Wearable light management system for Light stimulated healing of Large area chronic wounds

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CSEM at a glance

Our mission
Development and transfer of microtechnologies to the industrial sector – in Switzerland, as a priority – in order to reinforce its competitive advantage

• Cooperation agreements with established companies
• Creation of start-ups
Outline

• Light stimulated healing of chronic wounds
• Miniaturized smart system for light stimulation and monitoring (MEDILIGHT)
• Building-blocks
• Wearable light management system
• Conclusions
Light stimulated healing of chronic wounds

Diabetic foot ulcer & Visible light therapy

• Large area chronic wounds caused by diabetes
  o Diabetic foot ulcer (DFU)
  o Affected people: 170 Mio worldwide
  o Costs: 40 billion € per year
  o Difficult to treat

• Therapeutic effects of visible light have been proven
  o Blue light (450-495nm):
    Antibacterial effects at the skin surface
  o Red light (620-750nm):
    Growth of keratinocytes and fibroblasts in deeper layers of the skin

http://www.americanfoot.com
SSL systems on skin: state-of-the-art

* Ambulight/Ambicare (melanoma)

** Bluetouch (back pain)
Bluecontrol (psoriasis)

* LUMI-HEAL/KLOX
Photoconverter gel & LED (chronic wounds)

* Photodynamic methodology

** Photobiomodulation methodology (as in MEDILIGHT)
**MEDILIGHT**

*Advanced wound healing*

- Fully integrated intelligent phototherapy band aid with
  - Embedded light delivery
  - Sensors integrated in the wound dressing
  - Electronic control module

- Temporal delivery schemes in accordance with the therapeutic policy
  - exploitation of the proven biological impact of light irradiation on skin tissues
  - In-vitro & in-vivo studies

- Highly integrated components – modularization

*Property of the MEDILIGHT Consortium*
Concept & Partners

**TU Berlin**
- Module:
  - Miniaturization
  - Robustness
  - Energy supply

**SignalGeneriX**
- Electronic System
  - Development

**U Heidelberg**
- Medical concept
  - Development
  - Application cases
  - Field testing

**CSEM**
- Light Management
  - Transmission
  - Distribution

**URGO**
- Band aid
  - Integration
  - Fabrication
  - Product roadmap

**Microsemi**
- Module:
  - Industrial manufacturing

**Microsemi**
- Electro-Optical System:
  - Industrial manufacturing

**TU Berlin & CSEM**
- Electro-Optical System
  - Coupling
  - Development

Property of the MEDILIGHT Consortium
Objectives

- **Disposable wound dressing** with integrated light structures & electronic sensors
  Target size = 13cm x 13cm

- **Highly integrated electronic module** (controlling & data acquisition)
  Target size = 5cm x 3cm x 0.7cm

- **Illumination schemes** for the optimisation of the light therapy

- **Wireless device & software**
  Recording the history of wound healing and provision of an individualised therapy

- **Testing**: In-vivo (pre-clinical) studies & first human trials

Property of the MEDILIGHT Consortium
Building-blocks

- Module & Electronic System
- Electro-optical System
- Light management
- Sensors
- Band aid
System design

The MEDILIGHT system consists of 2 components:

- Electronic module
- Wound dressing (disposable)

Electronic Module

- Rechargeable battery

Wound Dressing

- Flexible large area optical waveguide
- Light management structures
  - Diffraction gratings (incoupling)
  - Diffusers (outcoupling & beam-shaping)
Light management system

Diffraction grating (light incoupling)

Diffusing microstructure (light outcoupling & beam-shaping)

Length: 150-300mm

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Waveguide: Material selection

- **Target properties:**
  - high optical transmission
  - low scattering
  - good surface quality
  - highly flexible/bendable
  - insensitive to humidity (swelling, etc.)
  - easy to be embossed/injection molded

- **Different materials** were tested:
  PET, PMMA, PC, COP, etc.

- **Thick glass slabs** were adopted as optical reference

Example: Surface of a measured PMMA sample
Waveguide: Light scattering

COP (188um) shows the lowest scattering
Waveguide: Measurement set-up

Red light source + incoupling prism

Incoupling / outcoupling prism

waveguiding

sensor

guided light on sensor
Waveguide: Propagation losses

COP selected for its high optical transmission & insensitivity to humidity

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Incoupling gratings: RCWA design

- Calculated maximum diffraction efficiency in T-1 = 50% (at 440-465nm)
- Measured diffraction efficiency = 25% (deviation of the fabricated profile from the simulation model)

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<th>T-1</th>
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<td>14</td>
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Incoupling gratings: High-refractive index coating

Increasing the thickness of the high-refractive index coating

- The theoretical maximum diffraction efficiency was increased up to 70% at 10-20°
- The angle dependence is reduced (higher acceptance angle)

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Incoupling gratings: Fabrication

**Measurement**

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</tr>
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</table>

**Simulation**

Property of the MEDILIGHT Consortium
Incoupling gratings: Optimisation

**RED**

Angular evaporation of the high-refractive index coating

- Maximum efficiency for the $T-1$ diffraction order at **normal incidence** ($\alpha_{in} = 0^\circ$) with **high angular tolerance**

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Outcoupling diffusers
Light management: Status & Outlook

1. Total light guiding efficiency is currently comparably low

2. Homogenous illumination of the wound area

3. Waveguide shape: holes, «fingers», etc. allowing the wound to breath

4. Integration of sensors (temperature and oxygenation)

5. Possible alternative concepts to be evaluated
Conclusion & Roadmap

- **In Vitro** proof of concept (UHEI)
- Product Design
- In-vivo, Clinical Studies / Medico-economical study
- Regulatory / Health authority issues
- Industrial scale up

- **Time to market**: 4.5-5 years after MEDILIGHT
- First roadmap (to be updated)
- Value chain partners identified

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Thank you for your attention!

Acknowledgements: