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# Thermochromic materials and their suitability for smart packaging

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# National Institute of Chemistry
## Ljubljana, Slovenia

- Public research institute
- Basic and applied research on:
  - biotechnology,
  - environmental protection,
  - structural and theoretical chemistry,
  - analytical chemistry,
  - materials research, and
  - chemical engineering.
- Transfer of knowledge
  - to younger generations and
  - to industry.

# National Institute of Chemistry

- **Laboratory for Spectroscopy of Materials** (1982 - 2013)
- **Laboratory for Materials Chemistry** (2013 →)

  Three groups:
  - Modern battery systems
  - Coating development
  - Electron microscopy and catalysts

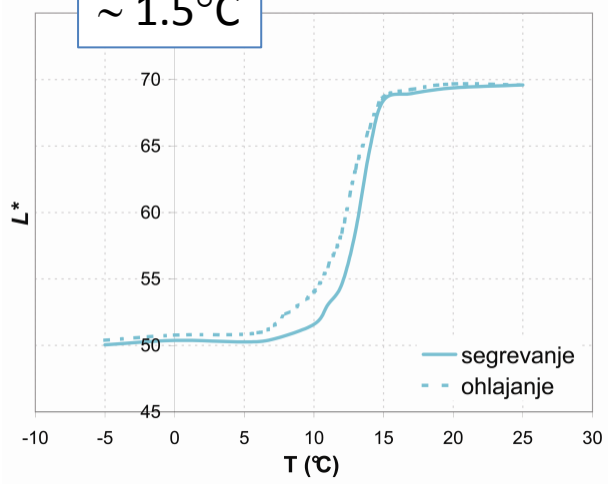
# Thermochromism

- Thermally induced transformation of material, that causes change of colour.
- Three origins
  - Reflection change
    - Liquid crystals with helical superstructure
  - Absorption change
    - Conjugated polymers
    - Inorganic pigments
    - Systems with leuco-dyes
  - Change of scattering
    - Thermotropic polymer systems

# Color hysteresis

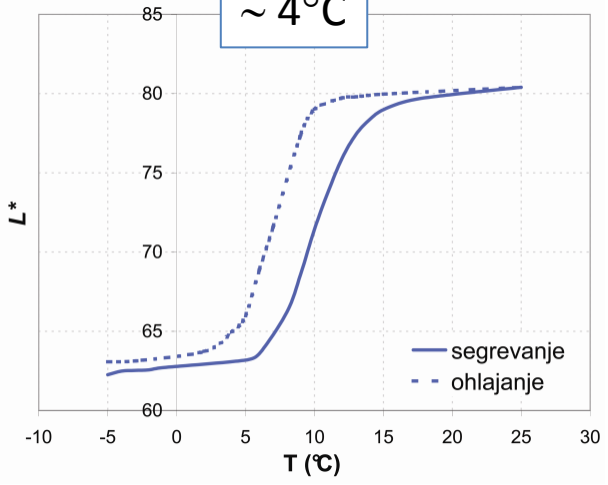
Discoloration occurs at higher temperature than recoloration
All states within hystereis are stable with time
The width of hysteresis loop is informationfor application

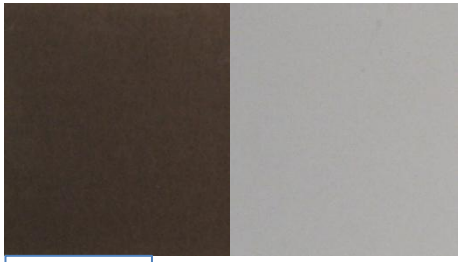

~ 1.5°C



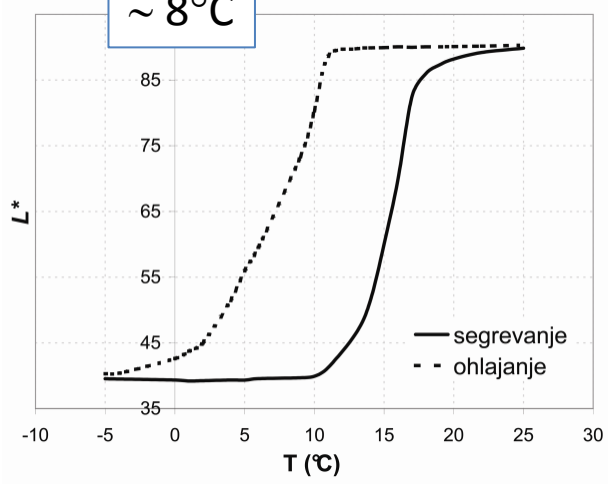


~ 4°C



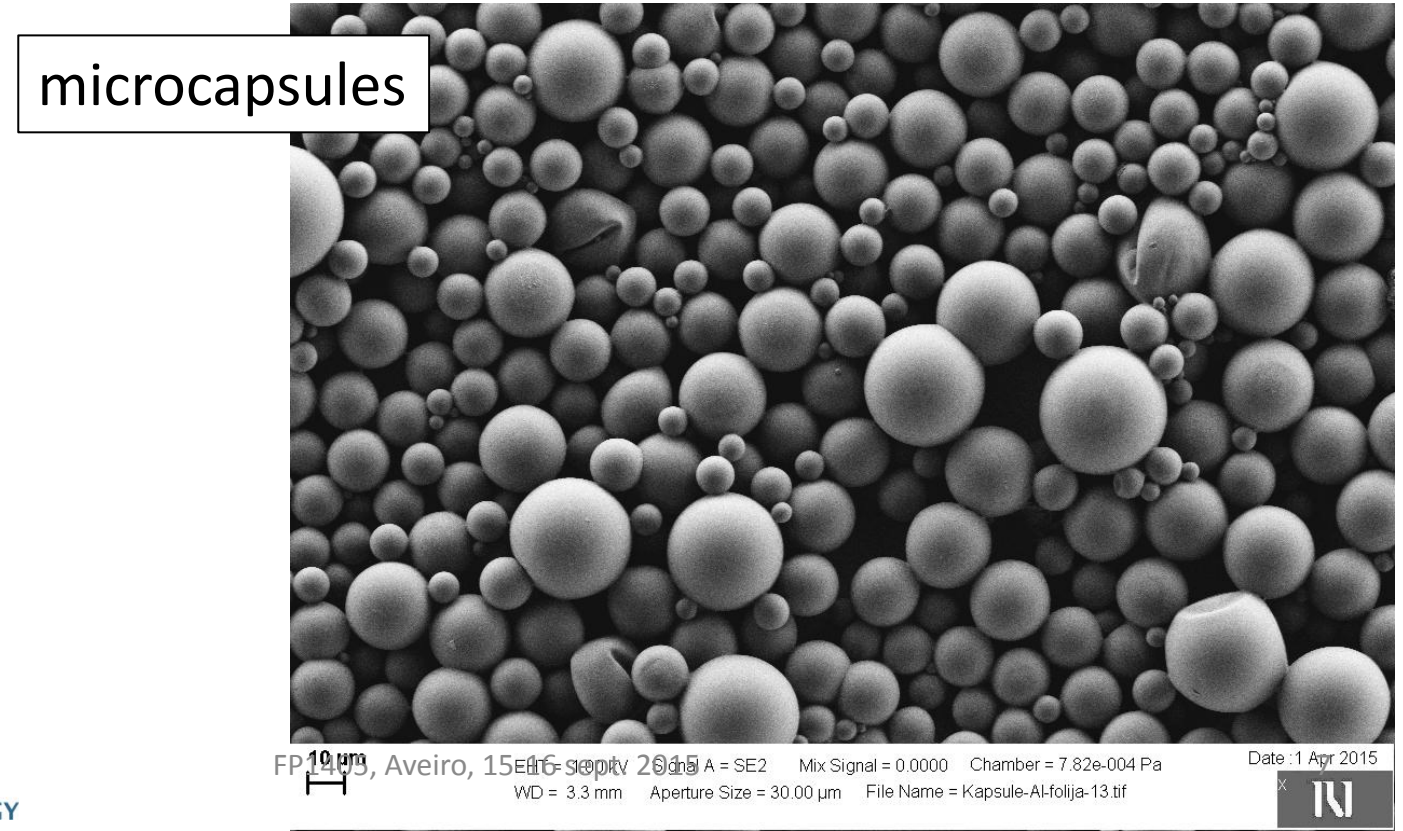



~ 8°C



# Thermochromic inks

- “pigments” in a suitable binder
- functional material = TC composite



# Temperature control / indication

Applications:

- Sterilization indicators
- Temperature indicators
- TTI – time and temperature indicators

These indicators apply a suitable active material.

Active material has temperature-dependent properties.

In many application the active material changes color.

The properties of the active material are changed at activation temperature. This is the most important characteristic property of the active material.

# Sterilization indicators

Indicate the quality of sterilization.

Types of sterilization:

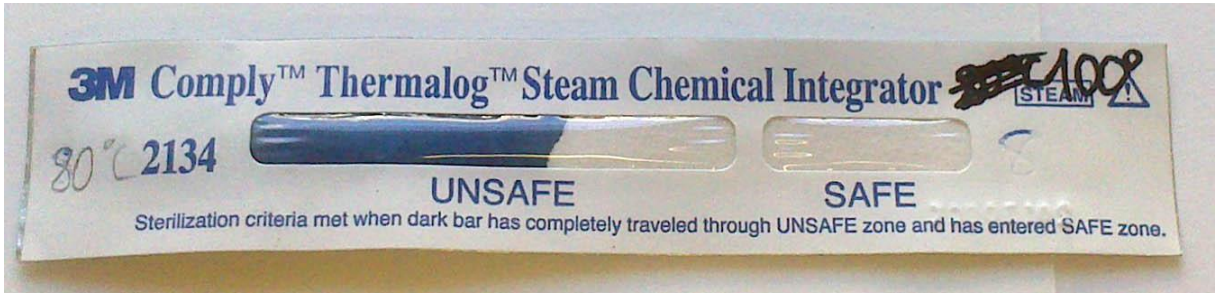
- steam sterilization
- dry-heat sterilization
- sterilization with ethylene oxide
- plasma sterilization
- sterilization with ozone or formaldehyde
- radiation sterilization

# Sterilization indicators

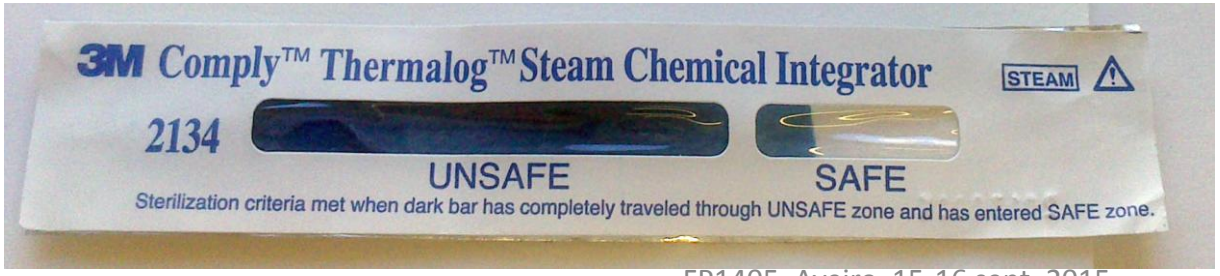

## Steam sterilization

Termalog (3M)

for 118-136°C steam sterilisation cycles (at least 10 minutes)



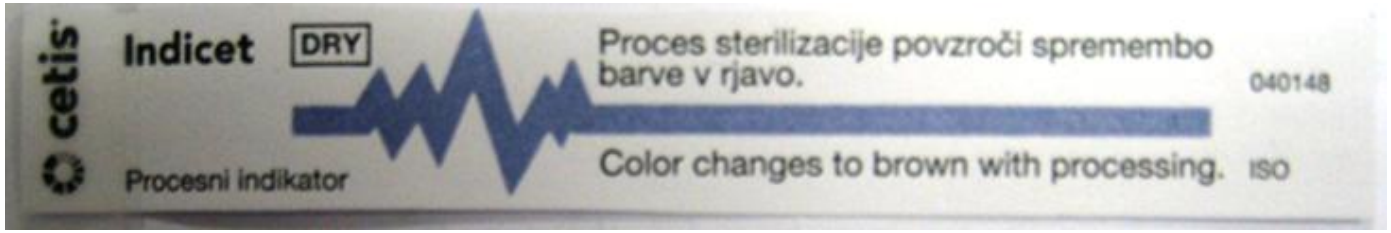

Not successful



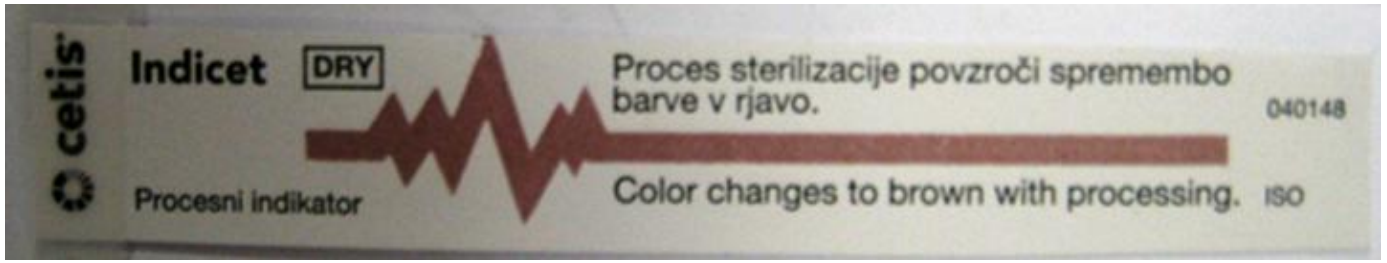

Successful

# Sterilization indicators

## Dry sterilisation (ISO 11140-1)




Before sterilization




After sterilization

Indicator is based on chemical reaction in the ink (change of color)

→reaction temperature is not defined very precisely

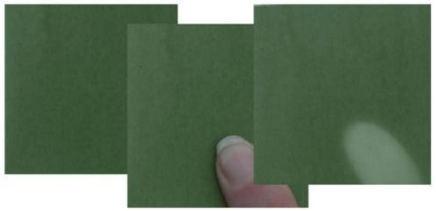
→may occur at lower temperature, but needs more time

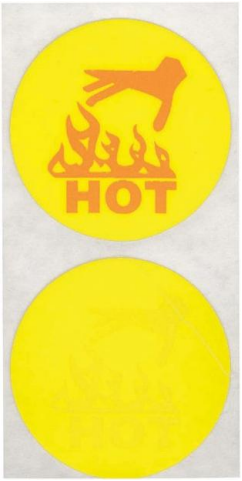
# Temperature indicators

## reversible temperature indicators

- thermochromic printing inks
- commercially available inks (leuco-dye based)
- show the current temperature of the object but not its history

several possibilities:

# Temperature indicators

## Irreversible temperature indicator


DeltaTRAK®
Total Cold Chain Management

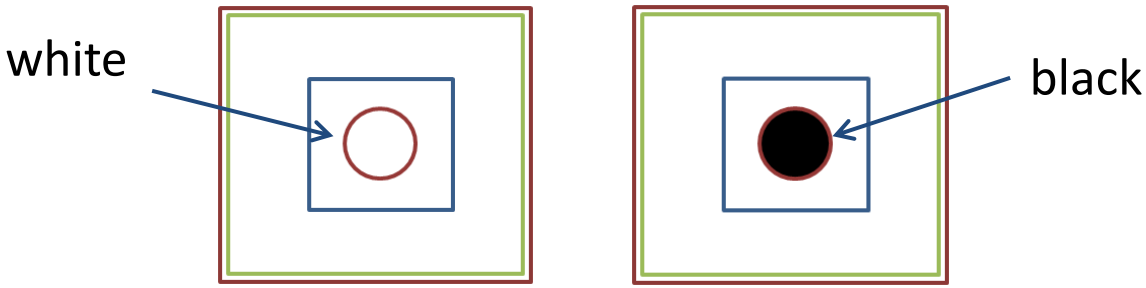
source: http://www.deltatrak.com/53146-54114-tempdot-thermolabels.phtml

the color changes from blue to orange if the surrounding temperature rises above the defined one (activation temperature, $T_A$)

# Temperature indicators

## Irreversible temperature indicators

Our work:




$T_A$ was not reached yet.

$T_A$ was reached and exceeded

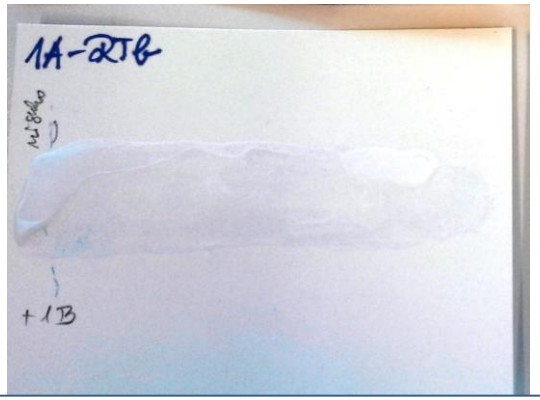
Current preparation possibilities
60 °C < $T_A$ < 80 °C, preciseness ~ 1.5 °C
the color change is detectable also in near IR

# Temperature indicators

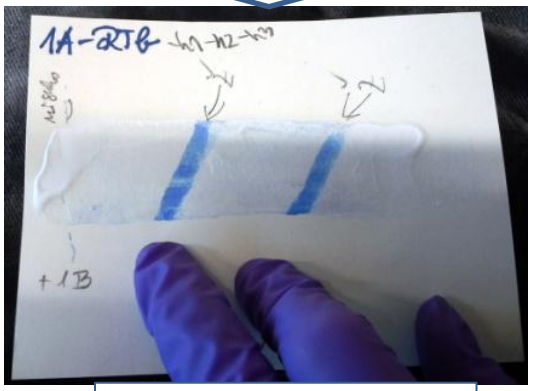
## Irreversible thermochromic ink

- not yet on the market
- $T_A$ < room temperature
  (for products in cold chain)

our work




Activated at T<<RT and placed at RT




Cooled at T << RT

## Advantages :

- Similar to “convencional” printing ink
- flexibility / thickness according to the substrate
- arbitrary graphic design

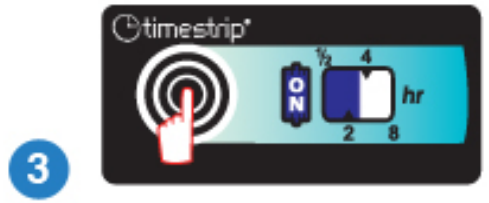
# Time and temperature indicators

## TTI: time-temperature indicator


activated by touching / pressing

→ the active material is enabled to move


when $T > T_A$ the active material moves in dependence on temperature and time




The acive material is colored

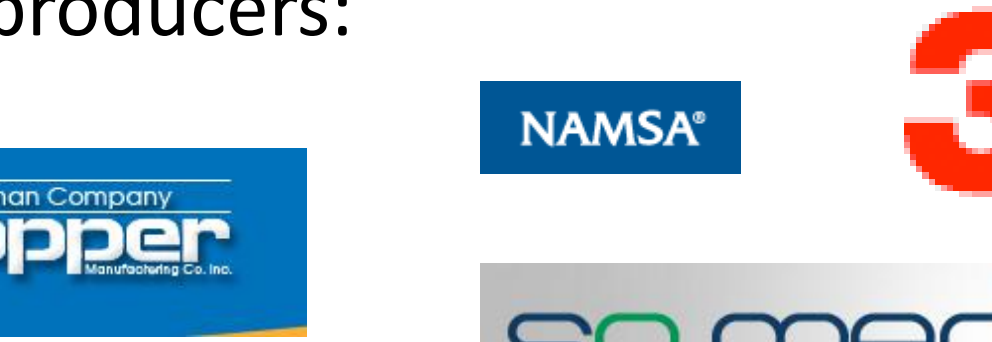
and cannot move back to the origional place if temperature lowers below $T_A$.

timestrip®

the smart way to measure time & temperature

# Time and time-temperature indicators

## Current producers:




SILTECH LTD
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http://www.proppermfg.com

http://www.siltechlimited.com

http://www.3m.com/

http://www.sterislifesciences.com

http://www.spmedikal.com

# Time and temperature indicators

## Our work

temperature control in the food cold chain

activated at room temperature

$T_{milk} > T_{refrigeration}$

placed in refrigerator

$T_{milk} < T_{refrigeration}$

# Irreversible temperature indicators

for low T applications:

paints, inks that should not be frozen

- food in cold chain
- medicine, farmacy

Plants in transport and warehousing

- ….


# Irreversible temperature indicators

Possible applications for other temperatures:

- Automotive industry
- Transport
- Technological processes – to controll the temperature of some processes
- Controlling of overheating

# Temperature indicators

## Current status of our work

- Optimised TC composites for -50°C < $T_A$ < 75°C
  - reversible, low-toxicity (food packaging applications)
- Encapsulated composites → inks
  - Reversible and irreversible forms
- Temperature indicators
  - Reversible, irrevesible, semi-irreversible
  - Preparation by printing technology
    - (labels, packaging)

COST Action FP1405
Active and intelligent fibre-based packaging – innovation and market introduction (ActInPak)

# Thank you for your attention

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