Above 0.6 A/W responsivity for 1064 nm – a new benchmark in infrared vision

The latest generation of First Sensor's Series-Q infrared photodiodes are one step ahead of nature. The new design of silicon photodiodes offers a unique combination of responsivity and response time.

Fig. 1: Possum enjoying supper

When catching sight of a mammal of the night, all one can usually see is a pair of bright glooming eyes that grants one a quick glance before disappearing into the darkness once again. This remarkable effect is known as "eyeshine" and can be found for various animals that are in need of enhanced night vision.

The biologic eye is hampered by the same handicap that is also known to designers of semiconductor based photodiodes (PDs). The absorption coefficients of reactive dyes in the retina are too low for catching all photons. Night active mammals have developed their own solution to this problem. Behind the retina there is a reflective layer of tissue known as "tapetum lucidum". This mirror reflects those photons that have passed the retina without having interacted with the receptors. Accordingly they travel a second time through the photoreceptors which gives them twice the chance of being absorbed. This mirror coating is also widely used in semiconductor PDs which are optimized for infrared (IR). Therefore the back of the detector chip is usually covered with a reflective metal. When taking a look at the Possum above one can easily see the limits of this invention. A considerable amount of light passes the active layer a second time without being caught by a receptor. What can give us a good scare at night is actually the light which is lost to the animal's vision.

For designers of PDs there are other ways to increase the efficiency of the detectors. One can choose materials with higher absorption coefficients or aim for thicker chips. For a wavelength of 1064 nm, the compound semiconductor InGaAs (Indium Gallium Arsenide) has a much higher absorption coefficient than silicon. Yet, these detectors usually come at much higher prices and with far higher dark currents.

While in nature the thickness of the retina and the dye concentration are limited by physiological constraints, the thickness of PDs is limited by the requirements for speed. Each 100 µm of thickness adds one additional nanosecond to the response time. This is due to the travelling time of charge carriers produced by the absorbed light. Where every nanosecond of rise time counts designers want to use chips as thin as possible. Having thin and fast chips is of course in contradiction to the requirements for high sensitivity. The table below gives an overview of different die thicknesses and responsivities.

Material / Design	InGaAs	Si	Si	Si with mirror coating	SIS series-Q: diffuse reflector
Die Thickness	300 µm	350 µm	500 µm	350 µm	380 µm
Responsivity at 1064 nm	0.70 A/W	0.25 A/W	0.33 A/W	0.42 A/W	0.64 A/W

Engineers at First Sensor have discovered a unique way of bringing together speed and quantum efficiency. Instead of a flat mirror, a diffuse reflective coating is applied to the back of the device. Light is not reflected straight back but at various angles back into the silicon. Instead of loosing light by reflecting it straight to the front a good amount of photons are trapped in the device by multiple total reflections. This leads to near total absorption (figure 2). With this feature SIS can provide outstanding products for high performance applications. For the first time one can obtain ultimate sensitivity with lowest noise levels and short response times.

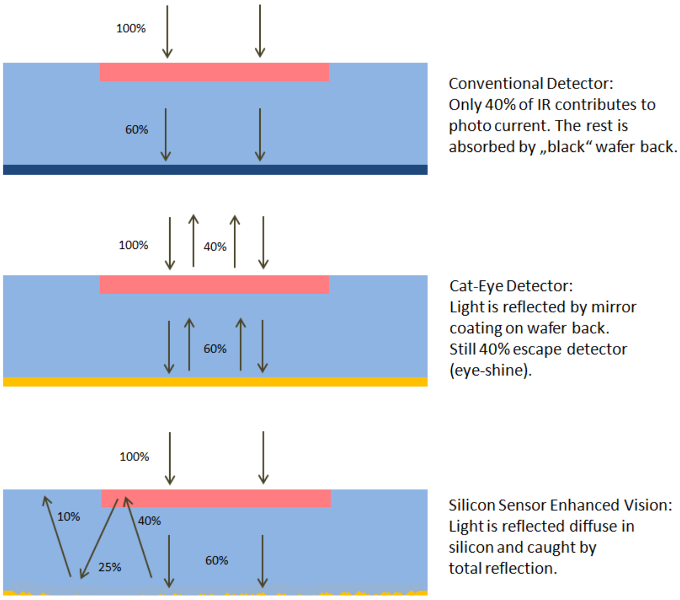

Fig.2: Mechanisms of IR absorption in Silicon

The graphic below shows comparisons between First Sensor's Series-Q IR-Diode vs. the latest IR-enhanced PDs available on the market. One can see that the responsitivity of the SIS device at 1064 nm is more than 5% above the performance of the market's leading product, guaranteeing optimized performance for this critical wavelength.

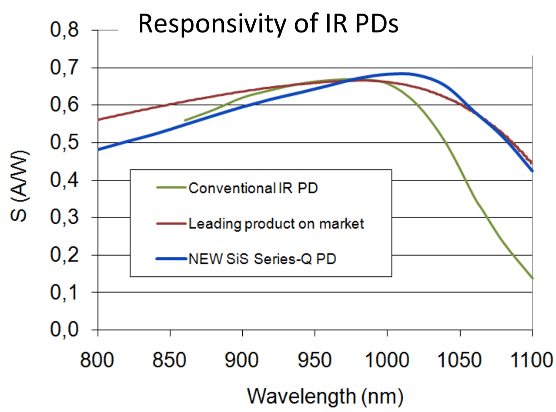

Fig. 3: Responsivity curves in comparison

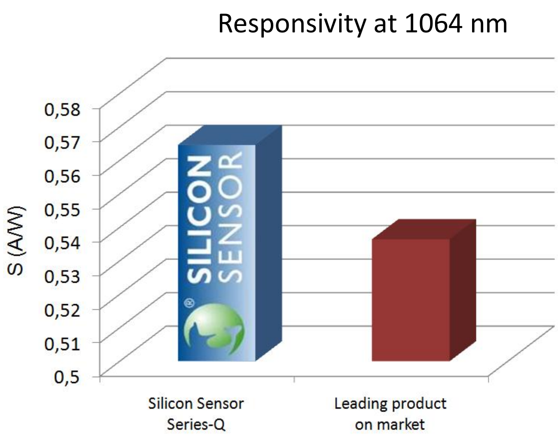

Fig. 4: Responsivity of packaged device (TO5)

First Sensor provides cutting edge technology for sophisticated sensor applications. Perhaps the felines envy First Sensor already for its night vision capabilities. For full details and customization options feel free to contact First Sensor at sales.opto@first-sensor.com.

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