Spectral crosstalk suppressing design of simultaneous two-color HgCdTe infrared focal plane arrays

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Abstract **Spectral crosstalk suppressing design of simultaneous two-color HgCdTe medium-wave/long-wave (MW/LW) infrared n-p-p-n detector is carried out, using commercial Technology Computer Aided Design （TCAD） software *Apsys*. A compositional barrier between two absorption layers is introduced and designed to suppress spectral crosstalk. MW-to-LW crosstalk can be notably suppressed to 2.1% while LW-to-MW crosstalk can be maintained less than 1%.**

Keywords two-color detector; HgCdTe; barrier layer; spectral crosstalk

I. INTRODUCTION

HgCdTe is the most widely used material for infrared detection, due to its advantages including continuously tunable bandgap, high electron mobility and the potential to operate at high temperatures[1,2]. Two-color HgCdTe infrared focal plane arrays (IRFPAs) can detect two distinct spectral bands and discriminate both absolute temperature and unique signatures of objects in the scene [3]. Two-color detectors can eliminate the spatial alignment and temporal registration problems that exist whenever two single-color IRFPAs are used, to simplify optical design, and reduce size, weight, and power consumption [4,5]. Spectral crosstalk existing between two bands can influence the function of discrimination. It will be effectively suppressed by incorporating a compositional barrier between two absorption layers [6]. In this paper, the barrier composition and thickness is optimized according to practical technical parameters.

II. MODEL AND METHOD

The investigated simultaneous two-color MWIR/LWIR $Hg_{1-x}Cd_xTe$ detector adopts a four-layer n-p-p-n structure grown by molecular bam epitaxy (MBE) on GaAs substrate. Figure 1 shows a cross-sectional schematic of the detector. The cutoff wavelengths of the two back-to-back photodiodes are approximately 5μm (x = 0.304) and 10μm (x = 0.225), respectively. The donor densities of the 2-μm-thick MW-n layer and LW-n layer are both $1\times10^{17}cm^{-3}$. The acceptor densities of the 6-μm-thick MW-p layer and 8-μm-thick LW-p layer are both $1\times10^{15}cm^{-3}$. The barrier is included between the MW and LW absorption layers with doping concentration of $1\times10^{15}cm^{-3}$ and adjustable thickness and composition. The device is modeled to operate at zero bias, 77K with light illumination at the bottom. Device performance in this work is calculated using finite-element modeling (FEM) simulator *Apsys* from Technology Computer Aided Design (TCAD) Software Crosslight, by simultaneously solving the Poisson equation and carrier continuity equations.

III. SIMULATION RESULTS

The quantum efficiency of devices with a 0.2-μm-thick barrier (x = 0.40) and without barrier are displayed in Fig.2. The barrier can increase the quantum efficiency of the MW diode in the MW-band while decreasing the undesired response of the LW diode in the same waveband. This implies that the barrier can effectively suppress the electron diffusion from the absorption region of the MW photodiode to that of the LW photodiode, and thus reduce crosstalk. MW-to-LW crosstalk is defined as the ratio of the signal produced by MW radiation to that produced by LW radiation among the output signal of LW photodiode. Correspondingly, LW-to-MW crosstalk is defined as the ratio of the signal produced by LW radiation to the signal produced by MW radiation among the output signal of MW photodiode. According to the data in Fig. 2, MW-to-LW crosstalk with barrier is 2.2%, much lower than the counterpart 5.7% while LW-to-MW crosstalk are 0.48% and 0.82%, respectively, both satisfying the actual application. Therefore, introducing a barrier is indispensible.

Figure 3 presents the comparison of the quantum efficiency with the barrier thickness d fixed at 0.2μm while composition x changing from 0.31 to 0.40. The quantum efficiency demonstrates a desired variation with ascending x and tends to be stable when x exceeds 0.36. Figure 4 displays the comparison of the quantum efficiency with x settled at 0.32 while d changing from 0.05μm to 0.8μm. The variation of the quantum efficiency is desirable when the barrier layer gets thicker. Subsequent work demonstrates that larger x will weaken the dependence of the quantum efficiency on d.

The relation between crosstalk and thickness d at different composition x's is summarized in Fig.5. MW-to-LW crosstalk decreases with increasing d, and LW-to-MW crosstalk has a negligible fluctuation below 0.83%. Consequently, acceptable spectral crosstalk can be obtained by the proper combination of sufficiently large x and d .

IV. CONCLUSION

Simulation results demonstrate that introducing a compositional barrier between two absorption layers can effectively suppress the spectral crosstalk of simultaneous two-color HgCdTe MW/LW n-p-p-n IR detector. With proper combination of sufficiently large barrier composition x and thickness d, MW-to-LW crosstalk can be optimized to be as low as 2.1% while LW-to-MW crosstalk can be controlled no more than 1%.

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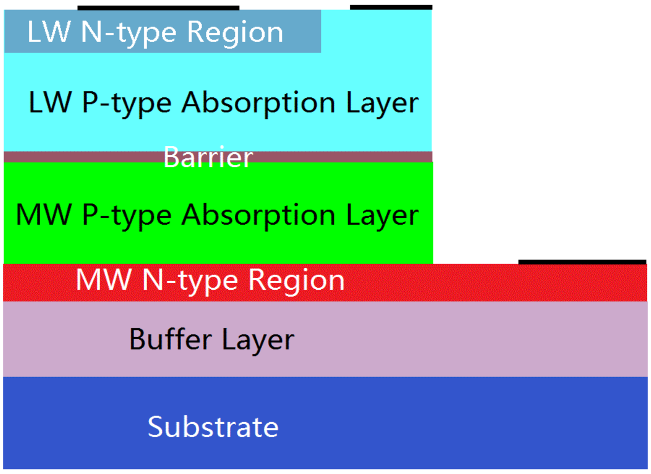

Fig. 1 Schematic of simultaneous two-color HgCdTe MWIR/LWIR detector investigated.

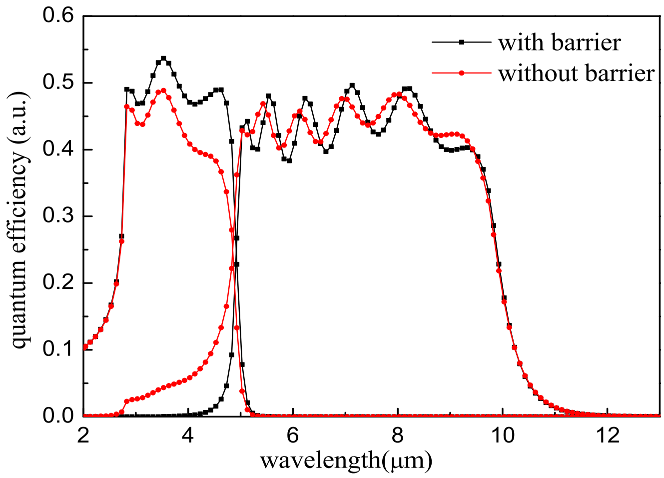

Fig. 2 Comparison of quantum efficiency between detectors with and without barrier.

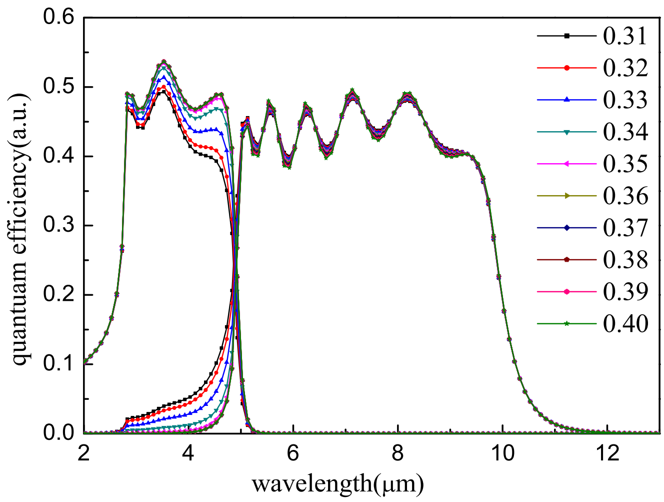

Fig. 3 Quantum efficiency related to x with d fixed at 0.2μm.

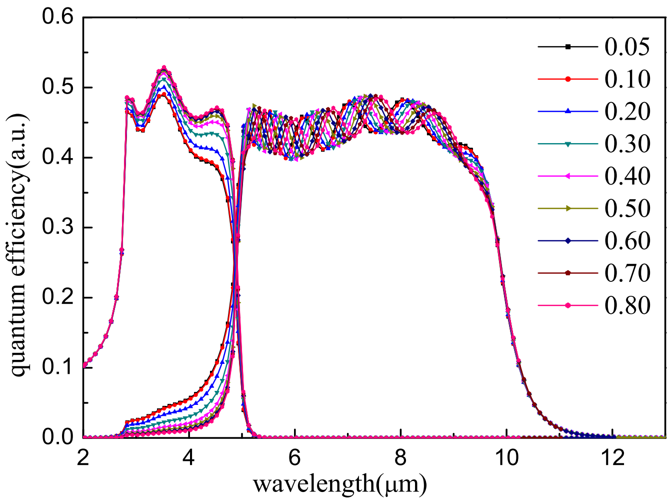

Fig. 4 Quantum efficiency related to d with x = 0.32

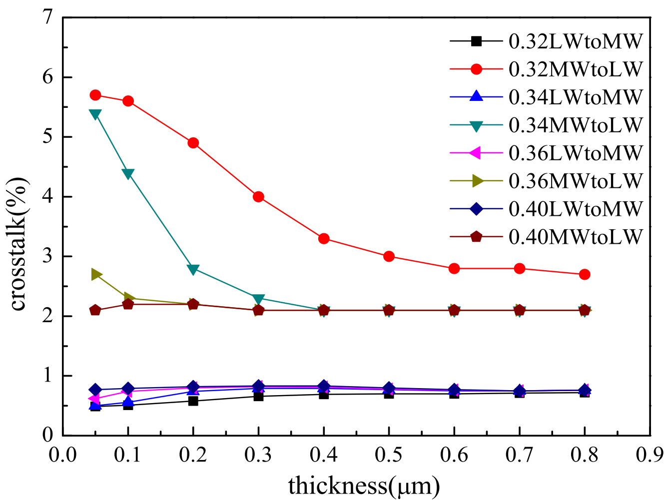

Fig. 5 Crosstalk as a function of d for different x's