Developing the next generation of passive infrared security sensors

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A novel microbolometer technology could replace the infrared sensors in industrial and home security systems, providing longer detection range, intelligent electronic readout, and an imaging capability.

Although the ubiquitous pyroelectric passive infrared (PIR) security sensor is reliable and cheap, and can be purchased from supermarket and hardware stores for under $100, the technology is decades old. These sensors have short detection range, typically 10–15m for human targets, are prone to false alarms, and possess limited capability for distinguishing people from pets or other animals. In addition, they cannot detect temperature changes such as occur with a developing fire or a failing electrical appliance. Modern infrared technology, although vastly superior in performance, is costly. Novel sensor design concepts are needed to challenge the high-volume PIR security sensor market.

Surprisingly few efforts have been made that specifically target either the low-cost PIR security sensor market or other high-volume consumer products that require short-range target detection, such as motor vehicle anti-collision sensors and human traffic monitoring systems. Players active in these fields include RedShift Systems in the US, InfraRed Integrated Systems in the UK, and the Swedish firm Acreo. By and large, although the infrared industry is forever increasing performance, modest capacity is adequate in applications for which detection range is at most 50m. Our company, Electro-optic Sensor Design (EOSD), a consultancy that specializes in design and development of PIR sensors, is pursuing a new patent-pending initiative that combines novel microbolometer detector concepts with low-cost optics, simplified packaging, and efficient electronic readout to achieve substantially enhanced performance at affordable cost.

Microbolometer focal plane array (FPA) detectors, commonly employed in IR sensors, are usually vacuum packaged for high performance, which impacts the cost of fabrication. Our initiative enables packaging at atmospheric pressure using high-volume micro-circuit processing. In its simplest form, the technology can be implemented as an upgrade to current PIR sensors, offering extended detection range and fire detection capacity. However, the primary objective is to develop a smart sensor capable of target recognition, high detection confidence, target counting and direction of movement, data storage and playback, and imaging display. Optional vacuum packaging and the use of a chalcogenide glass lens results in exceptionally high detective performance, approaching that of cryogenically cooled photodetectors. This suggests further possible applications, including low-cost medical imaging, short-range fire fighting, and pedestrian detection cameras.

It can readily be shown4 that to achieve a similar value of pixel sensitivity, expressed as noise-equivalent temperature difference (NETD), of an FPA operated in air compared to that in vacuum, we need to minimize the value of:

$$\zeta = \frac{V_n}{\text{Ad} \cdot V_d}$$

(1)
where $V_n$ is total noise voltage, $A\delta$ is the pixel area, and $V_d$ is detector bias voltage. We reduce detector noise using mosaic pixel FPA (MP-FPA), whereby a pixel comprises a number, $N$, of interconnected sub-pixel microbolometers. This arrangement results in a pixel with electrical resistance equivalent to $1/N$ of a sub-pixel bolometer, while both Johnson noise and $1/f$ noise are reduced by a factor of $1/\sqrt{N}$. Due to the short detection range, pixels can be larger and fewer than current production imagers, which also means a narrower noise bandwidth. Because speed of response at atmospheric pressure is much faster than in a vacuum, we can employ a signal detection method at higher frequency, with a further reduction in $1/f$ noise.

Today’s microbolometer thermal imager typically has a $160 \times 120$ or $320 \times 240$ format FPA with pixel size at 25–50µm and, using a chalcogenide glass or germanium lens, an NETD in the range 50–100mK. The temperature-sensitive material is either doped amorphous silicon or vanadium oxide (VOx). By comparison we have designed a $4 \times 4$ MP-FPA with 500µm pixels for upgrade PIR sensors and a $32 \times 24$ MP-FPA with 250µm pixels for smart PIR security sensors. Both have 50µm sub-pixel microbolometers, and so 100 and 25 sub-pixels, respectively. Based on data gathered over many years for FPAs designed and developed by EOSD, we predict an attainable NETD for packaging at atmospheric pressure of $\leq 100$mK using a fast plastic Fresnel lens. This performance is achieved for a proprietary silicon alloy or VOx. A 3D rendition of the photomask design employed for the $4 \times 4$ FPA chip fabrication is shown in Figure 1.

We conclude that next-generation PIR security sensors can be developed using novel microbolometer FPA design and high-pressure packaging which, in conjunction with a plastic Fresnel lens and low-noise signal detection, will have sensitivity approaching that of current thermal imagers but a cost of manufacture competitive with pyroelectric PIR security sensors.

EOSD is seeking development partners for its PIR sensor technology and offers rights to the associated IP.

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Kevin Liddiard is the owner and senior consultant of Electro-optic Sensor Design, which specializes in design and development of optical sensors. He previously headed a research group at the Defence Science and Technology Organisation, where he conducted leading-edge research on low-light-level detection, target and background radiometric signatures, acoustic and optical sensors, thin-film physics, and silicon microengineering. His best-known work is the invention of the silicon microbolometer and development of uncooled IR sensor systems. Recently he has worked on the design of silicon microbolometer FPAs and on developing active microbolometer and PIR security sensors. He holds an MSc in solid-state physics from the University of Adelaide and is a member of SPIE, the Optical Society of America (OSA), the Materials Research Society, and the Institute of Physics. He is a reviewer for OSA publications and other international journals.

**References**


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