UV measurements for medical applications using SiC photodiodes

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Abstract

In this contribution we report about SiC based UV photodiodes as the core component of smart UV sensors for various medical applications. In dialysis machines the transparency of urea is monitored by a SiC UV photodiode based UV transmission measurement module. A photodiode combined with an optical filter which reproduces the erythermal action spectrum helps Lupus patients to monitor their daily dose of solar UV radiation. sglux UVC sensor "UV-Safester" is a smartphone based tool to detect harmful UV radiation at a workplace employing the ICNIRP regulation. A wireless UV sensor module monitors the UV disinfection applied by disinfection robots in operating rooms.

1. Introduction

Ultra-violet (UV) radiation is harmful for human skin and eyes as it can cause erythema or damage the DNA causing cancer. Protection against natural sun light and artificial UV radiation sources is necessary. On the other hand UV radiation is a handy tool:

- UVC radiation efficiently sterilizes water, air and surfaces
- UVB radiation is used to treat certain skin diseases such as psoriasis
- UVA radiation cures the cure inks in high volume printing systems
- UV absorption is applied in online measurements for process control

Therefore sensors measuring the UV irradiance are obligatory either to protect humans or providing valuable information. In the following we will discuss the fundamentals of UV radiation measurements and our solution for a digital sensor. We complete this contribution by presentation of applications UV sensors in the medical sector.

2. Measuring UV radiation

2.1. UV radiation

UV radiation is electromagnetic radiation with a spectral range between 1 and 400nm. In the following will we speak about UVA (315-400nm), UVB (280-315nm) and UVC (200-315nm) radiation as defined by ISO-21348 (Figure 1). Natural suns radiation consists of about 3% UV radiation. The major part is UVA radiation (about 95%) and the reminder UVB radiation. UVC is absorbed by the atmosphere especially by the ozone layer. However, the skin is most sensitive to UVB radiation. Typical UVC radiation sources are low pressure mercury discharge lamp.-

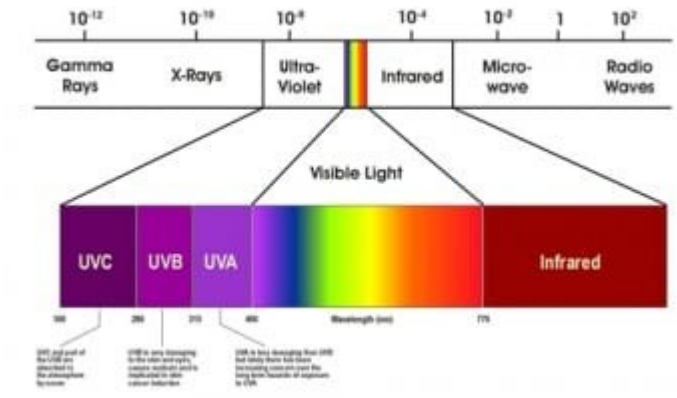

Figure 1: Definition of UVA, UVB and UVC spectral range.

In contrast to visible light, which is measured in the photometric unit candela, the radiometric unit irradiance in watt per square meter has to be measured by UV photodetectors.

2.2. SiC based UV Photodiodes

Such UV photodetectors have to be made by materials which do not degrade due to high energy radiation. They should be radiation hard to provide long lasting reliable measurements. SiC has been proven as a qualified material as it is radiation hard in contrast to III-V compound materials such as AlGaN. The bandgap of 3.26eV of SiC provides photodiodes with low dark currents and visible blindness, an advantage over Si-based photodiodes.

In Figure 2 a typical spectra response of SiC pin-photodiodes is given. SiC is able to detect UV radiation within the spectral range of UVA, UVB and UVC.

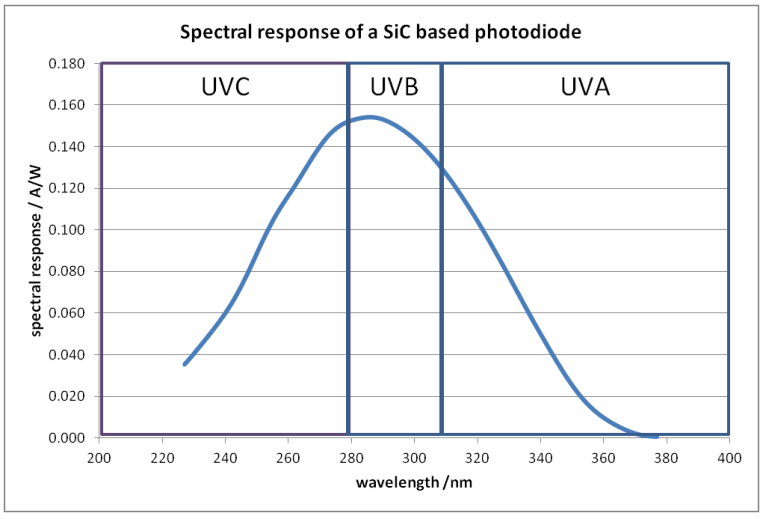

Figure 2: Spectral response of a SiC photodiode.

To determine the UV irradiance or dose at a certain point of interest it is necessary to calibrate the UV detector. This calibration is performed by measuring the emission spectrum of a UV radiation source with a traceable calibrated radiospectrometer and calculating the irradiance by integration. The irradiance value divided by the signal output

of the UV detector provides the calibration factor. The detector signal is always the convolution of the emission spectrum of the UV source and the spectral response of the sensor. Thus a calibration of a sensor is only valid for a certain combination of source spectrum and UV sensor.

2.3. Digital UV Sensor

sglux developed a variety of digital sensors which employ SiC-based photodiodes. The key of the digital sensors is a smart definition of the sensor parameters which are stored within the sensor. The digital sensor not only delivers a digital signal but contains information such as serial number, sensor type, and production as well as calibration date and up to five calibration values. This allows the usage of one sensor for different applications. As standard communication protocol the Modbus protocol is employed.

3. APPLICATION OF SIC BASED UV DETECTORS

3.1. Process control in hemodialysis

SiC photodiodes are embedded in many systems as process control monitors. An interesting medical application is the control of a dialysis machine. As described in [1] the UV absorbance of solutes in spent dialysate is direct proportional the urea concentration in the blood and can be used for real-time monitoring the Kt/V value, which is en indicator of the cleanness of the blood. The system measures the transmission of 280nm UV LED radiation with an SiC photodiode in an daylight enviroment.

3.2. UV index sensor

As mentioned before natural sun light contains UVA and UVB radiation. The detrimental effect of UV radiation on human skin is described the erythemal action spectrum. In short terms, UVB radiation is weighted much stronger than UVA radiation as UVB is much more harmful. The World Health Organization and the World Meteorological Organization defined the so-called UV Index to provide a simple measure for the danger of suns' UV radiation. The convolution of the suns irradiance spectra with the erythema action spectrum give times 40 is the UV index as defined in the ISO 17166. By employing an interference filter which imitates the erythemal action spectrum before the SiC photodiode we are able to built a UVI radiometer. The start-up Shade [2] integrates such sensors within their small and easy to wear UV detectors. The aim is to provide Lupus patients with dose information which allows them to participate in social live. Lupus patients have a much more limited exposure time to UV radiation. By measuring the suns weighted UV irradiance Shade smartphone-based software helps the costumer to control its personal exposure time.

3.3. Process control in cleaning robots

UVC radiation with a wavelength of 254nm efficiently damages DNA in bacterial in viruses thus hindering the propagation. Therefore UVC radiation is used in many applications to sterilize surfaces, air and water. The effectivity of disinfection depends on UVC radiation dosage. The measurement and documentation of the applied dose is

obligatory for the operator of such systems. In hospitals operating rooms UVC radiation disinfection is an alternative to chemical cleaning. The amount of chemical agents is reduced and the development of resistant bacteria is reduced. In such application mobile UV dosage sensors are convenient to measure the applied UV dosage.

3.4. Workplace safety sensors

Next to the erythema action spectrum for effect of sun light in human skin there is a more general approach by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) to describe the effect of UV radiation on human eyes and skin. ICNIRP issued a regulation which provides a calculation routine to determine maximum exposure time per day depending on the specific spectrum of the UV source employing the so-called ICNIRP action spectrum as described in [3]. In any situation where for instant UVC radiation is used for disinfection, workers must be protected and maximum exposure time per day should be determined. A simple way of measuring the maximum exposure time provides sglux' UV Safester UVC (Figure 3).

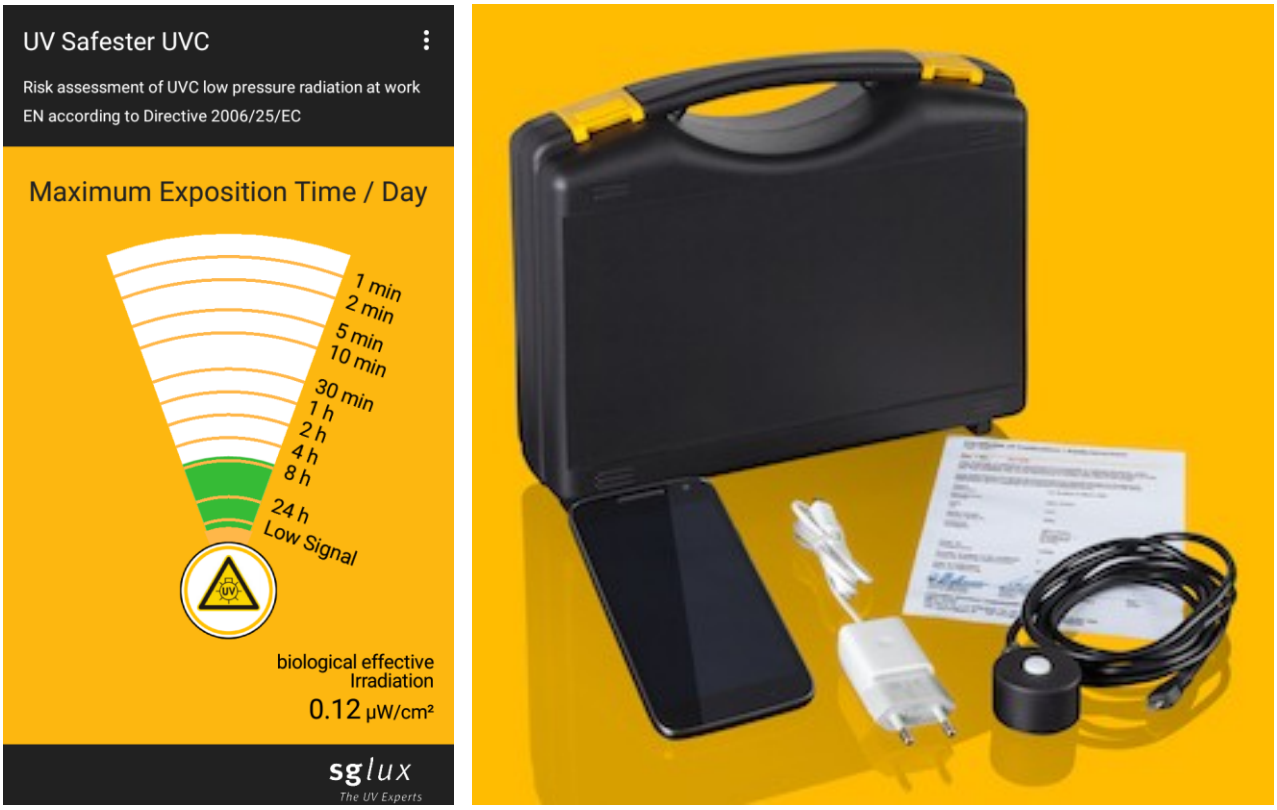

Figure 3: sglux' UV Safester. left: Screenshot of the UV Safester App. right: The UV Safester comes with smartphone, detector head and calibration certificate.

A digital detector head with a UVC filter and cosine corrected entrance optic is coupled with the smartphone App UV Safester. UV Safester calculates from the measured weighted irradiance a maximum exposure time and gives a signal if radiation is too high.

4. SUMMARY

In this contribution we presented applications for UV sensors. sglux' digital sensors allow

an easy connection to computer controlled applications and enabling such sensors for the Internet of Things. In the case of UV index sensors and the workplace safety sensors an integration to networks is doable and desirable to provide a global measurement of harmful UV radiaiton.

REFERENCES

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