Thermoregulation in Textiles

- Devan Chemicals
  - Phase Change
  - Thermoregulation / Comfort
  - Micro Encapsulation
  - THERMIC™ PCM Technology
  - Applications
  - Processing & Quality Control
  - Marketing Support
  - Conclusions
The Devan Group

PROTECTING and MODIFYING TEXTILE SURFACES

creating new and innovative properties and functionality
taking into consideration

SUSTAINABILITY
The company

The Company was established in 1977

Figures 2008

Volume: 4,500 T
Turnover: 13,400,000€ (Consolidated)
Export: 60% (worldwide)
Global thinking, local acting...
Sustainability Strategy: 1990

Since 1990, Ecology has been the DNA of Devan

- 1995: Halogen-free flame retardants (*Eco-flam™*)
- 1999: Non migrating antimicrobial (*ægis™*)
- 2001: Masterbatch for inherent performance properties (*@2spin™*)
- 2002: Non-chlorine wool shrink-resist (*Dylan™*)
- 2005: Environmentally more acceptable insect resist (*insecta™*)
- 2008: Reactive capsules (no need of binders) (*THERMIC™*)
Devan trademarks

CONCERN FOR ECOLOGY DRIVES NEW BUSINESS DEVELOPMENT AND IS REFLECTED IN OUR PRODUCT RANGE

FLAME RETARDANT TECHNOLOGY
ANIMICROBIAL TECHNOLOGY
SHRINK RESIST TECHNOLOGY
MOISTURE MANAGEMENT TECHNOLOGY
AFTER WASH APPAERANCE TECHNOLOGY
ANTI - STATIC TECHNOLOGY
STRETCH RECOVERY TECHNOLOGY
MASTERBATCH TECHNOLOGY
SENSORIAL MANAGEMENT TECHNOLOGY
INSECT CONTROL TECHNOLOGY
WATER REPELIENT TECHNOLOGY
ADVANCED ANIMICROBIAL TECHNOLOGY
INSECT CONTROL TECHNOLOGY
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THERMIC™

- Patented technology
- Reactive microcapsules of phase change material (PCM)
- Could be applied to all types of substrate composition
Mechanism of Phase Change

Change of physical phase at constant temperature

Solid PCM \(\rightarrow\) Excess Heat Absorption \(\rightarrow\) Liquid PCM

Energy absorption

Energy release

Absorb Energy from Solid to Liquid \(\rightarrow\) melting
Release Energy from Liquid to Solid \(\rightarrow\) solidification
Phase Change: Energy Buffer

**Phase Change**
Energy absorption or release without temperature change

- Melting
- Solidifying
- Evaporation
- Condensation

![Diagram](image-url)

Temperature

Energy Added (J)

Solid

Liquid

Gas

DEVAN CHEMICALS
Energy Buffer

Water in liquid phase above 0°C and below 100°C

- Each 1°C rise in temperature requires an energy input of 4 J/g

Water at a phase change temperature

- Ice → Water: requires heat input of 334 J/g at 0°C (32°F)
- Water → Ice: releases heat 334 J/g at 0°C (32°F)

More than 80 times more energy is needed to change phase than for raising the temperature by 1°C outside the phase change
Conclusions: Phase Change

- **Phase Change**: Going from one state to another

- Occurs at a constant temperature

- Absorbs or releases large amounts of energy when changing of phase

PCM have the capacity to absorb, store and emit heat energy without altering the temperature
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Body & Skin Temperature

- Average core body temperature: 37°C (98.6°F)
  - +2°C (+4°F): fever
  - -2°C (-4°F): hypothermia

- Average skin temperature: 32°C (90°F)
Comfort Zone

- **Comfort Zone**: Microclimate between the skin and the fabric that is perceived as most comfortable

- **28-30°C (82°F – 86°F)** (R.A. Scott, Textiles for protection, 2005)
Extending Time Comfort Zone

- Extend time in the comfort zone (28 - 30°C)
  - Need of a system that releases or absorbs heat at a constant temperature of 28°C

- Phase Change Materials
  - Have the capacity to absorb, store and emit heat energy without altering the temperature
  - Phase change needs to happen in comfort zone (28 – 30°C)
Active Thermal Insulation

- Standard garment thermal insulation - Passive
- PCM thermal regulation - Active

Temperature variation in microclimate is determined by:
- Body Heat
- Change in environment

The presence of PCM will buffer such fluctuations in temperature
Warming up

- Heat produced by body > Heat absorbed by garment
  - PCM absorbs the excess heat by melting
  - PCM extends time in comfort zone
Cooling down

- Heat retained by garment < Heat lost by body
  - PCM releases heat while staying at a constant temperature during phase change from liquid to solid
  - Extends time in comfort zone

![Graph showing temperature difference between microclimate with and without PCM]

- 30 °C 86°F
- 28 °C 82°F

Microclimate with PCM
Microclimate without PCM
Energy Buffer

- The bigger the Energy Buffer:
  - The longer in the comfort zone
  - The higher the thermoregulation effect

- Energy buffer is dependent on:
  - Quantity of PCM material
  - Type of PCM material

- Energy buffer is being quantified by J/g
Dynamic Conditions

- Body movements increase temperature (working, jogging, cycling, etc); body temperature falls during rest
- Change in environment temperature (moving from outside to inside and vice versa)

![Graph showing temperature fluctuations and comfort zone]

Temperature

30 °C  86°F
28 °C  82°F

Comfort Zone

Microclimate without PCM
Microclimate with PCM
Thermoregulation & Perspiration

- If body temperature exceeds 37.5°C (98.6°F) the body needs to cool down
  - Blood vessels under the skin dilate
  - Body produces perspiration
    - Cooling through evaporation

- PCM absorbs the heat from the body
- Microclimate stays in the comfort zone for longer periods of time
- Delays the onset of temperature rise to 37.5°C (98.6°F)
  - Less cooling needed for the body
  - Less perspiration
Conclusions Thermoregulation & Comfort

- PCM results in thermoregulation
  - Absorbs Heat
  - Stores Heat
  - Releases Heat

- Thermoregulation is quantified in J/g

- PCM keeps the microclimate temperature close to the body longer in the comfort zone

- PCM eliminates temp peaks next to the body

- Thermoregulation in textiles
  - Enhances thermal comfort
  - Reduces transpiration
  - Enhances quality of sleep
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PCM technologies

For application on textiles the PCM needs to be contained in a ‘capsule’

The PCM capsule can be applied to the fibre in three ways:

- PCM microcapsules melt spun inside the fibre
- PCM microcapsules bound to the fibre with a binder
- PCM reactive microcapsules – THERMIC™
What is Micro Encapsulation?

Size: 1-30μm

- Type of Capsule:
  - Capsules break to release their contents (fragrances)
  - Capsules do not break and keep their content (PCM)
PCM extruded in fibre

Advantage
- High wash durability

Disadvantage
- Only applicable in man-made fibre (mainly viscose & acrylic)
- Need to blend with other fibres
- Lower performance
- Expensive

Source: Outlast
PCM included in coatings and binders

Advantage
- Easy application

Disadvantages
- Reduces breathability
- Affects the hand
- Low durability to washing
- The binder increases microclimate temperature
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Microcapsules with functional reactive groups on the shell surface

Patent number: PCT/IB2006/050605

Without the use of binders, the capsules can react with:

- Cellulosic (Cotton, Viscose...)
- Synthetic (PES, PA,...)
- Protein (Wool)

Application can be through conventional textile processing
THERMIC™ Advantages

- Wash durability – up to 50 washes
- Use on both synthetic and natural fibres
- Greater heat capacity for the same loading of PCM
- Fabric characteristics are maintained
  - Handle unaffected
  - Breathability unaffected
  - Not visible to the naked eye
- Easy application
Two size options available:

**THERMIC™ G**
- Diameter: 20-30 µ
- Thermal capacity dry microcapsules: 180 J/g
- Up to 5 Washes

**THERMIC™ P**
- Diameter: 1-5 µ
- Thermal capacity dry microcapsules: 140 J/g
- Up to 50 Washes
THERMIC™ Binding System Cellulose

- Covalent bound
- Addition or nucleophilic substitution promoted solely by the pH of the solution normally alkaline, or resorting to initiators in case of an addition radical reaction
- Just as with reactive dyes, THERMIC™ has reactive groups that can react with the anion groups of ionized cellulose

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Less reactive groups available (only the terminal ones)

Linkage between the reactive microcapsules and the fiber occurs mainly by a strong physical adsorption/absorption phenomena

Physical Van der Walls interactions takes place between the polyester and the electronegative atoms.

The catalyst helps the kinetic behavior of the interactions between the reactive microcapsules and the PES fibres, in function of the pH presented in the medium.
Thermographic test

Samples on a hot plate (40°C).

Average Temperatures:

THERMIC™: 23,3°C
Untreated: 30,2°C
Thermographic test

Samples on a cool plate (10°C).

Average Temperatures:

THERMIC™: 26.1°C
Untreated: 21.1°C
Thermographic test

T-Shirt

THERMIC™ Untreated
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Applications

Bedding
- Mattress Interlines
- Mattress Ticking
- Mattress Protectors
- Quilts & Duvets

Apparel
- Underwear
- Hosiery
- Socks
- Sportswear
- Shirts
- Linings
- Work wear
- Fleece
- Jackets
- Hats
- Gloves

Footwear
- Shoes
- Boots
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Processing

- Classic application processes
  - Padding, Drying 140° C (284° F) 30sec
  - Exhaustion
  - Spraying

- Package of products
  - Microcapsules (P & G)
  - Catalyst
  - Softener
Differential Scanning Calorimeter (DSC)

- **Thermoanalytical equipment** that measures the **thermal transitions** that might occur in a material when it is subjected to a heating or cooling process, at a constant, pre-determined, velocity.

- When the PCM’s are subjected to a **heating process** the amount of energy breaks existing chemical links between molecules and it’s phase change temperature is achieved.

- This amount of **energy absorbed (or released)** is measured in terms of its **enthalpy value (J/g)** in the peak of the obtained thermogram given by the DSC.
Scanning Electron Microscope (SEM)

- Positioning of capsules on surface of fibre
- Linkage microcapsules-fibers
- Capsule morphology – size and shape
- Mechanical strength – intact capsules, none ruptured
- Demonstrates durability to washing
THERMIC™ Tracer Pen

First non destructive test

- The THERMIC™ treatment is provided with an invisible tracer
- Tracer lights up when illuminated with a IR laser pen
- Tracer only lights up at the right frequency
- Tracer pens are available at 200 €
- Tracer pens are meant for the post production supply chain
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Marketing Support

THERMIC
thermal intelligent comfort

powered by
Devan

THERMIC increases your comfort
by keeping you at a constant temperature for longer

powered by
Devan
Conclusions

- PCM have the capacity to absorb, store and release heat energy
- PCM controls the microclimate temperature keeping the body in the ‘comfort zone’ for longer
- Thermoregulation in textiles:
  - Enhances thermal comfort
  - Reduces perspiration
  - Enhance quality of sleep
- THERMIC™ – Reactive PCM Micro Capsules
  - No affect on fabric properties
  - Have a high wash durability
  - Greater thermal capacity
- Marketing support
- Technical support