Enhancing Thermal Properties of Natural Dyed Fabrics

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1. INTRODUCTION

Natural dyed textile products with high value-added properties must be developed using energy-saving technology in order to improve their competitiveness in the commercial market. Therefore, the development of natural dyed fabrics with thermoregulatory properties is very significant.

PCM microcapsules (MCs)-treated textiles can produce a temporary cooling or warming effect in the clothing layer for hot or cold environments, and can improve the thermal comfort of the human body[1].

The objective of this study was to develop natural dyed fabrics with thermo-regulating properties. The cotton fabrics that were dyed with natural indigo were treated with the PCM MCs using the dot-screen printing method. The thermal properties by DSC and the presence and distribution of the microcapsules by SEM were examined. In order to investigate the efficacy of the fixation of the PCM MCs on the natural dyed fabrics, the color, colorfastness and physical properties were evaluated along with the laundering durability with respect to the thermoregulatory effects.

2. EXPERIMENTAL

Materials

The fabric that was used in this study was scoured and bleached 100% cotton. The natural indigo dye was prepared from *Polygonum tinctorium* using the Korean traditional niram method[2]. The melamine-formaldehyde microcapsules containing *n*-octadecane or *n*-eicosane were procured from a local supplier (Human Tech., Korea)

Methods

The dyeing was carried out in a reduced dyebath with 16g/L of the indigo dye and 5g/L of sodium hydrosulfite in a liquor ratio of 1:50 at 40°C for 30min. The dyed samples were oxidized in air and then subsequently rinsed in tap water and dried.

The coating formulation included 40% PCM MCs, 20% rubber binder, 15% acrylic binder, 3% silicon emulsion, and 1% alkali thickener. The three different samples were prepared using the *n*-octadecane MCs, the *n*-eicosane MCs, and a 50/50 mixture of the two MCs. The PCM MCs were applied on the back of the dyed fabrics using the dot-screen printing method. The dot-printed fabrics were dried at 120°C for 5 min and cured at 150°C for 3 min

FT-IR, DSC, and SEM analysis were performed. Furthermore, physical properties, color properties, and laundering durability were estimated.

3. RESULTS AND DISCUSSION

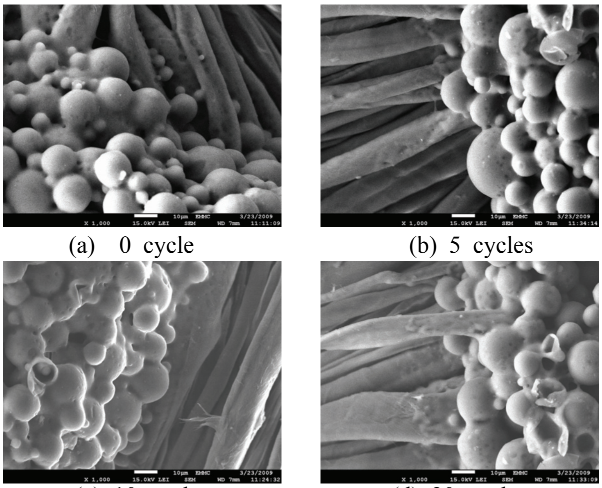
The heat storage capacities of the treated fabrics were calculated on the basis of the DSC results of dot printed parts of the fabric. The fabrics were capable of absorbing 18.66Jg^{-1}, 14.80Jg^{-1}, and 14.68 Jg^{-1} for the *n*-eicosane MCs, the *n*-octadecane MCs, and the mixture of the two MCs, respectively. The thermal storage/release effects of the PCM MCs-treated fabrics were high and followed the order of *n*-eicosane MCs > *n*-octadecane MCs > *n*-octadecane/ *n*-eicosane MCs(50/50). The PCM MCs-treated fabrics absorbed heat when the microcapsules on the fabric melted and emitted heat when the microcapsules on the fabric froze. The absorption (or emission) of heat by the microcapsules delayed the microclimate temperature increase (or decrease) of the clothing, enhancing the thermal comfort of the clothing wearer. Therefore, the fabrics that were treated with the *n*-eicosane MCs can be used for the hot summer season, and the fabrics that were treated with the *n*-octadecane MCs can be used for all seasons clothing. On the other hand, the fabric that was treated with the mixture of the two MCs was expected to be suitable for a wider temperature range from hot to mild.

Table 1 shows the laundering durability for the heat storage effect of the PCM MCs-treated fabrics. Regardless of the PCM MC species, the heat storage capacity slightly decreased little as the laundering was repeated. The PCM MCs-treated fabrics retained about 94.0% of their heat storage capacity after 20 launderings, indicating that the PCM MCs were firmly fixed on the fabric and relatively durable to the mechanical washing motion.

Table 1. Effect of laundering of the heat storage capacity of the MCs-treated fabrics

Cycle	*n*-Octadecane MCs		*n*-Eicosane MCs		*n*-Octadecane/ *n*-eicosane MCs (50/50)	
	ΔH_f (J/g)	Rtn. (%)	ΔH_f (J/g)	Rtn. (%)	ΔH_f (J/g)	Rtn (%)
0	[illegible]	100	18.66	100	14.68	100
5	l.m	98.7	18.25	97.8	14.66	99.9
10	14.24	96.2	17.88	95.8	14.17	96.5
20	14.00	94.6	17.55	94.0	13.86	94.4

Fig. 1 shows the SEM photographs of the *n*-octadecane MCs-treated fabrics that were washed for 0-20 laundering cycles. The spherical shaped microcapsules and the binder were observed on the dot area of the fabric surface before and after laundering. Some of the microcapsules were broken and some caved with increasing laundering. Similar results were observed for the *n*-eicosane MCs and the *n*-octadecane/*n*-eicosane MCs(50/50). The decrease in the heat storage capacity resulted from this deformation of the microcapsules on the fiber surface after laundering. The melting temperature was not affected by repeated launderings.



(a) 0 cycle (b) 5 cycles (c) 10 cycle (d) 20 cycles

Fig. 1. SEM photograps(1000X) n-octadecane MCs-treated fabrics after laundering .

Table 2 shows the add-on, stiffness, and air permeability of the dyed and PCM MCs-treated fabrics. The add-ons of the *n*-octadecane MCs, *n*-eicosane MCs, and *n*- octadecane/*n*-eicosane(50/50) MCs-treated fabrics were 17.92, 18.16, and 18.31%, respectively. After the fixation of the PCM MCs on the fabrics, the stiffness increased by 12.4-15.5%, and the air permeability decreased by about 25.9-26.6%, compared to the dyed sample. The changes in the physical properties of the treated fabrics varied depending upon the loading amount of the MCs. In the SEM pictures(Fig. 1), the microcapsules and binder filled some of the pores in the fabric, and the dot area(0.29mm) was thicker than the rest of the dot area(0.24mm). These changes made the treated fabrics stiffer and less air permeable.

Table 2. Add-on and physical properties of dyed and microcapsule-treated fabrics

Samples	Add-on (%)	Stiffness (cm)	Air permeability ($cm^3/min/cm^2$)
Control	-	1.84	23.62
Dyed	-	1.85	22.48
Dyed/*n*-octadecane MCs treated	17.92	2.08	16.64
Dyed/ *n*-eicosane MCs treated	18.16	2.18	16.78
Dyed/*n*-octadecane +*n*-eicosaneMCs (50/50)treated	18.31	2.19	16.49

Table 3shows the effects of MCs treatment and laundering on the color of fabrics. The color of the fabrics dyed with natural indigo changed negligibly with color difference (ΔE^*) ranged 0.45-1.00 after MCs treatment. Color difference ranged from 1.24 to 2.00 with increasing laundering. These differences were acceptable, and it was considered that the MCs treatment process was very reliable in terms of color stability.

Table 3. Effects of laundering on the color properties of the dyed/PCM MCs-treated fabrics.

Samples	cycles	H V/C	L^*	a^*	b^*	ΔE^*
Dyed	-	3.7PB 3.2/4.9	33.49	-3.23	-20.68	-
Dyed/ *n*-octadecane MCs treated	-	3.7PB 3.3/5.0	33.68	-2.96	-21.62	1.00
	5	3.7PB 3.3/5.1	34.70	-3.53	-20.78	1.25
	10	3.8PB 3.3/5.1	34.99	-3.19	-21.05	1.55
	20	3.9PB 3.4/5.1	35.38	-3.12	-21.33	2.00
Dyed/ *n*-eicosane MCs treated	-	3.8PB 3.2/5.1	33.60	-3.04	-21.52	0.87
	5	3.9PB 3.2/5.2	33.69	-2.89	-21.98	1.37
	10	4.0PB 3.2/5.2	34.06	-2.83	-22.09	1.58
	20	4.0PB 3.3/5.3	34.95	-3.17	-21.84	1.87
Dyed/ *n*-octadecane +*n*-eicosane MCs treated	-	3.7PB 3.2/5.0	33.53	-3.39	-21.10	0.45
	5	3.8PB 3.3/5.1	34.62	-3.10	-21.16	1.24
	10	3.8PB 3.3/5.1	34.75	-3.25	-21.14	1.34
	20	3.9PB 3.3/5.1	35.12	-3.10	-21.11	1.69

4. ACKNOWLEDGEMENTS

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5. REFERENCES

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