Fabrication of temperature-regulating functional fabric based on n-octadecane/ SWCNTs composite phase change material

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Abstract

Purpose – Fabrics with photothermal conversion functions were developed based on the introduction of shape stable composite phase change materials (CPCMs).

Design/methodology/approach – Acidified single-walled carbon nanotubes (SWCNTs) were selected as support material to prepare CPCMs with n-octadecane to improve the thermal conductivity and shape stability. The CPCMs were finished onto the surface of cotton fabric through the coating and screen-printing method. The chemical properties of CPCMs were characterized by Fourier transform infrared spectrometer, XRD and differential scanning calorimetry (DSC). The shape stability and thermal conductivity were also evaluated. In addition, the photothermal conversion and temperature-regulating performance of the finished fabrics were analyzed.

Findings – When the addition amount of acidified SWCNTs are 14% to the mass of n-octadecane, the best shape stability of CPCMs is obtained. DSC analysis shows that the latent heat energy storage of CPCMs is as high as 183.1 J/g. The thermal conductivity is increased by 84.4% compared with that of n-octadecane. The temperature-regulating fabrics coated with CPCMs have good photothermal conversion properties.

Research limitations/implications – CPCMs with high latent heat properties are applied to the fabric surface through screen printing technology, which not only gives the fabric the photothermal conversion performance but also reflects the design of personalized patterns.

Practical implications – CPCMs and polydimethylsiloxane (PDMS) are mixed to make printing paste and printed cotton fabric with temperature-regulating functional is developed.

Originality/value – SWCNTs and n-octadecane are composited to prepare CPCMs with excellent thermal properties, which can be mixed with PDMS to make printing paste without adding other pastes. The fabric is screen-printed to obtain a personalized pattern and can be given a thermoregulatory function.

Keywords Thermal conductivity, Cotton fabric, Latent heat storage, Composite phase change materials, Screen printing, Single-walled carbon nanotubes

Paper type Research paper

Introduction

Energy-saving and sustainable energy have always been the focus in the field of modern science. Solar energy, which is widely distributed, cost-free and clean to the environment, is considered to be an excellent clean and renewable energy source (Zheng *et al.*, 2021). It has been found that solar thermal energy can be stored and released by phase change materials (PCMs) in the form of heat energy (Gu *et al.*, 2020). The PCMs can absorb energy when heated by converting solid into

a liquid phase. When the ambient temperature drops, they release the energy previously absorbed and solidified again (Illampas *et al.*, 2021). For this reason, PCMs are suitable to manufacture textiles and clothing with the property of heat storage and temperature regulation (Mondal, 2008). The endothermic and exothermic processes that occur during the phase transition cycle can help to reduce temperature fluctuations. As a result, the fabric functionalized with PCMs generates a stable microclimate around the skin to support the body's thermal regulation system, even though the ambient temperature varies over a wide range (Zhao *et al.*, 2016). Organic PCMs show many prominent advantages such as high enthalpy of phase change, good thermal and chemical stability, economy and non-toxicity (Pielichowska and Pielichowski, 2014). Nevertheless, it also has some problems, including poor thermal conductivity and shape stability, leakage (Umair *et al.*, 2019). Low thermal conductivity is negative on phase transition efficiency and affects the storage and release process (Yu *et al.*, 2018). The improvement of heat transfer and enhancement of shape stability are essential ways to expand the application feasibility of organic PCMs.

Microencapsulation, polymer addition and impregnation of porous materials are often used to solve the problem of shape stability. Zhang *et al.* used methyl methacrylate as wall material, solid paraffin and butyl stearate as core material to prepare PCMs microcapsules, which solved the instability of PCMs (Zhang *et al.*, 2020a, 2020b). Zhu *et al.* prepared novel nano encapsulated n-octadecane PCMs, the organosilica wall as a physical protective barrier that slows the escape of the volatile products during the heating process and the thermal stability of the as-prepared samples are improved (Zhu *et al.*, 2015). Ramakrishnan *et al.* prepared CPCMs with excellent shape stability by impregnating paraffin in porous particles of hydrophobic epoxy resin (Ramakrishnan *et al.*, 2015). In terms of increasing thermal conductivity, it is generally solved by adding foam nickel, expanded graphite, silver nanoparticles and other materials (Yang *et al.*, 2020). Andrew *et al.* applied paraffin to impregnate porous graphite matrix, which increased the thermal conductivity of paraffin by two orders of magnitude (Mills *et al.*, 2006). Existence of graphene nanoplatelets enhanced both the latent heat and thermal conductivity of the beeswax, the thermal conductivity of 0.3 Wt.% beeswax/ graphene was 2.8 W/mK (Amin *et al.*, 2017). Paraffin/xGnP PCMs were prepared with exfoliated graphite nanoplatelets and liquid paraffin for high electric conductivity, thermal conductivity and latent heat storage (Kim and Drzal, 2009). From what has been introduced above, the addition of carbon materials with porous structures could improve poor shape stability and low thermal conductivity at the same time (Khodadadi *et al.*, 2013).

Carbon nanotubes have the advantages of high thermal conductivity, low density, good thermal performance, etc. As supporting material, it can not only improve the thermal conductivity of PCMs but also help to reduce the cooling degree at a specific temperature, as well as improve the stability range (Ssm *et al.*, 2019). Moreover, it also makes the PCMs shape stable, improves the thermal conductivity and reduces the latent heat loss to a minimum (Putra *et al.*, 2019). Zhang *et al.* added 10% acid-oxidized carbon nanotubes to prepare CPCMs. The thermal conductivity increases by 131.9%

compared to pure paraffin. Only a small amount of phase leakage was generated (Zhang *et al.*, 2020a, 2020b). With the increase of carbon nanotubes content in paraffin wax, the melting point of the composites decreased and the thermal conductivity increased (Zhang *et al.*, 2014). Everen *et al.* found that adding 1.25% carbon nanotubes to n-octadecane improved latent heat absorption capacity and exhibited excellent thermal stability (Bayramoglu, 2011). Carbon nanotubes acted like a conduction tree in n-octadecane PCMs and their interaction caused the delay locally in the melting of the PCMs (Shuja *et al.*, 2016). Single-walled carbon nanotubes (SWCNTs) are about one nanometer in diameter and from microns to tens of microns in length. The modulus of a single SWCNT is as high as diamond and its thermal conductivity is higher than metal (Gao *et al.*, 1999). Due to their unique structure, excellent physical properties and high thermal conductivity, SWCNTs have been widely applied in thermal management fields such as refrigeration devices and thermal interface materials (Cha *et al.*, 2021). However, there are few research studies on the support materials of PCMs.

As a typical organic PCM n-octadecane has high enthalpy and its phase transition temperature is 28°C (Zhang *et al.*, 2018). The nanocapsules with n-octadecane as the core material showed good thermal cycling and durability, which could be applied in thermal energy storage (Zhang *et al.*, 2021). Li *et al.* synthesized CPCMs using TiO$_2$ and n-octadecane as matrix and the relative enthalpy of the CPCMs was 85.8 J/g (Li *et al.*, 2020).

In this work, we reported the preparation of CPCMs with n-octadecane as PCM and SWCNTs as support materials, which were planned to apply to fabrics. To combine the CPCMs with the fabric more strongly, polydimethylsiloxane (PDMS) was chosen as the material of the encapsulation film layer. Screen printing, as a cheap, simple, direct and rapid way, could print different individual patterns on fabrics (Yang *et al.*, 2020). Functional cotton fabrics with different patterns were fabricated by this method. Scanning electron microscope (SEM), Fourier transform infrared spectrometer (FTIR), differential scanning calorimetry (DSC), infrared thermal imager (TIS10), thermal constant analyzer (TPS2500S) and flat heat preservation instrument (YG606L) were used to characterize the properties of the CPCMs and functional fabrics.

Experimental

Materials
Cotton fabric (yarn count: 35×35, density 130×70, twill, Hebei Ningfang Group Co., Ltd.), N-octadecane (99%, Macklin), single-walled carbon nanotubes (SWCNTs, the length is 10–$30\,\mu$m and the diameter is 10–$20\,$nm, Zhongke Times Nano Co., Ltd.), polydimethylsiloxane, curing agent (Dow Corning), concentrated sulfuric acid, concentrated nitric acid (all AR, China Shijiazhuang Reagent Factory), absolute ethanol (AR, Tianjin Damao Chemical Reagent Factory).

Pretreatment and modification of single-walled carbon nanotubes
SWCNTs with a mass of 1 g were added to a mixture of 400 mL of HNO$_3$ and H$_2$SO$_4$ (HNO$_3$: H$_2$SO$_4$ = 1:3) and stirred in a water bath at 50°C for 2 h. SWCNTs were washed with deionized water to neutralize and filtered with a

polytetrafluoroethylene membrane followed by drying in an oven at 80°C for 8 h to dry. The modified SWCNTs were represented by M-SWCNTs.

Preparation of composite phase change materials

CPCMs composed of n-octadecane and M-SWCNTs were prepared by the vacuum impregnation method. M-SWCNTs equivalent to 8%, 10%, 12% and 14% of the mass of n-octadecane were added to n-octadecane, respectively. They were placed in three-neck flasks and further stirred at a rate of 420 r/min for 1 h at 50°C. After the reaction was completed, the CPCMs were taken out and put into beakers.

Fabric coatings

Fabric coated with polydimethylsiloxane

The coating agent 1# was composed of PDMS and curing agents with a mass ratio of 10:1. The cotton fabric was cut into squares of 0.05×0.05 m^2 and the surface was uniformly scraped with a 4 g coating agent and placed in an oven at 120°C for 5 min to allow the fabric cross-linked with PDMS. The prepared fabric was represented as CPCMs-P.

Fabric coated with polydimethylsiloxane and composite phase change materials

The cotton fabric was cut into pieces with an area of 0.05×0.05 m^2. The PDMS and CPCMs were mixed uniformly in a mass ratio of 3:1 and 2:1, respectively, and stirred in a water bath at 40°C for 10 min. Then, curing agents (PDMS: curing agent = 10:1) was added and stirred for 3 min to prepare coating agent 2#. They were uniformly coated on the surface of the cotton fabric and placed in an oven at 120°C for drying. The PDMS film containing CPCMs was cured on cotton fabric surfaces. The prepared fabrics were represented by CPCMs-I and CPCMs-II, respectively.

Screen-printed fabric with composite phase change materials

The cotton fabric was cut into pieces with an area of 0.3×0.3 m^2. The CPCMs with the best heat storage performance were selected and mixed with PDMS at the optimal ratio. The curing agent (PDMS: curing agent = 10:1) was added and mixed evenly to prepare the printing paste. The cotton fabric was placed under the printing board and the paint was scraped on the fabric surface by screen printing. Finally, they were placed in an oven at 120°C for 10 min.

Testing and characterization

Microscopic morphology of single-walled carbon nanotubes

The sample was evenly coated on the conductive adhesive and compacted. After spraying gold treatment, the morphological changes of SWCNTs before and after acidification were observed by scanning electron microscope (SEM, S-4800-I, Hitachi, Japan).

Chemical composition of composite phase change materials

The sample was evenly mixed with potassium bromide and ground to make a tablet. Fourier transform infrared spectrometer (FTIR, Nicolet 6700, Thermo-Fisher, American) was used to analyze the chemical groups of M-SWCNTs, n-octadecane and CPCMs. In addition, observe whether there were new groups.

Shape stability of the composite phase change materials

The CPCMs and n-octadecane were made into cubes with a diameter of 1.5 cm and a height of 0.3 cm. The samples were heated on a constant temperature heating table at 45°C for 60 s, 180 s and 360 s, respectively, and the appearance of the samples was recorded by taking pictures.

Latent heat of composite phase change materials

The 4.5 mg sample was weighed, the latent heat energy and a melting point of n-octadecane and CPCMs were measured by a differential thermal analyzer (DSC-214, Netzsch, Germany) under the conditions of a temperature range of 0–60°C and the temperature change rate is 10°C/min.

Thermal conductivity of composite phase change materials

A constant thermal analyzer (TPS2500S, Hot Disk, Sweden) was used to test the thermal conductivity of n-octadecane and CPCMs in an environment of 20°C.

Step cooling curve

The fabric was placed in an incubator at 50°C and heated at constant temperature for 10 min. The fabric was placed in a room with no wind at room temperature to cool down. The temperature changes of each fabric were recorded with an infrared thermal imager (TIS10, Fluke, American).

Photothermal conversion performance

At noon in early summer, the fabric sample was placed in a dark place for 600 s to minimize the fabric sample temperature. Then it was moved to sunlight and the sample temperature was recorded every 200 s by a thermal infrared imager (TIS10, Fluke, American).

Thermal effects of thermoregulatory fabric

The fabric was placed 30 cm directly below the tungsten iodine lamp (power: 500 W) and irradiated for 300 s. Surface temperatures of each fabric were measured every 5 s by a thermal infrared imager (TIS10, Fluke, American). The recording was stopped when the surface temperature of the fabric was constant.

Thermal stability of the thermoregulatory fabric

The fabric was placed 30 cm directly below the iodine tungsten lamp (power: 500 W), turn on the lamp and heat it for 240 s, turn off the lamp and cool it for 240 s. The process was a thermal cycle, which was carried out four times. Temperature changes were recorded every 5 s by a thermal infrared imager (TIS10, Fluke, American).

The heat preservation performance of the thermostatic fabric

The raw fabric, coated fabric and printed fabric (0.3 × 0.3 m²) were tiled on the test board of the flat heat preservation instrument (YG606L, Yuan More, China). The temperature of the test board was set to 35°C. After preheating for 30 min, the test was carried out. The output results of heat transfer coefficient, Crowe value and heat preservation rate of the sample were the average values after five tests.

Results and discussion

Morphology of single-walled carbon nanotubes

Figures 1(a) and 1(b) show the surface morphology of the unmodified SWCNTs. They are entangled mutually with many nodes existing. In addition, the surface of SWCNTs is rough and uneven in diameter. The dispersion of original SWCNTs is poor and difficult to mix with the surrounding matrix, which limits the enhancement of high-strength nanotubes in polymer composite materials (Kim *et al.*, 2003). SWCNTs modified by the mixed acid are relatively dispersed. As shown in Figures 1(c) and 1(d), the agglomeration phenomenon is weakened and the crimping degree is reduced. After mixed acid treatment, new functional groups form on the surface of SWCNTs such as carboxyl (-COOH) and hydroxyl (-OH). Then, the chemical properties of these functional groups are effective to improve the solubility and dispersion of nanotubes (Ma *et al.*, 2010).

Shape stability and Fourier transform infrared spectrometer analysis of composite phase change materials

The phase leakage of PCM is a problem to be solved in its further application. The CPCMs containing 0%, 8%, 10%, 12% and 14% of M-SWCNTs were made into small pieces of the same shape and size and placed on a constant temperature heating platform at 45°C for continuous heating. Sample pictures were taken at 0 s, 60 s, 180 s and 360 s to detect the shape changes. As shown in Figure 2, n-octadecane will melts when heated for 180 s. When the CPCMs are in the heat storage process, n-octadecane changes from the solid phase to the liquid phase, resulted in leakage. As a support material, M-SWCNTs could solve this problem well by the immersion of n-octadecane with it. When the addition of M-SWCNTsis less than 12%, n-octadecane leaks to varying degrees with the increased heating time and CPCMs lose their shapes. With the increased addition amount, it can restrain partially molten n-octadecane from leaking out due to the pore structure and a large number of wall layers of M-SWCNTs. The local discontinuity of the M-SWCNTs connection causes the local melting delay of the n-octadecane, thereby improving the shape stability of the CPCMs (Suja *et al.*, 2016). It can be seen that the shape stability of CPCMs with 14% M-SWCNTs is significantly improved and only a small amount of n-octadecane leaks when heated to 360 s.

Figure 3 shows the FTIR spectra of n-octadecane, M-SWCNTs and CPCMs. The peak of M-SWCNTs is not

Figure 1 (a) SEM image of the SWCNTs with magnifications of × 100,000; (b) SEM image of the SWCNTs with magnifications of × 150,000; (c) SEM image of acid-modified SWCNTs with magnifications of × 100,000; (b) SEM image of acid-modified SWCNTs with magnifications of × 150,000
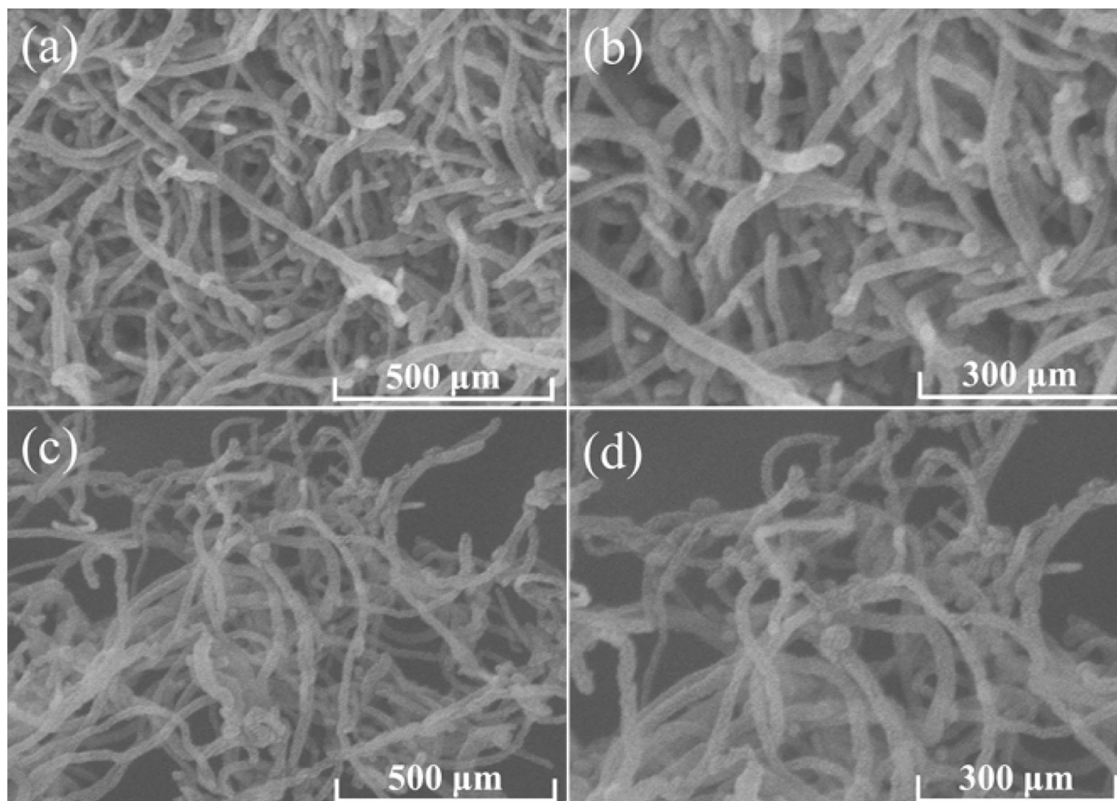
Figure 2 Shape stability of CPCMs prepared by adding M-SWCNTs with different mass percentages relative to n-octadecane
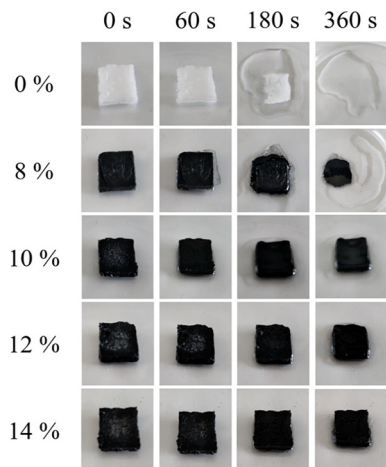

obvious enough compared with those of n-octadecane and CPCMs. To better observe the characteristic peaks, the transmittance range of M-SWCNTs was shortened to a suitable range and analyzed separately, which is shown in Figure 3(a). Several new functional groups appeared on the M-SWCNTs. The absorption peak at $1,612\,cm^{-1}$ iss a specific carbonyl group (C = O), which belongs to -COOH. The absorption peaks of more than $3,200\,cm^{-1}$ indicate the presence of hydroxyl groups, especially the peak at $3,456\,cm^{-1}$ proves the existence of hydroxyl and hydrogen bonds. The absorption peak at $1,110\,cm^{-1}$ is attributed to the C-O bond of the ether functional group (L. *et al.*, 2010). N-octadecane exhibits characteristic absorption peaks at $2,925\,cm^{-1}$, $2,855\,cm^{-1}$, $1,469\,cm^{-1}$ and $719\,cm^{-1}$, which are also shown in the CPCMs spectrum lines. It can be seen in Figure 3(b), the characteristic absorption peaks of CPCMs correspond to those of n-octadecane. There are no new characteristic absorption peaks appears, indicating no chemical reaction between the two components in CPCMs.

Thermal performance of composite phase change materials

The latent heat of n-octadecane was enormous, up to 235.84 J/g. As shown in Figure 4, with the additional amount of M-SWCNTs increases, the latent heat of CPCMs is significantly different. When the addition amount of M-WSCNTs is less than 10%, the latent heat properties of CPCMs are similar to that of n-octadecane, which may be caused by the no enter of most of CPMs into the M-SWCNTs. When it reaches 12%, the peak area of the curve decreases obviously. The area is the smallest when it is 14%.

Figure 3 FTIR spectrum of CPCMs and their components
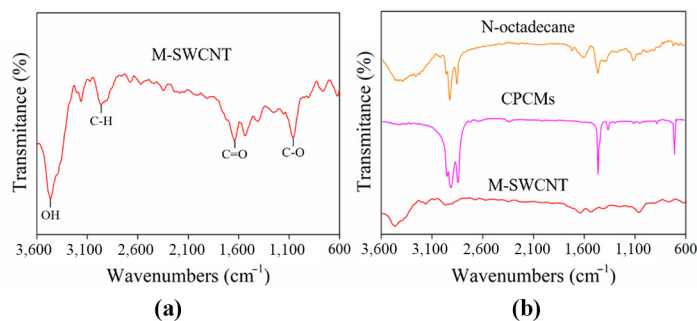
Figure 4 Analysis diagram of latent heat energy
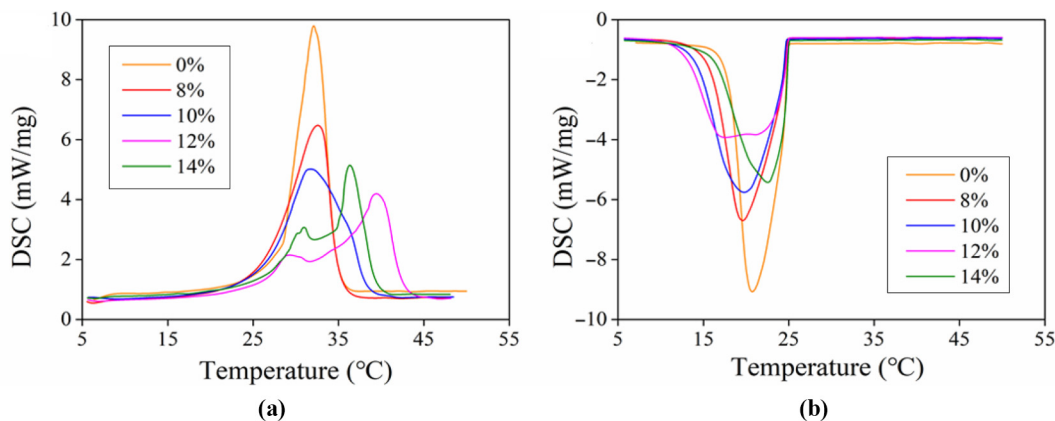
Notes: (a) DSC curve of CPCMs temperature rising; (b) DSC curve of CPCMs cooling

The latent heat of different CPCMs samples is listed in Table 1. The addition of M-SWCNTs will delay the phase transition termination temperature and increase the phase transition range so that it could better adapt to the changes of different ambient temperatures. However, as the amount of M-SWCNTs increases, the latent heat energy gradually decreases. The latent heat of CPCMs with 14% M-SWCNTs is 183.1 J/g, which is 22.4% lower than that of n-octadecane. For the same quality of CPCMs, the more M-SWCNTs content, the lower the n-octadecane content, which will inevitably cause the decrease of its latent heat.

The thermal conductivity of CPCMs with different amounts of M-SWCNTs is shown in Figure 5. As the amount of M-SWCNTs increases, the thermal conductivity also improves. The thermal conductivity of n-octadecane is 0.225 W/mK, while that of carbon nanotubes is 3,000 W/mK. Carbon nanotubes act as a bridge for conducting heat in n-octadecane, improving the thermal conductivity of CPCMs. Therefore, a small amount of M-SWCNTs would prominently increase the thermal conductivity of CPCMs. When the amount is 12%, the thermal conductivity increases by 67.5% compared to n-octadecane, while the value reaches 84.4% with the additional amount of 14% M-SWCNTs. In summary, it is finally determined that the CPCMs with 14% M-SWCNTs addition obtain the best overall performance.

## Analysis of thermal properties of the temperature-regulating fabric

Three different functional fabrics were prepared and the thermoregulatory performances of the fabrics were analyzed. They were: b was cotton fabric coated with PDMS (CPCMs-P); c was cotton fabric coated by PDMS and CPCMs and its mass ratio was 3:1 (CPCMs-I); d was cotton fabric coated by PDMS and CPCMs and its mass ratio was 2:1 (CPCMs-II).

Figure 6 shows the temperatures of each fabric under different sunlight exposure times. The photothermal conversion performance of the coated fabric can be analyzed through the change of temperature. The temperature of the original cotton fabric and CPCMs-P increases slowly with the increase of illumination time, which is almost the same as the initial temperature. After 800 s of sunlight, the temperature of cotton and CPCMs-P increase only 13.8°C and 16.1°C. After the coating is added with CPCMs, the temperature increases significantly. The CPCMs on the fabric surface can convert solar energy into heat energy and improves the photothermal conversion efficiency. The temperature of CPCMs-I increases rapidly during 0–200 s of sunlight and the final temperature is 57.5°C, which is 36.9°C higher than the initial temperature. The temperature of CPCMs-II is nearly twice higher than that of the original fabric when they are exposed to sunlight for 200 s. In the final, the temperature increases by 45.6°C and the photothermal conversion effect are significant. The

Table 1 The latent heat energy of CPCMs samples with different M-SCNTs

| Sample (%) | Heating | | | | Cooling | | | |
	Onset (°C)	Offset (°C)	Tm (°C)	ΔH (J/g)	Onset (°C)	Offset (°C)	Tm (°C)	ΔH (J/g)
0	7.68	36.54	32.09	235.84	25.05	2.31	20.74	−234.77
8	6.93	38.16	32.57	225.73	24.88	4.31	19.58	−218.55
10	10.44	42.95	31.76	227.08	24.77	2.13	19.78	−224.97
12	7.32	46.68	39.46	201.3	25.08	1.98	17.57	−194.76
14	6.31	41.07	36.32	183.1	25.09	2.49	22.52	−175.77

Figure 5 Thermal conductivity of CPCMs prepared by adding different content M-SWCNTs
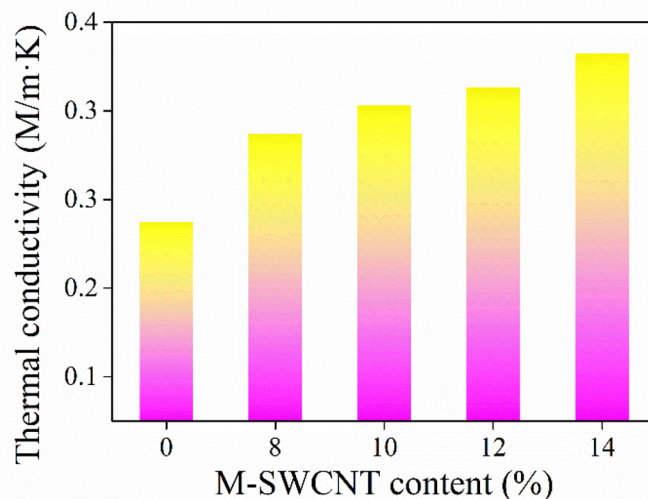
Figure 6 Temperature changes of the fabrics in sunlight
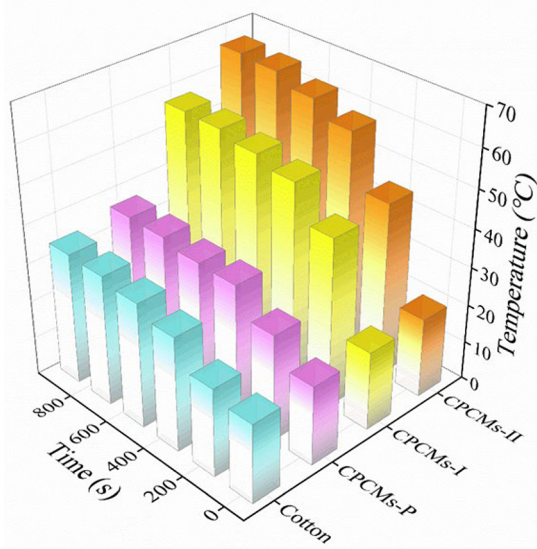
temperature of CPCMs-II is always the highest during the test and keeps increasing. In conclusion, CPCMs are positive for the photothermal conversion efficiency and the increase in CPCMs content in the coating enhances the efficiency.

During the cooling process, the stored heat is released for temperature regulation. Step-cooling curves of the four samples were tested to evaluate the heat storage performance. As shown in

Figures 7(a) and 7(b), the temperature curves decrease faster than (c) and (d). Due to the poor heat storage effect of cotton and CPCMs-P, the temperature drops rapidly to 34°C and then slowly to room temperature after heating stopped. At this time, the temperatures of CPCMs-I and CPCMs-II are 1.5°C and 2.4°C higher than cotton. With the increase of time, the temperature difference of the samples decreases gradually. The heat dissipation performances of CPCMs-I and CPCMs-II fabrics are not much different. After 300 s of placement, the temperature drops to 25°C, which is 1°C higher than cotton fabric. The results show that the addition of CPCMs can delay heat dissipation and make the fabric have the function of temperature regulation.

The photothermal conversions of different fabrics were tested using an iodine tungsten lamp to simulate high temperatures and a robust light environment. The heating rates of the original cotton fabric and CPCMs-P are relatively slow (Figure 8). As shown in Figures 8(c) and 8(d), the temperature rises rapidly in the early stage and slows down when it reaches about 35°C. This may be due to the conversion of CPCMs from the solid to the liquid phase. The heating rate of CPCMs-IIis always higher than that of CPCMs-I and the final temperature raises to 69°C. This indicates that the increase of CPCMs content in the coating would improve the photothermal conversion of the fabric. The four cycles of continuous 500 s heating-cooling tests were performed on CPCM-II. It can be seen from Figure 8(e) that the trend of the four-cycle curve is basically the same. As the test progresses, the high-temperature radiation of the iodine tungsten lamp increases the ambient temperature, resulting in a slight increase

Figure 7 Step-cooling curves of different fabrics
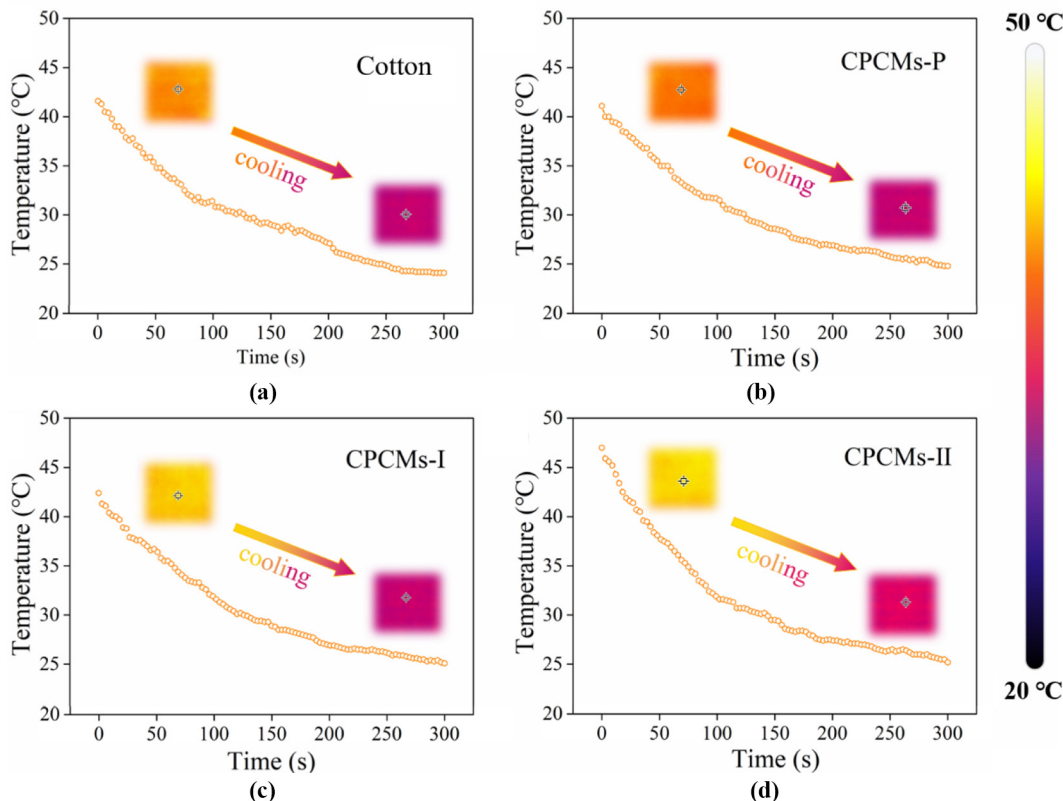
Figure 8 Comparison of photothermal energy storage of iodine tungsten lamp
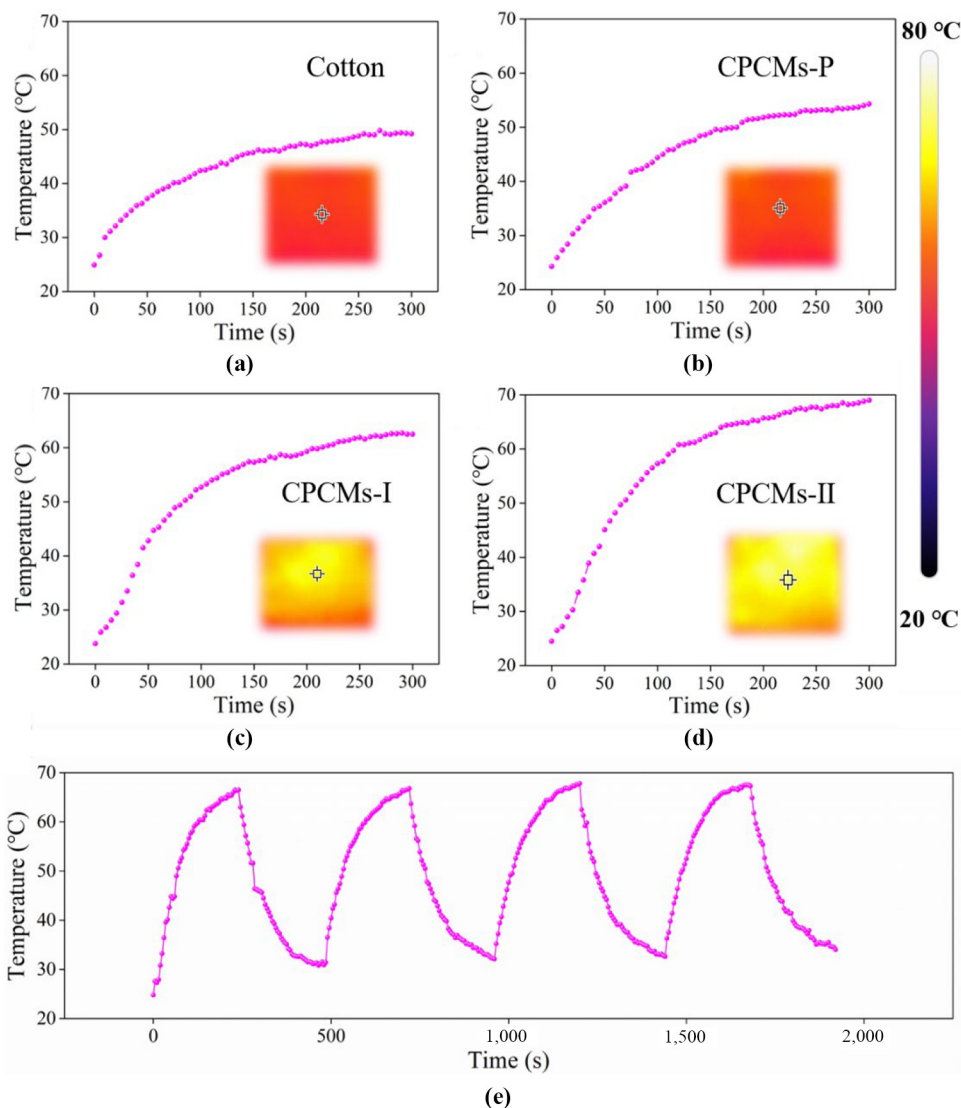
Notes: (a)–(d) The photothermal conversions of different fabrics; (e) heating-cooling test on CPCM-II

in the termination temperature of the sample after each thermal cycle. However, the warming trend of CPCMs-II is not affected, which reveals the good thermal stability of the sample.

Heat preservation performance of the temperature-regulating printed fabric

CPCMs-II with the best performance was selected as printing paste and the surface of cotton fabric was printed with pattern by screen printing board. Figure 9 shows the pictures of the screen-printing fabrics with expressed clear patterns. Due to the certain shape stability, CPCMs could keep shape well on the surface of the fabric. The first printed fabric in Figure 9 is taken as an example, the heat preservation performance is analyzed and compared with that of the coated fabric and the original fabric.

It could be seen from Table 2 that the heat transfer coefficient of cotton fabric is very high and the warmth-keeping

Figure 9 Screen printing fabrics with different patterns

efficiency is poor. The heat transfer coefficients of the coated and printed fabrics are significantly reduced and the heat preservation performance is excellent. The Crowe value of the original cotton fabric is close to zero and it shows a bad warmth-keeping efficiency. Compared with the original cotton, the heat preservation rates of coated fabric and the printed fabric are increased by 17.29% and 13.09%, respectively. The

Table 2 Thermoregulate properties of the fabrics

	Fabric	Printed fabric	Coated fabric
Heat transfer coefficient	153.42	45.17	35.03
Crow value	0.04	0.14	0.18
Heat preservation rate (%)	5.75	18.84	23.04

Crowe value and heat preservation rate of printed fabric are slightly lower than that of coated fabric because the printed fabric was coated with fewer CPCMs. In brief, the coating of CPCMs on the fabric surface could prominently improve the heat preservation performance.

Conclusions

The n-octadecane with high latent heat and M-SWCNTs were used as PCM and supporting materials to prepared CPCMs, to impart its shape stability and thermal conductivity. With the addition of M-SWCNTs, the shape stability and thermal conductivity of CPCMs were optimized. When the addition amount of SWCNTs was 14%, the shape stability of CPCMs was the best and the original shape could be maintained well when heated at a constant temperature of 45°C. Finally, the mixture of CPCMs and PDMS was coated and printed on cotton fabric surfaces. The functional finished fabric showed strong photothermal conversion and heat preservation performance. Coated fabric exhibited good thermal stability in cold-heat cycle tests. In conclusion, the synergistic effect of CPCMs with high latent heat and functional support materials such as carbon nanotubes has a good application prospect in photothermal conversion and heat preservation materials.

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