SYNTHESIS, FUNCTIONALIZATION AND CHARACTERIZATION OF HYBRID NANOSYSTEM

Abstract

Nanotechnology is defined as the engineering of structures, devices and systems by controlled manipulation of size and shape at nanometer scale to produce newer ones with at least one novel/superior characteristic or property. Nanoparticles are the basic constituents of nanomaterials with at least one of the three dimensions in the range of 1-100 nm. Nanoparticles have been attracting a considerable attention because of their unique physical and chemical properties enabling them to find multidisciplinary applications [1-3]. Due to the enhanced implementation of nanoparticles in biomedical field, research on the development of multifunctional hybrid nanosystem is gaining momentum since last few years. Hybrids are developed by integrating more than one nanocomponent either in host template or by conjugating them directly [4-5]. They are multifunctional in the sense that they can impart more than one function synergistically. For example, magneto-fluorescent hybrid nanosystem developed by combining magnetic and fluorescent nanoparticles together are useful for dual imaging application with enhanced contrast property [6]. Magnetic nanoparticles can serve as contrast agent for magnetic resonance imaging (MRI) technique whereas fluorescent nanoparticles are used in real time monitoring of tumor targeting and treatment.

In the thesis, we have presented an in-depth study on synthesis and properties of magnetic and fluorescent nanoparticles and their magneto fluorescent hybrid nanosystems developed by using silica as template. The multifunctional applicability of the so prepared hybrid nanosystems has been demonstrated in biomedical applications. Also, multifunctionality in a single moiety nanosystem as potential MRI contrast agent as well as therapeutic agent has been discovered.
Chapter 1 gives a general introduction and background of scientific research in hybrid nanosystem. This is followed by brief discussions of different imaging functionalities of hybrid nanosystems. Also, the strategy for delivery of such systems to targeted locations is touched upon. Then the synthetic approaches of multifunctional hybrid nanosystems are discussed. A brief introduction to the magnetic and optical imaging is also presented. Finally, the objectives of the thesis are identified at the end of this chapter based on the literature review.

In Chapter 2, the experimental details of the thesis work is outlined. All the chemicals used, the synthetic routes followed and the instrumentation techniques that were used to analyze the samples, are introduced in this chapter.

Chapter 3 is divided into two parts. Part A describes the synthesis of fatty acid capped superparamagnetic iron oxide nanoparticles (SPION) by a non-aqueous method involving thermal decomposition of precursor followed by isothermal heat treatment. Then a facile method is reported for controlled replacement of fatty acid from nanoparticle surface with a hydrophilic ligand to obtain ultrastable hydrophilic nanoparticles with unaltered morphology, phase and properties. The surface chemistry of functionalized SPIONs is analyzed by Fourier Transform Infrared spectroscopy (FTIR), thermogravimetric analysis (TGA) and X-ray photoelectron spectroscopy (XPS) revealing the presence of bound and unbound thiol groups and disulfides, leading to its prolonged stability in aqueous medium.

Part B of Chapter 3 describes a facile, aqueous, thermo-free, green synthetic route for developing an iron-platinum nanosystem using ascorbic acid as both reducing and capping agent. Detailed microstructural, magnetic and surface properties of the nanoparticles are studied with the aid of high resolution transmission electron microscopy, X-ray diffraction, vibrating sample magnetometer (VSM), FTIR and XPS results. Optimization of reaction conditions such as reducing agent, pH and sequence of
precursor addition is explained to obtain highly water soluble, superparamagnetic iron-platinum nanosystems stabilized with ascorbic acid.

**Chapter 4** is divided into two parts. **Part A** describes the aqueous colloidal synthesis of a size-tunable undoped and Mn$^{2+}$-doped cadmium telluride (CdTe) quantum dots with emission wavelength varying between 500 to 680 nm. Differentially tunable optical properties of doped and undoped CdTe quantum dots have been explained from UV-Visible absorption and photoluminescence spectroscopy. The size tunable emission of the QDs is achieved through Ostwald ripening phenomenon while in case of doped QDs, surface adsorbed Mn promotes ripening of the system as well as disintegration into smaller fraction after saturation in growth occurs. In the present chapter, photophysics of Mn$^{2+}$-doped nanocrystals is explained as well as an optimum size fraction is identified for both the doped and undoped QDs based on their PL quantum yield.

**Part B** of **Chapter 4** describes the facile synthesis of organic dye from oleylamine and glutaraldehyde. The dye compound is synthesized by dimer formation of glutaraldehyde molecules in alkaline pH and then its Michael addition with oleylamine. The identification of the compound is done with the help of GC-MS technique and is named as O-complex. The fluorescent property of O-complex originating from electronic transition is examined through UV-Visible absorption and PL spectroscopy.

**Chapter 5** describes the synthesis of silica based magneto-fluorescent hybrid nanosystems by employing template and template-free routes. Then their detailed microstructural, surface, magnetic and fluorescent properties are studied based on different characterization results. Also, formation mechanism of the nonporous, mesoporous and microporous hybrids with radial distribution of pore channels are proposed with schematic diagrams.

**Chapter 6** has reported an intensity quantized effect in the developed hybrid nanosystems. In the emission characteristics of the hybrids, Quantum Confined Stark Effect is observed due to the local electric field induced by charge dispersion at
SiO$_2$/polar solvent interface. Also, enhancement in the Stark shift is observed in case of mesoporous hybrid nanosystem due to greater specific charge in these nanosystems.

MRI contrast property results of the pristine magnetic nanosystems and their hybrids with fluorescent nanosystems are analyzed in Chapter 7. Along with it, other potential functions of the nanosystems are explored in biomedical application to obtain multifunctionality from the systems.

The main conclusions drawn from the complete thesis work and future prospects of it are described in Chapter 8.

References: