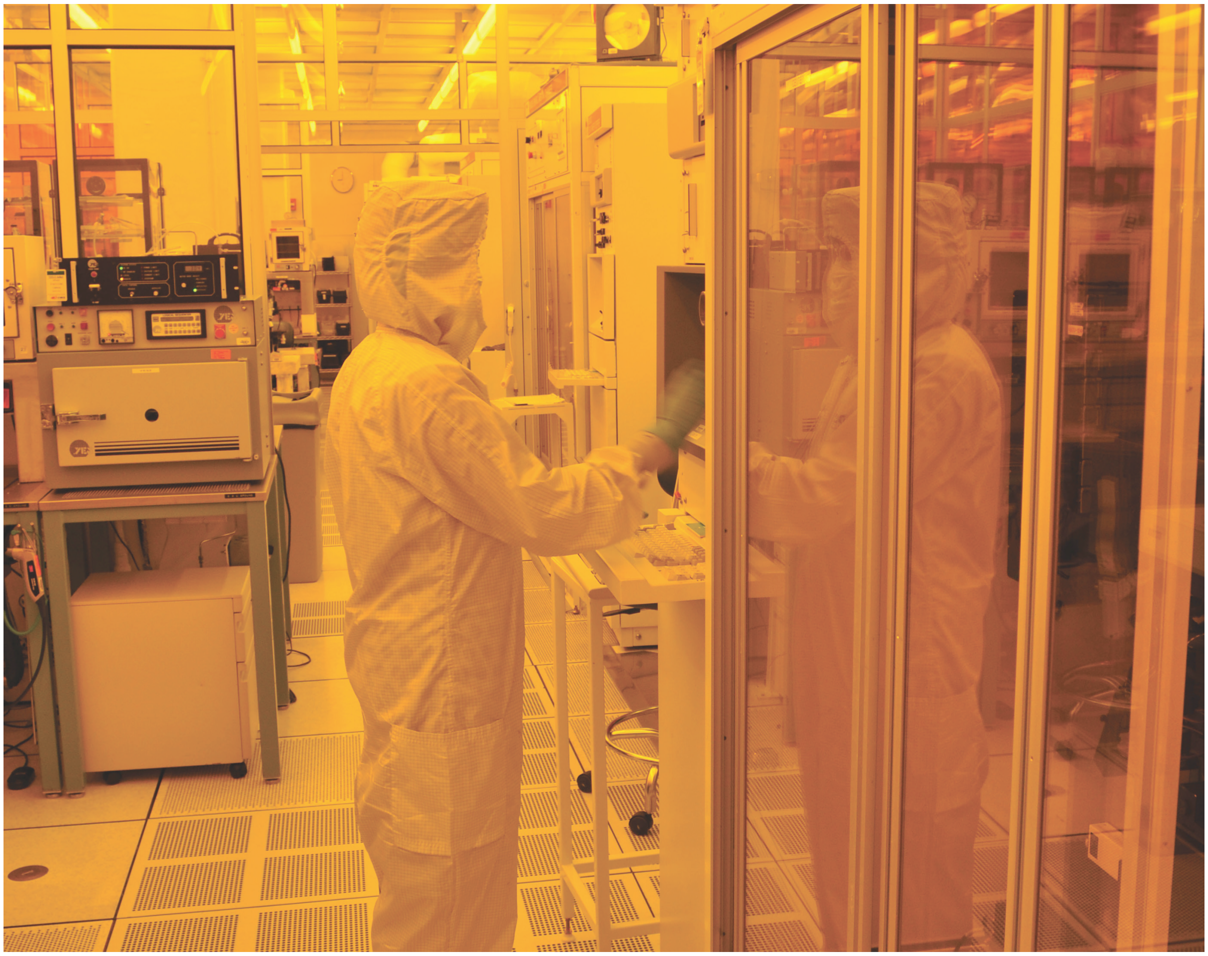
WHITE PAPER

ANSWERS TO QUESTIONS ON

MCT'S ADVANTAGES AS AN INFRARED IMAGING MATERIAL

Leonardo DRS, Electro-Optical & Infrared Systems



LEONARDO DRS

Answers to Questions on MCT'S ADVANTAGES AS AN INFRARED MATERIAL

– Leonardo DRS, Electro-Optical & Infrared Systems

Cooled infrared imaging is in many ways a mature technology, with its architectures well-defined and its past and present applications well-understood. Nevertheless, opportunities abound for:

- Improving range and resolution while reducing cost, device size, weight and power (SWaP).
- Expanding IR imaging's applications for users in the military, homeland security and commercial realms.

Perhaps no other variable is as important to this equation as the detector material itself. Today, many users, industry leaders and scientists agree that the best semiconductor material for capitalizing on these opportunities is Mercury Cadmium Telluride (MCT), or HgCdTe. The primary reasons:

- MCT is proven, reliable, and readily available.
- Its cost is now highly competitive with common indium antimonide (InSb).
- It offers users significant advantages over InSb in terms of range, resolution, device size, weight and power requirements – in short, the best performance-to-cost value.
- It is already demonstrating its utility for advanced applications such as two-color and active imaging and shows promise for SWIR imaging.

These are among the reasons that so many major players, including not only Leonardo DRS but also Raytheon, Teledyne, SOFRADIR, SELEX Galileo, AIM and SCD, continue investing in MCT's present reality and future potential.

DRS has been at the forefront of this effort for many years. As a world leader in electro-optical infrared (EO/IR) imaging for military applications, we have a proud history of meeting our Warfighters' mission- critical IR imaging needs in even the harshest environments. And we have fielded well over 100,000 DRS EO/IR systems on all major ground-vehicle, airborne and maritime platforms – including more than 70,000 MCT-based devices.

DRS can arguably take much of the credit for making MCT affordable, for resolving its early performance and fabrication challenges, and for demonstrating its across-the-board superiority over other detector materials.

In this document, we'll answer the most commonly asked questions about DRS MCT's key attributes, advantages and limitations. If we can answer any more for you, please contact us soon. You can reach us by calling 1-888.230.2372, by emailing sales@drsinfrared.com, or by visiting us at www.drsinfrared.com.

Answers to Questions on MCT's Advantages as an Infrared Imaging Material

Q1. What advantages can we expect from DRS MCT?

DRS' Mercury Cadmium Telluride (MCT), also known as HgCdTe, provides three overriding advantages as an infrared imaging material.

First and most important is its ability to deliver optimal performance at higher operating temperatures than InSb, for size, weight and power (SWaP) reductions and improved thermal management.

Second, it takes advantage of the industry's smallest pixels, leading to proportionate increases in range, reductions in optics size, or improvements in spatial resolution – or a combination of these advantages, tailored to the application.

And lastly, it provides access to such emerging applications as active and passive shortwave infrared (SWIR), two-color, 3D and active imaging, as well as the possibility of cooled handheld MWIR devices to make superb image quality truly portable.

Q2. Why did DRS choose MCT over InSb?

Indium antimonide (InSb) is one of several focal plane array (FPA) materials for infrared imaging. However, because of its limitations, scientists have continued advancing other FPA materials. MCT is arguably the most important of these materials.

The scientists at Texas Instruments (TI) who developed first-generation IR devices have been among the leaders in this effort. They anticipated game-changing advantages from MCT, in large part because it's the only known material that can detect IR radiation in all three atmospheric windows – shortwave (1.5-1.8 and 2.2-2.4 micron), midwave (3-5 micron) and longwave (8-14 micron).

Recognizing this unique characteristic, TI made major investments in MCT's development over the years, even as the organization underwent various divestitures and acquisitions to ultimately become a part of Leonardo DRS. DRS has continued this investment.

Today, this pioneering work is paying off. DRS scientists have overcome MCT's initial cost and operability disadvantages, letting its advantages take center stage. Many in the industry now consider MCT the preferred material for cooled IR imaging applications.

Q3. How high an operating temperature can MCT accommodate?

MCT requires cryogenic cooling in order to minimize the background noise from the "dark current" produced in the detector material itself – and therefore to achieve the ultra-high performance needed for today's military and security applications.

Cooling has a cost, of course, in terms of size, weight and power (SWaP), heat generation, and potential cryogenic reliability concerns. As lower temperatures are required and cooling requirements increase, larger coolers are needed, resulting in greater power requirements.

However, DRS has developed extraordinary High Operating Temperature Infrared (HOT-IR™) MCT detector technology, which can perform at significantly elevated temperatures to minimize these trade- offs.

Five years in the making, HOT-IR™ means that the detector does not need to be cooled down to 77°K. Instead, HOT-IR™ delivers superior performance at temperatures well above 110°K resulting in significantly less power required.

While the precise operating temperature is company-confidential, we can say that our HOT-IR detectors use smaller coolers and consume less power. And that adds up to substantial reductions in size, power requirements, and cooler-generated heat, as well as a tripling of cooler life – from under 10,000 hours to 30,000 hours or more.

Q4. Why should we consider choosing MCT over InSb or other technologies?

For years, there have been drawbacks associated with MCT, mainly in terms of power consumption, relatively high cost and occasionally inconsistent performance. DRS was able to overcome these challenges and is setting new performance standards for MCT.

DRS' HOT-IR MCT detectors require as little as one-third the power needed by comparable InSb devices. For example, the power consumption of our 12-micron HOT-IR MWIR camera is just 7.5 watts steady-state. Compare this to the 15 to 25 watts of steady-state power required by coolers for equivalent InSb cameras.

The high cost of MCT was primarily the result of challenges with composition control and low yields. With technological advances, DRS' high throughput of MCT has reduced its price to levels comparable to InSb's.

Until recently, MCT detectors had a slightly higher percentage of "dead" pixels, which could impact the quality of the infrared image. The seriousness of this issue may have been exaggerated; the actual operability difference between MCT and InSb was always under 0.1%. Nevertheless, MCT's operability is now at 99.5% -- equal to or better than InSb.

DRS continues to set new performance standards for MCT with such developments as these:

- Vertically Integrated Photodiode (VIP) and High Density VIP (HDVIP™) focal-plane array architectures for mono- and multi-color next-generation systems
- Very small-pitch, high-density formats
- Ultra-high operating temperatures
- Active/passive FPAs providing noiseless gain
- Very large-area FPAs

Other materials have emerged, including Quantum Well Infrared Photoconductor (QWIP) and such nanotechnology products as Quantum Dot Infrared Photo-detectors (QDIPs). However, their performance at comparable temperatures can't match MCT's, and DRS is convinced that MCT will remain the most effective and cost-efficient solution for cooled infrared imaging.

Unlike most other detector suppliers, DRS enjoys complete control over the entire process, from growing our own CZT substrate material to assembling the detector/cooler package. Because we focus on optimizing a single material, we're able to deliver world-class results.

As a result, DRS has succeeded in overcoming challenges and expanding the capabilities of MCT to produce environmentally responsible products of the highest quality, at costs comparable to InSb's.

Q5. Why have you gone to 12-micron pitch?

Among the most important traits of DRS' approach to FPAs is its ability to accommodate smaller pixels than InSb. DRS is producing MCT detectors with a 12-micron pitch, and smaller pitches are under development. InSb, on the other hand, is currently limited to 15-microns.

A 3-micron reduction represents a 20% reduction in pixel size. Multiplied out over the 640 pixels in a focal plane array, it makes a substantial difference.

Smaller pixels mean a smaller package. As the number of pixels is reduced, the focal plane array is smaller and the size of the optics is reduced. When we combine these reductions with the smaller cooler made possible by HOT-IR MCT, we can achieve valuable reductions in the size and weight of the overall package.

Q6. Can smaller pitch improve range or resolution?

It can improve both.

Smaller pixels can most directly improve spatial resolution – i.e., the smallest possible scene feature that can be accurately discerned in an image. Again looking to the previous 12- vs.-15-micron discussion, if we maintain FPA size and optics field-of-view, we can increase the number of pixels by 20%, thereby enhancing fine image detail.

Alternatively, the smaller pitch can be applied to seeing over greater distances. It's a simple geometric issue: A 20% smaller pitch will allow a 20% narrower field-of-view (FOV) and 20% increase in the magnification of the most distant scenes you can capture.

Resolution and range improvements are especially important in military applications. Higher resolution helps our troops identify a threat when it's farther away, giving them more time to respond appropriately and effectively. And a longer range can make it easier for them to operate while staying out of harm's way.

Q7. How can MCT help us on the Dirty Battlefield?

After the first shot is fired, the pristine battlefield rapidly becomes the Dirty Battlefield. Maneuvering forces raise dust, burning wrecks "bloom" excessively, masking smokes arise either intentionally or incidentally to the engagement. And the shorter the IR wavelength being used, the worse the utility of the resulting images.

Because it can't image wavelengths longer than 5 microns, InSb's value on the Dirty Battlefield is limited. Other detector materials, such as Quantum Well Infrared Photoconductors (QWIP), may operate at longer wavelengths, but at the cost of sensitivity or excessive cryogenic demands.

But DRS MCT is well-suited for the Dirty Battlefield. It's the only practical detector material that can image in the LWIR band, to minimize the effects of battlefield obscurants and artifacts. Add to this equation the higher resolution made possible with our smaller pixels, and it's clear that DRS MCT makes the best out of tough situations.

Q8. So when would a MWIR detector be advantageous?

If your requirements are not on the Dirty Battlefield, MWIR operation can be very attractive. Its shorter wavelengths allow sharper image quality and/or a smaller optical aperture to reduce SWaP, especially advantageous in applications such as airborne.

In high humidity applications such as in marine/littoral environments, MWIR contrast remains high for greater ranges than LWIR. Airborne sightlines avoid much of the MWIR blurring that is present in the turbulent layer near the ground.

Q9. Do you have product in the field offering these capabilities?

We've been fielding a range of MCT-based scanning and staring product s for many years – including key components for such leading-edge systems as these:

- The Arrowhead MTADS/PNVS system used in Apache attack helicopters (LWIR)
- The Phalanx CIWS shipboard defense system (LWIR)
- The IBAS target acquisition system used in Bradley Fighting Vehicles (LWIR)
- DIRCM countermeasure sensors for protecting military aircraft (MWIR)
- The LRAS3 Long Range Advanced Scout Surveillance System (LWIR)

What's more, we recently introduced the first midwave production camera to use our 12-micron HOT-IR technology. We've also introduced a surveillance system incorporating this camera – the new, high-performance Jalapeno LR+ system for military, homeland security and commercial applications.

Sensing in the 3-to-5 micron band with the inherent advantage of higher operating temperatures, this exclusive DRS MCT technology delivers an unprecedented combination of small size, light weight, ultra-low power requirements, and low cost. And with an expected 30,000-hour cooler life to extend service intervals in any operating environment, its reliability is unsurpassed.

These products are the first in a new generation that promises to leapfrog currently available systems in all key performance categories – including resolution, range, reliability and both initial and lifecycle costs.

Q10. Will MCT be useful for shortwave infrared (SWIR) imaging?

Definitely. We're already working on it.

As you probably know, SWIR imaging is capable of generating more detailed information than its midwave and longwave counterparts. And MCT can be used to great advantage in this waveband.

For instance, when there is minimal background illumination, MCT can be operated as an Avalanche Photodiode Detector (APD), to make the best possible use of limited scene photons.

MCT can also be applied to active SWIR imaging using a laser illuminator (see Q11). The detector materials currently applied to this task become degraded with use and so have very limited lifetimes. But SWIR MCT is not subject to such degradation, which means its lifetime is unlimited. And it requires minimal or no cooling in active mode.

These traits may also make DRS MCT ideal for SWIR 3D imaging – a promising technique for exposing and revealing previously indistinguishable features in hidden targets.

Q11. How can MCT contribute to active imaging?

In active imaging, the system floods the scene of interest with eye-safe bursts of photons, then enables the detector to "see" energy only at the moment that reflections from the laser-illuminated target are expected. Confusing reflections from the target foreground and background are ignored because they arrive too early or too late, and the resulting images contain only the high-contrast target information.

MCT may be the detector material best suited for this capability, because of its inherent ability to produce clear, sharp images. Add active imaging technology to the picture, and you'll be able to see threats that are not visible with conventional IR imaging – including enemy vehicles hidden in dense shrubbery.

This technology also promises to be useful for routine surveillance activities. It will allow users to conduct surveillance with conventional, passive-mode IR – and then, if a potential threat is detected, to switch instantly to active-mode gated EO/IR for highly detailed imaging of the suspicious object.

Q12. Is DRS working on multicolor imaging?

Multicolor imaging is attractive because it allows the best features of each waveband to be exploited. But until recently, multicolor systems needed separate detectors, cryogenic coolers and optical paths for each band being imaged. And that meant bulky and very expensive solutions.

With its unique ability to cover all wavelengths from SWIR to LWIR, MCT may be the only solution for affordable multicolor imaging. DRS has made it practical to combine a single optical path and cryogenic cooler with a layered, MCT-based detector. The resulting system gets the job done at less than half the cost and SWaP of earlier approaches – which will soon enable this technology to move out of the lab and into the field.

Q13. Are cooled detectors for handheld devices a possibility?

Today's Warfighter is weighed down with equipment as he enters the battlefield. The importance of reducing every ounce he carries cannot be overemphasized.

DRS' HOT-IR MCT can make a major contribution. Because it uses much smaller coolers and significantly less power, it may be just the breakthrough that will put man-portable cooled IR technology in the hands of the Warfighter.

Q14. How will this material impact the bottom line?

DRS' MCT detectors can save users money in several ways.

First, its smaller pitch means the entire package can shrink proportionately – including the optics. This in turn drives down the initial costs and purchase price.

Second, the higher operating temperatures made possible by our HOT-IR technology mean major reductions in power consumed. For some applications, these savings can be substantial.

Third, our higher operating temperatures also extend cooler life, for dramatic reductions in repair and replacement costs as well as in downtime. That's not an insignificant factor when you consider that coolers – the weakest link in any cooled-IR imaging chain – cost anywhere from $3,000 to $10,000 each.

To put numbers to it, a typical InSb-based system cooler is generally rated at 8,000 to 10,000 hours. But DRS has demonstrated 30,000 hours of cooler operation with HOT-IR™ MCT-based systems. Three times the reliability and operational life may not matter for equipment that's used only occasionally.

But for equipment that is used frequently or constantly, it can have a major impact on a system's lifecycle costs.

Q15. What's the significance of your growing your own raw MCT?

The fact that we grow our own MCT – technically speaking, MCT LPE (liquid phase epitaxy) HDVIP – is important to our customers for three reasons: cost, quality and R&D.

Because we grow it ourselves, along with the CZT substrate on which it's formed, we're not dealing with anyone else's mark-ups or profits. That's one reason we've been able to bring MCT's cost down.

Our control over this process also helps us produce MCT of the very highest quality. For instance, we're free to use a fabrication technique that eliminates thermal cycling. We're also free to test competing hybridization schemes to determine, for example, which enables the smallest pixels. (The answer: LPE-HDVIP, which samples both interfaces.)

And in the rare instance that an application requires a larger size FPA than can be produced with this technique, we have ready access to MCT produced via vapor-phase growth techniques by our sister company, SELEX.

As a result, we can say with confidence that our MCT material delivers consistently excellent performance and dramatic MTBF improvements across applications and operating environments.

Finally, we have underway aggressive Research & Development programs involving our HOT-IR MCT. Since much of this work requires fine-tuning the alloy itself, having this process close at hand helps us pinpoint the optimum values to use in future products.

For more information on DRS HOT-IR MCT infrared imaging technology and systems, contact us at 1-888.230.2372 or sales@drsinfrared.com.

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