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Sofradir infrared detectors

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Abstract

Starting mid 70's, France has developed a new infrared focal plane array technology based on Cadmium Mercury Telluride (CMT) and silicon materials.

The infrared laboratory (LIR/LETI) has prepared an Infra Red Charge Coupled Device technology which uses photovoltaic technique on Cadmium Mercury Telluride wafers for detection and Charge Coupled Devices (CCD) on silicon for the read-out circuit.

Due to this new approach it is possible to fabricate infrared detectors sensitive from 2 μm to 13 μm with a very large number of pixels (up to 16 000).

46 SOFRADIR has built a development center which uses now this process in production and there is no more question mark about producibility of such Infra Red Focal Plane Array. Typical (IRFPA) results on large detectors will be presented.

1. Sofradir technology

This technology (figure 1) developed by the well known laboratory, the *Laboratoire Infrarouge* (the Infrared Laboratory) which has the support of the French Ministry of Defense is based on Mercury Cadmium Telluride photovoltaic detectors coupled with CCD read-out circuits on silicon [1].

The Cadmium Mercury Telluride / Mercury Cadmium Telluride (CMT/MCT) material is obtained by liquid phase epitaxy on CdZnTe substrates. The advantages of this technique are numerous, only some of them are presented here.

With the liquid phase epitaxy method it is possible to control reproducibly the composition of the CMT/MCT layer as a function of the cut off wavelengths needed in the application. The process is so good that it is possible to obtain cut off wavelength with a better accuracy than plus or minus 0.1 μm through a wafer and better than plus or minus 0.2 μm from one wafer to another one.

Don't forget that homogeneity of an array is not only linked to the Direct Current (DC) response but also to the gain as a function of the wavelength. The importance of this parameter is not obvious for component manufacturers because it is a system problem but we feel that it is an important parameter.

With the liquid phase epitaxy method it is possible to be backside illuminated by using infrared transparent substrates like CdZnTe which allows the manufacture of very dense detectors like staring array.

With the liquid phase epitaxy method it is possible to grow just the CMT /MCT thickness needed therefore it is not necessary to polish the CMT/MCT which stresses the material after growing the layer.

The photovoltaic diodes are fabricated using an ion implantation technique through a planar technology approach.

These two characteristics are more important than people could imagine.

The planar technique is a silicon like technique and is a very important factor in the success of the process in production. It allows to passivate the CMT/MCT material before the process which is important for such an exotic material.

Ion implantation differs significantly from diffusion technique. By using ion implantation technique, diode areas can be controlled acurately which has a direct impact on the homogeneity of the array.

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For planar structure the diode area is controlled within plus or minus 1 µm which is only limited by the photolitography techniques which are used. Don't forget that this parameter is one of the most important factor of inhomogeneity when mesa structures or diffusion techniques are considered.

Developed read-out circuits are mainly oriented to a CCD approach only because it is the main way to obtain the best performances.

The CCD approach allows one to have a very simple way to increase performance on the direct basis of the square root of the number of pixels used in TDI (Time Delay Integration) mode. That allows one to have more performance or more margin (means less cost) on one hand and on the other hand allows one to obtain acceptable performance in difficult operating conditions like 200 K for the Focal Plane Array (FPA).

Connection technology is also one of the most important one for such IRFPA manufacturing.

Of course material differential expansion is one of the main topics but on an other side it is surely the stress which is done on the material itself. This factor is more important for long wavelength CMT material. The SOFRADIR technology has for a long time solved this problem by using not mechanical pressure but actual reflow soldering at a reasonable temperature. This technique allows one to obtain 100 % yield. It is not a cost driver.

Cooling techniques become now a critical issue because of the increase of size of the FPAS. This has caused an increase of cryogenic power consumption while system people want a decrease in cryogenic power consumption.

As glass, metal, ceramic techniques for dewar manufacturing are mastered by SOFRADIR it is possible to satisfy many new requirements. Therefore, new products are in development [2] and some of them have already been developed [3].

2. State of the art

For six years Sofradir developed different types of components well adapted for a lot of tactical application as missile seekers, FLIR (Forward Looking Infra Red) or surveillance and space application.

Some of them are already in the low rate initial production phase.

2.1. Current production

2.1.1. Infrared focal plane array

The current production is covered by different types of linear arrays including TDI arrays. The most complex arrays are the 288 x 4 and the 1 152 x 1 built from the 288 x 1 concept:

- the 288 x 1 (using a field of view of 0.3 SR (steradiant) presents an average pic detectivity of 1×10^{11} $W^{-1}.Hz^{1/2}.cm$ for a 300 K background temperature for a cut off wavelength of 10.5 µm. The homogeneity of the array is good as the standard deviation is less than 7 %; (figure 2a);

- the 288 x 4 which uses the TDI function on four pixels has an average pic detectivity of 2.1×10^{11} $W^{-1}.Hz^{1/2}.cm$ for a 300 K background temperature and a 0.3 SR field of view and a cut off wavelength of 10.5 µm; this shows the efficiency of the TDI function included in the FPA as the increase of performance is in accordance with the square root of the increase of the number of pixels per line (figure 2b);

(The homogeneity of the array is good as the standard deviation is better than 9 %).

- the 1 152 x 1, which in the 3 to 5 µm waveband, presents an average detectivity of 3×10^{11} $W^{-1}.Hz^{1/2}.cm$ for a 300 K background temperature, a 0.5 SR field of view and a cut off wavelength of 5.2 µm; the homogeneity of the array is very good with a standard deviation of 9 % (figure 2c);

- the 288 x 4 working in the 3-5 µm band presents an average pic detectivity of 6×10^{11} $W^{-1}.Hz^{1/2}.cm$ for a 0.5 SR field of view and a 300 K background temperature; the homogeneity of the array is good as the standard deviation is better than 7 %(figure 2d);

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2. 1.2. **Dewars**

The family of dewars have been developed using our standard metal technology:

- *dewar for missile seeker application:* it is a small dewar (50 ml) which is compatible with Joule Thomson (JT) cooler or standard Stirling machine; the cool down time is less than 3 s with a JT cooler.

- *dewar for FLIR application:* this dewar allows the integrations of large arrays as the 288 x 4 or the 128 x 128; it is compatible with Joule Thomson cooler or standard Stirling machine; the cool down time is better than 2 min;

- *dewar for very large focal plane array:* this dewar allows to cool down large IRFPA up to 70 mm length; it is cooled down by Stirling machine.

2.2. New products

Some applications using staring arrays appear now. Therefore the research activity of the Laboratoire Infrarouge (LETI - CENG Grenoble) is now transfered to Sofradir where the first prototypes are now available.

- 64 x 64 staring array

With a pitch of 60 µm in both direction and a cut off wavelength of 10 µm, this array presents an average detectivity better than 5 x 10^{10} $W^{-1}.Hz^{1/2}.cm$ for a field of view of 0.5 SR and a 300 K background temperature (Figure 2e);

- 128 x 128 staring array

With a pitch of 50 µm in both direction and a cut off wavelength of 5 µm, this array presents an average detectivity better than 3 x 10^{11} $W^{-1}.Hz^{1/2}.cm$ for a field of view of 0.3 SR and a 300 K background temperature (figure 2f);

3. Conclusion

The SOFRADIR technology for CMT IRFPA already in production is in fact very flexible. People can use it for different types of application:

- linear arrays,
- two dimensionnal arrays using TDI concept,
- staring arrays,
- 3 to 5 µm waveband,
- 8 to 13 µm waveband,
- 40 to 200 K.

Therefore applications are numerous.

As a matter of fact SOFRADIR is associated to or at the center of the development of all the major military programs using the new generation of infrared sensors. Among them are the TRIGAT European Anti-Tank program including both visionics and seeker in the 8 to 12 µm waveband, the MICA missile seeker program using the 3-6 µm waveband and the RAFALE visionic program. To be cited also the most important US visionics development, the LOSAT (line of sight anti-tank) program.

REFERENCES

1 - Advanced infrared focal plane arrays (April 13/14 1992 - FLORENCE ITALY)

2 - New dewar/cooling system generation

3 - SOFRADIR IRFPA state of the art

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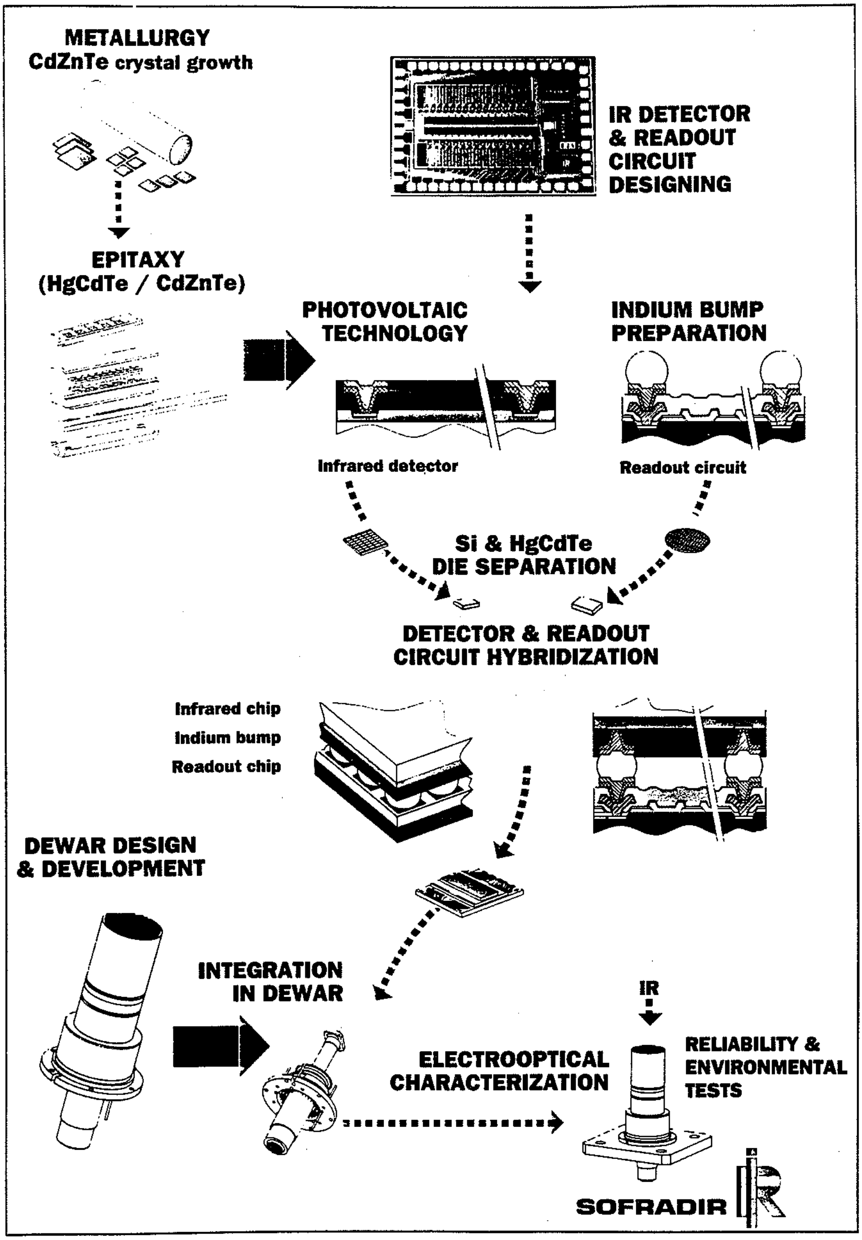

Figure 1
Sofradir technology

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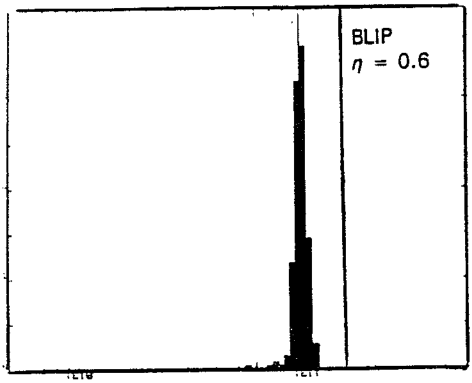
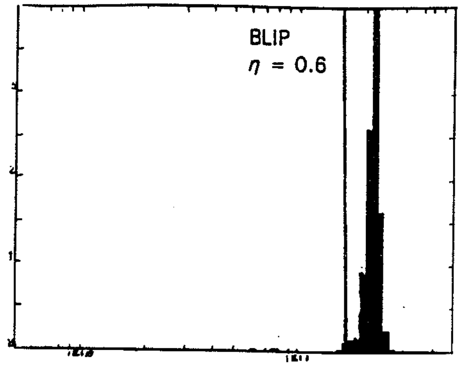


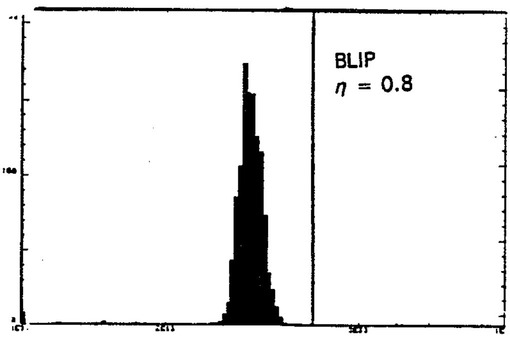
Average D^* : 1×10^{11} $W^{-1}.Hz^{1/2}.cm$ Sigma : 6.7 %

D^* 288 x 1 / 8-12 μm
(Figure 2a)



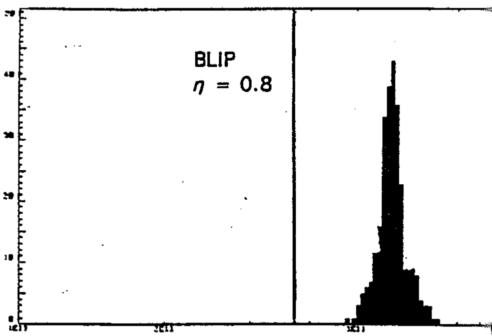
Average D^* : $2.1 \times 10^{11} W^{-1}.Hz^{1/2}.cm$
Sigma 8.9 %

D^* 288 x 4 / 8-12 μm
(Figure 2b)



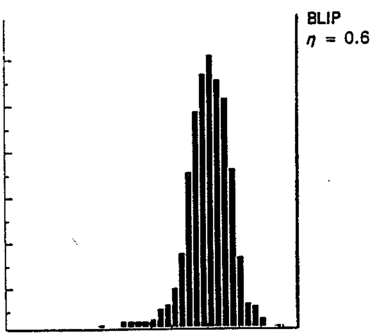
Average D^* : 3×10^{11} $W^{-1}.Hz^{1/2}.cm$
Sigma : 9 %

D^* 1 152 x 1 / 3-5 μm
(Figure 2c)



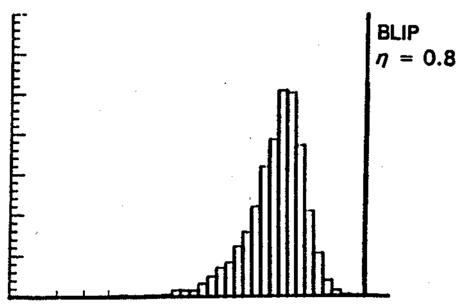
Average D^* : 6×10^{11} $W^{-1}.Hz^{1/2}.cm$
Sigma : 7 %

D^* 288 x 4 / 3-5 μm
(Figure 2d)



Average D^* : 5×10^{10} $W^{-1}.Hz^{1/2}.cm$
Sigma : 12,7 %

D^* 64 x 64 / 8-12 μm
(Figure 2 e)



Average D^* $3 \times 10^{11} W^{-1}.Hz^{1/2}.cm$
Sigma : 13 %

D^* 128 x 128 / 3-5 μm
(Figure 2f)

Figures 2
IRCCD detector performances