



Phase change composite based on porous nickel and erythritol

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ABSTRACT

We developed a phase change composite (PCC) using a porous metal with a thermal conductivity that is two orders larger than that of the original phase change material (PCM). A PCC of erythritol/porous nickel was prepared by vacuum impregnation, and its thermophysical properties such as effective thermal conductivity, latent heat, and melting temperature were measured by the laser flash method and differential scanning calorimetry (DSC). The effect of the porous structure was also examined. Results showed that the latent heat of the PCC could be simply explained by the impregnation ratio of the PCM, not by the pore size. The largest effective thermal conductivity, $11.6 \text{ W m}^{-1} \text{ K}^{-1}$, was recorded for PCC with 15 vol% of porous nickel having a pore size of $500 \mu\text{m}$ and 85 vol% of PCM; this value is 16 times higher than that of pure erythritol, i.e., 0.733. The developed PCC offers many benefits, including a high heat transfer rate and enhanced cost-effectiveness, and it will also contribute to the efficient utilization of solar heat and industrial waste heat.

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1. Introduction

The increasing gap between the global demand for energy and the supply of energy is becoming a major problem. This problem underscores the need to store excess energy that would otherwise be wasted as well as to bridge the energy gap. Thermal energy storage is one of the most effective approaches to realizing high energy efficiency, energy saving, and effective use of available resources and renewable energies [1–6].

For practical use, however, two problems need to be resolved. The first problem is the slow rate of heat transfer. The transfer rate between the PCM and the heat transfer fluid is generally unacceptably low owing to the low thermal conductivities of PCMs [7–10]. It has been proposed that the thermal conductivity of a PCM can be increased by mixing it with a high-thermal conductivity material [11–13]. The second problem is that PCMs cannot be used in high-temperature applications. PCM encapsulation for high-temperature applications (above 100°C) has not been realized thus far because of technical difficulties [14–16]. Liquid PCM tends to leak through cracks generated by volumetric expansion upon melting [17]. For this reason, the thickness of the capsule layer is required to be high, but this leads to a decrease in the heat storage density of the capsule beds.

Porous materials with a high thermal conductivity are promising candidates for solving these two problems simultaneously. It is considered that porous materials can assume a stable shape that prevents the leakage of liquid PCM owing to the capillary and surface tension forces of a porous structure. Thus far, many researchers have focused on the production of a *PCM composite* [18–20]. In a previous paper, the impregnation of a porous material with a PCM was studied; erythritol was selected as the PCM, and expanded perlite (EP), diatom earth (DE), and gamma-alumina (GA) were selected as the porous materials. Such materials are quite attractive from an economic perspective, although their thermal conductivity is still low. In addition, porous materials with a high thermal conductivity should be studied in order to increase the overall rate of heat transfer [21–25].

In light of the above, the purpose of this study was to prepare phase change composites using porous nickel as a support for increasing the thermal conductivity. The composites can be used to efficiently store heat in the form of latent heat. In our experiments, composites were produced by filling porous nickel with liquid erythritol as a PCM with a melting point of 118°C . Impregnation treatment was performed under the conditions of high temperature and vacuum. The thermophysical properties of the composites—thermal conductivity, latent heat, and melting temperature—were measured by the laser flash method at room temperature and differential scanning calorimetry (DSC). The effect of the porous structure on the melting point, latent heat, effective thermal conductivity, and stability of the PCM was also examined.

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