Non-invasive sun protection factor determination using LED light

Outline

1. Introduction
   • UV light and its effects
   • What is the sun protection factor (SPF) ?
   • Current method for SPF determination
2. Materials and methods of our approach
3. Results of proof of principle studies
4. Conclusion and outlook on forthcoming system
Introduction
Introduction

Relative spectral distribution of sun irradiation near the equator

Wavelengths reaching Earth’s surface:
- UVB: (290 – 320) nm
- UVA: (320 – 400) nm
- VIS: (400 – 760) nm
- NIR: (760 – 3000) nm

Kochevar IE, Pathak MA. Dermatology in General Medicine, 220-229, 1999
Introduction

Action spectra for erythema and for previtamin D formation in human skin

UVB causes e.g.
- Sunburn
- Previtamin D production
- Tanning (by melanin synthesis)
- Skin cancer
Introduction

Action spectrum of the formation of free radicals in the human skin *ex vivo*

UVA causes e.g.
- Premature skin aging
- Increased melanoma risk

**Introduction**

*In vivo SPF test (current standard method)*

1. UVB irradiation applied at different doses
2. Evaluation of erythema 24h post irradiation
3. MED = minimal dose causing erythema
4. SPF = \( \frac{\text{MED}_{\text{with sunscreen}}}{\text{MED}_{\text{without sunscreen}}} \)
5. >10 test subjects per sunscreen required

⇒ FDA and EU call for non-invasive method
**Introduction**

**In vitro test**

- Spectroscopic transmission measurement
- Substrate with roughness similar to skin required
- Poor agreement on absolute scale e.g. due to other specific properties of skin
- Only successfully used to measure attenuation of UVA range (UVA-PF) relative to UVB range (SPF) if SPF is known a priori (ISO 2443:2012)

=>$\textbf{In vitro test could not replace the erythema based SPF test so far}$
Introduction

*Roughness of the skin*

picture of the skin surface

![Picture of skin surface with roughness](image)

![Height profile](image)

- 3 mm
Introduction

**light tissue interaction**

- Fresnel reflection
- diffuse reflection
- absorption
- collimated transmittance
- diffuse transmittance

Monte Carlo Simulation

Distance from incident light [µm]
Introduction

diffuse reflectance spectroscopy on skin

• Skin is the best substrate
• Transmission measurement is not possible in vivo on skin
• Diffusely reflected light is measured
• Spatial offset of illumination and detection => Light passes sunscreen layer twice
Materials and Methods
Method

Schematic of first functional sensor design

Fiber bundle

One LED at 308nm (0.6mW, FBH)
Methods

**Study I on porcine skin**
- Carefully cleaning of the ear
- 2 mg/cm² cream application (4 x 4 cm²)
- 30 min incubation time
- 30 measurements per area

**Study II on human volunteers**
- 2 mg/cm² cream application on the back of the volunteers
- Area = 10 x 10 cm²
- 30 min incubation time
- 30 measurements per area
Results

- Very good correlation with the results from the test institutes (SPF reference)
- Applicable for formulations containing chemical UV-filters only or in combination with particulate filters
- Samples with fluorescence disturb the SPF determination

Results

porcine skin compared to human skin at the forearm

- Comparison using three selected creams
- different slope compared to porcine skin
- Human skin shows lower backscattered signal

Is the back of the volunteers a better area?

each cream was tested on 6 subjects

![Graph showing SPF values for porcine and human skin.](graph.png)
Results

comparison of inner forearm and back

- comparison with three creams on 6 volunteers each
- the back provides higher signal

Measurements should be performed on the back of the volunteers
Results on human skin at the back of volunteers

- Very good correlation with the results from the test institutes
- Verification on 7 creams in total
- Repetition using an UVA LED is planned

Each cream was tested on 3 to 9 subjects
Conclusions

- Measurements using one LED at 308 nm showed already very good correlation to the results of the test institutes
- Applicable on porcine skin and human skin
- The back is more suitable than the forearm
- The method is non-invasive (no sunburn)
- Quick method (don’t need to wait 24 hours for the erythema formation)
- Possible fluorescence of the cream could interfere with the backscattered light

Spectrometer based set up is necessary
Outlook

New system with spectrometer

Spectrometer

multi-λ light source

Fiber coupling

Spectrometer

CCD

7 sensor subunits
Outlook

New light source which cover the whole UV range

8 LED simulate the sun UV radiation

Composed LED spectrum
Acknowledgments

Charité project team:
• Prof. Dr. Jürgen Lademann
• Prof. Dr. Martina Meinke
• Sabine Schanzer
• Susanna Kobylniski
• Dr. Maxim Darvin

Cooperation partner:
• Courage &Khazaka
• Hans Karrer GmbH
• Freie Universität Berlin, Fachbereich Wirtschaftswissenschaft

Thank you!

Weitere Informationen:
www.advanced-uv.de