comparable to biologically important objects are very useful for biomedical applications. Magnetic nanoparticles allow some new and exiciting approaches to bioseperation and biodetection along with targeted drug delivery due to unique response to external magnetic fields which allow biomolecules to be tagged and detected magnetically (Dobson, 2006; Gupta & Gupta, 2005b; Sunderland, Steiert, Talmadge, Derfus, & Barry, 2006). Due to their resonating response to the alternating magnetic field they MNPs function as heaters, thereby, offering a promising therapeutic solution by magnetic fluid hyperthermia (Jeun et al., 2009; Rui et al., 2010; Thomas et al., 2009).

In most of the applications mentioned above, the particle gives best performance below a certain critical value depending upon the material but a range is 10-20 nm. In this size regime each magnetic nanoparticles shows a supermagnetic behaviour above a certain temperature called as blocking temperature. Such individual nanoparticles acting as single domains has a large constant magnetic moment and behave like a giant paramagnetic atom with negligible remanence (residual magnetism) and coercivity (the field required to bring the magnetization to zero) due to the fast response to applied magnetic fields,