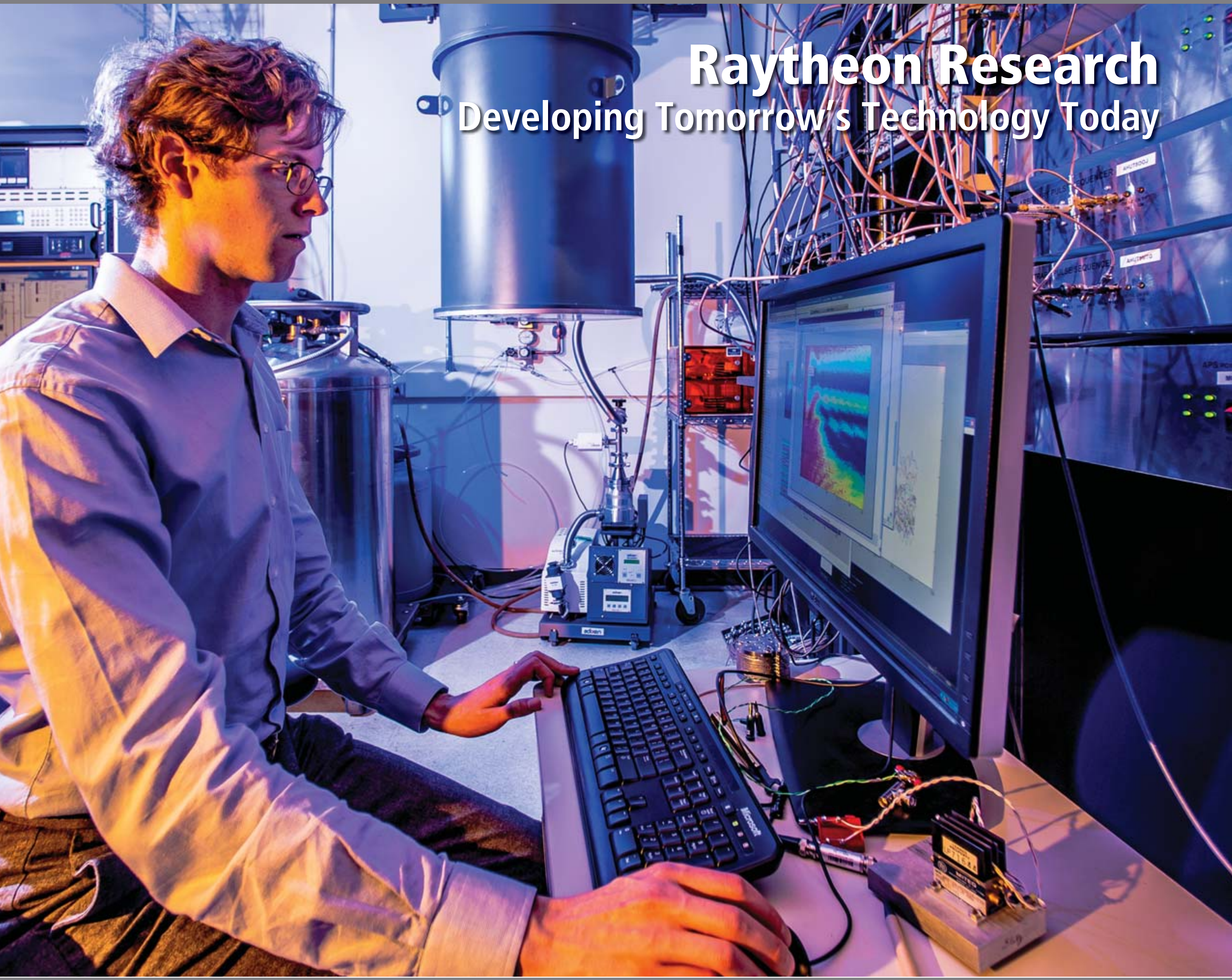
Technology Today

HIGHLIGHTING RAYTHEON'S TECHNOLOGY

2014 ISSUE 1

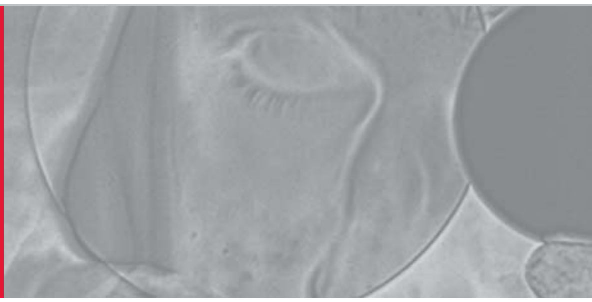


Raytheon Research
Developing Tomorrow's Technology Today

Raytheon

Customer Success Is Our Mission

NEXT GENERATION EO/IR Detectors



Electro-optical/infrared (EO/IR) system capabilities are continuously being expanded and improved. This is in part due to the development of high-performance focal plane array (FPA) technology. Raytheon Vision Systems (RVS) is actively advancing the state-of-the-art for new and discriminating FPA technologies in the 3–5 micrometer (μm) mid-wavelength infrared (MWIR) and the 8–12 μm long-wavelength infrared (LWIR) spectral regions by using a variety of semiconductor materials and FPA architectures. These include advanced III–V[1] semiconductor strained-layer-superlattice (SLS) FPAs, II–VI[2] semiconductor mercury cadmium telluride (HgCdTe) dual-band FPAs and uncooled bolometer FPAs using micro-electromechanical systems (MEMS). Each of these FPA technologies address different mission requirements and are being developed to not only increase sensor capability and performance, but also to provide improved manufacturability and reduce costs.

Advanced III–V Materials

MWIR FPAs with higher operating temperatures are advantageous for reducing the size, weight and power of cooled systems. For this reason, high operating temperature (HOT) FPAs are being developed based on molecular beam epitaxy (MBE) grown indium arsenide/gallium antimonide (InAs/GaSb) strained-layer-superlattice (SLS) bandgap engineered barrier device structures. The goal is to develop materials that have the producibility advantage of traditional III–V indium antimonide (InSb) technology, but the operating temperature advantage of HgCdTe. The InAs/GaSb family of SLS is the only known IR detector material with fundamental properties that provide a theoretically predicted higher performance than HgCdTe (lower dark currents at the same wavelength and temperature, with a comparable absorption coefficient). This SLS family has features whereby unique device architectures that provide performance advantages can be realized using multiple lattice-matched layers with a wide range of bandgap energy on a GaSb substrate as shown in Figure 1. These III–V semiconductors have greater latitude in process parameters (such as temperature) and tolerance to process-induced defects, and there is also a broader industrial base such that larger substrates and merchant-supplier MBE growth houses are available to produce the material and contribute to the technology development. Together these factors offer the promise of improved performance, higher yield and reduced cost for FPAs fabricated on SLS material.

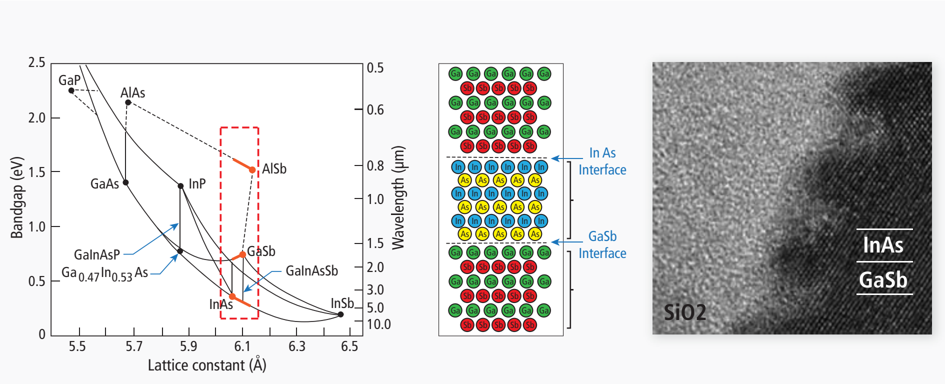


Figure 1. The semiconductor bandgap versus lattice constant graph on the left shows various binary compounds that can be used to create, for example, an InAs/GaSb strained-layer superlattice (SLS) structure (middle) whose bandgap can be varied by the thickness of the individual layers. The picture on the right is a high resolution transmission electron microscopy (TEM) image of an SLS structure which shows the amorphous nature of the SiO2 passivation layer in contrast to the atomistic nature of the crystalline InAs/GaSb SLS.

Dual-band FPAs

Raytheon has developed an industry leading dual-band HgCdTe infrared FPA architecture (Figure 2) that is in production for advanced missile interceptor applications, and is being further refined and expanded as a third generation upgrade to existing tactical systems for ground and airborne applications. The availability of spectral information from a second spectral band enables the discrimination of absolute temperature and unique signatures of objects in a scene (Figure 3). When coupled with advanced signal processing algorithms, two-color infrared detection provides improved sensitivity compared to that of single-color devices. These advanced FPAs are necessary in order to improve acquisition, discrimination and the tracking of ballistic missile warheads, or the identification and engagement of tactical battlefield targets. This FPA architecture utilizes MBE-grown HgCdTe on 6 x 6 centimeter (cm) cadmium zinc telluride (CdZnTe) substrates, but there is also a significant development focus on using 6-inch diameter silicon (Si) substrates to substantially lower cost. Achieving the highest dual-band FPA performance, particularly for the LWIR band, is more challenging when using a Si

[1] *The III–V semiconductors are compounds composed of elements from the IIIA and VA CAS-standard groups of the periodic table or equivalently groups 13 and 15 based on the modern group-numbering standard.*

[2] *The II–VI semiconductors are compounds composed of elements from the IIB and VIA groups of the periodic table based on the CAS group-numbering standard. These are groups 12 and 16, respectively, using the modern group-numbering standard.*

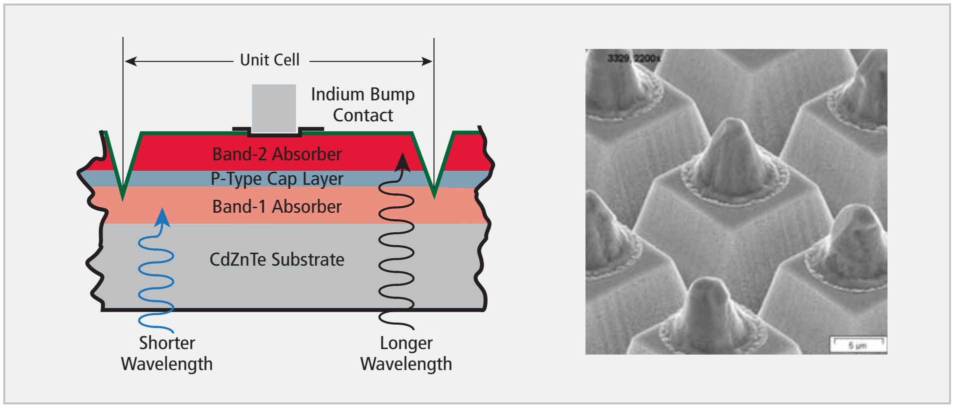


Figure 2. The left figure shows a schematic cross-section of Raytheon's single-contact, single-mesa dual-band HgCdTe detector architecture, and the right shows a scanning electron microscope image of dual-band detectors with indium bumps on individual diode mesas.

substrate due to the very large lattice and thermal mismatch between Si and HgCdTe that contributes to elevated material dislocation densities. Improvements in device design and material growth makes the goal of low cost dual-band HgCdTe FPAs on 6-inch diameter Si substrates attainable.

Uncooled FPAs

LWIR uncooled FPAs employing MEMS-based microbolometer structures are now widely used in both commercial and U.S. Department of Defense (DoD) applications. By its nature, uncooled technology is lower cost because it is operated at room temperature and can utilize simpler, smaller packaging without the need for a cooler. Additionally, it is fabricated on large area Si substrates using commercial manufacturing technology. Raytheon uncooled technology uses vanadium oxide (VO_x) microbolometers which are fabricated monolithically on 200 millimeter (mm) Si read-out integrated circuit (ROIC) wafers. Over the last few years, this technology has been further enabled by Raytheon partnering with a high-volume commercial semiconductor company, Freescale Semiconductor, to fabricate the bolometers.

Typical uncooled FPA formats use 640 x 480 pixels or smaller with a pixel size of 25 µm. Raytheon, in partnership with the Army Night Vision and Electronic Sensors Directorate (NVESD) and the Defense Advanced Research Projects Agency (DARPA), is also developing three mega-pixel-class uncooled FPAs with a 2048 x 1536 format for very large format, high resolution sensors.

An example of the dramatic resolution improvement using this very large format FPA is illustrated in Figure 4, which compares the uncooled LWIR images of the Santa Barbara Mission taken with 640 x 480 and 2048 x 1536 pixel FPAs. Note that these images were taken at different times of the year so the details around the mission vary, e.g., the truck on the left in the top image was gone when the bottom image was taken.

Additionally, RVS in partnership with DARPA is developing wafer scale manufacturing processes to enable uncooled camera-on-a-chip technology as part of the Low Cost Thermal Imager – Manufacturing (LCTI-M) program. The goal of this effort is to dramatically lower the cost of this technology to enable wide use of infrared imaging technology and insertion in compact systems.

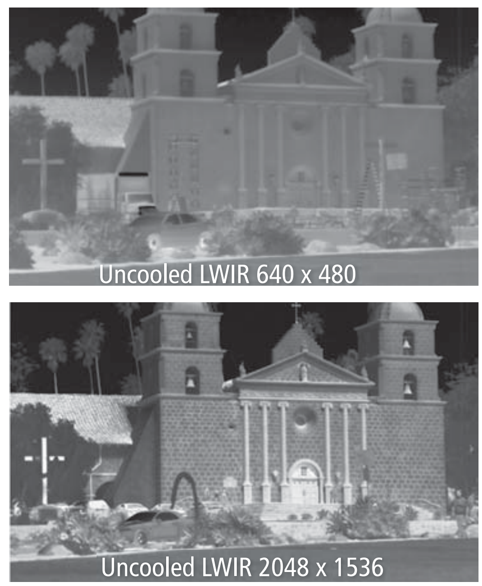


Figure 4. The dramatic resolution improvement using large format FPAs is illustrated in the images above that compare an uncooled LWIR image of the Santa Barbara Mission taken with a 640 x 480 pixel FPA (top) with an uncooled 2048 x 1536 pixel FPA (bottom).

Through these and other activities, RVS continues to advance the state-of-the-art in FPA technology to achieve higher performance, lower cost and smaller size EO/IR sensor systems. •

S.M. Johnson and E.P.G. Smith

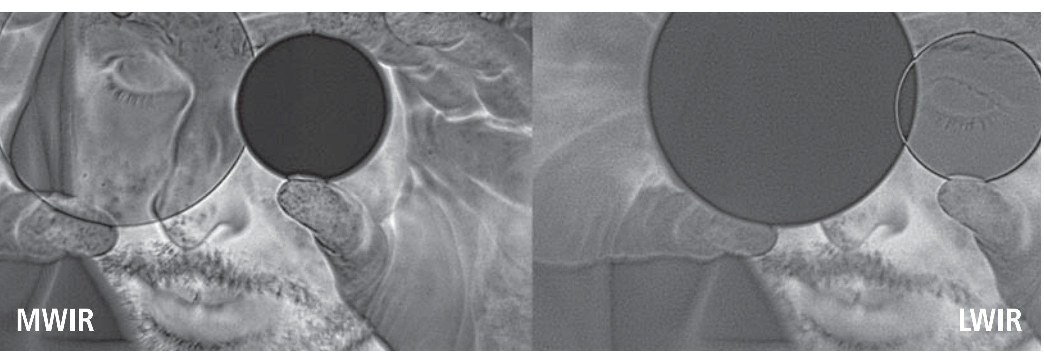


Figure 3. Example of imaging using a MWIR/LWIR dual-band FPA produced using HgCdTe grown on a low-cost Si substrate as part of an Army Night Vision and Electronic Sensors Directorate (NVESD) development program. The image from the MWIR band on the left shows transmission through the MWIR filter but not the LWIR filter, while the LWIR image on the right shows the opposite effect.