

# List of Figures

1.1	Magnetic Hyperthermia equipment (Magnetherm, nanoTherics, U.K).....	3
1.2	Schematic representation of the magnetism of the materials.....	4
1.3	Representation of the surfactant over MNPs for colloidal stability.....	4
1.4	Schematic of the Brownian and Néel Relaxation loss.....	6
1.5	Schematic diagram reaction mechanisms during semiconductor photocatalytic process.....	11
1.6	Schematic representation of Li-ion battery.....	16
1.7	Positions of the atoms (Fe and C) of orthorhombic iron carbide system.....	21
1.8	Schematic polyhedral model for cubic inverse spinel structure of Fe <sub>3</sub> O <sub>4</sub> .....	22
2.1	Schematic representation of synthesis protocol for nanocomposites.....	29
3.1	a) Rietveld refined X-ray diffraction pattern of ultrafine Fe <sub>3</sub> C, nanoparticles and b) Atomic position of Fe and C atoms in the unit cell as obtained from VESTA software.....	38
3.2	TEM analysis of Fe <sub>3</sub> C nanoparticles (a) bright field micrograph and inset represents the SAED pattern, and (b) histogram of size distribution.....	40
3.3	(a) The wide range of X-ray photo spectra of Fe <sub>3</sub> C sample, (b) spectrum for Fe2p states, (c) spectrum for C 1s and (d) core level spectrum for absorbed O 1s.....	41
3.4	M vs. H plot for as-synthesized Fe <sub>3</sub> C magnetic nanoparticles.....	42
3.5	Mössbauer spectrum of Fe <sub>3</sub> C nanoparticles recorded at room temperature.....	43
3.6	Colloidal stability of Fe <sub>3</sub> C nanoparticles.....	45
3.7	(a) Temperatures vs. time plots (b) SLP, and (c) ILP values obtained for various concentrations of Fe <sub>3</sub> C MNPs under two different magnetic fields.....	47

3.8	Biological study of A549 lung cancer cell lines treated with Fe <sub>3</sub> C nanoparticles a) control cells growth after 24 h of incubation, b) cells treated with the 1 mg/mL of MNPs for 24 h, c) % cell viability with bare particles as well as with its ferrofluid at varying concentrations (0.1, 0.5, 1, 1.5, 2, 2.5 and 3 mg/mL) after 24 and 48 h of incubation, and d) fluorescence image of the cells stained with acridine orange.....	49
4.2	Rietveld refined diffraction patterns of Zn <sub>x</sub> Fe <sub>3-x</sub> C ( $x = 0.1, 0.3, 0.5, 0.7$ and 1) system.....	55
4.3	Variation in the lattice parameter for Zn <sub>x</sub> Fe <sub>3-x</sub> C ( $0.1 \leq x \leq 1$ ) system and inset showing decrease in unit cell volume.....	57
4.3	Transmission electron micrograph for sample $x = 0.1$ a) bright field micrograph, b) SAED pattern c) HR-TEM micrograph and d) histogram of the particles.....	58
4.4	Transmission electron micrograph for sample $x = 1$ a) bright field image, b) SAED Pattern, c) HR-TEM micrograph and d) histogram of the particles.....	59
4.5	XPS spectra of sample $x = 0.3$ (a) Fe 2p core level spectra, (b) C 1s core level spectra, (c) Zn 2p and (d) O 1s.....	61
4.6	Mössbauer spectra of Zn <sub>x</sub> Fe <sub>3-x</sub> C for (a) $x = 0.1$ and (b) $x = 0.5$ samples at RT....	63
4.7	(a) M vs. H plots for all the samples Zn <sub>x</sub> Fe <sub>3-x</sub> C ( $x = 0.1, 0.5$ and 1) (b) Variation in the saturation magnetization (M <sub>s</sub> ) values and (c) Coercivity (H <sub>c</sub> ), remanent (M <sub>r</sub> ) plots for samples Zn <sub>x</sub> Fe <sub>3-x</sub> C ( $x = 0.1, 0.5$ and 1) with Zn substitutions.....	65
4.8	Temperature rise dependent on magnetic fluid hyperthermia curves are (a) and (b) for the concentration of 10 mg/mL at two fields, (c) magnitude of the SLP and (d) ILP for all the ferrofluids Zn <sub>x</sub> Fe <sub>3-x</sub> C ( $x = 0.1, 0.3, 0.5, 0.7$ and 1) at both the	

fields .....	67
4.9 Compatibility of $Zn_xFe_{3-x}C$ nanoparticles with A549 lung cancer cell lines. a) control cells morphology after 24 h incubation period b) cells were treated with the $MNP_S$ ( $x = 0.5$ ) of 1 mg/ml concentration for 24 h c) % cell viability of the F127 functionalized samples $x = 0.5$ and 1, with varying concentrations (0.1, 0.5, 1, 1.5, 2, 2.5 and 3 mg/mL) at different incubation period d) Fluorescence imaging after stained with acridine orange.....	70
5.1 X-ray diffraction patterns for the nanocomposites (a) FC and FOC and (b) N1FOC, N3FOC and N5FOC.....	75
5.2 TEM analysis of the sample FC a) bright field micrograph, b) histogram of the particles distribution.....	76
5.3 TEM analysis of the nanocomposite N3FOC a) bright field micrograph, b) SAED pattern and c) histogram of nanoclusters size.....	77
5.4 XPS spectra for sample N5FOC nanocomposite a) Fe2p, b) C1s, c) Ni2p and d) O1s.....	79
5.5 Mössbauer spectroscopy of the samples N1FOC, N3FOC and N5FOC nanocomposite.....	81
5.6 (a) Magnetization vs. field curves and (b) the variation in the $M_s$ , $H_c$ and $M_r$ values with Ni substitution of nanocomposites N1FOC, N3FOC and N5FOC.....	83
5.7 The induction heating behavior for the ferrofluids (FOC, N1FOC, N3FOC and N5FOC) (a) Time vs. temperature plots, (b) SLP values and (c) ILP values.....	84
5.8 <i>In-vitro</i> study of N3FOC nanocomposite with A549 lung cancer cell lines. a) % cell Viability with varying concentrations 0.1, 0.5, 1, 1.5, 2, 2.5 and 3 mg/mL b)	

Fluorescence imaging after stained with acridine orange.....	86
5.9 Tauc plots of the nanocomposites (FC, FOC, N1FOC, N3FOC and N5FOC) for the direct transitions and inset shows their direct bandgaps.....	87
5.10 UV- Vis spectra of degradation of PNP using FOC Catalyst under (a) Fenton and (b) Photo Fenton condition.....	88
5.11 UV- Vis spectra of degradation of PNP using N5FOC Catalyst under (a) Fenton and (b) Photo Fenton condition.....	89
5.12 Catalytic kinetics plots of PNP degradation at $\lambda_{\max}$ 317 nm under (a) Fenton and (b) Photo Fenton condition.....	89
5.13 UV- Vis spectra of degradation of PNP using FOC Catalyst under (a) Fenton and (b) Photon Fenton condition.....	92
5.14 UV- Vis spectra of degradation of MO using N5FOC Catalyst under (a) Fenton and (b) Photo Fenton condition.....	92
5.15 Catalytic kinetics plots of degradation of MO at $\lambda_{\max}$ 505 nm under (a) Fenton and (b) Photo Fenton condition.....	93
6.1 X-ray diffraction patterns for the FC, M2FOC, and M7FOC samples.....	99
6.2 Morphological analysis for the nanocomposite M2FOC a) bright field image b) high resolution micrograph c) SAED pattern and d) histogram for the particle size.....	101
6.3 TEM analysis for the nanocomposite M7FOC a) bright field image b) high resolution micrograph c) SAED pattern and d) histogram for the particle size.....	103
6.4 XPS spectra for the sample M7FOC after the decovolution of the peaks a) Fe 2p	

b) C 1s c) Mn 2p and d) O 1s.....	105
6.5 Mossbauer spectrum for the nanocomposites M2FOC and M7FOC samples....	106
6.6 Magnetic properties of the nanocomposites M2FOC and M7FOC samples.....	109
6.7 Temperature vs. time plots for the ferrofluids of M2FOC and M7FOC samples.....	110
6.8 <i>In-vitro</i> study of M2FOC nanocomposite with A549 lung cancer cell lines. a) % cell viability with varying concentrations 0.1, 0.5, 1, 1.5, 2, 2.5 and 3 mg/mL b) Fluorescence microscopy after stained with acridine orange.....	111
6.9 Electrochemical performance of the nanocomposite FC (a) cyclic Voltammograms curves for initial three cycles at the scan rate of 0.1 mV s <sup>-1</sup> , (b) Galvanostatic lithiation/delithiation cyclic voltage profiles, and (c) variation of specific capacities and coulombic efficiency with cycle number.....	113
6.10 Electrochemical performance of the nanocomposite M2FOC (a) cyclic Voltammograms curves for initial three cycles at the scan rate of 0.1 mV s <sup>-1</sup> (b) Galvanostatic lithiation/delithiation cyclic voltage profiles and (c) variation of specific capacities and coulombic efficiency with cycle number.....	115
6.11 Electrochemical performance of the nanocomposite M7FOC (a) cyclic voltammograms curves for initial three cycles at the scan rate of 0.1 mV s <sup>-1</sup> (b) Galvanostatic lithiation/delithiation cyclic voltage profiles and (c) variation of specific capacities and coulombic efficiency with cycle number.....	117