Abstract—Existing passive cooling solutions limit the short-term thermal output of systems, thereby either limiting instantaneous performance or requiring active cooling solutions. Active cooling requires relatively large amounts of power, and cannot easily and efficiently handle temperature spikes. PCMs (phase change materials) are materials that can change phase at a device’s operating temperature, absorbing energy in the process. PCM-based heatsinks are able to tolerate short-term spikes in energy output with substantially less (or even no) active cooling. In this project we aim to examine the tradeoffs made by PCM-based heatsinks by simulating software workloads on a temperature-aware simulator.

I. INTRODUCTION

Conventional electronic cooling systems usually consist of a metal heatsink coupled to a fan, which turns on and off based on the load in the system. These systems are not particularly efficient at dissipating heat in a dynamic system that outputs large amounts of heat for short periods of time. PCMs have the ability to absorb very large amounts of heat without increasing in temperature, as long as the heat output occurs during the phase transition of the material. This ability to absorb energy without requiring airflow over short periods could lead to reduced necessity of active cooling techniques. These materials therefore present an opportunity in heatsink design to absorb the heat dissipated during particular workloads with a greater efficiency than conventional active cooling systems. In addition, PCMs present an interesting capability of being able to store heat output for a reasonably long period of time. It may be possible to use a large-scale PCM-based system to cool large-scale systems, retaining the heat for periods of low computing demand to use for other purposes.

II. PREVIOUS WORK

The use of PCMs for cooling electronics is a new area of research. Most works focus on creating accurate parameterizations of various materials or validating their robustness in real systems. Tan and Tso; and Kandasamy et al. developed numerical models from empirical data using different materials (n-eicosane and paraffin wax, respectively) [1] [2]. Rostamizadeh et al. developed a theoretical model for PCM from first principles and validated it with experimental results using calcium chloride hexahydrate [3]. Efforts have been made, specifically by Wang and Baldea, to simulate power-management systems using PCM [4]. However, none of these works involves a study of how different software workloads might affect the use of PCM versus conventional cooling methods.

III. TECHNICAL DESCRIPTION

Before Phase change materials are materials which undergo a change in physical phase when a sufficient amount of heat is supplied. An example would be turning from solid into liquid (melting). During the time when the material is actively melting, additional heat applied to the material will not change the temperature of the material. This phenomenon continues until the entirety of the material is melted. The temperature graph of a PCM looks similar to the graph in figure 1 [3].

![Temperature of a PCM over time.](image)

Utilizing these materials to absorb heat in their phase change region is more efficient than using materials which do not undergo a phase change because during the phase change an essentially unlimited amount of heat can be input into the material without the external temperature changing, which is untrue of typical metallic heat sink materials, which undergo a linear change in heat as heat is applied.

Phase change materials typically also change shape and physical characteristics as they undergo changes in phase. This poses challenges for use in mobile systems which have restrictions on space and do not allow for expansion and contraction of the materials inside. Thus, existing research has shown that suspending the PCM inside of a thermally conductive matrix of something like epoxy provides similar heat sinking capacities to pure PCM while not changing shape. This has the added benefit of increasing the surface area of the PCM, thus allowing it to absorb and release heat more quickly.
The limitation of PCMs is that they can only absorb a finite amount of heat in their phase change region before they return to a linear relationship of output heat vs applied heat as shown in figure 1.

Thus, PCM-based heat sinks still need active cooling if the applied heat will exceed the temperature at which the PCM exits its phase change region. However, we believe that this active cooling will be less than the active cooling that is necessary in existing heat sink models, or may not be necessary at all, depending on the application.

Once the PCM has reached the end of its phase change, it is capable of storing the obtained heat for a limited time if it remains at a similar external temperature. Thus, these PCMs might be capable of being a sort of thermal “battery” and transporting heat to somewhere where it could be used productively instead of going to waste. The implications and feasibility of this idea will be researched and discussed at a later date if time permits.

IV. MILESTONES AND SCHEDULE

Table 1 contains a list of project milestones and the dates at which we predict they should be completed.

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Date</th>
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<tbody>
<tr>
<td>Obtain or create a thermal model of a processor for use in HotSpot.</td>
<td>October 10</td>
</tr>
<tr>
<td>Obtain or create a simulation model for a PCM-based heat sink.</td>
<td>October 24</td>
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<tr>
<td>Obtain hard numbers for PCM-based heat sink performance.</td>
<td>November 11</td>
</tr>
<tr>
<td>Compare and contrast PCM-based heat sink performance with existing heat sinks.</td>
<td>November 25</td>
</tr>
<tr>
<td>Final paper. Thermal “battery” and heat reuse feasibility as reach goals.</td>
<td>December 4</td>
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REFERENCES


Very interesting idea, but you may want to talk more about the simulation infrastructure. And how could you simulate the interaction between PCM and processor?