Abstract

The quantum efficiency (QE) for mid-wavelength InSb infrared focal plane arrays has been numerically studied. Effects of the absorption length and thickness of p-region on device QE have been investigated. Our work shows that the optimum thickness of p-region is largely dependent on the absorption characteristics of the InSb.

I. INTRODUCTION

InSb which is a narrow-bandgap compound semiconductor has a response cutoff wavelength of 5.5 μm at 77K. Due to its excellent absorption ability in the spectral range of 3 μm-5 μm and superior fundamental properties, InSb has been widely used in military and civil fields[1-8]. Therefore, it is particularly important to fully understand the photoresponse mechanisms of InSb to improve device performance[9]. In this paper, effects of the absorption length and thickness of p-region on the device QE are numerically investigated. The optimum thickness of p-region is largely dependent on the absorption characteristics of the InSb.

II. SIMULATION MODELS

For plain drift-diffusion simulation, the well known Poisson equation and continuity equations are self-coupled. The carrier generation-recombination process consists of SRH, Auger, and optical generation-recombination terms. Additionally, the tunneling effect is implemented in the continuity equations[10-13].

III. RESULT AND DISCUSSION

The InSb focal plane arrays discussed in this study are composed of three pixels, as shown in Figure 1. The n-region with the doping density of 10^{15} cm^{-3}, has a thickness of 10μm. The p-region is doped with 10^{17} cm^{-3} and its thickness is an adjustable parameter in the simulated process. The pixel pitch and filling factor are 50μm and 92% respectively. It should be noted that each element including an individual p-n junction forms an island on the 20-μm-thick Si substrate. During the simulation, only the center pixel is front-side illuminated using a 5μm incident light under 77K background, i.e., the optical energy is incident on the p-region. And the effect of antireflection coating is not taken into consideration. Finally the QE curve from pixel 2 is obtained.

For the conventional InSb detectors, the infrared radiation is incident on the n-type bulk InSb substrate. The photo-generated minority carriers will diffuse a long distance to p-n junction to be converted into electrical response. However, it is impossible to limit all inter-pixel migration of carriers. Some of them diffuse into neighboring junctions to form the crosstalk[14]. In our calculations, the light is directly incident on the thinner p-region instead of n-region. The carriers can diffuse to junction more easily with less recombination to lead a higher QE[15]. Moreover, all of the diodes are spaced from each other and the effect of crosstalk can be significantly reduced.

![Optimization of InSb Infrared Focal Plane Arrays](image-url)
However the light can not be fully absorbed in the p-region due to its thinner thickness. Some of optical energy penetrates through the p-region into the n-region where still more minority carriers are generated\[16\]. Part of these additional carriers will diffuse back to the junction to contribute to the response. So the QE is dependent on not only carrier diffusion length \(L_d\) but also light absorption length \(L_a\). In this paper, \(L_d\) refers to electrons diffusion length and that of holes is fixed at 81.2\(\mu m\).

Figure 2 shows the simulated QE as a function of the p-region thickness with \(L_a\) changing from 0.951 to 4.0\(\mu m\) for different \(L_d\), i.e., 3.6, 7.106\(\mu m\) (left column). By fitting the curve of the optimum p-region thickness \(d_{opt}\) as a function of \(L_a\) (right column), two empirical formulas which have the same polynomial format for different \(L_d\) are obtained:

\[
d_{opt} = 0.52472 + 0.34239 \ln(L_a) + 0.13974 \ln^2(L_a) \quad \text{for} \quad L_d = 3.6\mu m
\]

\[
d_{opt} = 0.8449 + 0.83016 \ln(L_a) + 0.14969 \ln^2(L_a) \quad \text{for} \quad L_d = 7.106\mu m
\]

**IV. CONCLUSION**

The quantum efficiency of mid-wavelength InSb infrared focal plane arrays has been numerically simulated with a two-dimensional simulator. Effects of the absorption length and thickness of p-region on device quantum efficiency have been investigated. The empirical formulas about the optimum thickness of p-region and the absorption length are obtained.

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**REFERENCES**


