WEARABLE UV/HEV LIGHT SENSOR AND SMARTPHONE APPLICATION
for personal monitoring and personalized recommendations.

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Prolonged exposure even to sub-erythemal UV doses has many associated risk factors, including skin cancer and photo-aging. Recent studies also indicate that high energy visible light (HEV) induces oxidative stress in the skin which is ultimately linked to visible signs such as pigmentation and aging. Personalized monitoring of UV/HEV radiation is necessary for recommendations of personal sun-safe behaviors. Here, we demonstrate a wireless, battery-free, miniature, wearable UV/HEV sensor that can be mounted on t-shirt, sunglasses, wristband, shoes or necklace. The sensor is the first electronic UV/HEV dosimeter that measures true cumulative UV/HEV exposure that is directly comparable to skin exposure. It also operates as a personalized digital skin coach that provides user with actionable data and recommendations to improve skin health. We run several clinical evaluation studies to demonstrate functionality of the sensor. One study involved healthy volunteers engaged in recreational activities. Subjects wore devices on the thumbnail or the middle fingernail, while they participated in causal activities including playing games, showering, swimming with use of skin care product. Another study demonstrated that measurements from different body locations can be used to extrapolate total body UV/HEV exposure. The studies demonstrated sensor accuracy, reliability, and versatility. They also showed that measurements of UV/HEV exposure from different body locations can be used for reliable estimations of personal UV/HEV exposures.

Figure 1. UV/HEV Sensor communication schematics

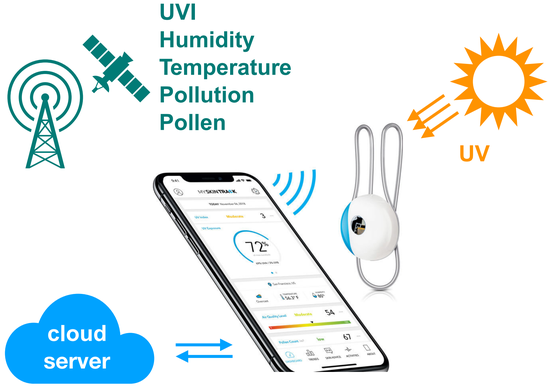


Figure 2. Sensor Architecture

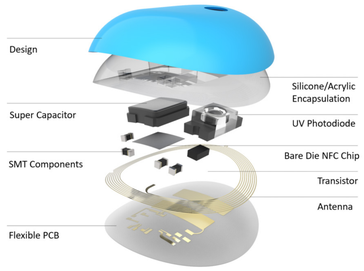


Figure 3. Sensor Characterization:

a) UV sensor response to EMS demonstrates peak intensity response to 360-380 nm wavelengths.

b) HEV sensor response to EMS demonstrates peak intensity response to 400-480 nm wavelength.

c) UV sensor response to different UV intensities x time *(total energy)* demonstrating linear response.

d) HEV sensor response to different HEV intensities x time *(total energy)* demonstrating linear response.

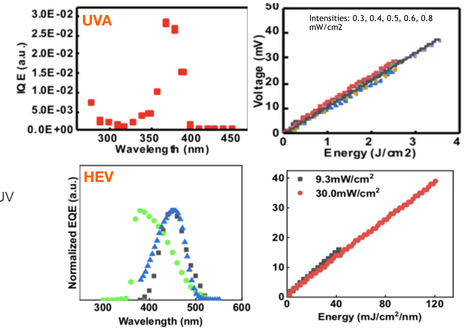


Figure 4. Study demonstrating sensor readouts from different body locations.

Objective: determining relative UV doses at different body locations.

Study summary: 20 subjects;

6 sensors per subject

Sensor Locations:

top of head, sunglasses, collar, sleeve, wrist, and shoes

Study design:

The subjects performed different activities during 3 days of the study.

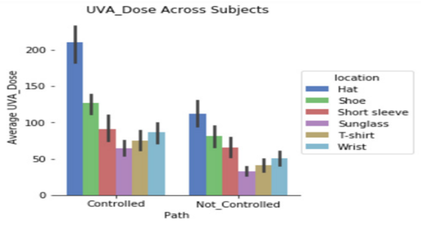
Day 1: Controlled Walk

(morning, noon, afternoon)

Day 2: Free activities at beach

Day 3: Free activities at city park

Figure 5. Study Results: average relative UV doses measured at different body locations



CONCLUSION

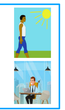
The sensor attachment location has large effect on the sensor readouts. However, the relative differences between different sensor locations were relatively constant for different subjects. Therefore, it is possible to provide estimates for exposures at different body locations from single sensor locations

Figure 6. High Energy Visible (HEV) Light Exposure on Subjects with Different Lifestyle

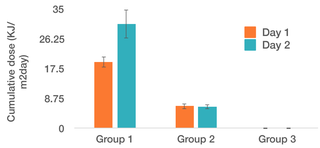
Objective: Comparing HEV exposures from solar light and indoor light sources, e.g. lamps, computer and tablet screens

Group 1 (N=10)
Exposure to Solar light
Day 1 - Controlled walk
Day 2 - Free walk
(direct sun and shade)

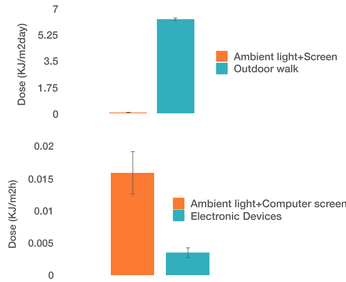
Group 2 (N=10)
Combination of outdoor & indoor
Day 1 – Indoor + Outdoor walk
Day 2 – Indoor + Outdoor walk
Indoor –> lamps and electronic devices



Group 3 (N=10)
Exposure to electronic devices only
Days 1& 2 – Exposure to electronic devices in minimally lightened setting



- Group 1 exposed to sunlight showed significantly higher levels of HEV accumulation per day *(Group 1>Group 2> Group 3)*



- Sun exposure contributed to high levels of HEV dose for group 2
- Ambient light+ computer screen is lower but measurable by the sensor
- HEV from ambient light + computer screen > electronic devices
- Very low intensity of HEV light emitted by electronic devices

CONCLUSION

- **HEV exposure varies in different lifestyle conditions with solar exposure being the major contributor followed by ambient exposure**
- **Blue light device enables continuous monitoring of HEV light exposure**
- **Electronic devices emit very low intensity HEV light**
- **Next Steps:**
  Controlled exposure to HEV doses to measure clinical end points for photodamage by:
  - Pigmentation changes
  - Biomarker analysis

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