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Editorial

Special Issue on "Phase Change Materials: Design and Applications"

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1. Introduction

In recent years, science and technology have revolutionized our way of life, improving well-being and comfort for all mankind. The discovery of new materials with unique features at macro- and nano-scales has played a significant part in this advancement. The possibility of producing materials able to perform different functions and of responding to external stimuli will undoubtedly be an extremely important research area for the foreseeable future.

There is increasingly intensive research for energy storage technologies development due to the enhanced energy needs of the contemporary societies. Global energy consumption, together with greenhouse gasses and CO_2 emissions, is increasing at a very fast pace due to rapid global economic growth, global population growth, and the human dependence on energy-consuming appliances. This increment in global energy consumption has specific environmental implications that pose serious challenges to the environment and human health. Moreover, the enhanced global energy consumption results in the reduction in the availability of traditional energy resources, such as coal, oil, and natural gas. Therefore, there is an urgent need for new systems development based on the conversion and storage of sustainable and clean energy.

An effective way for the energy systems efficiency increment is the use of latent heat thermal energy storage because of its high energy density in comparison to sensible heat storage systems. Phase change materials (PCMs) are one of the key components for the development of advanced sustainable solutions in renewable energy and engineering systems. PCMs enable either the storage or release of large amounts of energy, while their temperature is slightly changed or kept constant. PCMs have the ability to accumulate and store lots of energy. The activation of this high storage potential of PCMs is accomplished when their phase is changed.

In order to update the field of renewable energy and engineering systems with the use of PCMs, a Special Issue entitled "Phase Change Materials: Design and Applications" has been introduced. This editorial manuscript gathers and reviews the collection of ten contributions (nine articles and one review), with authors from Europe, Asia, and America accepted for publication in the aforementioned Special Issue of *Applied Sciences*.

2. Macro- and Micro-Encapsulated PCMs

The encapsulated PCMs consist of the core material, i.e., the PCM, and an organic or inorganic shell material. Depending on their size, PCMs can be characterized as nano-encapsulated when their size is less than 1 µm, micro-encapsulated when their size is between 1 and 1000 µm, and macro-encapsulated when their size is bigger than 1000 µm. Four articles have been published in this Special Issue related to the synthesis and characterization of macro- and micro-encapsulated PCMs. The micro-encapsulation of sodium nitrate ($NaNO_3$) in zinc oxide shells as PCM for high temperature latent heat storage was investigated by Neagoe et al. [1]. The aim of their work was to evaluate the potential of $NaNO_3$-ZnO microcapsules with respect to thermal energy storage applications together with cost reduction related to metal corrosion in installations and storage tanks. Charge/self-discharge experiments revealed that the $NaNO_3$ content of the microcapsules influences the amount of thermal energy stored in the corresponding interval. Moreover, it was proved that prototype-scale thermal energy storage in microcapsules can be predicted from laboratory measurements on small material samples.

In the study of Borreguero et al. [2] micro-encapsulated PCMs were fabricated based on a core of paraffin Rubitherm® RT27 and a shell that consists of ethyl–vinyl acetate and low density polyethylene. The goal of this work was the production of polyurethane elastomeric materials demonstrating thermoregulating properties due to the incorporation of the aforementioned micro-encapsulated PCMs. The obtained results revealed that the mechanical properties and the density of the synthesized elastomeric materials together with the thermal synergy effects were related to the wt% content of the micro-encapsulated PCMs in order improved structural stability and enhanced latent heat to be demonstrated.

In the work of Gschwander et al. [3] the storage capacities of PCMs emulsions based on even- and odd-numbered paraffins with different purities are investigated, taking into account the corresponding supercooling effect and phase transition behavior. The obtained results revealed that the nucleation agent and the emulsified PCM influence both the storage and supercooling factors of the PCM emulsions. It was observed that the PCM´s hydrocarbon chain and the purity of the materials affected the degree of supercooling.

3. Design and Applications

The design of the energy storage material encapsulation is one of the most important parameters that critically influence the heat transfer in charging and discharging procedures of the storage system. The study of Vérez et al. [4] examined the effect of the design of the PCM macro-encapsulation on the thermal behavior of a latent heat thermal energy storage systems during both the charging and discharging processes. The obtained results revealed that the design of the thermal energy unit should be performed and analyzed based on the requirements of the application due to the fact that the macro-encapsulation design has a relevant impact on the heat transfer.

Ohmura and his team [5] conducted experiments on the investigation of hydrate heat storage systems. An evaluation of the kinetic characteristics of thermal energy storage using tetrabutylammonium acrylate hydrate as PCMs was performed. It was found that either mechanical agitation or ultrasonic vibration improved the thermal energy storage kinetic characteristics because of the detachment of the hydrate adhesion on the heat exchanger, which could be a thermal resistance between the thermal energy storage medium and heat exchanger.

The work of Karantonis and his team [6] reports the methodology that applied the estimation of thermodynamic and kinetic information to the interaction of lytic polysaccharide monooxygenases enzymes using a filamentous fungus. This class of enzymes boost the release of oxidized products from the biomass plant. Taking into account that these enzymes are redox, their exploitation was conducted through their immobilization on electrode surfaces and investigating the parameter standard electron transfer rate constant (k_0) between the immobilized electrode and the enzyme. The obtained results revealed that it is feasible for the system to be rendered reversible and consequently to be used for bio-electrocatalytic purposes.

Additionally, Abdi and coworkers [7] numerically examined the thermal improvement of a latent thermal energy storage (LTES) component, including mini-channels as dry air passages. The thermal performance of the LTES in charging and discharging processes with ranging flow rates and a varying number of channels was estimated. The results revealed that the LTES-phase change power is enhanced by increasing the number of channels. On the other hand, a decrease in the storage capacity was observed. Moreover, it was noticed that at a constant air flow rate there is an increment of the mean heat transfer rate because of the influence of the heat transfer coefficient due to the increase in the heat transfer surface area of the increased number of channels.

A very interesting concept developed by Luna and his team [8] based on the examination of sugar alcohols as PCMs. The effect of thermal treatment on sugar alcohol erythritol thermal, chemical, and physical properties was assessed. Moreover, experiments with erythritol and its mixtures with antioxidants were performed in order to enhance its thermal stability. It was found that in the presence of air, mixtures of erythritol with antioxidant had a lower degradation rate in comparison with pure erythritol.

In another study, Nicolalde et al. [9] reported that the use of a PCM layer of 20 mm can improve the thermal comfort in the vehicle, reducing the need to use the heater or the air conditioner. It was found that the PCM reduced the temperature of the air by 9 °C when heating and by 4 °C when the temperature dropped.

Finally, in the review paper of Kartsonakis et al. [10], the principles of latent heat thermal energy storage systems with PCMs are discussed. This paper presents the research status of the materials that can be used as PCMs, together with the most effective methods for improving their thermal performance. Moreover, several passive applications in the building sector are highlighted. Finally, special attention is given to the encapsulated PCMs that consist of the core material, which is the PCM, and the shell material, which can be either organic or inorganic, and their utilization inside constructional materials.

4. Future Strategies

Although the Special Issue has been closed, more in-depth research in the field of the synthesis of PCMs and the design of corresponding components as well as their application is expected. It can be anticipated that more effective and eco-friendly applications will be demanded in large numbers in the future for the utilization of thermal energy storage. In this case, suitable strategies should be ready for consolidation and utilization.

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