ABSTRACT

There is an alarming increase in the mortality rate due to the cancer all over the world. Cancer diagnosis at the early stage is the key to reduce the mortality rate and for the proper treatment. Magnetic resonance imaging (MRI) is a three dimensional technique to view the soft tissues with high spatial resolution. But the limitation of this technique is its poor sensitivity. To improve the sensitivity, the MRI can be combined with highly sensitive optical imaging. By combining the two imaging modalities, dual modal imaging is achieved. Europium (Eu^{3+}) ions with its superior luminescent properties can be doped into the gadolinium oxide nanoparticles which intrinsically possess favourable magnetic properties for dual modal imaging. Europium doped gadolinium oxide ($Eu:Gd_2O_3$) nanoparticles were synthesized by three different techniques such as co-precipitation method, polyol method and microwave-assisted combustion synthesis.

In the Chapter 2, the $Eu:Gd_2O_3$ nanorods were prepared by using co-precipitation method and then it was coated with silica to increase the biocompatibility. Initially, $Eu:Gd(OH)_3$ nanorods were formed and after the calcination process $Eu:Gd_2O_3$ nanorods were produced. In the XRD spectrum, it was noted that the peak position and the intensity matches the standard crystallographic data. $Eu:Gd_2O_3$ nanorods posses cubic crystal system with the unit cell parameters a = b = c = 10.82 Å, $\alpha = \beta = \gamma = 90$ °, and cell volume = 1266.74 Å^3. The crystallinity of the nanorods decreases after coating with silica. TEM images proves that the prepared $Eu:Gd_2O_3$ nanoparticles exhibits 'rod-like' morphology with a length of around 600 nm and a diameter of 40 nm. Silica layer with the thickness of 15 nm was coated over the nanorods. The silica coating was also confirmed by the FTIR studies. Emission peak at 611 nm was observed due to the presence of Eu^{3+} ions in both the uncoated and silica-coated $Eu:Gd_2O_3$ nanorods. The emission intensity of the silica-coated nanorods was found to increase, due to the total internal reflection phenomenon that exists at

the silica interface. The color co-ordinates of the uncoated and silica-coated nanorods were found to be (0.63, 0.37) and (0.65, 0.35) respectively. The lifetime of the uncoated and silica-coated nanorods were determined to be 1.16 ms and 0.90 ms respectively. *Invitro* cytotoxicity of the silica-coated nanorods shows a slight decrease in the cell viability till the concentration of 200 μg/mL. The paramagnetic nature of the uncoated and silica-coated nanorods was confirmed by VSM. *Invitro* magnetic resonance images of the silica-coated nanorods shows bright contrast images when the concentration is increased. The relaxivity value was calculated to be 3.581 $mM^{-1}s^{-1}$.

Chapter 3 summarizes the preparation of $Eu:Gd_2O_3$ nanoparticles by polyol method at low temperature. Further, the nanoparticles were coated with silica to improve the biocompatibility. Triethylene glycol was used as a solvent which limits the particle size and prevents aggregation. XRD studies show that the uncoated $Eu:Gd_2O_3$ nanoparticles possess cubic crystal system with the unit cell parameters a = b = c = 10.81 Å, $\alpha = \beta = \gamma = 90$ ° and cell volume = 1263.21 $Å^3$. Silica influences the crystallinity of the nanoparticles and it was found that after coating with silica, the crystallinity decreases. TEM result proves the spherical morphology of the prepared uncoated $Eu:Gd_2O_3$ nanoparticles. The average diameter of the nanospheres was found to be 40 nm. Uniform coating of silica with the thickness of 5 nm was observed. The emission spectra of both the uncoated and silica-coated nanoparticles show a peak at the wavelength of 612 nm which corresponds to $^5D_0 \rightarrow {}^7F_2$ transitions of Eu^{3+} ions. The CIE color co-ordinates (x, y) of the uncoated and silica-coated nanoparticles were found to be (0.62, 0.37) and (0.53, 0.45) respectively. The color co-ordinates lie in the red region, which implies that the synthesized nanoparticles are suitable for optical imaging. The lifetimes of uncoated and silica-coated $Eu:Gd_2O_3$ nanoparticles were found to be 1.14 ms and 0.83 ms respectively. *Invitro* cytotoxicity for the silica-coated nanoparticles was performed in the MG63 cancer cell line. The cell viability of the silica-coated nanoparticles was calculated to 86%, which is higher for the concentration range of 200 μg/mL.

The paramagnetic nature of the uncoated and silica-coated nanoparticles was confirmed by the VSM studies. *Invitro* MR images of the silica-coated nanoparticles confirm the ability to produce bright images while increasing the concentration. The relaxivity value of the silica-coated nanoparticle was calculated to be 4.8 $mM^{-1}s^{-1}$.

Chapter 4 discusses the preparation of Eu:Gd_2O_3 nanoparticles by microwave-assisted combustion technique. Initially, Eu:Gd_2O_3 nanoparticles were synthesized and further it was coated with silica to reduce the toxicity. XRD pattern of the uncoated nanoparticles proves that they belong to the cubic crystal system with the lattice parameters a = b = c = 10.81 Å, $\alpha = \beta = \gamma = 90$ ° and cell volume = 1263.21 $Å^3$. Silica coating decreases the crystallinity of the nanoparticles due to its amorphous nature. TEM images of the uncoated Eu:Gd_2O_3 nanoparticles shows spherical nanoparticles with the average diameter of about 10 nm. In the FTIR spectrum, the presence of peaks at 470 and 554 cm^{-1} confirmed the Gd-O bonding. The silica coating in the sample was proved by the appearance of a peak at 858 cm^{-1} which is attributed to the asymmetric vibration of Si-O bond. Emission peak at 612 nm due to the Eu^{3+} ion ($^5D_0 \rightarrow {}^7F_2$ transition), were present in both the uncoated and silica-coated nanoparticles. The CIE color co-ordinates of the uncoated and silica-coated nanoparticles were observed at (0.50, 0.50) and (0.51, 0.50) respectively. These color co-ordinates lies in the orange region, which is ideal for the fluorescent imaging. The lifetime of the uncoated and silica-coated nanoparticles were determined to be 1.1 ms and 0.9 ms respectively. *Invitro* cytotoxicity of the silica-coated nanoparticles was assessed using MTT assay in the bone cancer cell line. The nanoparticles exhibit little toxicity at a higher concentration of 200 μg/mL. VSM result proved the paramagnetic behaviour of the synthesized nanoparticles. *Invitro* magnetic resonance images shows bright contrast images while increasing the concentration. The relaxivity value of the silica-coated nanoparticles was found to be 5.01 $mM^{-1}s^{-1}$.