



Spatial Regulation of Light and Heat for Maximizing Useful Solar Thermal Energy Storage in Phase Change Materials

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ABSTRACT

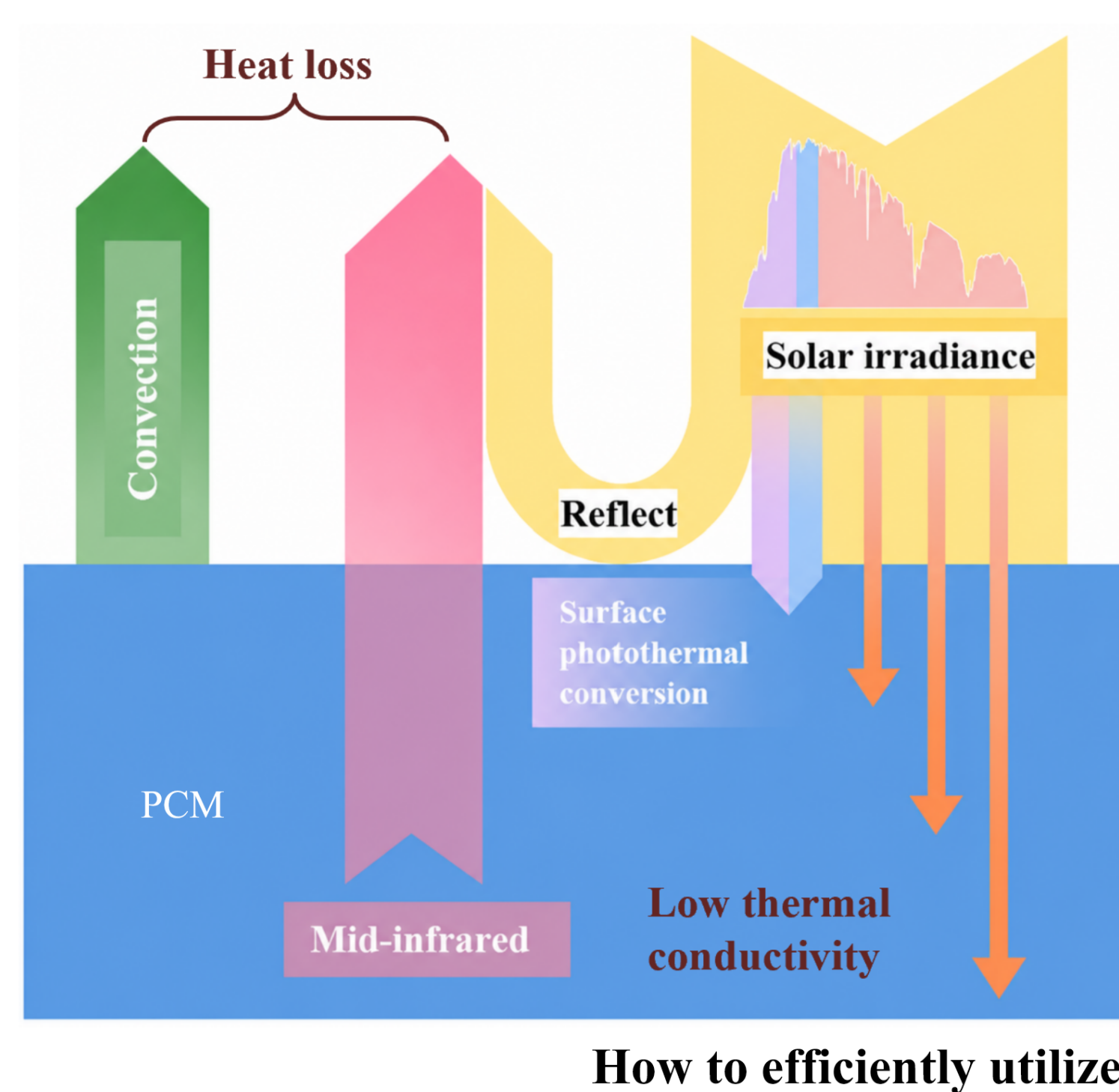
Photothermal phase-change materials (PCM) are limited by surface heat loss and uneven heat distribution. This work includes hot mirror, targeted light channel, and transparent PCM strategies to regulate light absorption and internal heat transport. This study provides new strategies for improving solar thermal storage efficiency and developing advanced PCM systems for building energy applications.

KEYWORDS

Photothermal conversion; Radiative heat loss; Heat distribution control; Volumetric absorption; Spectral regulation

PROBLEM

Conventional photothermal PCMs often absorb sunlight mainly at the exposed surface. This makes the surface very hot, so part of the collected heat is lost to the surroundings before it can be stored. The heat is also not evenly distributed inside the material, which limits how much solar energy can be stored and later used.



OBJECTIVE / HYPOTHESIS

This study aims to improve the thermal energy utilization efficiency of photothermal conversion PCMs. To achieve this aim, it focuses on regulating light absorption and heat generation, reducing surface radiative heat loss during energy storage, and increasing useful thermal energy output.

AUDIENCE

Researchers and engineers in Solar energy, Green house, and Thermal management.

RESEARCH QUESTION

How can light and heat be spatially regulated in PCMs to reduce energy loss, improve internal heat storage, and enhance useful thermal output?

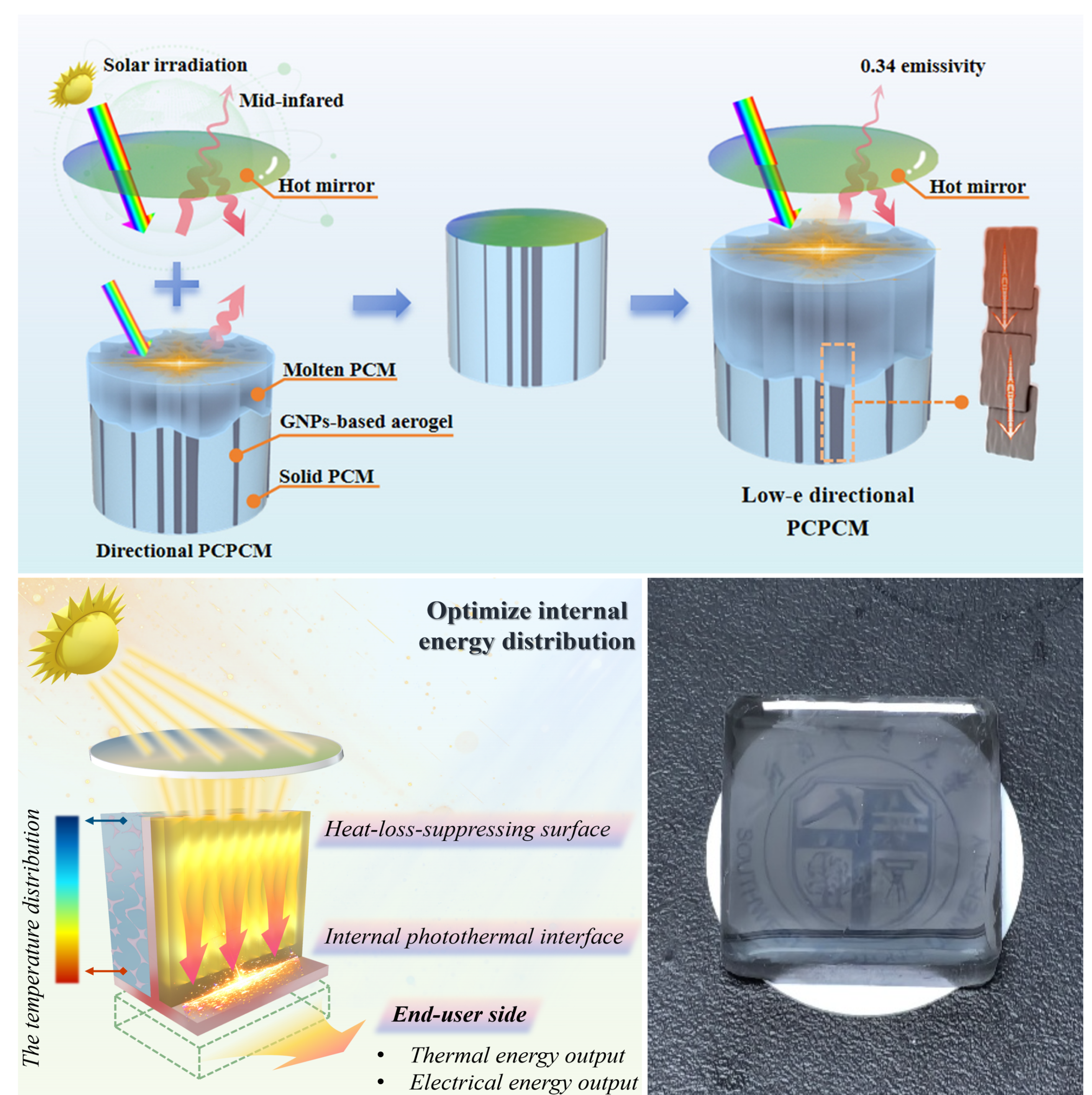
ORIGINALITY

This work improves thermal utilization in photothermal PCMs by spatially regulating light absorption and heat generation. Rather than simply increasing optical absorption, it addresses a key limitation of conventional photothermal PCMs: surface-localized absorption at an exposed interface causes radiative heat loss and reduces useful heat. The framework suppresses surface heat loss through emissivity control, improves heat storage by optimizing heat-transfer pathways. It further shifts photothermal conversion from the surface into the PCM interior, using targeted light delivery and transparent PCM absorbing matrices to enable volumetric absorption.

METHODOLOGY

The main methodology is experimental, supported by modeling and qualitative analysis. Experiments include material chemical characterization, photothermal performance tests, and application-oriented evaluations, while thermophysical and thermodynamic analyses are used to model heat storage, heat transfer, and energy utilization.

RESULTS



CONCLUSION

Spatial control of light absorption and heat transport is critical for improving photothermal PCMs. By combining hot-mirror spectral regulation, targeted light channels, and transparent PCM design, this work proposes a new strategy to reduce surface heat loss, promote internal heat storage, and improve useful thermal output. The study highlights that efficient solar thermal storage depends not only on material properties, but also on where light is absorbed and how heat is distributed inside the PCM. This work provides design guidance for advanced PCM systems in solar thermal storage and building energy applications.

Resources

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