Phase Change Materials.

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Phase change materials (PCMs) allow the storage of large amounts of latent heat during phase transition. They have the potential to both increase the efficiency of renewable energies such as solar power through storage of excess energy, and to reduce overall energy demand through passive thermal regulation. NASA has identified more than a hundred of these materials. In addition to passive energy storage, they have application in thermo-regulated fabrics, high power electronics, telecommunication installations and microprocessors. PCMs are not suitable for use without prior encapsulation. Encapsulation in a shell material provides benefits including protection of the PCM from the external environment and increased specific surface area to improve heat transfer.

Introduction

There are two main approaches for thermal energy storage: sensible heat storage (SHS), and latent heat storage (LHS). Sensible heat refers to heat that can be detected by a temperature change in a linear relationship with temperature (as seen in Fig. 1). The heat stored is dependent on the specific heat capacity of the material. SHS is the simplest and most developed form of heat storage but suffers from low energy density and loss of thermal energy at any temperature

Latent heat storage refers to heat transfer associated with phase transitions, which cannot be detected with a thermometer. LHS is more effcient and has a far superior storage density than SHS.

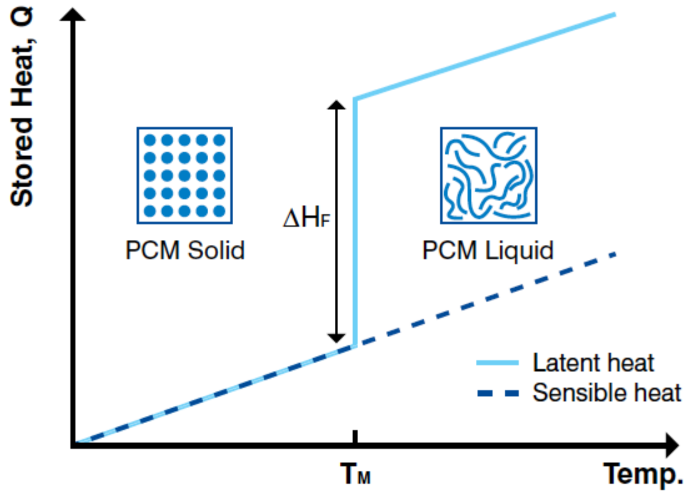

Fig 1: Comparison between SHS and LHS, ΔHF is the latent heat of fusion during melting. TM is the melting temperature.

Materials that utilise LHS are known as phase change materials (PCMs). Examples of phase transitions include melting and freezing (solid–liquid), evaporation and condensation (liquid–gas) or changes in crystalline structure (solid–solid). Essentially, the energy associated with these changes corresponds to the number of chemical bonds broken. Therefore, solid–gas transitions store the highest amount of energy. However, the large volume change of these transitions means pressurised containers are required. Solid–solid and solid–liquid PCMs have been researched since the oil crisis of the 1970s brought energy to the fore of scientific research. However, they were largely forgotten until the 2000s. With the current focus on clean energy sources, PCMs have become widely studied at an increasing rate. As can be seen from Fig. 1, an ideal LHS material stores a large amount of heat isothermally during melting. Once the material freezes, this energy is released. PCMs also store thermal energy sensibly whilst not undergoing phase transition. PCMs are far more efficient than SHS materials, especially over the small temperature range associated with their phase transition.

PCM classification

PCMs can be classified according to the specific phase transitions they undergo. As mentioned above, the sublimation and evaporation give the highest latent heat of fusion but are not practical due to the large volume change and need for specialised containment to prevent material loss. There are several categories of PCMs, as seen in Fig. 2. Solid–solid PCMs have low latent heat of fusion and are not considered useful for practical applications. Solid–liquid PCMs give a good balance between high latent heat of fusion and manageable volume change.

Solid–liquid PCMs can be divided into organic or inorganic materials (Fig. 2). Organic PCMs include paraffin wax, fatty acids and polyethylene glycol (PEG), whilst inorganic PCMs can be salt hydrates, salts or metallic.

Paraffin waxes are linear alkanes containing between 8–40 carbon atoms. Paraffins often display additional LHS in the form of solid–solid transitions associated with different crystalline phases. Their disadvantages include low thermal conductivity, bad odour, flammability and high cost.

Paraffin waxes are also non-renewable, as they are refined from petroleum with bleaching agents. Commercial paraffin contains formaldehyde and vinyl chloride as well as benzene, toluene, naphthalene and methyl ethyl ketone which are volatile and carcinogenic in nature, so care must be taken while using these materials in building applications.
Fatty acids can be produced from vegetable-based oils which are non-toxic. They have lower flash points and longer flame propagation than paraffins. However, their high cost (even higher than paraffin waxes)
has rendered them unusable in practical applications. Due to the large volume change on melting, they must also be contained.
Salt hydrates are the major class of inorganic PCMs, and most promising PCMs overall due to their high latent heat, high energy storage density, low cost, abundance, reasonable thermal conductivity and wide variety of melting temperatures in the domestic application range (5–130°C).

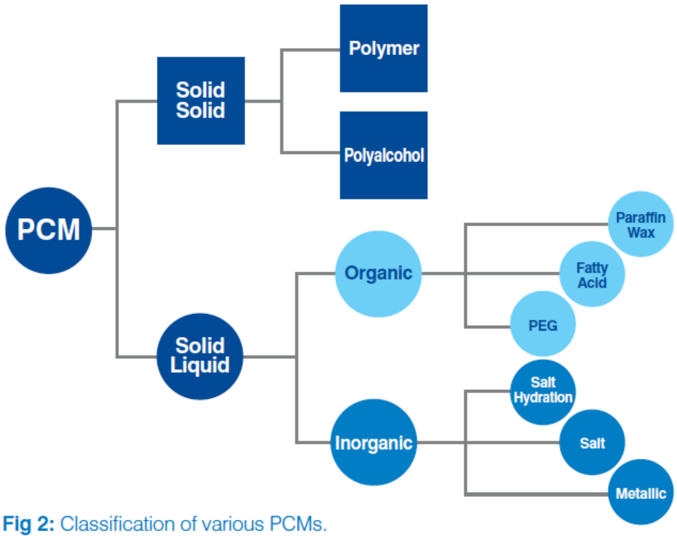

Fig 2: Classification of various PCMs.

Applications

PCM microcapsules expand the application fields of the PCMs, due to their unique properties such as (1) chemical and thermal stabilization, (2) higher amount of energetic changes, and (3) suitable solid-to-liquid phase transition. PCM microcapsules provide a reliable way for mixing liquid and solid PCMs with polymer and other structural materials, which reduce toxicity and protect core material from environmental influence.
Textiles: Some of these PCMs change phases within a temperature range just above and below human skin temperature. This property can be harnessed for making protective all-season outfits and for abruptly changing climatic conditions. Fibre, fabric and foam with built-in PCMs store the warmth the body creates, then release it back to body, as it needs it. Garment layering with auto thermal regulation can help lighten the load and increase human efficiency by keeping the temperature of the body constant; something that is particularly useful in a military environment.
Foams: Applying PCM microcapsules in foams can improve thermal performances, especially in thermal insulating. For example, rigid polyurethane foams containing PCM microcapsules have improved thermal energy storage capacity.
Building: PCM microcapsules can be embedded into a very wide variety of building materials offering smoother fluctuations of temperature and thermal inertia providing energy saving. These materials include both structural items such as concrete and walling as well as decorative materials such as paints and coatings. In addition, adding PCM microcapsules to concrete has been found to significantly increase its mechanical resistance and stiffness.

Manufacturing considerations

Traditional composite PCMs appear loose and diffuse to the surface gradually and suffer leakage of melted storage materials. To overcome these problems, microencapsulated PCMs have been developed. PCM microcapsules contain two main parts: a PCM as the core and a polymer or an inorganic shell as the PCM container.
Careful consideration of the choice of shell materials is required to ensure high efficiency, long-term PCM performance.

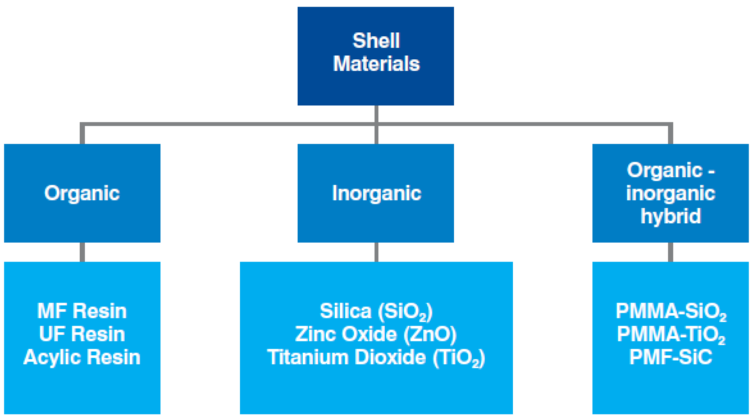

Fig 3: Microencapsulation shell materials for PCMs.

The Micropore difference

Micropore Encapsulation is a tried and tested technique using a robust continuous membrane technology to produce monodisperse PCM capsules.

Fig 4: Manufacturing methods for PCMs. Micropore's encapsulation technology has been applied to all the above chemical physio-chemical encapsulation methods with great success. The resulting uniformly sized capsules behave in a consistent and predictable way because the surface area to volume ratio is the same for each capsule, thereby reducing the variability of thermal transmission through the capsule and resulting in a clear latent heat transition. Micropore's technology is scalable to tonnes per hour.

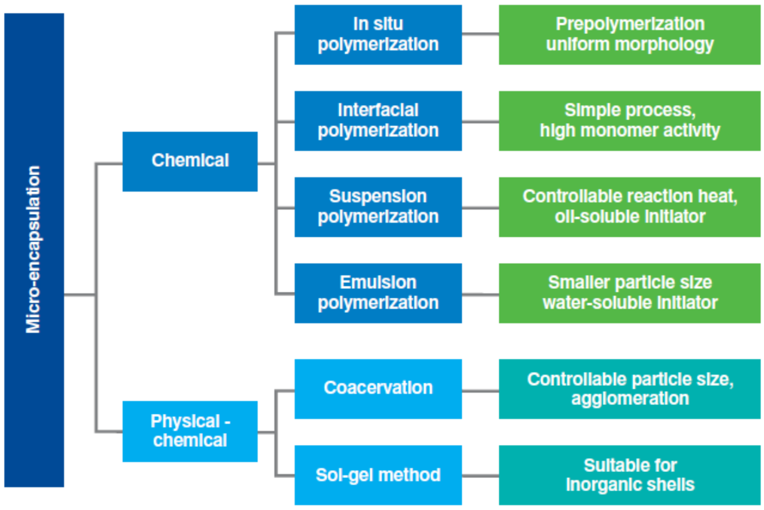

Fig 4: Manufacturing methods for PCMs.

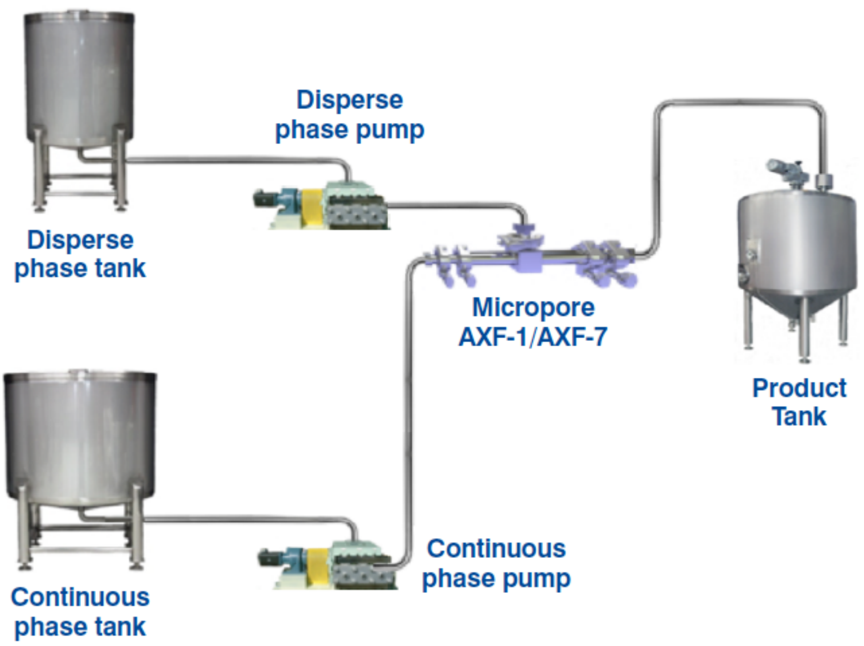

Fig 5: Schematic of Micropore crystallisation plant

We're ready to help you with your PCM challenges.