Figures	Title	page
1.1	Principal consumption of energy through fuel during 1980-2040	1
1.2	Types of thermal energy storage systems	3
1.3	Schematic for basic principle of (a) sensible heat storage and (b) latent heat storage	4
1.4	Flow chart demonstrating the thesis structure	5
2.1	Phase change materials explored for thermal energy storage applications	10
2.2	Schematic for types of phase changes in PCMs	11
2.3	Requirements for selection of PCM	12
2.4	Cooling of PCM with Supercooling before starting solidification	13
2.5	Classifications of phase change materials	14
2.6	Methods for thermal conductivity coefficient enhancement for LHTESS	10
2.0	Applications of phase change materials	19
2.7	D8 advance powder X-ray diffractometer installed at IIT Jodhnur	25 26
2.1	Schematic of a SEM (Source: Long 2012) (b) actual photograph of ccamping electron	20
3.2	microscope system (Carl Zeiss) combined with EDS at IITJ	2/
3.3	(a) Schematic of optical diagram of Raman microscope (Source: Leng, 2013), (b)	28
	Nomadic Raman microscope in our lab used to measure the vibrational properties of	
	selective absorber materials in this study	
3.4	Bruker FT-IR spectrometer vertex 70v in our lab used to collect the reflectance spectra	29
	of spectrally selective absorbers	
3.5	Schematic structure of (a) power compensation DSC, (b) heat flux DSC	29
3.6	(a) Actual photograph of DSC Q10 (TA Instruments), and (b) DSC thermograph explaining melting and solidification process	30
3.7	(a) Schematic representation of T-history set up and (b) temperature profile for	31
2.4	sample (violet), reference (red) and environment (blue) for a T-history measurements	
3.8	(a) Schematic structure, and (b) actual photograph of TPS 2500S thermal constant	33
<u> </u>	analyzer	
4.1	Actual photograph of (a) 1-history installation and (b) glass test tube with EPP	37
	insulation and K type thermocouple used for T-history measurements	
4.2	Schematic structure of T-history measuring setup assembled at IITJ	37
4.3	Cooling curves for four deionized water test tubes placed at different locations of air chamber	39
4.4	(a) The recorded cooling curve of palmitic acid (red color), water (blue color) in conjunction with environmental temperature of chamber (black color) and (b) rate of heat transfer from water test tube as a function of temperature difference between water and ambient temperature $(T_w T_{amb})$ with fitting of second order polynomial.	40
4.5	Enthalpy versus temperature curve for palmitic acid derived from T-history data	40
4.6	DSC thermograph of palmitic acid	41
4.7	(a) Cooling curve of sodium acetate trihydrate using T-history method and (b) DSC	42
	thermograph for sodium acetate trihydrate	
5.1	DSC thermographs of (a) 1-deodecanol, (b) lauric acid, (c) myristic acid, and (d) palmitic acid	48
5.2	(a) Computed thermal phase diagram for 1-dodecanol and lauric acid binary system, and (b) DSC thermograph of 1-dodecanol and lauric acid binary eutectic system	50
5.3	(a) Computed phase diagram for 1-dodecanol and myristic acid binary system and (b)	51
	DSC thermograph of eutectic composition of 1-dodecanol and myristic acid binary system	
5.4	(a) Computed phase diagram for 1-dodecanol and palmitic acid binary system, and (b)	52
	(a) Temporaturo chango Vorsus timo response for liquid dele spel et embiente	
5.5	(a) remperature change versus une response for liquid 1-dodecanol at ambient	53
	temperature 25°C (b) temperature change of versus function t(t) for liquid 1-	
	addecanol corresponding to results $\Delta I$ versus t and (c) average thermal conductivity	
	or pristine ratty acids, 1-dedecanol and ratty acid/1-dodecanol eutectic PCMs	
5.6	Molecular structure of (a) acetamide, (b) benzoic acid; and (c) thermal phase diagram of acetamide-benzoic acid binary system, with eutectic point.	55

5.7	Molecular structure of (a) benzoic acid, (b) Phthalimide, and (c) thermal phase diagram of benzoic acid-phthalimide binary system, with eutectic point	56
6.1	Schematic representation for use of sodium acetate trihydrate PCM (a) reusable PCM heat pack, (b) PCM hot vest, (c) PCM floor heating for buildings and (d) seasonal solar thermal energy storage and building heating	58
6.2	(a) Measured powder X-ray diffractographs for samples A, B, C, D and E, (b) calculated X-ray diffraction pattern with inset showing lattice parameters, (c) crystal structure of SAT crystal with Orange large sphere: Na atom; blue smaller circle: Oxygen atom, green smaller circle: hydrogen atom, black circle: carbon atom and (d) FTIR spectrographs of sample A, B, C, D and E	59
6.3	Scanning electron micrographs with 500 X (top panel) and 15000 X (bottom panel) magnifications for sample A, B, C, D and E	61
6.4	(a) T-history graphs for samples A, B, C, D, E and F nucleated at 60 °C and ambient temperature ~23 °C, (b) Enthalpy vs. temperature curves corresponding to graph 6.4(a), (c) T-history graphs for samples A, B, C, D, E and F nucleated at ~30 °C and ambient temperature ~23 °C, (d) Enthalpy vs. temperature curve corresponding to graph 6.4(c)	62
6.5	Differential scanning calorimetric (DSC) thermograph for sample A (a); samples B, C, D, and E (b) and supercooling temperature for these samples, measured using DSC and T-history methods (c)	64
6.6	Schematic representation of SAT molecules (a), EG molecules (b), macroscopic arrangement of SAT crystals (c), hydrogen bond interactions between water H atoms of SAT and hydroxyl oxygens of EG (d), and macroscopic arrangement for insertion of EG as laminar vesicles (red lines) in SAT matrix (e). The blue, black, yellow and red spheres represent the H, C, O and Na atoms respectively. The hydrogen bond between bydrogen atom of water and bydroxyl atom of EG is represented with doted black lines.	66
6.7	Schematic and pictorial representation of heat releasing process from PCM heat packs: (a) flexing triggering device to start nucleation in supercooled liquid PCM for its solidification at t=0 second, (b) growth of solidification at t=5 seconds, (c) complete solidification of supercooled liquid PCM at t= 55 seconds and (d) T-history curves for heat packs consisting of water, sample A and C	68
7.1	Schematic scheme (left) and real photograph (right) of dish solar energy concentrator with a container painted by black paint and kept at the focal point of dish. The rightmost photograph represents the arrangement of shadow mechanism to keep parabolic dish in normal direction to the Sun	71
7.2	(a) Heating and cooling response of 2.5 kg water and respective ambient temperature and (b) variation of water and ambient temperature difference with time, with semi log plot (inset)	72
7.3	Performance parabolic dish characteristic graph for different ambient temperatures and solar insolations for heating water up to 100 ℃	74
7.4	Thermal response of water while charging of heat packs using parabolic dish, demonstrating sensible heat storage (solid PCM), latent heat storage (solid-liquid phase change) and sensible heat (liquid PCM) heat storage during 0 – 18 minutes, 18 - 32 minutes and after 32 minutes respectively	75
7.5	Different stages for heat releasing mechanism from heat pack (a) heat pack containing liquid PCM and metallic triggering disk (b) Pressing metallic disc to initiate nucleation in liquid PCM (c) growth of nucleation and solidification (d) movement of solidification in liquid PCM (e) complete solidification of liquid PCM	75
7.6	Discharging thermal response of PCM heat pack at ambient temperature -10 °C, after starting nucleation.	76
8.1	Schematic representation for (a) natural graphite flake, (b) graphite intercalation compounds, and (c) exfoliated graphite respectively	79
8.2	Schematic representation to get graphite intercalation compounds from natural graphite flakes. (a) natural graphite flakes (NGFs) in beaker, (b) adding $H_2SO_4$ , $HNO_3$ and $KMnO_4$ solution in NGFs, (c) stirring of solution using magnetic stirrer for ~3 hours, (d) addition of DI water to reduce pH of chemically treated NGFs to 6-7 and (e) graphite intercalation compounds after	80
8.3	Flow diagram for the process of exfoliation of graphite from natural graphite flakes, with exfoliated graphite (right panel) in beaker	80

8.4	SEM micrographs for (a) NGFs (magnification 1kx), (b) GICs (magnification 1kx), (c) ExG (magnification 240x)and (d) ExG (magnification 1kx)	81
8.5	Powder X-Ray diffractographs of natural graphite flakes, graphite intercalation compounds and exfoliated graphite	82
8.6	Raman spectrograph of natural graphite flakes, graphite intercalation compound and exfoliated graphite	82
8.7	<ul> <li>(a) Schematic of set up for preparation of PCM-ExG composite, (b) photograph of MA,</li> <li>(c) photograph of ExG and (d) photograph of PCM-ExG composite</li> </ul>	83
8.8	SEM micrograph of MA-Exg (a) at 1 k X, and (b) at 2.82 k X	84
8.9	FTIR spectra of MA and ExG-MA composites with 5, 10 and 15 weight percentage of ExG	85
8.10	Real photographs of (a) transparent dye, (b) compression machine and (c) pallets of MA-ExG composite sample with 5, 10 and 15 weight fraction of ExG	86
8.11	Measurement of thermal conductivity of PCM-graphite composite samples, (a) Sensor for measuring thermal conductivity, (b) placement of sensor between two identical samples, (c) Average thermal conductivity of MA/ExG with 0, 5, 10 and 15 wt% of ExG	86
8.12	(a) Cooling response of Pristine MA, MA+5% ExG, MA+10% ExG and MA+15% ExG and (b) reduction in heat release time from 70-50 °C for , MA+5% ExG, MA+10% ExG and MA+15% ExG	87
8.13	Actual photographs of LiNO <sub>3</sub> -NaCl/ExG composites with (a) 5%, (b) 10%, (c) 15%, and (d) 20% ExG	88
8.14	Differential scanning calorimetric thermographs for salt eutectics, (a) 54.8% LiNO <sub>3</sub> - 45.2% NaNO <sub>3</sub> , (b) 48.8% LiNO <sub>3</sub> – 51.22% NaNO <sub>3</sub> , (c) 52% NaNO <sub>3</sub> – 50% KNO <sub>3</sub> , and (d) 88.8% LiNO <sub>3</sub> – 11.2% NaCl	89
8.15 8.16	Actual photographs of LiNO <sub>3</sub> -NaCl/ExG composites with 5, 10, 15 and 20 wt% of ExG Thermal conductivity of LiNO <sub>3</sub> -NaCl/ExG composites at densities 520, 620, 1000, and 1400 kg m <sup>-3</sup> with (a) 10% ExG, (b) 15% ExG, and (c) 20 % ExG.	90 91