Phase-Change Materials for Additive Manufacturing

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Introduction

Additive manufacturing of plastic thermal energy storage systems (TESSs) is an emerging hot topic in thermal science due to their lightweight and novel geometries.

Current thermal management and storage methods utilize heavy metals that require moving components to pump a cooling fluid through the system.

Phase Change Material (PCM) has the ability to absorb large amounts of latent heat at a constant temperature while undergoing a solid-liquid phase change.

Extruded PCM/polymer filament can be used to develop lightweight and passive heat exchangers with additive manufacturing techniques [1].

Different percentage-by-mass PCM/high-density polyethylene (HDPE) mixtures were investigated.

The thermal properties were experimentally investigated using differential scanning calorimeter (DSC) measurements and the filament composition was explored using a scanning electron microscope (SEM).

Custom matrices have been produced through the use of 3D printing and novel geometries for PCM based thermal management storage systems will be investigated for the first time using additive manufacturing.

Applications

Thermal control with PCM gives a broad range of potential applications, from building insulation, photo-voltaic panel temperature, to lithium-ion battery cooling.

https://www.uk-exchangers.com/heat-exchange-products/air-to-air-heat-exchangers/

http://www.grenie.nl/es/home/14-12-volts-120-watts-portable-folding-polycrystalline-pv-solar-panel.html

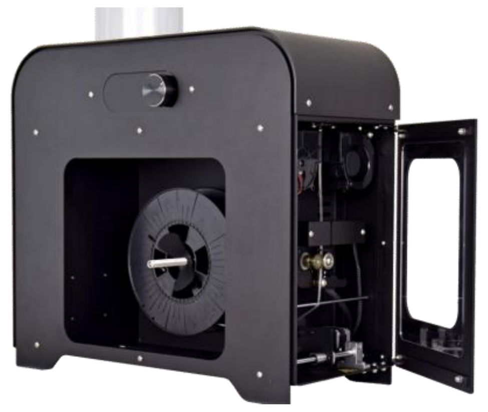
Research Objectives

- Extrude PCM-HDPE filament and analyze the material properties to explore additive manufacturing capabilities.
- Investigate 3D printing abilities with the extruded PCM-HDPE filament to create custom matrices capable of storing thermal energy.

Materials and Method

Puretemp PCM 42

HDPE

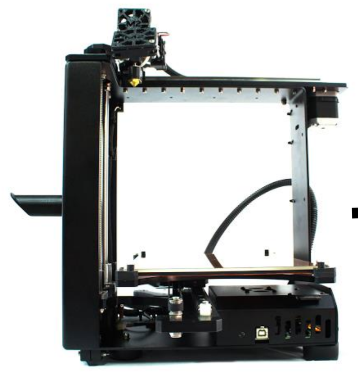


Filament Extruder [2]

PCM-HDPE Extruded Filament

Scanning Electron Microscopy [3]

Differential Scanning Calorimeter [4]



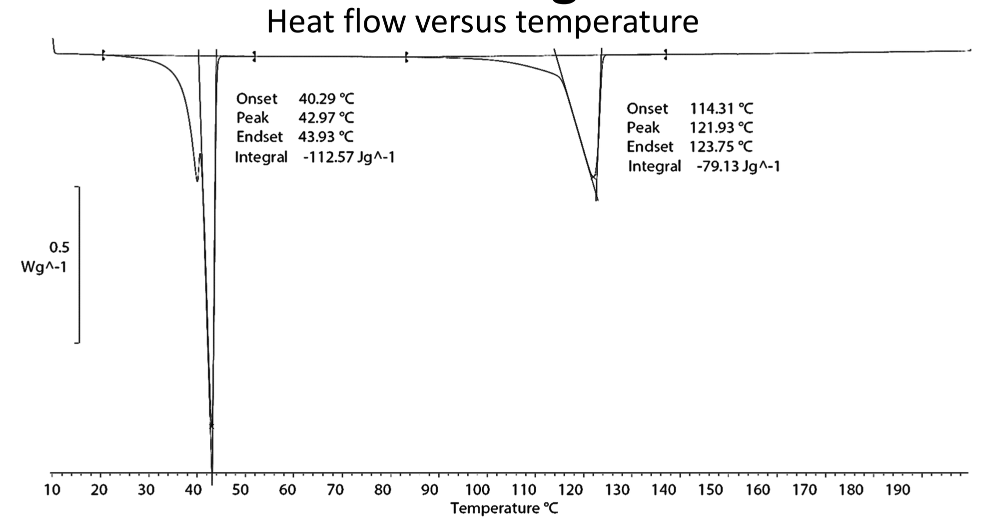
3D Printer [5]

Printed PCM-HDPE Composite

Results

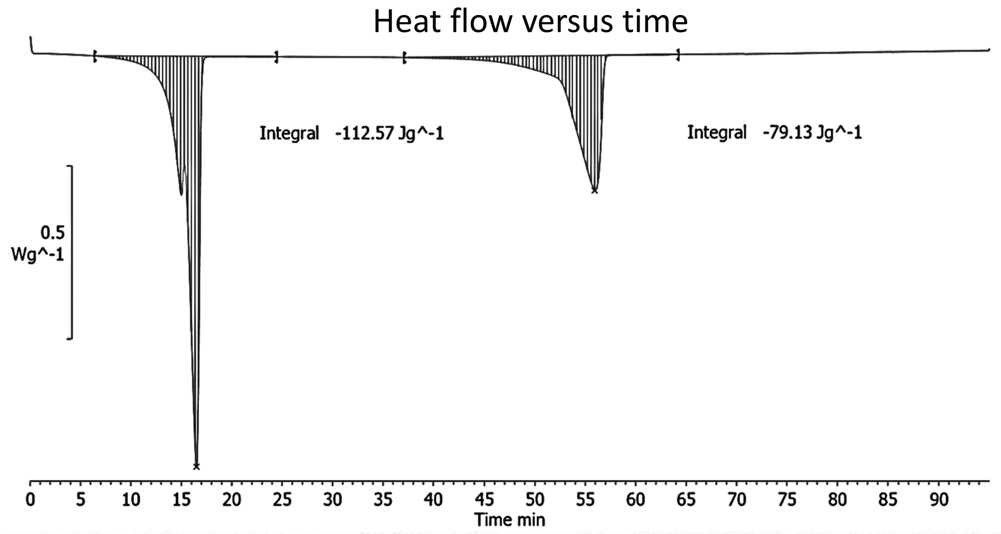
Melt Ranges

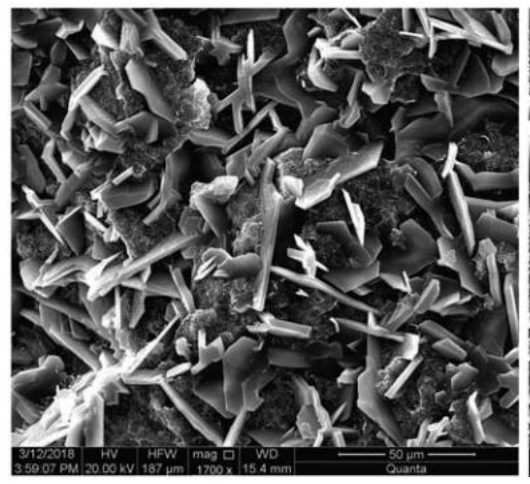
Heat flow versus temperature



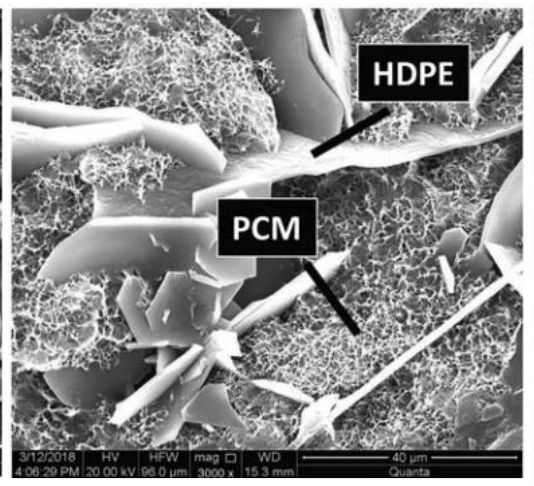
Latent Heat of Fusion

Heat flow versus time

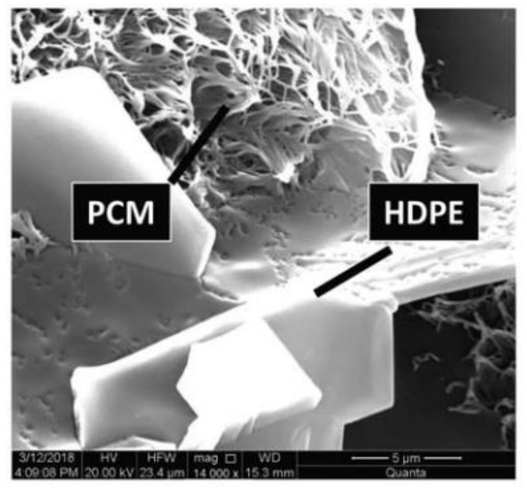




Magnified 1700x



Magnified 3000x



Magnified 14,000x

Conclusions

From the DSC, the melt of the PCM occurs at the first peak and the melt of the HDPE occurs at the second peak. The area under each peak divided by the heating rate was used to determine the latent heat of fusion. When mixed, the latent heat of fusion decreases when compared to pure PCM and pure HDPE.

The plate-like microstructure of the HDPE encapsulates the PCM to prevent leakage. The SEM depicts the PCM/HDPE mixture being quite homogeneous. In the 14,000x magnification, it appears that the PCM and HDPE may be bonding.

The combination of PCM and HDPE has led to achieving a filament that contains 60% PCM with a melting temperature of 42ºC and 40% HDPE by mass and has 3D printing capabilities.

Future Work

Further material testing will be conducted by tensile testing the PCM-HDPE composite and the thermal conductivity will be measured. The composition will be improved through topology optimization and the use of additives will be explored.

Additional testing will be conducted on the material after 3D printing. Heat exchanger designs that allow parallel air flow to occur over the filament (left) and 3D printed custom matrices (right) will be explored further.

Acknowledgements

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References:
[1] T. B. Freeman, D. Spitzer, P. N. Currier, V. Rollin, and S. K. S. Boetcher, "Phase-Change Materials/HDPE Composite Filament: A First Step Toward Use with 3D Printing for Thermal Management Applications," J. Therm. Sci. Eng. Appl., vol. 11, no. 5, Oct. 2019, doi: 10.1115/1.4042592.

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[3] "Quanta SEM," ThermoFisher Scienctific. https://www.fei.com/products/sem/quanta-sem//

[4] "Differential Scanning Calorimeter," UseScience. https://scientificservices.eu/item/differential-scanning-calorimeter/5321

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