Color changing textiles: Active and passive

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Color changing textiles: Flexible displays

- Emissive Flexible displays:
  - Luminescence
    - EL luminescent structures LED, (OLED)
  - Optical Fibers integration

- Reflective flexible displays:
  - Electrophoretic
  - Chromisms
    - Visible optical properties modification (visible, UV, IR)
    - Provoked by an external stimuli (photo, thermo, electro, ...)
    - Reversible
1. Active colour changing textiles
   Light emitting

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Optical Fiber Fabric Displays  Vladan Koncar
Active colour changing textiles
Light emitting

Figure 1. Scanning electron microscope picture of OFFD structure (a two-layer basic-velour fabric).

Weaving optical fibres
Active colour changing textiles
Light emitting

(a)

Original optical fiber

(b)

Processed optical fiber

Figure 2. Principle of lateral light emission. (a) Original optical fiber; (b) processed optical fiber.

Light emitting laterally
Active colour changing textiles
Light emitting

Figure 3. Micro perforation obtained by mechanical treatment (particle projected on the cladding of optical fiber). Picture obtained by nanoscope.

Light emitting laterally, micro holes obtained by projection of particles
Active colour changing textiles

Light emitting

Figure 4. Micro perforations obtained by chemical treatment (solvent action on the cladding of optical fiber). Picture obtained by nanoscope.

Light emitting laterally, micro holes obtained by chemical solvent
Active colour changing textiles
Light emitting

Figure 5. Micro perforation obtained by chemical treatment (solvent action on the cladding of optical fiber). Picture obtained by scanning electron microscope.

Light emitting laterally, micro holes obtained by chemical solvent
Active colour changing textiles
Light emitting

Optical fiber screens provide access to simple and animated visual information, such as texts or pictograms.

Connections of OF beams to light sources (diodes)
Optical fibres flexible displays, micro bendings

Lateral light emitting obtained by OF bending
Textile Light Diffuser

• The confinement of light in an optical fiber is determined by the refractive indices of the fiber core ($n_1$) and the surrounding cladding ($n_2$).

• Total internal reflection occurs under the condition $n_2 < n_1$

• If the bending angle of the fiber is greater than a critical angle $\psi_c$, side-emission effect is created by “leaking” some light from the fiber’s core

• $\psi_c = \arcsin (n_2/n_1)$
Textile Light Diffuser

Figure 6. Transmission as a function of the bending angle $\gamma$, bending radius $R_0 = 4$ mm, $R_1 = 0.5$ mm, $\psi_c = 70^\circ$ and $\omega = 8^\circ$. Image of a bent fibre at $\gamma = 180^\circ$; cylinders indicate locations of first-order light emission at equivalent angles along the bend.
Textile Light Diffuser

Light distribution

- Coupling of light sources to both fiber ends improve uniformity of the light distribution.
Textile Light Diffuser

Weaving patterns play a major role. Patent pending.

Figure 8. (A) Weaving patterns frequently used in reinforcement fabrics for textile composites; (B) geometrical models of optical fibres integrated into the depicted fabric patches.
Textile Light Diffuser

• **Automatic Weaving Machine**
Textile Light Diffuser, Laser light source

Prototype INSERM U703: 20 mw/cm²
Textile Light Diffuser

Prototype INSERM U703: 20 mw/cm²

22.5 x 22.5 = 506 cm²
Textile Light Diffuser
LIGHT EMITTING FABRIC

2. Passive color changing textiles
Light reflecting
Electrochromism

- **Electrochromism**: ability of a material to change its color, in a reversible way, when an electrical potential is applied across it [3-5]
- Linked to oxidation-reduction processes
- Still very few used for textile applications
- Main advantages:
  - Reversible color change
  - Memory effect
  - Large color palette
  - Low power consumption
  - Large viewing angle
  - Reflective
Electrochromisme

• Rigid applications
  – Windows
  – Car equipments
Flexible applications

- 7 layer structure

Transparent substrate → Transparent electrode → Electrochromic material → Electrolyte → Ions storing layer → Electrode → Substrate

Electrolyte stores ions, which are transported to and from the electrochromic material to change its color. The transparent electrode allows light to pass through, while the transparent substrate supports the entire structure.
Electrochromisme applied to textiles

• Since 1976:
  – Textile = as substrate
  – Textile = as electrode
Electrochromisme applied to textiles

- 5 layer structure developed at GEMTEX
- Textile: multifunctional:
  - Contrasting
  - Substrate
  - Storing layer
  - Spacer
  - PET
  - ITO
  - Textile
  - + el chromic compound
  - + electrolyte
Electrochromism applied to textiles

1st generation displays

- **Prussian blue**

PET + ITO → Textile + Prussian blue (aq) → PET + ITO

- Fast aging (1 cycle)
- Liquid -> manipulation is difficult
- Spontaneous reaction -> storing is difficult
Electrochromisme applied to textiles 2\textsuperscript{nd} generation displays

- The use of PANI for fabric deep coating

On viscose yarns

On PET yarns

Film PET + ITO

Textile + PANI + electrolyte

Film PET + ITO

3V, 1 min
• El chromic polymers (polythiophènes)
• Electrolyte in sol-gel form
Electrochromism applied to textiles
3rd generation displays
Prototypes 3G
Prototypes 3G
Electrochromisme applied to textiles
3rd generation displays

EDOT and B-arylene EDOT electrochromic polymer films on ITO/glass
Simplified 3 layer EC textile displays:

4\textsuperscript{th} generation

- 3G
  - PT
  - 5 layers

- 4G
  - PEDOT:PSS
  - 3 layers

- 5G
  - PEDOT:PSS
  - 1 layer
3 layer textile EC structure:
4th generation

- 3 layers textile structure
- 100% textile
- Flexible

Textile substrate (PET, cotton, silk) coated by PEDOT:PSS
3 layer textile EC structure:
4th generation
3 layer textile EC structure:
4th generation

Mask, Indipendent electrodes
Flexible textile EC display
4th generation
Prototypes 4G
T shirt with embedded display and electronic circuit
Prototypes 4G
Prototypes 4G
3 layer textile EC structure: 4\textsuperscript{th} generation

- 3G: PT, 5 layers
- 4G: PEDOT:PSS, 3 layers
- 5G: PEDOT:PSS, 1 layer
1 layer textile EC display: 5\textsuperscript{th} generation

- All the structure is located in one single layer
- Fineness and thickness improved

- (PET, cotton, silk)
- 2 electrodes
1 layer textile EC display:
5\textsuperscript{th} generation
1 layer textile EC display:  
5th generation

PET fabric, voltagede 5 V,
1 layer textile EC display: 5th generation

Jersey cotton

PET
1 layer textile EC display:
5th generation
Concluding remarks

- Textile is an optimal support for electronics & displays
- Research is in an early stage
- Commercially available products may be expected on the market in 5 years
- Reliability & cost are important issues
- Further investments are necessary in R&D
Concluding remarks

• Opportunities in
  - fashion
  - communication
  - advertising
  - professional application
  - military camouflage