# Development of Silicon- on- Insulator (SOI) UV Sensor IC

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The skin care product market is expanding due to the threat of ultraviolet (UV) rays caused by the destruction of the ozone layer[1], provoking a sense of alarm regarding sunburn and following television commercials in which the cosmetic products market presents methods to counter ultra-violet rays. Due to such circumstances demand is also rising for UV sensors, which can play a role in skin care by providing measurements of ultra-violet light intensities. The sensitivity of individual photo diodes fluctuates greatly in UV sensors currently available on the market, inhibiting a wider popularity of such sensors. For this reason OKI developed the "ML8511", a new UV sensor IC that reduces fluctuations of the sensor, through the integration of the sensor and peripheral circuit onto a single chip. The photo diode of the sensor on the "ML8511" is formed based on a thin-film silicon-on-insulator (SOI), giving it the capability to convert the output current from the UV sensor to the voltage, which is easily handled, using a built-in operational amplifier on the same chip. Furthermore, by calibrating the circuit section, according to the fluctuation of individual sensors, before the product is shipped, also makes it possible to unify sensitivity on a level that never existed before. The ML8511 does not use any expensive compound semiconductors and there is no need for any external circuitry, which is the reason it requires fewer parts and components for mounting.

## Ultra-violet (UV) light and UV sensors

UV sensors, which convert light (photons) into electric current, are elements highly sensitive to the wavelength of light in the ultra-violet region. Ultra-violet light is classified as "UV-A", "UV-B" and "UV-C", depending on the wavelength and as the wavelengths become shorter more damage is caused to life forms. These sensors are used in industrial applications as light source monitors for equipment that sterilizes using UV-C with a short wavelength. Sensors used in our daily lives are primarily intended for detecting UV-A and UV-B ranges with longer wavelengths from UV light that is included in the sun's rays. The UVIndex[2], recommended by the World Health Organization (WHO), which indicates the intensity of UV light on a standard scale, is an example that indicates the degree of danger from exposure to the sun.

Compound semiconductors with gallium nitrides have been used with conventional UV sensors. It is more difficult to mount a UV sensor and a peripheral circuit on a compound semiconductor than it is to incorporate them into the silicon process. Furthermore, the use of silicon in bulk resulted in a wider sensitivity that covers the UV range through to the infrared range, making it necessary to use a filter (optical filter) to cut out infrared light, which raised the issues of lowering costs and unifying the sensitivity of photo diodes.

At OKI we focused our attention on the spectral sensitivity characteristics of a thin-film SOI structure and we have been researching and developing their application in optical sensors. We were able to develop a mass production process for sensors that have enhanced sensitivity characteristics in the UV range. The adopted SOI-CMOS technologies are silicon processes and are essentially technologies that have been implemented in the past to increase the integration of circuits and lower electrical power consumption. For this reason it is possible to readily load a combination of a UV sensor and peripheral circuit, which is a difficult feat with compound semiconductors.

## Outline of SOI UV sensor

The spectral sensitivity characteristics of photo diodes used in ML8511, which are based on thin-film SOI, are shown in **Fig. 1**. Although this is a silicon photo diode it is highly sensitive, selective only to the UV-A (wavelengths of 320 to 400 nm) and UV-B (wavelengths of 280 to 320 nm), due to its SOI structure.

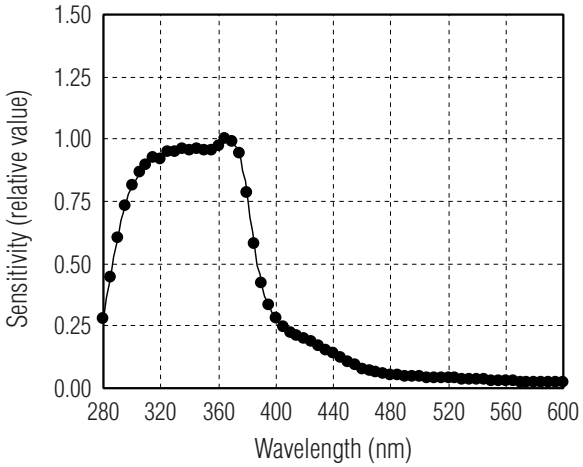


**Fig. 1 Spectral sensitivity characteristics**

## Block structures of ML8511

An example of a structure for UV meters, using ML8511, is shown in **Fig. 2**. The UV sensor shown in the figure is a photo diode that uses a thin-film SOI. Electric

current proportional to the UV light intensity is output from the photo diode. Voltage proportional to the amount of electrical current is output by a current-to-voltage conversion amplifier, comprised of an operational amplifier and resistor, Rf. The output voltage can be linked directly to the analog-to-digital converter (ADC), where it is converted into a digital signal and input into the micro-controller unit (MCU) via an interface (I/O). The amount of UV light corresponding to the output value is converted by the MCU and shown to the user in figures on a liquid crystal display (LCD). Furthermore, an "Enable" (EN) pin is incorporated to reduce the electric current consumption when the equipment is not taking measurements (Standby mode). The gain of current-to-voltage conversion amplifier is adjusted according to the sensitivity of individual UV sensors during testing at the manufacturing plant in order to reduce fluctuations in the sensitivity relating to the intensity of UV light and output voltage.

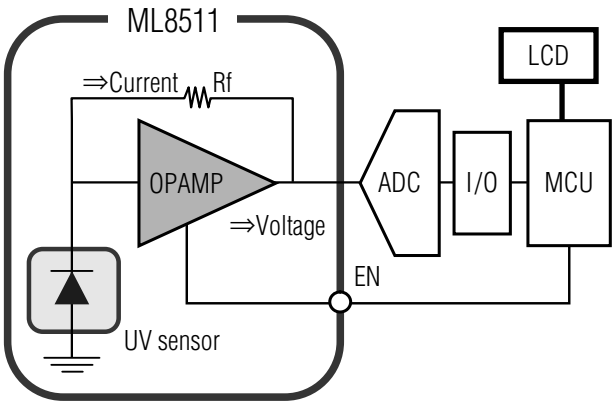


**Fig. 2 Example of configuration for UV meter using ML8511**

## Main specifications of ML8511

The main specifications of ML8511 are indicated below and its external appearance is shown in **Photo 1**.

- Wavelength of maximum sensitivity: 365 nm.
- Power supply voltage: 2.7 to 3.6 V.
- Electric current consumption: Typically 300 μA (operation) and 0.1 μA (standby) at 3.0 V.
- Output voltage: 1.0 V (dark room) to 2.2 V (10 mW/cm$^2$ at 365 nm).
- Recommended temperature range: 0 to +70 degrees Celsius.
- Package: 3.7 × 4.0 × 0.73 mm, QFN.

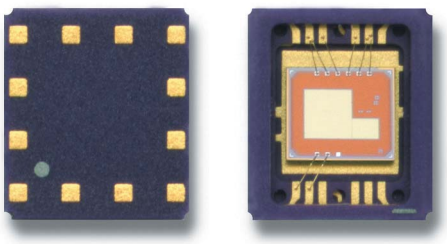

**Photo 1 QFN package (pin pitch: 1.0 mm)**

## Future development of SOI UV sensor ICs

The development of UV sensors in the future will require enhanced family ICs and developed application software to provide UV intensity information that can lead to peace of mind and satisfied customers.

In order to respond to the market demand for mobile devices, digitization is further promoted with family ICs by integrating ADC and I/O, shown in **Fig. 2**. Furthermore, various sensors that can be integrated and peripheral circuits will be incorporated to continually raise the level of functional sophistication.

Two application software groups are being considered, one for short-term applications and the other for long-term applications. Those used for short-term applications make it possible to display the information necessary for users to make decisions on the spot, such as the calculation of the UV index. Others used for long-term applications are critical items, since damage caused by UV light is accumulated over days. One such application may be the display of the amount of UV light received over a period of one day to a week, which can be read with a glance, providing information that is useful as a reference for skin care.

## Conclusion

OKI developed "ML8511", a UV sensor IC, using the SOI-CMOS technology to provide analog voltage output, a feat ahead of the rest of the world, without optical filters. A peripheral circuit is mounted on the same chip with the ML8511 and its characteristics prevent sensitivity fluctuations using circuit control. We intend to launch highly value added product groups on the market by integrating sensors and peripheral circuits in the future in our efforts to expand the market for UV sensors.

## References

1) Tsutomu Sugahara and Keiichi Nozu, Ultra-violet Light of the Sun and Health, Shokabo Publishing, pp. 13 to 21, 1999.
2) World Health Organization, www.who.int/uv/health/en/.

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