INNOSTORAGE – USE OF INNOVATIVE THERMAL ENERGY STORAGE FOR MARKED ENERGY SAVINGS AND SIGNIFICANT LOWERING CO_2 EMISSIONS

Beneficiaries:

Partners:

D7.2 - Report on Staff Exchanges

	Name and Institution	Date
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Objectives

The objective of this study is to experimentally investigate and quantify the specific heat capacity (C_p) increase of $NaNO_3$ enhanced with silica and graphene nanoparticles for use in thermal energy storage (TES).

Introduction

TES systems can store and release heat normally by the use of phase change materials (PCM), taking profit of the high latent heat of phase change these materials have in their fusion/solidification processes [1].

PCM are classified in organic (fatty acid, sugar alcohols and paraffin) and inorganic (salt hydrates and metals). Organic PCM usually are non-corrosive materials with low or null subcooling and good cycling stability. Inorganic materials highlight due to their higher phase change enthalpy and thermal conductivity. However, both families present drawbacks. Organic materials are flammable and have lower energy storage capacity, and inorganic materials normally present subcooling, phase separation and null cycling stability, being most of them corrosive. To overcome these problems composites have been formulated to improve, mainly, thermal conductivity, but also the cycling stability of materials. Moreover, the use of nucleating agents has become a wide applied solution to decrease subcooling [2-7].

A relatively new field in PCM property enhancement and that is currently receiving much interest is the use of nanomaterials [8-9]. Advances in nanotechnology have become commercially available and, consequently, its use has spread in the thermal energy storage field. The dispersion of nanometer sized materials as nanoparticles, nanofibers, nanosheets and nanotubes in the PCM base material is used to enhance the energy exchange capacity of the base material. Properties such as the thermal conductivity, latent heat, viscosity and subcooling can be significantly changed, enhancing the PCM performance and increasing the efficiency of the TES system in which they are used.

The present work is focused on enhancing the specific heat capacity of sodium nitrate, a molten salt commonly used in concentrated solar power plants (CSP) sensible heat storage, by the dispersion of graphene and silica nanoparticles. To do so and based on the literature studies consulted, the weight percentage of nanoparticles dispersed in the base salt was fixed on 1%, as it is the proportion in which the best results have been obtained so far. Three different nanoparticle sizes were considered for both graphene and silica in order to study the influence of this parameter and see, if so, the particle sizes in which the C_p enhancement is favored.

Materials and methodology

Acid-treated Graphite Asbury 3494 (GIC) provided by Asbury Carbons and technical grade acetone from Chem-supply were used to synthetize graphene nanoparticles. 98 % tetraethyl orthosilicate (TEOS) along with 28-30 % ammonium hydroxide and > 95% ethanol reagents, all of them produced by Sigma Aldrich, were used to synthetize silica nanoparticles. Deionized water was used throughout the experiment.

- Synthesis of graphene nanoparticles

Graphene nanoparticles were obtained using Acid-treated Graphite Asbury 3494 (GIC) and following the procedure explained in [10]. The sonication time defines the nanoparticle size, thus, different sonication times have been used depending on the desired particles size. After the sonication, the solution is then filtrated and the precipitate separated and dried in an oven at 60 ºC for 1 hour to remove the acetone and get dry graphene nanoparticles.

- Synthesis of silica nanoparticles

Silica nanoparticles were prepared by hydrolysis of TEOS in ethanol medium in the presence of ammonium hydroxide, following the procedure explained in [11]. First, an ethanol solution is prepared and after sonication, the exact amount of TEOS needed is added and the solution is again sonicated. Finally, ammonium hydroxide, which acts as the reaction catalyst to the formation of silica, is added and the resultant solution is sonicated again, after which a white suspension is obtained.

- Synthesis of NE $NaNO_3$

The nanocomposites synthesis procedure was based on the Shin and Banerjee method, the most used one in the literature studies consulted, and was the same for both graphene and silica nanocomposites. First, the salt was diluted in deionized water (1:10 ratio) and then the nanoparticles were added and dispersed by sonication in a water bath during 2 minutes. Finally, the suspension was dried at 100 ºC in a hot plate in order to avoid boiling, which could cause nanoparticle agglomeration in the resulting NE salt.

Results

The particle size of the nanoparticles and its dispersion in the $NaNO_3$ has not been determined yet. TEM samples have been prepared and will be analyzed in the next weeks in both UniSA and UdL.

The C_p of the NE $NaNO_3$ was measured with a PerkinElmer DSC 8000 operating under a constant Nitrogen flow of 200 ml/min. Experimentation is not over yet and more DSC analyses will be done in University of Lleida to complement the preliminary results obtained during the 3 months period in UniSA, presented in Table 1. Two samples of NE NaNO3 were analyzed for every of the nanoparticle sizes listed.

Table 1. Percentage of C_p enhancement obtained with silica and graphene nanoparticles addition for both solid and liquid states

	C_p Enhancement %	
Nanomaterial	**Solid state**	**Liquid state**
Graphene size 1*	10	17
Graphene size 2	20	28
Graphene size 3	25	-5
Silica 1, 225 nm	2	19
Silica 2, 80 nm	12	17
Silica 3, 20 nm	19	10

*Graphene particles sizes are still to be determined by TEM. The size pattern expected according to the nanoparticles synthesis is: size 1 > size 2 > size 3.

Results show C_p enhancements by the use of both nanomaterials, being the increases obtained with graphene nanoparticles more important compared to the silica enhancements. Also the nanoparticle size has a direct effect on the C_p improvement, being the smallest nanoparticles the ones that provide a higher enhancement in solid state. The tendency is not that clear in liquid state, as for graphene 3 a small decrease was obtained and for silica better results were obtained for bigger nanoparticle sizes. Further DSC analyses will be conducted to confirm the results and have more clear conclusions.

Preparation of more samples and more DSC tests are needed to ensure repeatability and obtain more accurate results to confirm the enhancements observed so far and clarify the liquid state values.

Outcomes or future work

It is expected that at least one paper will be published from the experimentation carried out during this research stay.

References

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Assessment

This secondment has been a great opportunity on working during three months with worldwide well-known researchers in the field of thermal energy storage. I could work on a different environment and with different working methods from the ones I was used to. Very enriching discussions allowed both University of Lleida and University of South Australia research groups to work on the nano-enhancement of PCM for use in TES, obtaining promising results that are thought to be published during this 2016.