Chapter 1

Introductory Chapter: Phase Change Material

Mohsen Mhadhbi

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.79432

1. Introduction

The discovery of phase change material (PCM) starts from the early 1900s in the work of Alan Tower Waterman of Yale University [1]. While studying thermionic emission of certain hot salts, Waterman noted some peculiarities in the conductivity of molybdenite (MoS_2). It was found that the conductivity of the chalcogenide can be altered progressively.

Phase change material or latent heat storage material is the most efficient used method to store thermal energy. Energy per unit mass is stored during phase changes from solid to liquid, and released during freezing at a constant temperature. The energy absorbed by the material allows increasing the vibrational energy states of the constituent atoms or molecules [2]. During melting, the atomic bonds loosen and consequently the material changes its state from solid to liquid. However, during solidification, the material transfers energy and, consequently, the molecules lose energy and order themselves in solid state.

There are several types of phase change material available, but the there are three main types: organic (paraffin and nonparaffin), inorganic (salt hydrates and metallic alloys), and eutectic (mixture of two or more PCM components: organic, inorganic, and both).

In the last decades, the researchers place emphasis on phase change material in which heat storage is carried out due to latent heat of fusion [3]. Application such PCM allows to lower the volume of heat storage units (HSUs), essentially. Low-temperature PCM became objects of prime investigations. However, the limited reserves of fossil fuel, the increase in greenhouse gas emissions, and the rapid growth of energy consumption have shed the light on the importance of effectively utilizing energy. For these reasons, the development of new sources of energy has been the focus of several researches. The use of phase change material for thermal energy storage provides a suitable solution, cheap and efficient energy storage, for improving the performance of energy systems and therefore reducing peak demand and energy consumption. Thermal energy storage (TES) includes latent heat storage and thermochemical heat storage. Sensible heat storage requires large volumes because of its low energy density and requires proper design to discharge thermal energy. Hence, latent heat storage systems are low coast and easier to work than those thermochemical heat storage systems.

In this context, PCM-based cooling is a very attractive process of thermal control, considering the advantages of the PCM, such as high latent heat storage capacity, small volume change in the phase transformation, high specific heat capacity to provide additional sensible heat storage, chemical stability and no degradation for large number of cycles, phase transition occurs within the desired operating temperature range of the system high nucleation rate to avoid supercooling of the liquid phase, high thermal conductivity to assist the absorption and release of energy in the storage system, high density, noncorrosiveness, nonflammable, nontoxicity, relatively low cost, and high availability [4–6]. On the other hand, different solutions were then developed to improve the heat transfer in PCM-based thermal control units (TCUs), all related to the insertion of conducting paths or materials in the heat storage volume such as metal matrices or foams, micro- and nanosized metal and metal oxide fillers, discrete elements such as pins and fins, graphite, carbon nanotubes or fibers, and exfoliated graphite or graphene [7, 8].

2. Applications of PCM

The application of PCM has grown incrementally in various industries, such as the solar cooling and solar power plants [9], photovoltaic electricity systems [10], electronic industry [11], waste heat recovery systems [12], solar dryers in agricultural industry [13], domestic hot water [14], pharmaceutical products and preservation of food [15], and space industry [16]. Apart from the preceding utilizations, PCM improves energy performance and thermal comfort in buildings [17]. Therefore, PCM applications could be a powerful tool in designing net zero energy buildings [18]. PCM must be put in specific containers that depend on the thermal storage application [19]. The content of PCM depends on the specific thermal storage application. For example, in the case of building integrated latent heat storage, PCM can be contained in a porous matrix (wood, concrete, plasterboard, etc.).

The aim of this book is to assist the scientists and to provide the reader with a comprehensive overview of the properties of phase change material with a focus on their technological applications. The phase change characteristics by various investigators are reviewed with the applications of the phase change characteristics in information storage applications. The present status and future perspectives of phase change material are discussed.

Author details

Mohsen Mhadhbi

Address all correspondence to: mhadhbi_mohsen@yahoo.fr

Laboratory of Useful Materials, National Institute of Research and Physical-Chemical Analysis, Technopole, Sidi Thabet, Ariana, Tunisia

References

[1] Waterman AT. Positive ionisation of certain hot salts, together with some observations on the electrical properties of molybdenite at high temperatures. Philosophical Magazine. 1917;**33**:225

[2] Fleischer AS. Thermal Energy Storage Using Phase Change Materials: Fundamentals and Applications. SpringerBriefs in Thermal Engineering and Applied Science. Kulacki FA, Series editor. Minneapolis, MN, USA; 2015. 97 p. DOI: 10.1007/978-3-319-20922-7

[3] Kenisarin MM. High-temperature phase change materials for thermal energy storage. Renewable and Sustainable Energy Reviews. 2010;**14**:955-970. DOI: 10.1016/j.rser.2009.11.011

[4] Heine D, Abhat A. Investigation of physical and chemical properties of phase change materials for space heating/cooling applications. In Sun: Mankind's Future Source of Energy. Proceedings of the International Solar Energy Congress, New Delhi, India (January 1978;**1**:16-21). (A79-17276 05-44). Elmsford, N.Y.: Pergamon Press, Inc; 1978. pp. 500-506

[5] Khudhair AM, Farid MM. A review on energy conservation in building applications with thermal storage by latent heat using phase change materials. Energy Conversion and Management. 2004;**45**(2):263-275. DOI: 10.1016/S0196-8904(03)00131-6

[6] Tyagi VV, Buddhi D. PCM thermal storage in buildings: A state of art. Renewable and Sustainable Energy Reviews. 2007;**11**(6):1146-1166. DOI: 10.1016/j.rser.2005.10.002

[7] Fan L, Khodadadi JM. Thermal conductivity enhancement of phase change materials for thermal energy storage: A review. Renewable and Sustainable Energy Reviews. 2011;**15**:24-46. DOI: 10.1016/j.rser.2010.08.007

[8] Sarier N, Onder E. Organic phase change materials and their textile applications: An overview. Thermochimica Acta. 2012;**540**:7-60. DOI: 10.1016/j.tca.2012.04.013

[9] Aydin D, Casey SP, Riffat S. The latest advancements on thermochemical heat storage systems. Renewable and Sustainable Energy Reviews. 2015;**41**:356-367. DOI: 10.1016/j.rser.2014.08.054

[10] Ma T, Yang H, Zhang Y, Lu L, Wang X. Using phase change materials in photovoltaic systems for thermal regulation and electrical efficiency improvement: A review and outlook. Renewable and Sustainable Energy Reviews. 2015;**43**:1273-1284. DOI: 10.1016/j.rser.2014.12.003

[11] Dhaidan NS, Khodadadi JM. Melting and convection of phase change materials in different shape containers: A review. Renewable and Sustainable Energy Reviews. 2015;**43**:449-477. DOI: 10.1016/j.rser.2014.11.017

[12] Fang G, Tang F, Cao L. Preparation, thermal properties and applications of shape-stabilized thermal energy storage materials. Renewable and Sustainable Energy Reviews. 2014;**40**:237-259. DOI: 10.1016/j.rser.2014.07.179

[13] Shalaby SM, Bek MA, El-Sebaii AA. Solar dryers with PCM as energy storage medium: A review. Renewable and Sustainable Energy Reviews. 2014;**33**:110-116. DOI: 10.1016/j.rser.2014.01.073

[14] Seddegh S, Wang X, Henderson AD, Xing Z. Solar domestic hot water systems using latent heat energy storage medium: A review. Renewable and Sustainable Energy Reviews. 2015;**48**:517-533. DOI: 10.1016/j.rser.2015.04.147

[15] Belman-Flores JM, Barroso-Maldonado JM, Rodríguez-Muñoz AP, Camacho-Vázquez G. Enhancements in domestic refrigeration, approaching a sustainable refrigerator: A review. Renewable and Sustainable Energy Reviews. 2015;**51**:955-968. DOI: 10.1016/j.rser.2015.07.003

[16] Zhou Z, Zhang Z, Zuo J, Huang K, Zhang L. Phase change materials for solar thermal energy storage in residential buildings in cold climate. Renewable and Sustainable Energy Reviews. 2015;**48**:692-703. DOI: 10.1016/j.rser.2015.04.048

[17] AL-Saadi SN, Zhai Z. Modeling phase change materials embedded in building enclosure: A review. Renewable and Sustainable Energy Reviews. 2013;**21**:659-673. DOI: 10.1016/j.rser.2013.01.024

[18] Bastani A, Haghighat F, Kozinski J. Designing building envelope with PCM wallboards: Design tool development. Renewable and Sustainable Energy Reviews. 2014;**31**:554-562. DOI: 10.1016/j.rser.2013.12.031

[19] Konuklu Y, Ostry M, Paksoy HO, Charvat P. Review on using microencapsulated phase change materials (PCM) in building applications. Energy and Buildings. 2015;**106**:134-155. DOI: 10.1016/j.enbuild.2015.07.019