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HgCdTe technology in France

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Abstract

SOFRADIR is one of the leading companies worldwide for the production of second generation InfraRed (IR) detectors. This success is due to the top level quality of the unique and production oriented French HgCdTe technology for manufacturing IR focal plane arrays based on an HgCdTe array and a CMOS readout and multiplexed silicon array. This technology and main products are presented in this paper. Finally, in order to prepare for future military and industrial needs, SOFRADIR has been working in close relationship with CEA-LETI/LIR on third generation developments based on HgCdTe material using Molecular Beam Epitaxy (MBE) growth. ***To cite this article: P. Tribolet, C. R. Physique 4 (2003).***

Résumé

La filière HgCdTe en France. SOFRADIR se situe au premier rang mondial pour la production de détecteurs InfraRouge (IR) dits de seconde génération. Ce succès est dû à la qualité exceptionnelle de la technologie française basée sur le matériau HgCdTe. Cette technologie permet la production de détecteurs plans focaux constitués d'un circuit de détection en HgCdTe et d'un circuit de lecture/multiplexage qui, bénéficiant des progrès des technologies silicium, est aujourd'hui réalisé en technologie CMOS. Cette technologie et ses principaux produits sont présentés dans cet article. Enfin, pour répondre aux besoins des futurs systèmes IR, SOFRADIR avec CEA-LETI/LIR préparent la troisième génération de détecteurs IR toujours basés sur HgCdTe mais fabriqués par épitaxie par jets moléculaire. ***Pour citer cet article : P. Tribolet, C. R. Physique 4 (2003).***

Keywords: Infrared detector; HgCdTe; Focal plane array; IRFPA; IRCMOS; SOFRADIR

Mots-clés : Détecteur infrarouge ; HgCdTe ; Plan focal ; IRFPA ; IRCMOS ; SOFRADIR

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1. Introduction

France is one of the leading countries worldwide for the production of second generation InfraRed (IR) detectors. In fact, SOFRADIR has been producing at volume levels [1] for more than eleven years and has delivered more than 10 000 Time Delay and Integration (TDI) 8–11 μm HgCdTe cooled arrays up to now. These TDI linear arrays are close to the theoretical limit regarding spatial and thermal performance [2] and have demonstrated their ability to answer all the high performance system needs, including ruggedness regarding severe environmental conditions, high blooming levels and optical counter counter measures.

This high number of deliveries outlines that the second generation IR detectors have been well mastered in France, based on the high maturity of the French HgCdTe (Mercury Cadmium Telluride also called MCT) technology.

Regarding the 3–5 μm waveband for imaging applications, the use of 2D arrays is necessary for performance reasons. Consequently 2D arrays, sensitive in the medium IR waveband, are used for second generation. However, their resolution has

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to be increased before being competitive with respect to high performance linear arrays used in the Long Wave (LW) IR band. However, at the same time, the size of the array is a key driver regarding the total array manufacturing cost and therefore limits the increase in resolution. Based on these limitations, the market of 2D staring arrays in the 1990s was mainly dedicated to missile applications or medium performance FLIR by using the most affordable format: 320 × 256. These 2D arrays have been called the 2.5 generation.

The French HgCdTe technology offers specific resolutions and an improved HgCdTe technology, well adapted to the production of this 2.5 generation, allowing SOFRADIR to be one of the leading companies worldwide for the 2D array production. At present, larger formats (640 × 512) [3] start to be available, but still have to demonstrate that they can be cost effective at mass production levels. Therefore the next generation, the third, will request a further step in terms of performance, operability, functionality and cost, to replace these existing 2 and 2.5 generations, and research is now launched in France mainly based on HgCdTe growth by Molecular Beam Epitaxy (MBE).

2. HgCdTe technology

2.1. History at a glance

At the end of the 1970s, the CEA-LETI founded the InfraRed Laboratory (LIR) with the French MOD support, in order to concentrate all the second generation IR detector research efforts, mainly dedicated to HgCdTe materials, in a unique entity able to make the best trade-off regarding the entire technology manufacturing steps.

This new generation of IR detectors is defined by the use of a Silicon pre-processing array on-focal plane including an analog multiplexer, as described in Fig. 1.

Based on this new structure the number of pixels on-focal plane was in principle no longer limited. These new array structures are called InfraRed Focal Plane Array (IRFPA).

The step from first generation to second generation infrared detectors opened the way for high-resolution scanned arrays with Time Delay & Integration (TDI) as well as high-resolution staring arrays and signal processing on the focal plane.

Regarding the sensitive array subassembly, the second generation is mostly based on photovoltaic diodes in order to reduce the electrical power dissipation per pixel, and the material chosen for the sensitive array was HgCdTe (Mercury Cadmium Telluride/HgCdTe/MCT). This material offers unique properties and high performance for detection from 1 µm to 14 µm and further.

The feasibility demonstration of the second generation IR detectors was made in 1986 and the HgCdTe technology was transferred to SOFRADIR in 1987/1988 within a six month period as presented in Fig. 2.

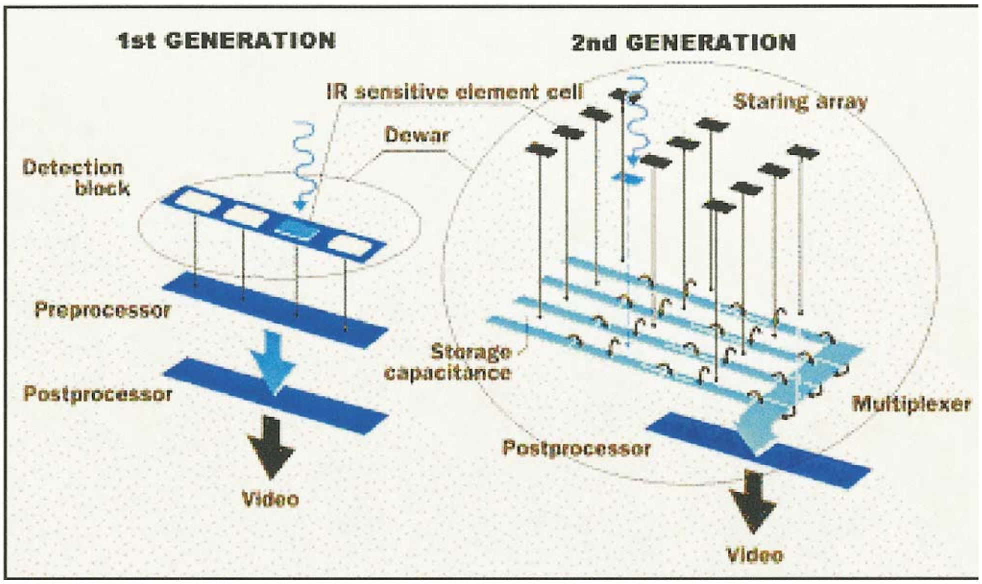

Fig. 1. Second generation IR detector principles.

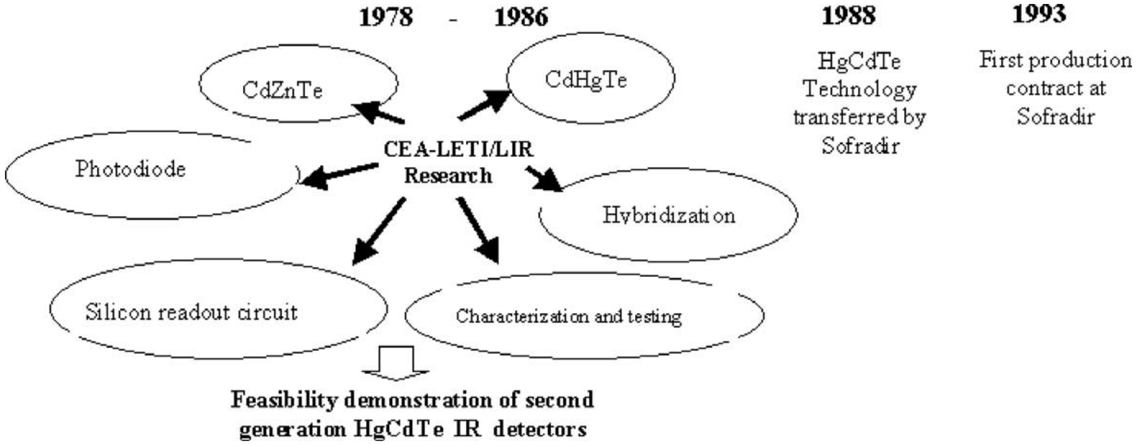

Fig. 2. A unique approach: CEA-LETI/LIR.

This success was due to a complete technology validation before transferring the technology and to an optimized cooperation between research and development [1].

Based on this transfer, an important effort of product development was carried out at SOFRADIR and small quantities of prototypes were delivered for system demonstration purposes. Finally in 1994, the first production program of several hundreds of second generation IR detectors started and demonstrated the success of this technology transfer.

Another important issue is the on-going performance improvements, which were conducted by CEA-LETI/LIR in cooperation with SOFRADIR since the technology transfer. Regarding 2D arrays, the development started in 1991 with a 64 × 64 demonstrator and the feasibility of was demonstrated in 1992 based on a 128 × 128 format for MWIR and LWIR wavebands.

In order to answer 2.5 generation needs, a 320 × 256 format was developed and offered in the mid nineties, and 640 × 512 (TV format) with 20 µm pitch have been offered since beginning of 2002 [3]. These development efforts are mainly based on the following key technological points [4,3]:

- High HgCdTe wafer sizes;
- A silicon-like ion implantation process: PhotoVoltaic (PV) process;
- A small pitch technology;
- A unique hybridization technology.

Based on these key technological points SOFRADIR is producing, with success, 2D arrays for 2.5 generation IR systems and in parallel, can prepare further third generation developments.

2.2. A high maturity level HgCdTe technology

2.2.1. Introduction

SOFRADIR has a Vertically Integrated Production Facilities (VIIPF) dedicated to Mercury Cadmium Telluride (HgCdTe) IRFPA production and dewar-cooler-electronics integration as described in Fig. 3. The manufacturing of these IR detectors is based on the following universal steps [4,7]:

Specific HgCdTe activities include growth of the Cadmium Zinc Telluride (CdZnTe) ingot using a Bridgman Method, slicing of CdZnTe substrates from the ingot according to specific process steps, growth of the HgCdTe layer using a Liquid Phase Epitaxy (LPE) method (Te-rich corner and slider technique) which yields a very accurate material composition and thickness. The homogeneity of the cut-off wavelength of the material is better than 0.1 µm over the entire substrate for a 10 µm (77 K) cut-off wavelength.

The processing of PhotoVoltaic (PV) diodes uses a well controlled ion implantation technique which allows accurate control of the pixel size giving very good Modulation Transfer Function (MTF) and which allows the use of a totally planar technology, which is the easiest way to obtain the best passivation and therefore the best long term stability.

General purpose activities which may be used for HgCdTe, InSb, QWIP [5] include design of PV diodes and Silicon readout circuits including the multiplexing and signal processing functions, test of Silicon wafers coming from the Silicon foundry, manufacturing of Indium bumps, hybridization of PV diodes and Silicon readout circuits using an unique Indium bump reflow

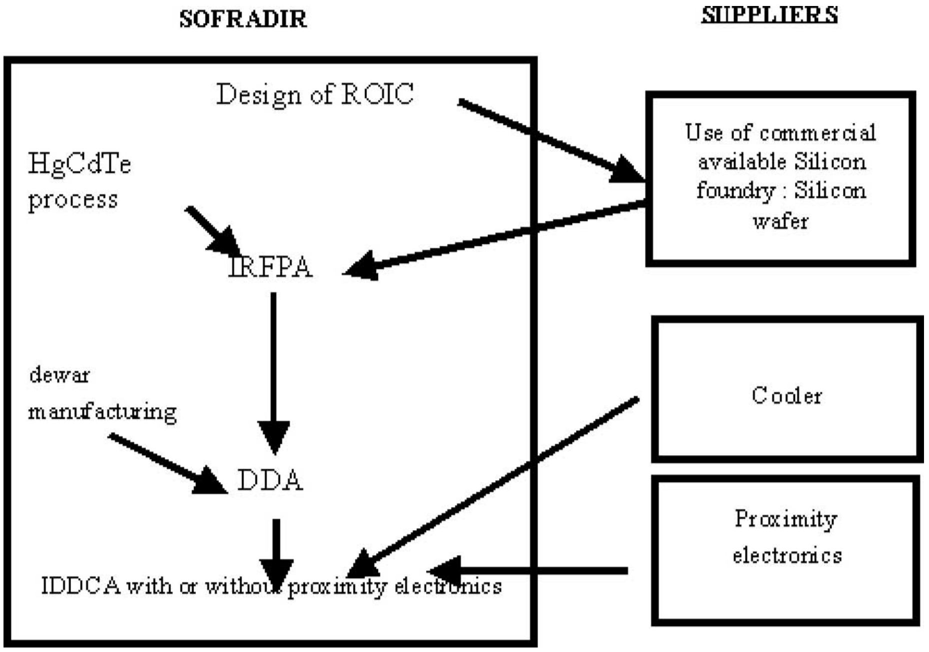

Fig. 3. SOFRADIR industrial organization for HgCdTe.

technique (with a 100% bonding yield) which minimizes stress to the diodes and therefore improves results in long term stability and reliability. These general purpose activities also include dewar design and manufacturing, integration of the IRFPA inside the dewar, integration of a 'slip-on' cooler (Stirling cycle or Joule Thomson) or an integrated dewar cooler assembly (Stirling cycle or TE cooler types), and final testing with or without integrated Command and Control Electronics.

2.2.2. *Wafer size and quality*

The substrates are derived from house-made Cadmium Zinc Telluride (CdZnTe) ingots sliced into crystal-oriented rectangular wafers. Since 1996, SOFRADIR has manufactured 60 mm (2.4″) diameter CdZnTe ingots from which wafers are sliced and 90 mm diameter CdZnTe ingots are now validated at the production level. Since 1998, the CdZnTe wafers have been shifted up to 36 mm × 38 mm at the production level, enabling larger detectors and/or more detectors per wafer. This shift enabled for instance the development of large focal plane arrays with a length of the array greater than 30 mm and to increase the number of die per wafer for large 2D arrays! This is a key point regarding manufacturing capabilities.

At present, wafer size close to two inches diameter (46 mm × 46 mm) has been qualified for mass production and is used to manufacture large staring arrays.

On the detective process part, the Liquid Phase Epitaxy (LPE) growth of the HgCdTe layer has been the technological choice for more than 15 years. This process step is critical for the detection quality, spectral cut-off uniformity and reproducibility. It has been well mastered and has demonstrated high yield and high reproducibility, making it a key point for the high performance detector manufacturing.

As to Short Wave (SW) and Medium Wave (MW) bands, the next step is the move to large wafer sizes (3 to 4 inches) based on Molecular Beam Epitaxy. In fact, the MBE process on Germanium substrates (211 orientation) was demonstrated [6] many years ago at CEA-LETI(LIR) and is currently validated [7,8] and will be in production end of 2004. One of the advantages of this approach is the well-mastered thickness of the sensitive thin film deposition.

Consequently, this approach leads to a new generation of HgCdTe SW and MW 2D array detectors based on a perfect control of the material and the possible use of more complex structures and allows the manufacture of cost effective large 2D arrays using 4″ wafers and taking advantage of the strengths of the hetero substrate.

As far as detector sensitive in 8–12 m waveband are concerned, the move to large wafer sizes is in development based on MBE process and will be transferred to production in the next years.

2.2.3. *PV process*

The electrical properties of un-doped $Hg_{1-x}Cd_xTe$ [9] are mainly dominated by two features. Firstly, the mercury vacancy which is the native acceptor and which is present in HgCdTe at a concentration related to the thermal history of the crystal (growth, anneals). Secondly, the residual impurities (or defects) which are more often than not residual donors. While the residual donor concentration is typically in the range 10^{14}–10^{15} cm^{-3}, and remains constant after heat treatments, the metal vacancy concentration can be controlled up to several 10^{17} cm^{-3}, or down to less than 10^{14} cm^{-3} by annealing. The critical parameter of this technology is the control of the epilayer P-type doping.

Once the sensitive layer is grown, polished and P-type doped, the remaining step is to manufacture the photovoltaic (PV) diodes. The chosen process in France is the ion implantation process [9] which allows very precise control of electrical junction geometry and leads to a graded $n + n$–p junction, which reduces the electric field at the junction and reduces consequently leakage current sources. These enables sharp diodes with high fill factor, leading to a good trade-off between pixel Modulation Transfer Function (MTF) and Noise Equivalent Temperature Difference (NETD).

This is a Silicon-like planar technology, which has been used at a large scale at SOFRADIR for more than 15 years.

2.2.4. Decrease in IRFPA pitch

The first key point to optimizing the large IRFPA format production forced the reduction of the array size by reducing the array pitch. However, decreasing pitch the ROIC storage capacity has to be improved or at least maintained in order to maintain high performance for low pitch staring arrays.

Research efforts were launched mid of the nineties at CEA-LETI/LIR in order to adapt critical technological steps to pitch reduction. Many steps have been regularly developed and transferred to production. Finally, full technological adaptations for 20 µm pitch have been available since 1999 and fully validated. It concerns PV technology and hybridization process, and especially regarding the collective processing approach. Following the Vertically Integrated Production approach, the 20 µm pitch is now produced on the standard production line at SOFRADIR!

Regarding smaller pitch (15 µm), technological adaptations are now validated at CEA-LETI/LIR, available for SOFRADIR and will be in production in 2004. Fig. 4 shows the pitch evolution of the 2D arrays.

In parallel, on-going efforts are made in common between CEA-LETI/LIR and SOFRADIR to study and validate new pre-processing functions on focal plane and to validate the use of new CMOS Silicon technologies.

However, thanks to the performance increase of CMOS technologies, the readout silicon circuit is not a limiting subassembly regarding these pitch decreases, but linearity of these circuits is of primary interest and many improvements have been introduced in new readout silicon circuits.

2.2.5. Hybridization process

The French indium bump hybridization process is based on a unique reflow technique. This technique allows the HgCdTe array to be accurately and automatically self-aligned on its silicon Read-Out Integrated Circuit (ROIC), and gives a perfect connection yield. Moreover, it enables simultaneous multiple HgCdTe PhotoVoltaic (PV) array hybridization on a single Silicon wafer or a connecting support [7,10], for very large array manufacturing. Another key point of this approach is its ability to facilitate the hybridization of always-smaller pitch 2D arrays.

This unique process is used at mass production level and leads to an increase in production capacity as well as a decrease in cost.

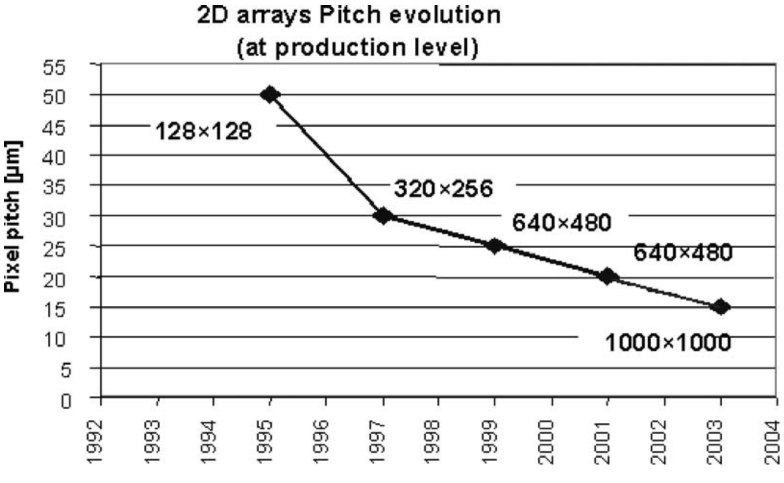

Fig. 4. Decrease of 2D-array pixel pitch at SOFRADIR.

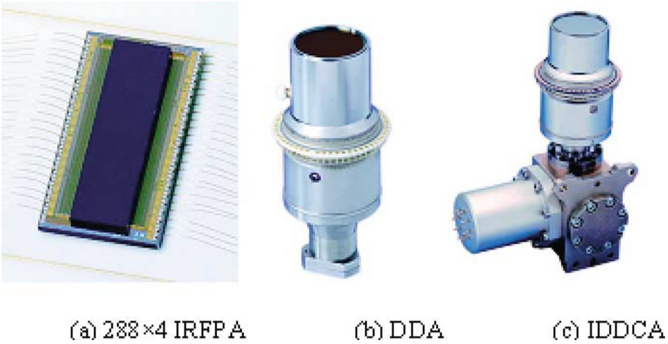

Fig. 5. 288 × 4 IRFPA DDA or IDDCA in production.

2.3. *Second generation applications*

Worldwide FLIR development programs came into production mid of the 1990s and since 1998, SOFRADIR has been dedicated to high volume production of 288 × 4 LW IR detectors and since the end of 1999 for the 480 × 6 LW IR detectors. Up to the mid 1990s, the CCD readout integrated circuits (ROIC) were the standard for these detectors. Since then, the systems requirements and the foundry technologies have opened the way for CMOS ROICs, enabling increased flexibility and electrical interface simplification. Then the CMOS ROIC for the 288 × 4 has been developed and offered to upgrade the CCD version at the production level.

At present, most of the second-generation Forward Looking InfraRed thermal cameras (FLIR), which are currently developed or produced worldwide, are based on this type of detector (Fig. 5). Consequently, more than ten thousand 288 × 4 detectors, in different dewar configurations (DDA and IDDCA) have been shipped up to date for FLIR applications such as IRIS from SAGEM/France, SOPHIE from THALES Optronique S.A. (TOSA)/France, CATHERINE from TOSA, SYNERGI from TOSA and PILKINGTON/UK and ZEISS/Germany, and the thermal sight from OFFICINE GALILEO-ALENIA/Italy. Few companies in the world are in a position to show such experience and success in this field.

As far as the high definition format is concerned, the US ARMY tested successfully the French technology and awarded SOFRADIR contracts in September 1995 and July 1996 for the delivery of several Standard Advanced Detector Assembly (SADA) II prototypes for qualification. The SADA II definition has been defined as part of the Horizontal Technology Integration (HTI) program and is a 480 × 6 IRFPA, IDCA concept with integrated split Stirling cooler and integrated readout and drive electronics.

SOFRADIR has therefore been involved for many years in Detector Dewar Assemblies development efforts with the SADA family and is now in production for SADA II units for the US ARMY.

2.4. *Second generation performance*

The high quality of LWIR TDI linear arrays has already been extensively demonstrated and recognized by SOFRADIR customers through the quantity of detectors already ordered, delivered and used in operation field worldwide.

Fig. 6 summarizes the performance over 3560 ‘288 × 4’ arrays (representing 4 100 000 photodiodes), manufactured over the last years, measured for 0.28 sr field of view, 20 µs integration time and 20 °C background temperature. The specific peak Detectivity mean value is 19×10^{11} $\mathrm{cm}\cdot\sqrt{\mathrm{Hz}}/\mathrm{W}$ (also called ‘Jones’) and the standard deviation is 11.5%. The Responsivity mean value is 1.72×10^8 V/W and the standard deviation is 12%. This shows the maturity and reproducibility of SOFRADIR MCT array production. In addition to this high performance result, an important feature available on the CMOS scanning arrays is the pixel de-selection: this is of great interest for the system, since it potentially enables a further increase in the array performance in terms of a decrease of bad channels.

As far as Residual Fixed Pattern Noise (RFPN) is concerned, measurements of TDI LW focal plane arrays, for correction temperature reference: $-3\,^\circ\mathrm{C}$ and $+32\,^\circ\mathrm{C}$ for example, shows that in the worst case the ratio of the RFPN over the temporal NETD is less than 20%, which means that the RFPN is less than 20% of the detector average NETD. As a consequence, the detector performance degradation due to the RFPN is very low leading to a very good image quality.

It is worthwhile to note that systems which use scanning mechanisms associated to TDI linear focal plane arrays can carry out frequent update of correction tables of IRFPA spatial non-uniformity in a frame so that the RFPN of the detector does not degrade as a function of time due to environmental condition changes. This is a major advantage of second generation systems as well as their behavior regarding optical counter counter measures.

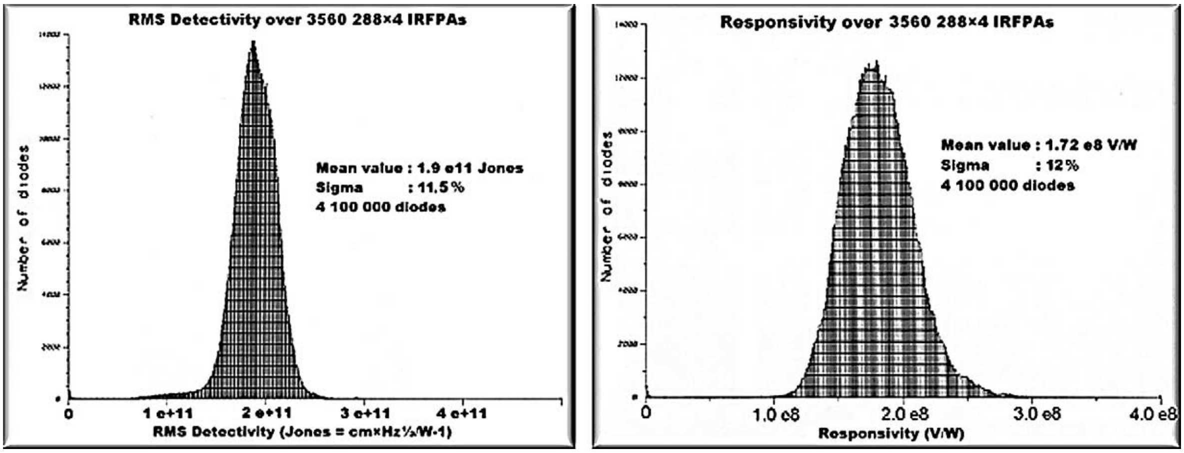

Fig. 6. 288 × 4 Detectivity and Responsivity cumulated histograms for 3560 delivered IRFPA.

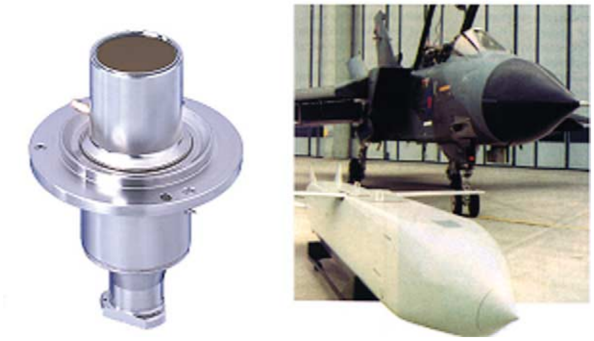

Fig. 7. Storm Shadow/Scalp EG Missile and its 320 × 256 detector.

3. 2D staring arrays for 2.5 generation production

3.1. 320 × 256 MW 2D arrays at mass production level

A great success was the award in 1999 for the production of the 320 × 256 MW detector for the current European stand off missile programs called Storm Shadow and Scalp EG (see Fig. 7). This production order established SOFRADIR as a key player in the Mid Wave staring arrays field and SOFRADIR is now at full production rate [1].

The 320 × 256 MW CMOS IRFPA production results (see Fig. 8) highlighted the high performance level achieved [11] for MW waveband over a very large statistical population (1132 on this histogram), close to 100 million pixels, including the high operability (random distribution of dead pixels and low numbers of clusters) with a high manufacturing yield.

The temporal Noise Equivalent Temperature Difference (NETD) is very low (a few mK in these conditions) and these devices are photon limited. This temporal NETD correspond to the maximum performance the system can reach. Thanks to HgCdTe technology these performance remains constant up to 110–130 K operating temperatures depending on the detector operating conditions. That means that Argon gas cooling could be used for missile applications leading to a decrease in cool-down time, in total gas quantities and thus in total system mass. For Stirling coolers, the high operating temperature will lead to an increase in cooler engine efficiency and therefore a decrease in input power and an increase in cooler reliability.

In the last years, systems have started to request high performance 2D arrays for long-range applications inducing low scene fluxes. Low flux ROICs were then developed and to offer 320 × 256 low flux MW IRFPAs as well as 320 × 256 Short Wave (SW) detectors [10].

As far as long waveband is concerned, 2D staring arrays market is just emerging for performance and cost effective reasons. However 320 × 256 LW HgCdTe are offered by SOFRADIR as well as large format quantum well (QWIP) detectors in cooperation with THALES [12,11,5].

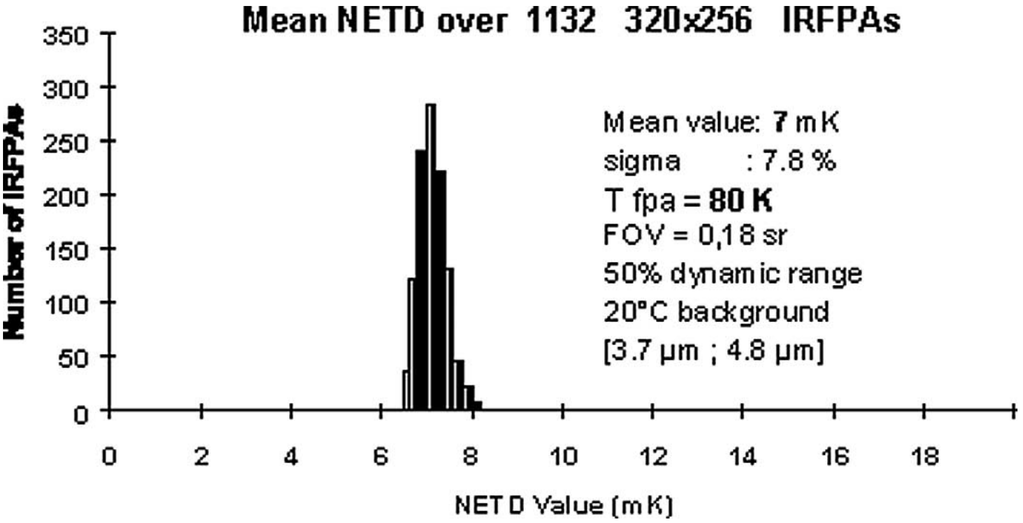

Fig. 8. Cumulated mean NETD histogram for 1132 IRFPA (320 × 256 format).

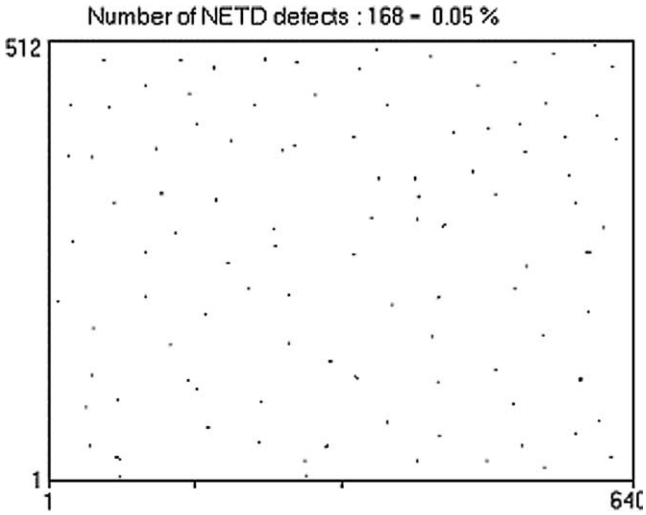

Fig. 9. 640 × 512 HgCdTe MW NETD defects at 110 K operating temperature.

3.2. 640 × 512 MW IRFPA

This high performance HgCdTe 640 × 512 MWIR, 20 µm pitch, detector was validated at the end of 2001. The main characteristics are a snapshot multi-format 2D array with a 20 µm pitch, 120 Hz maximum frame rate with four outputs and this array includes many on-focal-plane array functions: Integrated Then Read (ITR) and Integrate While Read (IWR) modes with a 4.8 million electron charge storage, a sub frame imaging (windowing function) mode, high rejection circuit inputs and user friendly interface.

The results of performance measured on 640 × 512 MW IRFPAs exhibit high constant average performance up to 130 K [11], but in order to offer a cost effective detector with a very low number of defective pixels, an operating temperature of 110 K is a good trade-off. Average NETD is about 15 mK for $f/2.2$ aperture, 40% well fill in the 3.7–4.8 µm bandwidth.

A defective pixel map is given in Fig. 9 and exhibits a very low number of NETD defects (criteria $> 1.5 \times$ average): about 170 defects, i.e. 0.05% of defects. In addition, the defects are randomly distributed over the array with few clusters.

The low number of electro-optical defects demonstrates the low density of defects achieved in the MCT material. Even with a decrease in the pitch down to 20 µm, the material defects do not impact neither the number of defective elements, nor the number of clusters.

Based on the beginning of the production for 640 × 512 MW, we can see in Fig. 10 the cumulated histogram on ten IRFPAs showing the reproducibility of the process including high operability figures. This result allows demonstrating the maturity and high performance of these 640 × 512 MW 20 µm pitch detectors.

The next step is to offer a 640 × 512 MWIRFPA with 15 µm pitch in order to be fully competitive in term of cost with TV/4 format and therefore to offer a competitive upgrade of existing systems for improving the resolution or suppressing the micro-scanning constraint. This new product will include optimized cryogenics and will be in production in 2004 at SOFRADIR.

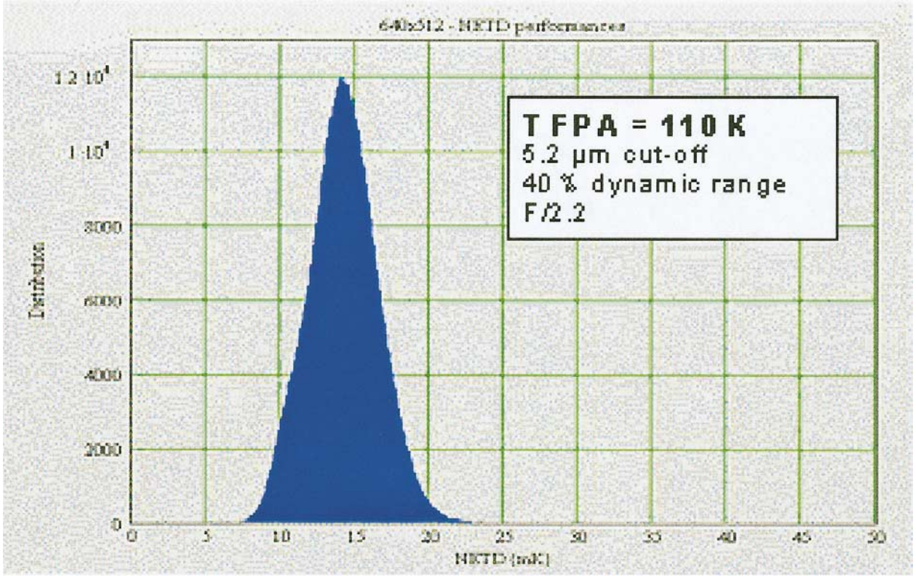

Fig. 10. Cumulated histogram on ten 640 × 512 MCT MW detectors: Average 14.2 mK with a sigma of 2 mK.

Fig. 11. 1000 × 256 SWIR for hyper spectral applications.

3.3. Very large 2D arrays: 1000 × 256 SWIR IRFPA 30 µm pitch

Using almost the same process as for MW arrays, SOFRADIR has demonstrated very high performance for 1–3 µm waveband (SWIR) applications. The ability of SW MCT arrays to operate at focal plane temperatures near 200 K and above, depending on the cut-off wavelength, is of first interest in order to be compatible with passive cooling systems (less expensive than cooling engines). In addition, MCT technology enables to adapt the detector cut-off wavelength in function of the application need.

Among space applications in the SWIR waveband, hyper spectral applications are emerging. Thus, at the beginning of 2000, SOFRADIR was selected by the European Space Agency (ESA) for undertaking detector bread boarding activities [10,13]. Based on this support, a very large 2D arrays was developed fully dedicated to hyper spectral needs. The array (see Fig. 11) format is a 1000 × 256 sensitive in the 0.8–2.5 µm bandwidth. The first deliveries of flight models are planned for the end of 2003.

4. Third generation development approach in France

4.1. Key points for third generation

What is called third generation is a new type of detector able to offer a breakthrough for the systems including more performance, less operating constraints and lower price than the existing generation. Consequently third generation implies cost effective 2D staring arrays (about 1000 × 1000 pixels and more) with high reliability, high thermal and spatial performance, high frame rates, and optionally multicolor capabilities;

Therefore the candidate technology for third generation IR detectors must have the following performance and characteristics:

- A semi-conductor material which should present very high performance (high quantum efficiency, low dark current) in order to offer BLIP thermal resolution at high operating temperature (low cost and high reliability cryogenics) and in high frame rate conditions even in worst case operating conditions: cold scene temperature and high $f/$number. Based on these requirements, MCT has already demonstrated its capabilities and is still the best choice in comparison of QWIP, InSb or microbolometer.
- A small pitch technology keeping constant the performance and the uniformity in order to manufacture affordable large format: again the French MCT technology has already demonstrated its ability to reduce the pitch down to 15 µm thanks to its ion implantation technology and its unique hot reflow hybridization process. This is a key point that can be very difficult for other materials/technologies.
- Very large wafer sizes are necessary for producibility and cost issues: indeed, the challenge for large array production is to be cost effective. This is allowed thanks to the optimization of the size of the array as well as increasing the detector wafer size, together with optimization of the cooling constraints. A strong advantage of HgCdTe versus competition materials is its ability to work at much higher temperature than 77 K [7,12]. Thus the goal of SOFRADIR MW IDDCA s is to give direct benefit to the systems by lowering the cooling constraints at a high operating temperature, about 120–140 K, and making the systems design and performance easier (smaller coolers, lower power consumption, longer cooler life time,...) following a cost effective approach. To answer those needs, large wafer sizes are accessible for the different material candidates including for MCT for which large wafers (4 inches and more) will be available on Germanium in France [14,8].
- The use of heterojunctions is necessary for manufacturing the multicolor detectors: Molecular Beam Epitaxy (MBE) is a way to answer this need and it is available for MCT in France.

In consequence, MCT technology has potentially the necessary performance and characteristics to answer the needs of the third generation IR detectors and is still a key technology for new developments. Moreover, MCT technologies are the more advanced, taking into account all the know-how accumulated for many years and the high performance already demonstrated, even based on LPE material for conventional structures or based on MBE material for the more complex structures!

Finally, other considerations as synergy with other production, as well as strategic issues, may also impact the material choice.

4.2. A unique R&D organization

R&D for third generation is really a challenge and a specific organization is important in order to lower the R&D risks and to guaranty a fast move of the third generation developments to the mass production level.

SOFRADIR and CEA-LETI/LIR have chosen to put together the researchers from CEA-LETI/LIR and the R&D people from SOFRADIR to optimize the R&D program efforts between both organizations. This concurrent R&D organization will guarantee that production issues will be taken into account during R&D development choices and then the move to the mass production level will be quicker and will follow a low risk approach.

5. Conclusion

French HgCdTe technology is one of the most mature worldwide for manufacturing 2 and 2.5 generations IR detectors. This success is due to the long experience in this field in France and to a unique development and production approaches.

In order to prepare future military and industrial needs, SOFRADIR and CEA-LETI/LIR are carrying on research on the third generation, mainly based on HgCdTe materials with MBE growth and using a concurrent R&D organization. Two approaches are followed for these 3rd generation developments:

- Single color very large format arrays with small pitch, high performance and high frame rate. These arrays will use very large wafer size based on CdZnTe substrates or heterosubstrates on germanium,
- Multicolor arrays based on the growth of complex structures using MBE and with several thickness compositions and doping levels.

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