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Characteristic of Erythritol and Alumina Mixture as Phase Change Materials for Thermal Energy Storage Application

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Abstract:- In this work, we describe the characterization of Erythritol as a phase change material by adding 0.5% and 1% mass fraction of Alumina as a nanoparticle. First, we examined the effect of thermal cycling on the chemical stability of erythritol by adding nanoparticle in FT-IR and XRD. Second, we investigated the thermal stability of erythritol by adding nanoparticle in DSC. In this experiment we performed 50 cycle's test of melting and solidification on erythritol with 0.5 % and 1.0 % mass fraction of alumina nanoparticles. Erythritol has a melting temp 117℃ and heat of fusion 340 J/g, and, thus it is more attractive PCM in a medium Temperature Range Thermal energy storage system. The experimental result in FT-IR indicated that the mixture of Erythritol and alumina composition is stable in 0.5wt % and 1% of mass fraction. In DSC we found that After 50 cycles Erythritol with alumina nanoparticles with 0.5 and 1.0 wt. % it was showing decrease of 5.97 and 9.8% in heat of fusion respectively.

Keyword:- *PCM, Erythritol, Alumina, FT-IR, DSC, XRD, SEM, Thermal Cycling*

Abbreviation

PCM	Phase change material
TES	Thermal energy storage
DSC	Differential scanning calorimetry
FT-IR	Fourier transform-infra-red
XRD	X-ray diffraction
SEM	Scanning electron microscopy

I. INTRODUCTION

There are mainly two types of thermal energy storage systems sensible and latent heat storage. Latent heat storage is particularly attractive due to its ability to provide a high energy storage density and its characteristics to store heat at a constant temperature corresponding to the phase transition Temperature of the heat storage substance.PCM is a one of the option, where we can used a latent heat of fusion as a storage energy in a thermal energy storage tank. Selection of PCM is a main criteria in particular TES system so Before selection of any PCM we have to check the properties like heat of fusion, melting temperature, thermal conductivity etc.[12] A. Abhatclassified the various PCM on the basis of organic, inorganic and their application in thermal energy storage system.

There are some studied related thermal cycling of PCM [1] Aran Solé et al. presented the various sugar alcohol based PCM stability in a inert or vacuum atmosphere to prevent the Oxidation. [2] Anant Shukla et al. examined various property which effect on organic and inorganic PCM and he found that inorganic is not suitable for thermal stability test , melting temperature and heat of fusion as compare to organic PCM [3] Fei He et al. studied the microencapsulated Al-Si alloy by adding the Al2O3 for 20 thermal cycling from room temperature to 1000℃ result during a thermal cycling crack at an interface release several thermal stress [4] R.K. Sharma et al. focus on the organic and inorganic PCM material ,encapsulation and their used in a various recent development application, they observed that organic PCM having low melting point therefore it cannot used in a high temperature application [5] Y.B. Tao et al. Investigated few PCM based nanomaterial composited and effect of surface active agent .From all this literature review we get idea about the selection and thermal behaviour of various PCM [6] G. RaamDheep et al. studied the thermal cycling on benzamide and sebacic acid in a solar application, they found that it give the superior thermal stability after several thermal cycling [7] Aziz Babapoor et al. examined the thermo-physical properties of paraffin nanoparticle, they showed that it given a good thermal and chemical stability and adding Al_2O_3 nanoparticle decrease latent heat of fusion significantly very small.

[8] Seul-Yi Lee et al. studied erythritol and expanded graphite composites as a phase change material, result evaluated that it is a best suitable material for improving heat transfer enhancement and energy storage capacity. It shown superior thermal stability after 3rd thermal cycle [9] Jia-Nan Shi et al. studied that small amount of nanoparticle improve the thermal conductivity and shape stabilization of PCM by adding nanoparticle. [10] LuoZhichao et al. studied that by adding nano-titania into the erythritol , they found that increase the heat capacity due to increased interfacial thermal resistance.[11] TeppeiOya et al. developed the phase change composited of erythritol and nickel, graphite, They found that there is increase thermal conductivity as compare to the pure Erythritol.

From the above discussion adding nanoparticle there is change the properties of Pure erythritol .in this paper we study, wherein 0.5% to 1% mass percent of Nano alumina serving as the additive is added into the material, and a composite intermediate temperature as a phase change material in heat storage system.

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II. MATERIAL

We can use many PCM in various thermal Energy storage system applications. Basically, selectionof PCM on the basis of melting point, phase change enthalpy and density. In this paper we can used a Erythritol as a PCM having 118°c melting point and in this temperature range Erythritol having more latent heat of fusion (340 J/) which is more than other PCM, therefore it is best option suited for medium temperature range application. Kakiuchi et al. give the following properties of erythritol.

Properties	Numerical Value
Chemical Formula	$C_4 H_{10} O_4$
Molecular weight	122.2
Heat of Fusion (KJ kg^{-1})	339.8
Melting Point (°c)	118
Density at 20deg (g cm^{-2})	1.48
Heat conductivity (KJ $m^{-1}h^{-1}$°c)	2.64

III. EXPERIMENT SETUP

In this experiment taken a hot plate Heater fig(1) having a temperature range up to 350 deg. Calibrated K-type thermocouple range attached to the hot plate and temperature controller which is set to the temperature just above the melting point of Erythritol to measure the temperature of PCM. To reduce heat loss from Heater to atmosphere we provide the glass wool around the surface.

Fig 1.Hot plate with temperature control

Melting was carried out by placed a bowl in the hot plate. Kept the temperature controller at a preset temperature 130 dag for erythritol melt completely. After melting solidification started and erythritol allow solidifying up to the room Temperature by taking a bowl outside hot plate.

After melting and solidification of erythritol and 0.5 & 1 mass percent alumina up to 50 cycle, studied thermal and chemical characterization in a DSC and FT-IR. In this experiment used a perkinelmerdsc 6000 for measuring melting and solidification temperature of Erythritol sample. In DSC used Indium has a standard reference material and accuracy within a range of ± 2 %. Difference between the reference material and Erythritol temperature with respect to heat flow give latent heat of fusion under the curve. Erythritol sample (10 ± 1) mg was weighted and heating rate 5deg/min heated from 40deg to 150 deg.

For FT-IR analysis, we taken a different sample which is placed into a FT-IR instrument spectrometer (PerkinElmer/Spectrum 2) having range 400-4000 wavenumber.

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IV. RESULT AND DISCUSSION

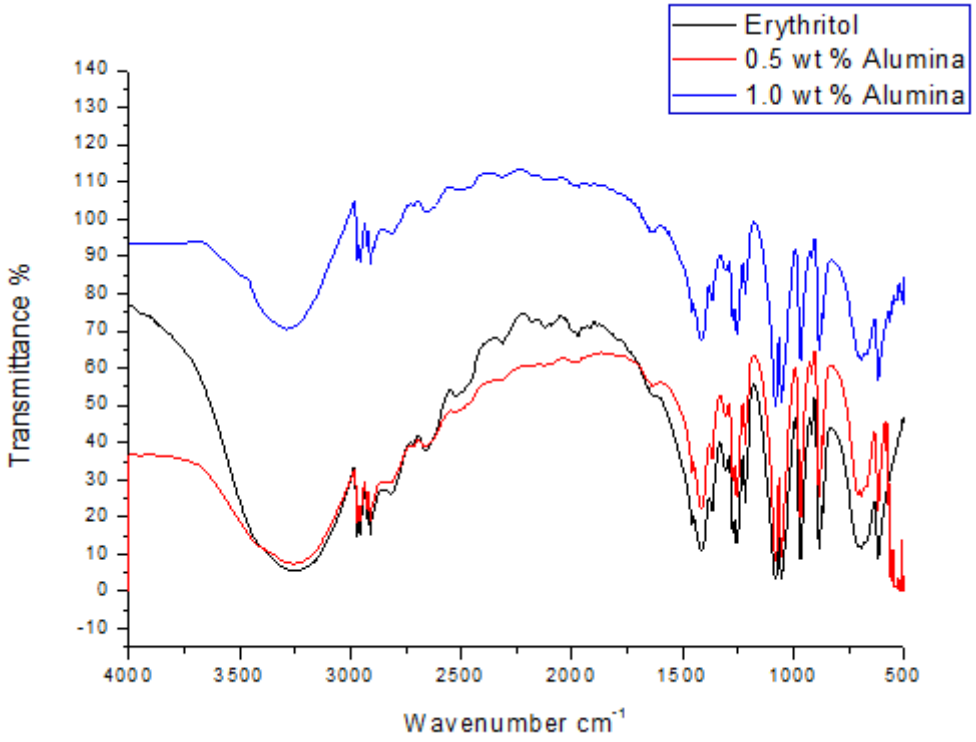
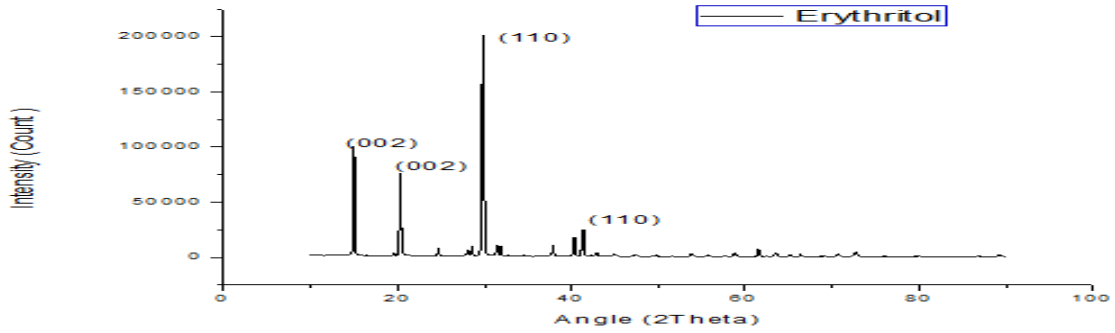


Fig 2. FT-IR spectra of Erythritol and adding nanoparticle.

Studied Chemical stability of erythritol and alumina nanoparticle with 0.5 and 1 mass fraction composite in a FT-IR after Thermal cycling and compare the result of them. Fig 2 .shows the result of FT-IR of 0^{th} cycle of FT-IR result .The spectra having higher wavenumber region than 3000 cm-1 show band that to be assigned as the vibration mode of NH and OH starching. Symmetric and unsymmetrical starching mode of CH, CH_2 and CH_3 in the region from 3000 cm-1 to 2800 cm-1 band. In the low wavenumber from 1700 cm-1 to 900 cm-1 are observed the characteristics bending mode of free amino acid, lipids and proteins.

In the FTIR spectra of erythritol, composite structure of erythritol and alumina nanoparticle are shown in fig 2. In FTIR spectrum of erythritol, there were peaks observed at 2950 cm-1 , 1340 cm-1, 1250 cm-1 which are represent stretching of C-H ,C=O and C-C bond. By adding aluminaNano powder were found that, 0.5wt % observed one peak at 1920 cm-1 which is belong to C=O vibration of ketone, acids and aldehydes which is found due to oxidation , in this result no new bond generated by adding nanoparticle. It indicated that the prepared erythritol and alumina composite did not occurs chemical reaction during preparation.

The XRD pattern showed three intense peaks in the whole spectrum of 2θ value ranging from 10 to 80. Fig 3. Shows the XRD pattern of Erythritol and 0.5, 1%wt of alumina nanoparticle. The Erythritol represent maximum intensity of (110) peak at $2\emptyset = 28.019$. After adding a nanoparticle in a ball milling machine the crystallite size is reduce and intensity of maximum peak is found (010) at $2\emptyset = 20.43$ 28.3.Average size of the particle synthesized was 34.92nm before ball milling and 28.3 nm after ball milling with size range with cubic and hexagonal shape. The typical XRD pattern reviled that the sample contains a mixed phase (cubic and hexagonal) structures of erythritol with alumina nanoparticles.



(a)

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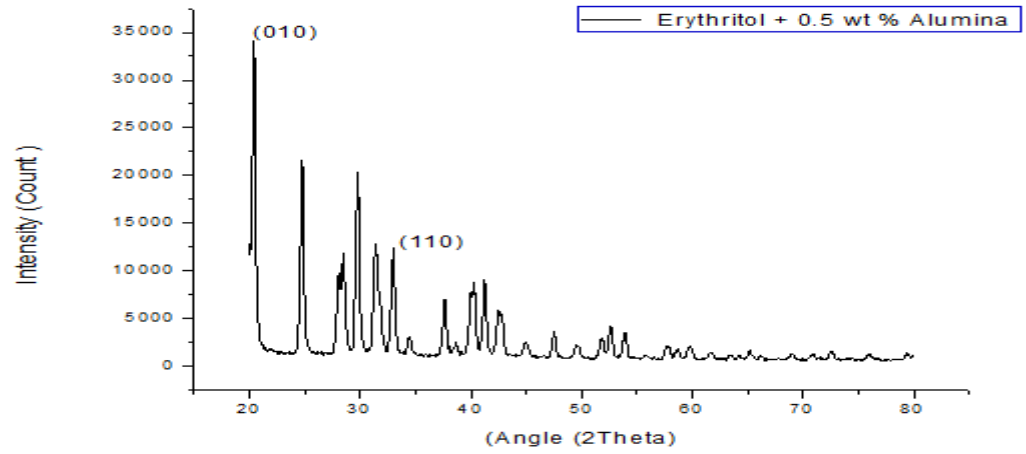
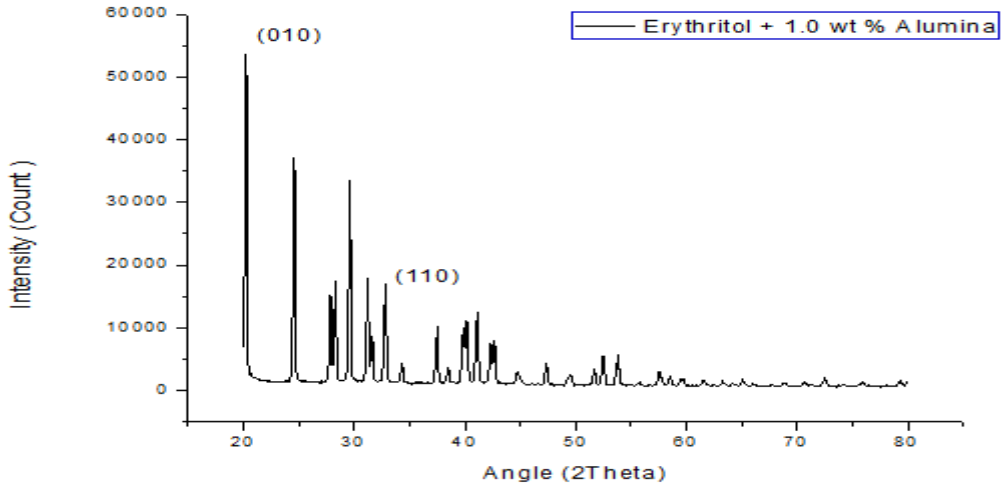


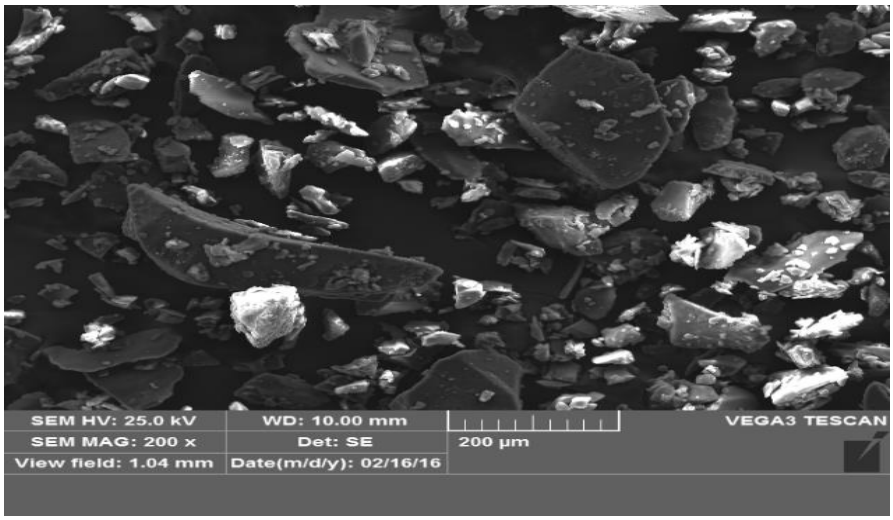
(b)



(c)

Fig 3. XRD pattern of a) erythrirol b) 0.5 wt.%and c) 1% wt. of alumina nanoparticles composite.

Fig.6 Showed SEM image of Erythritol with Alumina composite. Which is illustrated the morphology structure. There were no gap between the alumina nanoparticle in a Erythritol.so its demonstrating that nanoparticles are uniformly distributes and small aggregation is there and some places there is no nanoparticles present.



(a)

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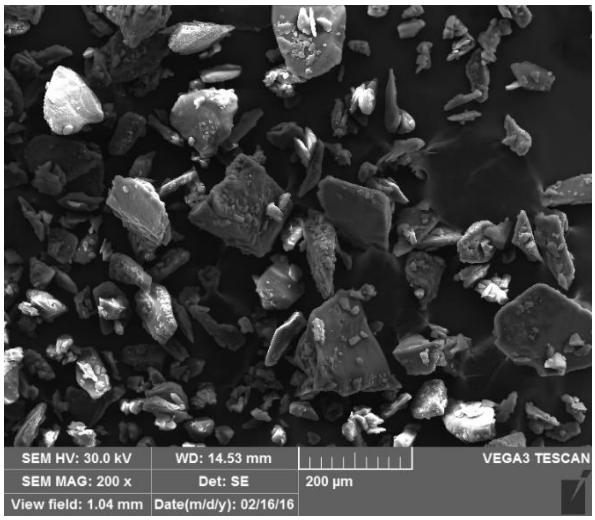

(b)

Fig.5 SEM image of a) erythritol b) erythritol with alumina nanoparticle

Thermal reliability tests were carried out by differential scanning calorimetry (DSC) at 5 K min^{-1}. Before and after thermally cycling the PCMs thermo physical properties were measured by DSC at 5 K min-1. Sample masses used were between 6.4 mg placed in 40 µl closed alumina crucibles, under 50 ml min-1 of N_2 atmosphere. To ensure repeatability, the samples of Erythritol and Erythritol with nanoparticle were analyzed. Fig 4 and 5 shows the heating curve of DSC for 0^{th}, 50th cycles. Melting Temperature, Onset Temperature and Heat of fusion are described before and after thermal cycling.

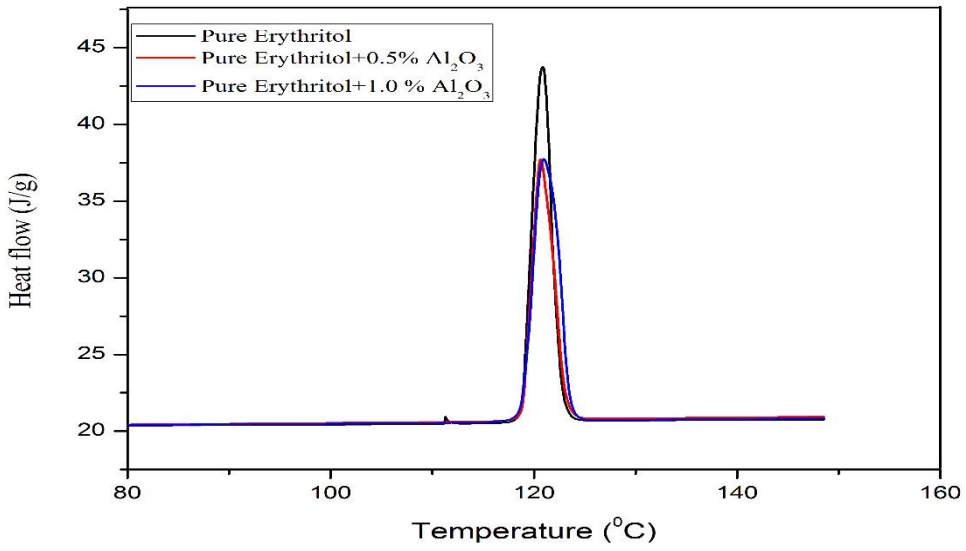

Fig.4 (a) DSC curve for alumina nanoparticle and erythritol composites and pure erythritol

Sample	0.0wt %	0.5wt%	1wt%
Melting Temperature (℃)	121.47	121.29	120.86
Onset Temperature (℃)	118.28	118.44	118.61
Heat of Fusion (J/g)	336.5	332.3	329.7

Table.1 Phase Change Properties before Thermal Cycling

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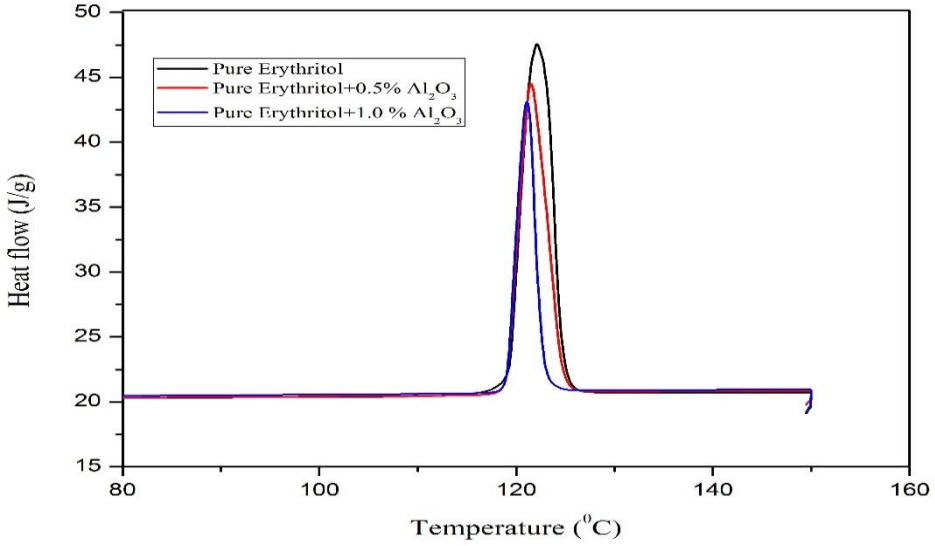

Fig.4 (b) DSC curve for alumina nanoparticle and erythritol composites and pureerythritol after 50 cycle

sample	0.0wt%	0.5wt %	1wt %
Melting Temperature (℃)	121.05	120.56	119.72
Onset Temperature (℃)	118.56	117.98	117.57
Heat of Fusion (J/g)	331.4	319.7	306.8

Table.2 Phase Change Properties after Thermal Cycling

DSC curve Fig 4 (a) shown the pure erythritol having 336.5 J/g latent heat of fusion , after adding alumina with 0.5 and 1.0 wt. % there is decreases in heat of fusion 1.28 , 2.06 % respectively. Erythritol having 121.4 ℃melting and 118.28℃ onset temperature , after adding alumina decrease in melting and onset temperature 121.29 , 118.44 ℃ in 0.5 wt. % and 120.86, 118.61 ℃respectively.

After 50 cycle thermal cycling erythritol indicated 331.4 J/g latent heat of fusion. By adding alumina it is observed that decrease latent heat 5.97, 9.8 % in 0.5 and 1.0wt % respectively. Melting and onset temperature also decrease after thermal cycling. Adding alumina in erythritol there is decrease malting temperature and onset temperature 120.56, 117.98 ℃in 0.5 wt. % and 119.72, 117.57 ℃ respectively.

V. CONCLUSION

In this study, Erythritol used as a PCM and Alumina used as the additive to make a composite structure. The composite structure were studied using a DSC and FT-IR tests.FT-IR result indicated that the prepared erythritol and aluminum composite did not occurs chemical reaction during preparation. While heat of fusion by adding alumina in erythritol, it shows not much decrease. After 50 cycles erythritol with alumina nanoparticles with 0.5 and 1.0 wt. % it was showing decrease of 5.97 and 9.8% in heat of fusion respectively. These result show that erythritol with alumina nanoparticle is thermally and chemically efficient that can be used in many thermal energy storage application.

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