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APPLICATION OF PHASE CHANGE MATERIALS FOR TEXTILES

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ABSTRACT

Textile industry is focusing more to provide protection to human being from extreme climatic conditions. PCM based textiles can be refereed as smart textiles due to their capability of sensing surrounding temperature fluctuations by absorbing as well as releasing latent heat during melting and cooling process, respectively and thus produce a thermo-regulating effect. The use of PCMs for development of thermoregulatory textile was witnessed since 1980s. In recent years, research has gained momentum in improving cutting edges to manufacture PCMs and applying them in textiles using various processing technologies. The use of PCMs in textile provides good opportunity to industry to fabricate smart and innovative textile products.

INTRODUCTION

Now-a-days, textile industry is focusing more to provide protection to human being from extreme climatic conditions. The normal human body temperature is changes from 37°C to 40°C depending upon the physical activity performed by the individual (Havenith et al., 2008). Usually clothing protects us from water, open fire, extreme heat and cold, toxic chemicals, high voltage, propelled bullets, nuclear radiations etc. Phase Change Materials (PCMs) are smart materials which absorbs, stores as well as releases heat with fluctuation in temperature and hence used in manufacturing of smart textiles products. During process, while transforming into solid state PCMs release the heat whereas they absorb heat when come back to liquid state. This property of PCMs is capable for increasing the comfortness for consumers of sports equipment, bedding, military gear, building materials, clothing and many other consumer products.

WORKING MECHANISM OF PCMs

The phase change process is called a dynamic process, as continuously changing of materials from solid to a liquid or liquid to a solid takes place based on level of physical activity of the body as well as outside change in temperature. The functioning of PCMs is depended on the latent heat of fusion. The increase in the temperature melts the PCMs and absorbs heat from surrounding and gives the cooling effect (Fig. 1). Whereas, decline in temperatures solidifies the PCMs and releases heat to the surrounding and offer the warmer effect (Fig. 2). This cyclic process keeps temperature comfortable within the microclimate between the fabric and the human skin by absorbing, storing as well as releasing latent heat.

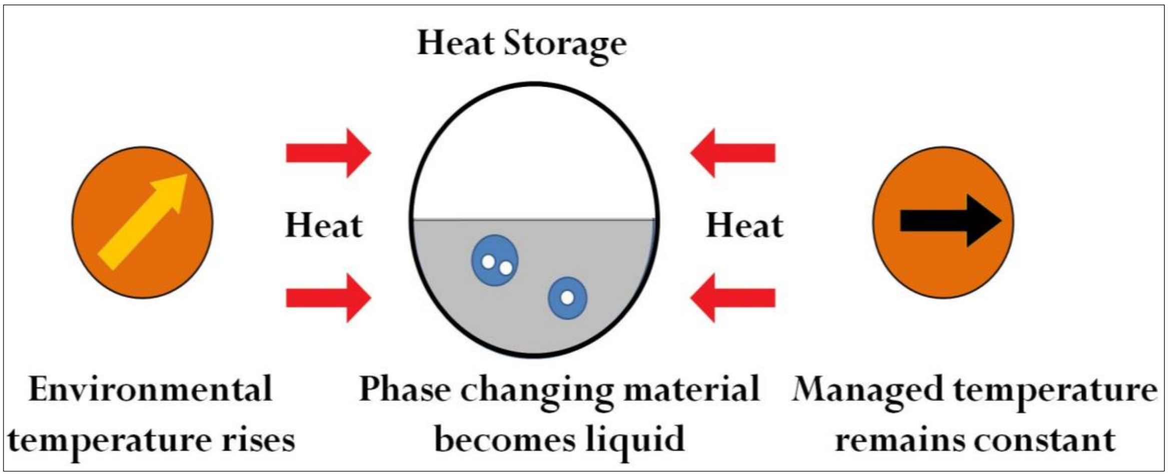

Fig. 1 Changes in phase change materials under hot environmental conditions

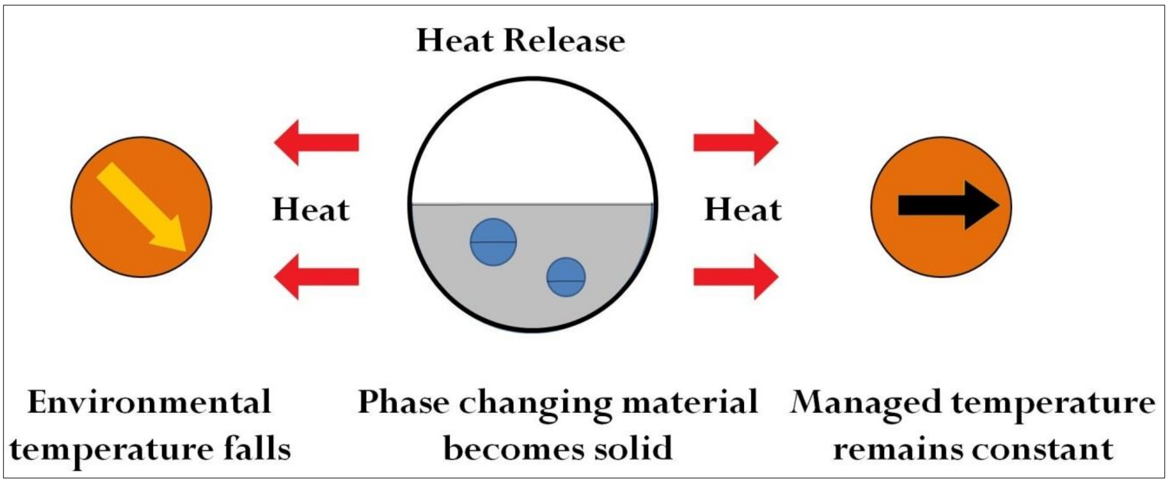

Fig. 2 Changes in phase change materials under cold environmental conditions

There are different kinds of PCMs available with different phase changing temperatures. For application in textiles, PCMs should be lie in the temperature range from 20 to 40°C and from 30 to 10°C for heat absorbing and heat releasing temperature, respectively (Ramesh Babu and Arunraj, 2018).

BASIC SELECTION CRITERIA FOR PCMs IN TEXTILES (Mondal, 2008)

- Melting temperature range from 15 to 35°C
- Large heat of fusion
- Low temperature gap between freezing and the melting point
- Stable at repetitive melting and freezing
- High thermal conductivity for quick heat transfer
- Chemically stable
- Compatible with the textile materials without any negative effects
- No toxicity
- Harmless to the environment
- Non-flammable
- Low cost
- Ease of availability

CLASSIFICATION OF PCMS

Currently, more that 500 number of organic and inorganic PCM material are available possessing different latent heat and melting points. Paraffins are the most commonly used PCMs with the sizein the range of 15 to 40 µm. It can be applied on textile in microencapsulated form either by coating, lamination or by incorporating into fiber (Pause, 2002).

Table 1. Comparison of organic PCMs, inorganic PCMs, and eutectics

Classification	Advantages	Disadvantages
Organics	1. Non-toxic 2. High thermal and chemical stability 3. High heat of fusion and no corrosives 4. Offers large temperature range 5. Highly compatible with other materials	1. Poor thermal conductivity 2. Less phase change enthalpy 3. Relative large volume change 4. Inflammability 5. High cost
Inorganics	1. Excellent thermal conductivity 2. High phase change enthalpy 3. Low volume change and low cost	1. Corrosiveness to most metals 2. Instability leading to phase decomposition 3. Subcooling 4. Improper re-solidification

Eutectics	1. High volumetric thermal storage density 2. Sharp melting temperature	1. Low thermal conductivity 2. Corrosion in high temperature

(Source: Zalba et al. 2013; Haiting et al. 2003; Shenglin et al. 2004; Kenisarin 2010; Khare et al. 2012, Zhou et al. 2012).

INCORPORATION METHODS OF PCM IN TEXTILES

The fabric or fibre incorporated with PCMs could absorb and store the heat generated by body and release it back to body, when needed. The thermoregulatory properties can be imparted to manmade fibers by adding microencapsulated PCMs to polymer during extrusion process. By this way, PCM microcapsules are merged with the fiber itself. Some convenient techniques used for incorporation of PCMs into fabric material are melt spinning, coating lamination, fiber extrusion, injection moulding, foaming etc.

Fiber technology

Microencapsulation is an essential requirement for the incorporation of PCMs within a fiber matrix. For this, PCMs are shelled inside suitable polymer or base material, then integrated into fibre by conventional methods such as dry or wet spinning and polymer extrusion etc. (Mondal, 2008). The microencapsulated PCM based fibres have ability to store heat for longer time. These fibers radiate heat slowly when there is a temperature drop.

Coatings

For coating on textile material, a homogeneous solution of microencapsulated PCM dispersed in a binder, dispersant, antifoaming agent, surfactant, and thickener is prepared. This solution will be then applied to a textile surface. Acrylic and polyurethane are widely used polymers for PCM coatings. The coating can be done by any of the available processes such as pad-dry-cure, knife-over-roll, dip coating, knife-over-air, gravure etc. (Mondal, 2008).

Lamination

To enhance comfort properties (thermo-physiological) of protective garments, lamination process can be opted by incorporating PCM material in a thin polymer film followed by application to inside of the fabric (Mondal, 2008).

VARIOUS USES OF PCMS IN TEXTILES

Application of PCM in textiles field (Mondal, 2008; Ying et al., 2004; Shisho, 2002) are listed as follows:

- Aerospace textiles (space suit and gloves)
- Sportswear (active wear, snowboard gloves, ice climbing and underwear for cycling as well as running)

- Medical textiles (surgical apparel such as gloves, caps, gowns, bedding materials, bandages and products for maintaining temperature of patients in ICUs)
- Bedding and accessories (blankets, quilts, pillow, mattress)
- Automobile textiles (seat cover, helmets)
- Fire retardant fabrics (firefighters' outfits and gloves)
- Shoes (skiing boots, mountaineering boots, race car drivers boots, golf shoes etc.)

SUMMARY

PCM based textiles can be refereed as smart textiles due to their capability of sensing surrounding temperature fluctuations by absorbing as well as releasing latent heat during melting and cooling process, respectively and thus produce a thermo-regulating effect. The use of PCMs for development of thermoregulatory textile was witnessed since 1980s. In recent years, research has gained momentum in improving cutting edges to manufacture PCMs and applying them in textiles using various processing technologies. The use of PCMs in textile provides good opportunity to industry to fabricate smart and innovative textile products.

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