Processing window broadened by a barrier structure in dual-band HgCdTe IRFPAs

Yiyu Chen1,2, Zhenhua Ye1*, Peng Zhang1,2, Weida Hu1, C. Lin1, X. N. Hu1, R. J. Ding1, L. He1
1. Key Laboratory of Infrared Imaging Materials and Detectors, Shanghai Institute of Technical Physics, Chinese Academy of Sciences
Shanghai, China
2. University of Chinese Academy of Sciences
Beijing, China
(*author for correspondence, E-mail: zhye@mail.sitp.ac.cn)

***Abstract*—Dual-band HgCdTe IRFPAs are one of the most important developing frontiers for 3rd generation IRFPAs. A barrier has been implemented in the dual-band HgCdTe detectors to overcome the electrical cross-talk between two layers with different compositions. Moreover, we now reveal another benefit of this barrier structure. This barrier can relieve the critical demands in photo-lithography of the implantation process, which shows great advantages as the dimension of a single element in an advanced dual-band IRFPAs is becoming less than 30µm. When the implantation pattern migrates about 2µm, the profile in the dual-band structure is exposed under implantation. An n-type connection between LW layer and MW layer will be created. Without a barrier, the dark current of the MW layer is completely ruined by fractions from the LW layer. While a modified barrier is utilized, the dark current can be restrained to the same order as those with perfect implantation.**

Keywords: dual-band; HgCdTe; implatation; process window

I. INTRODUCTION

Detecting signals from two IR wavelength can significantly increase the accuracy in discriminate the object.[1] While, the dual-band HgCdTe IRPFAs with simultaneous read out provide signals from the exactly same time, eliminating the difficulty in spatial alignment and temporal registration. Nowadays, the dimension of a single element of the simultaneous dual-bands structure have shrunk to less than 30 μ m, as demanded by the advanced IRFPAs. The photo-lithography is becoming critical in fabricating the advanced IRFPAs. Any deviation will deteriorate the capability of the detector, especially in the implantation process, which defines the basic p-n junction in a photovoltaic detectors. However, we have recently revealed that the barrier utilized in the structure can nearly eliminate the influence of the migration at the same time.

II. SIMULATING PROCEDURE

A. *Simulating assumption*

The simultaneous dual-band structure we simulate was proposed by Rockwell [Tennant Thomas JEM 2001], as is illustrated in Fig.1. All junctions are set as 10 μ m^2. The gray level signals the Cd composition in HgCdTe, the blue level signals the damage level created by B+ implantation, which then defines the Hg interstitial in the material. The n doping level in the profile is supposed to be proportional to Hg interstitial created. When the profile angle is set as 75°, the implantation angle set as 7°, the B+ reaches the profile is less than 1/10 compared to those reach the planar material. Thus, the parameters used in our simulation are listed in Table1, by setting doping concentration created by implantation to be the level of 10^{16}/cm^3. The lateral layers aside the barrier with graded compositions are also considered in the simulation with a thickness of 100nm. The temperature is set 77K. This simulation is completed with a commercial TCAD Crosslight software. In this software, dark current can only be obtained under certain bias, thus, all dark currents simulated here are under reverse bias of 0.5V.

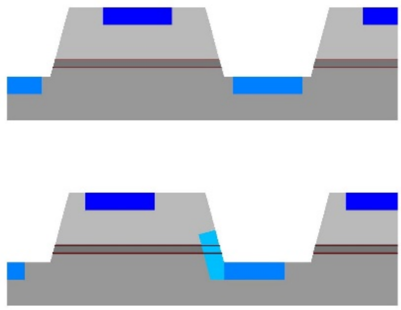

Fig.1 The illustrated structure simulated in the report. Remind the shallow implantation in the profile.

Layer	x	thickness	Basic N_D	After IM	The profile
LW	0.225	8 μ m	10^{16}/cm^3	10^{16}/cm^3	10^{15}/cm^3
Barrier	0.4-0.5	1 μ m	10^{16}/cm^3	10^{16}/cm^3	10^{15}/cm^3
MW	0.3	5 μ m	10^{16}/cm^3	10^{16}/cm^3	10^{15}/cm^3

Table 1. The parameters used in the simulation.

B. *The effect of a barrier*

When the implantation pattern is perfect transferred, no B+ will be implanted into the profile. The two junctions are separated completely, the dark currents of the two junctions are both in good agreement with those of single junctions of 10 μ m dimension. If the implantation deviates a little, the profile will be converted to n-type, creating an n-type channel for the electron.

The n-type connection in the profile can be obstruct by a barrier, which has been proposed in the nBn structure[2], where the barrier must block the electrons from non-absorber layer. As is known to all, the capability to block electrons of a composition barrier in MCT is reasonable, because of the special affinity of this material, where 4/5 of the barrier is constructed on the conduction band. The carrier concentration is also very important for such this barrier, n-type carrier with high concentration will drag the barrier down due to its high Fermi level. Barrier with carrier concentration higher than $10^{16}/cm^3$ will lose its effect to block the electrons. Fortunately, the barrier is implanted in the profile, where implantation dose is greatly reduced compared to normal junction area. By careful calculation, the dose in a unit area is less than 1/10.

C. Modification of the barrier

First, we modified the x composition of the barrier to investigate the optimal composition for the barrier. The results are shown in Table2.

x composition	MW dark current (A/cm^2)	LW dark current (A/cm^2)
0.3(no barrier)	3.66E-6	9.98E-6
0.35	3.14E-6	1.03E-5
0.4	3.44E-8	1.30E-5
0.45	5.46E-10	1.30E-5
0.5	4.78E-10	1.30E-5
0.55	4.73E-10	1.30E-5
0.3(good IM)	3.24E-10	1.33E-5

When the barrier was absent, the dark current of the LW layer was cut about 1/3, which went to the circuit via the MW contact. This is detrimental for the MW junction, as the normal dark current of the MW junction is about 5 orders less than that of the LW junction.

When the barrier goes up to 0.45, nearly all unintended dark current from the profile area is blocked by the barrier. While further higher barrier shows no difference in blocking the electrons. Under 77K, when the composition goes up to 0.45, the bandgap is about 0.51eV, while the 0.225 corresponds to 0.14eV, the ΔE_C is about 0.37eV. This value is comparable to the value in the nBn structure. This is reasonable, because the block here is utilized to obstruct the majority carrier. In this structure, the connection in the profile in all n-type, which in part is similar to the nBn structure.

The current-voltage of different structures is shown below. Within a single figure, it has been clearly shown that, the barrier structure and good implantation

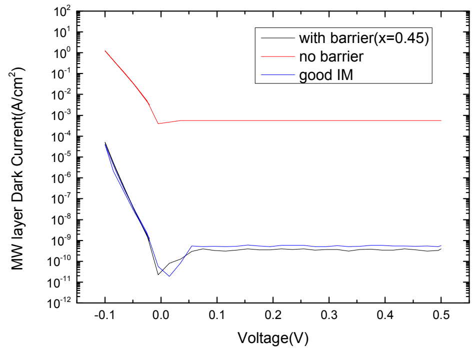

Fig.2 The dark current of the MW layer in there conditions: 1. Perfect implantation; 2. Deviated IM without barrier; 3. Barrier utilized with deviated IM.

D. Discussion

The bandgap engineering in other material is very popular, especially in the superlattice material, where the bandgap can be modified easily by changing the thickness of each sub-layer. While for HgCdTe the bandgap is defined by the composition, the bandgap diagram is decided by the affinity. Fortunately, the barrier here is utilized to block the electrons. A barrier may not be useful to block holes in HgCdTe, except for the type III superlattice fabricated by HgTe/CdTe sublayers.

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