# Development of a novel thermoelectric module based device for thermal stability measurement of phase change materials

*by* Bambang Ariantara -

**Submission date:** 22-May-2023 02:18PM (UTC+0700)
**Submission ID:** 2099023951
**File name:** bility_measurement_of_phase_change_materials_-_ScienceDirect.pdf (264.06K)
**Word count:** 2495
**Character count:** 13975

ScienceDirect

Journal of Energy Storage
Volume 22, April 2019, Pages 331-335

# Development of a novel thermoelectric module based device for thermal stability measurement of phase change materials

Nandy Putra [a], Imansyah Ibnu Hakim [a], Fadel Prawira Erwin [a], Nasruddin A. Abdullah [a] [b], Bambang Ariantara [c], Muhammad Amin [b], Teuku Meurah Indra Mahlia [d], Eny Kusrini [e]

Show more

Share Cite

https://doi.org/10.1016/j.est.2019.02.030
Get rights and content

## Abstract

A recently developed method for the thermal stability measurement of phase-change materials (PCMs) involves thermal cycling using a thermoelectric module as a heating and cooling element. However, the utility of this approach was found to have some limitations, mainly because the thermoelectric polarity is changed according to time rather than the actual sample temperature. A method for thermal cycling test, where the thermoelectric polarity is automatically changed according to the sample temperature was developed in this study. In addition, a new cartridge design in this device requires a small sample volume (1.53 $cm^3$) and can be easily assembled and disassembled. This proposed device was tested on beeswax as a PCM sample. This is very important for savings PCMs material which usually expensive. The results showed that the apparatus had automatically cycled between the melting and cooling temperatures of beeswax. The thermal data showed that beeswax retains consistent melting and freezing temperatures after 1000 cycles, however, its heat of fusion degrades over repeated thermal cycling. This apparatus can be readily applied to study a wide range of PCMs for such as thermal energy storage materials for energy conservation. To our best knowledge, yet no study has been performed on this kind of equipment so far.

## Introduction

Thermal energy storage (TES) has been widely studied to meet our daily energy needs and to reduce the consumption of fossil fuels [1], and it can also be leveraged for thermal heating and cooling. In the domestic and industrial sectors, including superior storage efficiency, phase-change materials (PCMs) offer several advantages for TES applications [2,3]. For instance, PCMs store energy by transforming between the solid and liquid phases while absorbing or releasing heat. A high thermal conductivity of PCMs is desirable for TES applications to facilitate rapid heat distribution and absorption. PCMs can be grouped into organic, inorganic, and eutectic materials [4], each of which offers certain advantages and disadvantages. Organic materials provide excellent thermal resistance, nontoxicity, and low sub-cooling potential, but they have poor thermal conductivity and low latent volumetric capacity [1].

Nanoparticles have been used to increase the thermal conductivities of PCMs and to reduce the sub-cooling potential, but they also decrease the latent heat capacity [5,6]. All the PCMs provide good calorific storage efficiency. The other unique thermal characteristics of PCMs, such as conductivity, melting and freezing temperatures, and heat storage capacity are important factors for applications, including air conditioning systems, solar energy systems, and cooling systems for electronics [[7], [8], [9], [10]]. Unfortunately, the thermal characteristics of PCMs tend to degrade over a certain period of time. This characteristic is very important for commercial PCM. Thus, there is considerable interest in developing PCMs that provide consistent performance or without an excessive change in its thermos-physical and chemical properties over a long period of time [4]. That performance is called thermal stability and reliability. A period of charging and discharging of PCM or thermal cycling of PCM can happen one or more times in a 24 h time period, implying at least a 1000 cycle for a 3 years life of a PCM storage [11].

There is a need for a device to measure the thermal stability and reliability of a PCM over repeated cycles of heating and cooling. Generally, thermal cycling test devices utilize specific measuring instruments for heating and cooling. However, there is no standardized device for testing PCMs under thermal cycling [12]. Build-up methods have been proposed in several studies to test the thermal stabilities of PCMs. For example, Sari et al. used a thermostatic bath of a fatty acid-based PCM by heating it with a heating controller until it reached the melting point and then switching off the controller to allow the sample to cool to room temperature [[13], [14], [15]]. Sharma et al. used an electric hot plate to heat the PCM sample inside a stainless steel container followed by cooling to room temperature [[16], [17], [18]]. Shukha et al. introduced an oven to heat the PCM to a fixed temperature and removed the sample from the oven to allow it to cool to room temperature [19]. Silakhori et al. fabricated a copper box, filled it with the PCM, and attached a strip steel heater to one side and a heat pipe, heat sink, and cooling fan to the other side [20]. Sharma and Shukla used two chambers filled with water to heat and cool the PCM samples [21]. These previous studies conducted the thermal cycle always 1000 cycles and lower than 1000 cycles.

Recently [11], have measured the thermal cycle of organic binary PCM. They developed a new tailor-made thermal cycling apparatus, which consist of heating and cooling sources, water pump, the whole water tube network, water tank, and two solenoid adjusting valves. Three types of composite fatty acids Capric acid (CA) & Lauric acid (LA), CA & Myristic acid (MA), and CA & Palmitic acid (PA), were tested with several mass ratios. The thermal cycling number is up to 4000 and DSC tests are carried out after each testing stage.

Lately, we have proposed a new method, employing pouring the PCM (in this case, RT22HC) into a cartridge as a test cell and attaching thermoelectric elements to both sides of the cartridge for heating and cooling the sample [22]. With this setup, we demonstrated the PCM could undergo heating and cooling process up to 1000 cycles [22]. However, in this method, the change in the polarity of the thermoelectric elements, which was controlled by a programmable DC power supply, was triggered only by the elapsed time according to the predicted time required for the PCM to melt and solidify. Moreover, the cartridge requires a large sample volume, makes it difficult to remove the sample after the test, and it must be cleaned after every single use. Thus, the research aimed to develop a thermal cycling test method using a thermoelectric module that can change its polarity based on the sample temperature and cartridge, and the module can be easily dismantled.

In order to test the proposed device, the thermal cycling tests on beeswax was performed as an example of a PCM and characterized its thermal properties by differential scanning calorimetry (DSC). The main contribution of this study is an integrated cartridge design development and cycling testing for PCM as an advantage from the previous method. To our best knowledge, yet no study has been performed on the development of an integrated cartridge design development and cycling testing for PCM application so far.

## Section snippets

### Cartridge design

The disadvantage of the previous method was that a large amount of the PCM sample had to be poured into the cartridge because of its large dimensions. The excess PCM sample requires significant costs when the raw PCM is expensive and not widely available in the market. Thus, a modified cartridge was developed for the thermal cycling test, as shown in Fig. 1. In this case, the cartridge was sandwiched between thermoelectric modules on the left and right sides to provide simplicity and…

### Beeswax thermal cycling test process

Fig. 6 shows the result of the beeswax thermal cycling test using the modified method. The results show that the newly proposed device successfully changed the polarity to alternately heated and cooled the beeswax sample automatically. The heating and cooling processes were adjusted during the operation based on the melting and freezing points of the beeswax sample.

The heating process lasted for 3 min, and the cooling process took 4 min; thus, each cycle for the beeswax sample was approximately …

### Conclusions

The proposed new device using thermoelectric modules was demonstrated to be an effective alternative for PCM thermal cycling tests. The device is automatically switched the thermoelectric polarity based on the sample temperature. The heating process was tested on a beeswax sample, and the results showed that the sample reached its melting point and was heated to 65 °C during the heating process. Moreover, the cooling process continued until the sample reached its freezing point at 46 °C. The…

### Acknowledgments

The authors thank the DRPM (Directorate of Research and Community Service), Universitas Indonesia for funding this research through the PITTA Scheme 2018 and WCP Kemenristek Dikti RI.…

## References (23)

N. Putra
Characterization of the thermal stability of RT 22 HC/graphene using a thermal cycle method based on thermoelectric methods
Appl. Therm. Eng. (2017)

A. Sharma *et al.*
Thermal cycle test of binary mixtures of some fatty acids as phase change materials for building applications
Energy Build. (2015)

A. Shukla *et al.*
Thermal cycling test of few selected inorganic and organic phase change materials
Renew. Energy (2008)

S.D. Sharma *et al.*
Accelerated thermal cycle test of latent heat-storage materials
Sol. Energy (1999)

A. Sharma *et al.*
Accelerated thermal cycle test of acetamide, stearic acid and paraffin wax for solar thermal latent heat storage applications
Energy Convers. Manage. (2002)

G. Raam Dheep *et al.*
Influence of accelerated thermal charging and discharging cycles on thermo-physical properties of organic phase change materials for solar thermal energy storage applications
Energy Convers. Manage. (2015)

A. Sarı *et al.*
Preparation, thermal properties and thermal reliability of palmitic acid/expanded graphite composite as form-stable PCM for thermal energy storage
Sol. Energy Mater. Sol. Cells (2009)

A. Sarı *et al.*
Preparation, thermal properties and thermal reliability of capric acid/expanded perlite composite for thermal energy storage
Mater. Chem. Phys. (2008)

A. Sarı
Thermal reliability test of some fatty acids as PCMs used for solar thermal latent heat storage applications

Energy Convers. Manage. (2003)

G. Ferrer
Review on the methodology used in thermal stability characterization of phase change materials
Renew. Sustain. Energy Rev. (2015)

View more references

## Cited by (5)

### Ab initio prediction of enhanced thermoelectric performance from bulk to monolayer Sb<inf>2</inf>S<inf>2</inf>Te

2021, Materials Science and Engineering B: Solid-State Materials for Advanced Technology

> *Citation Excerpt :*
> …In recent years, various types of TE materials have been studied. For example, double-filled p-type skutterudites [5,6], layered cobalt oxides [7,8], half-Heusler alloys [9–11], superlattices [12–15], composite films [16–18], phase change materials [19–20], and so on. In the last few years, Sb2(S,Te)3 has been synthesized into a variety of nanostructured forms, which exhibits reinforced electronic properties to obtain optimal ZT [46–48].…

Show abstract

### Interfacial stability of CoSb<inf>3</inf> in contact with chromium: Reactive diffusion and microstructure evolution

2020, Journal of Alloys and Compounds

> *Citation Excerpt :*
> …Thermoelectric materials have high potential as alternative energy sources due to the capability of converting waste heat directly into electricity [1–12].…

Show abstract

### Performance of beeswax phase change material (PCM) and heat pipe as passive battery cooling system for electric vehicles

2020, Case Studies in Thermal Engineering

> *Citation Excerpt :*
> …The research quite encouraging but did not give an optimized result and therefore Amin et al. [10] attempt to analyse a new material from beeswax/graphene thermal as PCM. This research then following by using beeswax/multi-walled carbon nanotubes and attempted to used novel thermoelectric module based devices for thermal stability measurement of PCM [11,12]. One of the reasons for global warming is the increasing number of vehicle owners each year, which has consequences for emissions and fuel availability [13].…

Show abstract

## Hybrid hydrogen-battery storage to smooth solar energy volatility and energy arbitrage considering uncertain electrical-thermal loads

2020, Renewable Energy

*Citation Excerpt :*

…The pumped-storage hydroelectricity is also used to level the output power of hydro system and handle its uncertainty [11]. The energy storage systems not only can handle the uncertainty in the system [12], but also can be applied for the other purposes such as energy arbitrage [13], power flow control [14], stability improvement [15], load leveling and peak cutting [16], network expansion deferral [17], bill saving [18], congestion management [19], and thermal application [20]. The hybrid storage system comprises the advantages of both the fast and slow speed energy storage systems and may be properly utilized to handle the uncertainty of renewable energies.…

Show abstract

## Thermal properties of sonicated graphene in coconut oil as a phase change material for energy storage in building applications

2020, International Journal of Low-Carbon Technologies

# Recommended articles (6)

Research article

## Differences in cultural competence between nursing students in academic and professional programs

Enfermería Clínica, Volume 29, Supplement 2, 2019, pp. 528-531

Show abstract

Research article

## Bio-diesel production using mobile processing units: A case in Indonesia

Agricultural Systems, Volume 152, 2017, pp. 121-130

Show abstract

Research article

## Students' ability in delivering transcultural nursing linked to their place of origin: A cross-sectional study

Enfermería Clínica, Volume 29, Supplement 2, 2019, pp. 556-559

Show abstract

Research article

The occurrence of Simpson's paradox if site-level effect was ignored inthe TREAT Asia HIV Observational Database

Journal of Clinical Epidemiology, Volume 76, 2016, pp. 183-192

Show abstract

Research article

The influence of insulin resistance in the occurence of non-alcoholic fatty liver disease among first degree relatives of type 2 diabetes

Diabetes & Metabolic Syndrome: Clinical Research & Reviews, Volume 13, Issue 2, 2019, pp. 1431-1435

Show abstract

Research article

Evaluation of electronic pressure injury alarm prototype based on user acceptance testing at hospital acquired pressure injury

Enfermería Clínica, Volume 31, Supplement 2, 2021, pp. S432-S435

Show abstract

View full text

© 2019 Elsevier Ltd. All rights reserved.

ELSEVIER

Copyright © 2023 Elsevier B.V. or its licensors or contributors.
ScienceDirect® is a registered trademark of Elsevier B.V.

RELX™

# Development of a novel thermoelectric module based device for thermal stability measurement of phase change materials

ORIGINALITY REPORT

| 23% | 18% | 20% | 15% |
|---|---|---|---|
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

3%

★ Wu, S.. "Dynamic discharging characteristics simulation on solar heat storage system with spherical capsules using paraffin as heat storage material", Renewable Energy, 201104

Publication

| | | | |
|---|---|---|---|
| Exclude quotes | On | Exclude matches | < 1% |
| Exclude bibliography | On | | |