MID WAVE 2D MCT DETECTORS

Comparison of MCT and InSb infrared detectors

INTRODUCTION

MOVPE Heterostructure Device Technology

Selex Galileo has developed a device technology based on MCT heterostructures grown by MOVPE. This technology is particularly suitable for the manufacture of large, high performance 2D arrays at relatively low cost.

MOVPE allows us to produce MCT heterostructures that are designed to minimise dark currents while maintaining high quantum efficiency. These devices can therefore operate at higher temperatures (up to 150K) than so-called homo-junction devices and still be background limited.

For FPAs up to full-TV format, operating in the 3-5 or 8-12μm range, Selex Galileo has a large-scale MOVPE reactor that is capable of producing MCT device layers on GaAs substrates. This reactor has been producing layers for the manufacture of detectors since 2002. A second production MOVPE reactor is under construction for commissioning later in 2008.

DARK CURRENT AND OPERATING TEMPERATURE

For MW MCT detectors made from MOVPE with a cut-off at 4.95 μm controlled by the window, background-limited performance (BLIP) is achieved when cooled to 94 K and viewing a room temperature background down to f/4 or f/5.

It is important that staring arrays have very few defective pixels. NETD defects are usually randomly scattered over the array but can be clustered together where there is a growth defect; i.e. a hillock. For arrays made on GaAs substrates, there are fewer NETD defects than on other substrate types and typically less than 0.1%.

INSB AND MCT COMPARISON

There are a number of important differences between InSb and MCT technology when applied to detectors operating in the 3-5um waveband. From fundamental physics, both materials are capable of achieving the same quantum efficiency (approximately 80%). In practice, however, MCT starts with the intrinsic advantage that the band gap increases with increasing temperature whilst the reverse is the case for InSb. This fact alone means that MCT will always have an advantage in terms of operating temperature and this in turn leads to lower power and longer cooling engine life.

IMAGE RETENTION

Conventional InSb technology has a number of problems due to the structure. The top surface is part of the IR sensitive volume so the passivation of the front surface becomes important and trapping at this surface causes image lag problems. This is where a highlight remains in the image for a long time (hours) resulting in streaks for a crossing highlight for instance. Furthermore diffusion of carriers within the bulk of the material provides for crosstalk and a poorly defined sensitive area. This leads to a much worst modulation transfer function than the Selex Galileo approach.

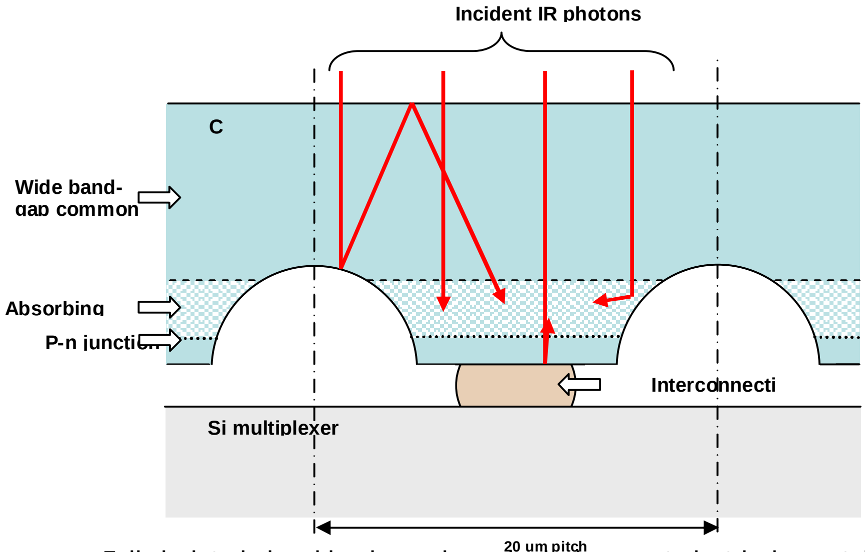
SELEX GALILEO MCT STRUCTURE

Selex Galileo at Southampton uses a new device structure which has a significantly improved electro-optic performance compared with other technologies. Imaging artefacts such as crosstalk, blooming and image lag have been effectively removed.

The pixel elements are physically separated resulting in complete isolation and so short and long range crosstalk is eliminated. Because of the heterostructure design the IR sensitive part is completely separated and so there is no mechanism for blooming. Internal reflection from the mesa side walls gives very high quantum efficiency and a well defined sensitive area. The sensitive area falls within the pixel boundaries so that microscan can be used to provide a real MTF advantage.

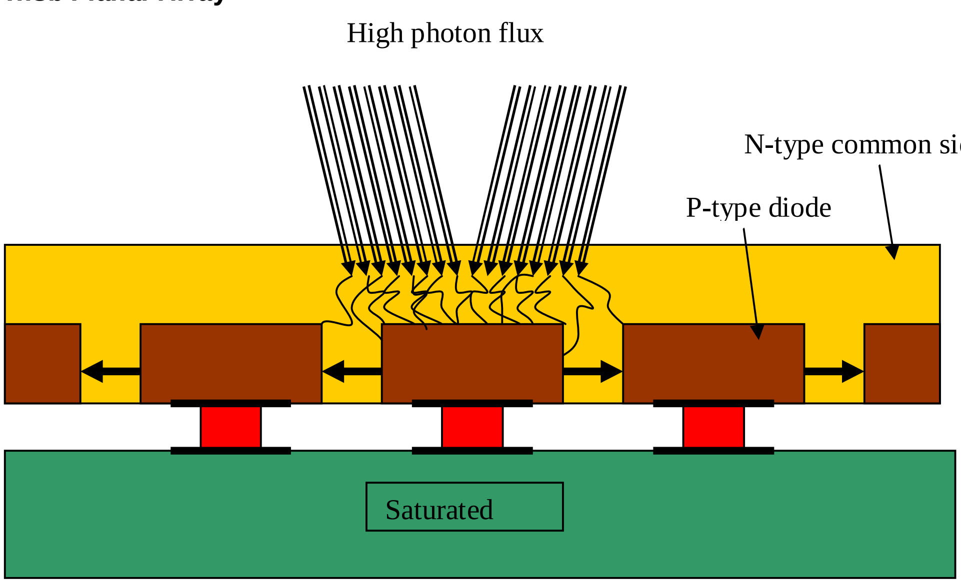
A typical InSb planar diode array, in comparison, has a mechanism for electrical crosstalk.

MCT mesa array



Fully isolated absorbing layers in each pixel prevent electrical crosstalk

InSb Planar Array



Planar structure permits crosstalk through carrier diffusion

SELEX GALILEO MCT STRUCTURE

Image lag is removed completely by making the effective front surface a compositional boundary with no possibility of charge trapping, thus creating a well-defined sensitive area with no blooming or short range crosstalk.

Long range crosstalk can occur if an optical highlight causes a voltage drop in either the multiplexer circuitry or the MCT earth plane. The device structure enables a low resistance earth plane to be used to prevent de-biasing due to a highlight. The very low sensitivity to long range crosstalk means that images can still be obtained looking directly into the sun.

One of the key advantages of MCT over InSb is the flexibility to reduce the cut-off wavelength of the array to match the spectral band pass. InSb has a fixed wavelength of about 5.5 µm. Its main disadvantage is that the trap densities are typically 10 times higher than MCT and this reduces its performance at temperatures above 80K. In fact, MCT can operate at temperatures some 60-80K (see figure 2) higher than InSb for the same dark current due to tuneable band gap and the device structure. The higher operating temperature results in reduced cooler power, longer engine life and reduced cool down time.

BLOOMING

Blooming is one of the most damaging imaging artefacts. Blooming occurs in matrix IR detectors due to phototransistor action in the diode matrix. Most manufacturers use backside illumination which requires that the lifetime in the substrate layer of the array is high. A high lifetime leads to phototransistor action. Figure 3 explains the physical mechanism. The high optical flux is absorbed by the n-type common layer. The photo-generated carriers then diffuse to the nearest junction. If the pixel becomes saturated, the diode loses its reverse bias and so it must emit a carrier for each photo-generated carrier absorbed. The carriers will be emitted preferentially in the direction of the next reverse biased diode, which will then absorb it and so on. In this way a single pixel highlight can result in a large cluster of saturated diodes. The flaring effect is quite visible in most InSb images. InSb arrays have a particular problem because of the high diffusion lengths and lifetime in the n-type common layer.

SUMMARY

The main strengths of the Selex Galileo device structure with respect to InSb

- Defined sensitive area for elimination of optical crosstalk, elimination of blooming, and accurately defined sensitive area
- Band gap engineering for low junction capacitance (improved response in high F-numbers), reduced dark current, no image lag (remote front surface), and very low series resistance (to eliminate long range crosstalk)
- Manufacturing advantages: MCT grown on 75mm (or 150mm in future) low cost substrates
- Thermo-mechanically very stable
- Operational advantages: higher long term storage temperatures and higher operating temperatures/lower dark current
- In particular, the use of higher operating temperature results in significant system benefits in terms of reduced cooler power, longer engine life and reduced cool down time.