Modern Technology versus Rapid Economical Growth in Smart Textiles Incorporated with Encapsulated Phase Change Materials Containing Latent Heat for Special Workers and Extreme Weather Conditions

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Review Article

Modern Technology versus Rapid Economical Growth in Smart Textiles Incorporated with Encapsulated Phase Change Materials Containing Latent Heat for Special Workers and Extreme Weather Conditions

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Article History:
Published: June 08, 2019

Abstract

Smart textiles especially phase change materials in the stage of development process and still many important accomplishments are hidden with the success corner of related researchers due to unavailability of testing standards for clothing containing micro capsulated PCMs, compatibility of materials, matching with material properties and thermal performances, difficult to incorporate PCMs in clothing structure, polymeric shell puts dead weight to clothing, durability of PCM incorporated textile in repeated uses, higher price materials, toxicity which are the question marks for smart textiles. Challenges associated with PCMs while there can be significant advantages to using PCMs in certain encapsulation (as reviewed above), there are also a number of challenges regarding the research. Phase Change Materials (PCMs) are getting attention because these materials can provide regulation of wearer's body micro-environment and provide comfort in the temperature fluctuations during the physical activities and others like sports, space wears, undersea low temperature rescue, automobile, medical application, extreme weather, health & safety applications etc. Leading players in the PCM market are BASF (Germany), Rubitherm Technologies (Germany), and Enlropy solutions Inc. (U.S.), Outlast Technologies (U.S.). With the increased demand of smart textiles and comfort wears, the PCM market in textiles is bound to get steady growth in future.

Introduction

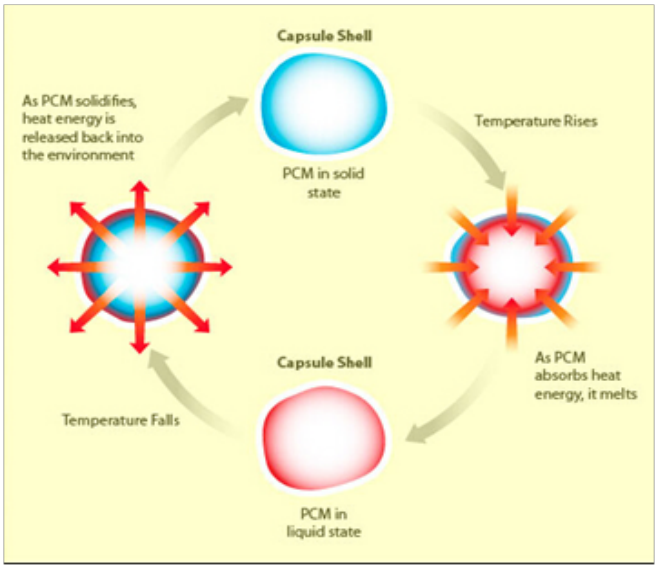

Figure 1: How PCM works

Smart textiles and its rapid economical growth

Technology is the seed of development for any country. Smart textiles is one of them which may create a revolutionary changes in economical and life style development. Development of Bangladesh economy is dependent much on exporting textile products, but only exporting of traditional readymade garments products can't vibrate the improvement of our economy as the international technology is going ahead very fast where Bangladesh government can concentrate to produce value added products and exporting such product can make as enforce development to make strong economy which can fight to build the country as developed country and positively Bangladesh textile product has a good reputation in world textile market where, without doubt, the exporting of smart textiles and clothing can make vital role as smart textiles and clothing have huge demand in developed countries like USA, UK, Canada, to survive their daily life, so research and development of such textile may have potential outcome in exporting.

Citation: *Anowar Hossain. Modern Technology versus Rapid Economical Growth in Smart Textiles Incorporated with Encapsulated Phase Change Materials Containing Latent Heat for Special Workers and Extreme Weather Conditions. JRL J Sci Technol. 2019; vol1-iss1: jst1005.*

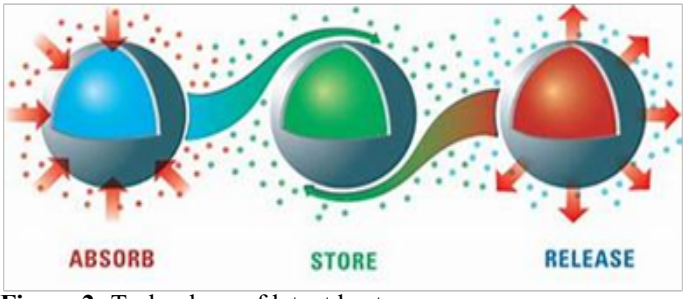

Figure 2: Technology of latent heat

As Asian countries like Bangladesh, China, India is earning major foreign currency from textile sector as well as has tremendous opportunities to do apply-based work on smart textiles which may be produced here with lower cost labor compared to the developed countries. where higher prices is the major drawback of phase change material based smart textiles production and due to lower prices product of smart textiles in Bangladesh, Myanmar, India will have a great attraction to the foreign investor and customer that may enhance an exceptional development of textile sector will make an economical rebellion to focus developing countries as developed all over the world without which it may have negative impact to keep the sustained growth in textile market as competitors of developed countries in textiles are increasing day by day where developed countries in textiles may fall to keep the reputation considering the view of economical growth without developing value added product the same as smart textile based product from research field from NASA to our common daily life where we are always depending on others technology which is vigorously deteriorating the chances of our sustained growth. The interconnectedness of the global economy can be enforced in the developed countries in textiles with the new innovative based competition as manufacturing and export capabilities especially in new concentration based research field of performance textiles like this proposed research which can also provide domestic support as geographically peoples are always facing the problem of extreme weather which is not only an exceptional demand of research and development of performance textiles but also the improvement of life style of people living in comfortable level.

Technology of smart textiles

Solvent evaporation technique will be employed for the encapsulation of phase change materials depending on the hydrophilicity or hydrophobicity of the active ingredient to be encapsulated. This method generally consists of four steps.

(1) Dissolution or dispersion of active ingredient in the organic solvent containing the polymer;
(2) Emulsification of this phase called dispersed phase in an aqueous phase called continuous phase;
(3) Extraction of solvent from dispersed phase accompanied by solvent evaporation forming droplets of dispersed phase into solid particles; and
(4) Post processing to get the solid capsules in powder form

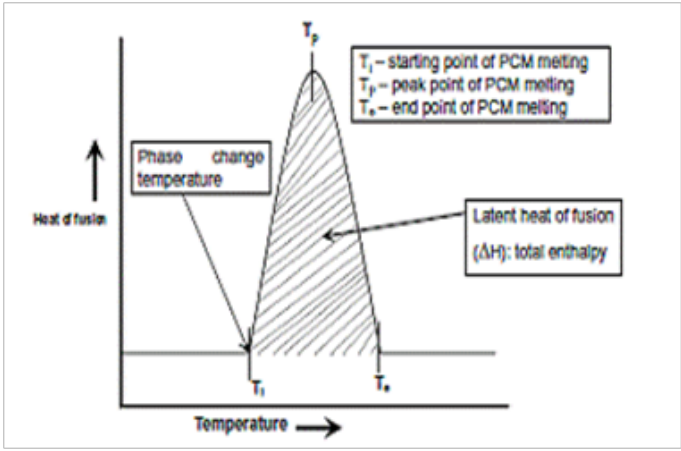

Figure 3: Technology of PCM melting in latent heat

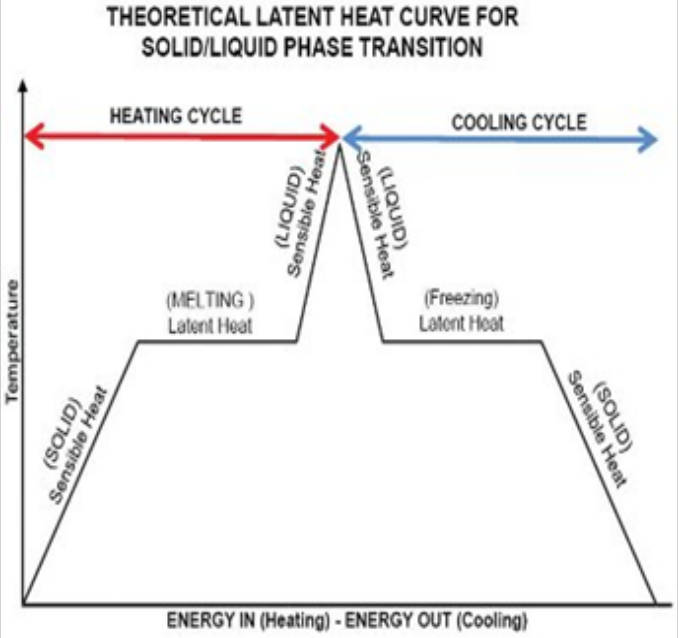

Figure 3: Theoretical latent Heat Curve for Solid/Liquid Phase Transition

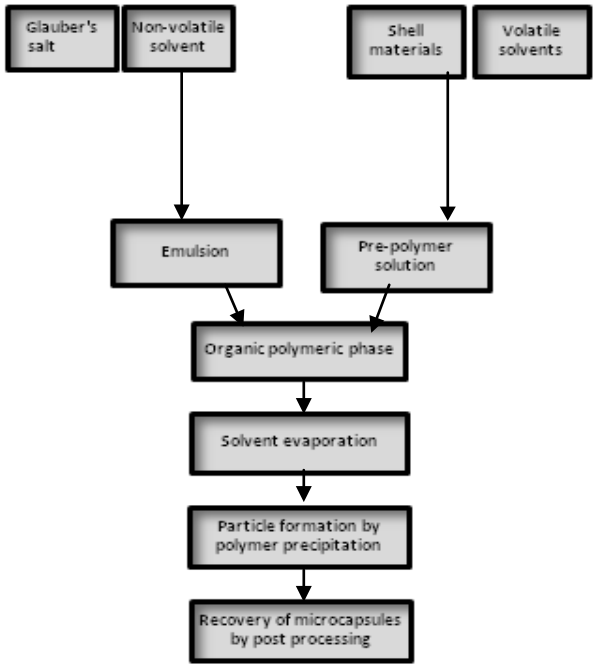

Figure 3 : Flow chart of encapsulation by solvent evaporation technique

A brief literature on smart textiles

The heat and moisture transfer behavior of clothing has long been recognized to be critically important for human survival for special workers and extreme weather conditions. Phase Change Materials (PCMs) are organic or inorganic compounds having large amount of heat energy stored in the form of latent heat, which is able to be absorbed or released when the material changes phase from solid to liquid or liquid to solid. When the temperature of environment or body increases, phase change materials absorb extra heat from environment or body as latent heat and keep this energy stored. When the temperature falls down outside the PCM environment, it releases the stored energy to body keeping the wearer in comfortable zone. Thermoregulation according to the textile glossary is defined as the ability of textile to maintain the constant temperature conditions without being affected by the dynamic environment conditions outside. Comfort may be divided into four categories containing thermo-physiological comfort, sensorial comfort, garment fit and psychological comfort, and the most important of these is thermo-physiological comfort [1]. Normal human body temperature is 37°C which increases up to 38°C, 39°C or occasionally 40°C during exercise [2]. The most comfortable skin temperature is 33.4°C and when it changes more than 4.5°C below or above the comfort temperature, human body feels uncomfortable [3]. One of the primary functions of clothes is to prevent the temperature of skin to fall or rise too far from the stated comfort temperatures [4].

By using phase change materials which in certain cases can increase evaporative resistance [5]. Smart textile is an emerging area in textile field which is becoming more significant by the demand of society through consumer needs. Despite the increasing impact of science and technology, smart textile demands the advancement through interdisciplinary support like fashion, design, engineering, technology, human and life sciences. In textile sector, smart textiles have application in interior textiles, technical textiles and clothing in which the last one contains higher percentage in terms of usage of smart textiles [6]. Phase change materials are kind of smart materials which were used in clothing by US National Aeronautics and Space Administration (NASA) in 1980 to make thermo-regulated garment for space and to protect apparatus in space with drastic temperature changes [7-9]. The composite PCM was prepared by blending polymethyl methacrylate (PMMA) and myristic acid (MA) in different weight percentages and the composite PCMs demonstrated good thermal reliability after 1000 times thermal cycling. The latent heat of melting reduced by only 0.16% and 1.02% for the PCMs coated with conformal coating and polyacrylic coating [10]. PCMs are attractive for storing energy in all the available heat energy storage techniques due to high density, compact storage system and high latent heat [11,12].

The pioneer study of phase change material was applied for space craft's on small scale and then on large scale was applied in buildings and solar energy systems to build thermal energy storage system [13-15]. A large number of inorganic and organic PCMs are available in the temperature range of -5°C to 190°C [16-20].The organic phase change materials ranging from 18-65°C are used in textiles and buildings thermal comfort effect [21]. Developers complained that materials can decrease the fabric thickness required to protect from cold environment [9, 22]. Currently, phase change materials are being used in different textiles including bedding, apparel, footwear and non-woven under the trade names Outlast™, Temper Tex™ and Comfor Temp®. Outlast Technologies has succeeded in marketing viscose and polyacrylonitrile (PAN) fibres incorporated with MPCM [23]. Paraffin's are organic phase change materials which absorb approximately 200 J/g of latent heat during phase change [12]. Chemical bonding is responsible for the above phenomenon as increase in temperature goes to break chemical bonding in the molecules of PCM material causes material to melt resulting in storing heat energy [24]. Phase change materials are theoretically able to change their phase at nearly constant temperature and are able to store large amount of energy [25]. Synthesis of nano encapsulated n-eicosane (PCM) with the silica shell material through sol-gel process can be a perspective technique to prepare the nano-PCMs with enhanced thermal transfer and phase change properties for potential applications to thermal-regulating textiles and fibers [26]. Glauber's salt (Na2SO4.10H20) is very attractive and convenient because of its physical and chemical properties. It has a melting temperature of 32.4°C which is very suitable for textiles and has large amount of latent heat of 254J/g [27].

Technical implementation of smart textiles

Phase change materials have potential applications for performance garments for people such as special workers like firefighters, undersea rescuers, etc and extreme weather condition. Currently the commercially available encapsulated PCMs are paraffin based and they have relatively lower latent heat. Sodium sulphate decahydrate has phase change temperature near to the comfort temperature of human body. It has larger amount of latent heat than paraffin and much cheaper. There is no published research work most probably due to the highly soluble nature of it hence difficulties in encapsulation, and it needs to be investigated. The overall aim of this research is to conduct experimental and theoretical studies of thermal regulating textiles, by developing melt spun filaments incorporated with phase change materials and predicting the thermal regulating effect of PCM incorporated textiles using finite element (FE) method. The specific identified objectives are noted below:

(1) To develop and characterise thermo-regulating cotton fabric with natural and artificial phase change materials.
(2) To develop the heat transfer behavior of textiles incorporated with MPCM & NPCM (nano encapsulated phase change material).
(3) To synthesise MPCM & NPCM with phase change temperature near to the skin comfort temperature and particle size in nano range suitable for encapsulating paraffin/rubber in the core.
(4) To synthesis nano encapsulated sulphate decahydrate by selecting suitable reaction ingredients and optimize process parameters of encapsulation.

Conclusion

The encapsulated PCM can be applied to textiles through extruding process to make PCM filaments yarns and possible to apply the encapsulated PCM onto conventional fabrics through coating/padding process. Melt and wet spinning methods can be used to produce manmade filament incorporated with PCMs. The thermal conductivity of the filament and fabric containing PCMs can be tested.

Definitely, the survival of textile industry is based on the high value added segment and establishing the new technology will face competitive advantages. Establishment of PCM based textile product will play an integral role in renewing the economy and the success of this research may have well connection with the world famous performance textile manufactures. This review focuses on recent advances in the field of Smart Textiles and pays particular attention to the materials and their manufacturing process.

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