Mid-wave InAs/GaSb Superlattice PiBN Infrared Photodetector Grown on GaAs Substrate

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***Abstract*—We present a GaAs based PiBN InAs/GaSb type II superlattice photodetector for mid infrared application with peak responsivity of 0.44A/W at 4.1um at 77K under 0V.**

Keywords—InAs/GaSb type-II superlattices, infrared detectors, barrier detectors, mid wavelength

I. INTRODUCTION

Recently, InAs/GaSb type II superlattice(T2SL) has attracted lots of interests in infrared photodetectors due to its tunable operating wavelength, which can be toiled form 3um to 32um by adjusting the thickness of InAs or GaSb layer [1]. In addition, T2SL materials also have some advantages than traditional HgCdTe, such as good uniformity, lower leakage current and larger effective mass which can reduce tunneling current. Incorporating a barrier in a detector can eliminate the generation-recombination (GR) currents associated with Shockley-Read-Hall (SRH) centers and mesa lateral surface imperfections, which have resulted in an increase of operating temperature [2]. The PiBN is a unipolar barrier blocks one carrier type (electrons) but allows unimpeded flow of the other (holes). The introduction of a unipolar barrier into various configurations of photovoltaic structures suppresses dark current and noises without impending photocurrent flow.

Currently, the high cost and small size of commercially available GaSb substrates is a huge obstacle to large volume production. In this paper, we present a PiBN InAs/GaSb T2SL photodetector grown on GaAs substrate, can could be more attractive for high volume, high-throughput manufacture.

II. DEVICE DESIGN

Fig. 1 shows the structure of the device. The devices were grown on GaAs substrate, following the substrate was the buffer layer. Then a 500 nm thick p type bottom contact layer was formed by 10 monolayer InAs(ML) /10 ML GaSb SLs doped with Be, followed by a 2000 nm thick non-intentionally doped (n.i.d.) absorber region formed by 10 ML InAs/10 ML GaSb SLs. Then a 250 nm thick 6 ML AlSb/12 ML InAs SLs barrier was grown, followed by a 200 nm thick n type top contact layer formed by 5 InAs(ML) /5 ML GaSb SLs doped with Si. The contact layer was capped with a 50 nm thick n InAs to improve ohmic contact properties.

After the material growth, the wafer was processed into a set of mesa-isolated test structures with device diameters ranging from 20 μm to 500 μm using standard UV photo-lithographic processing technique. Mesa structures were defined by citric-acid based wet etching and mesa slopes were passivated by SU-8. Finally, 50 nm/50nm/300 nm Ti/Pt/Au were deposited by e-beam evaporator as the top and bottom contact layers.

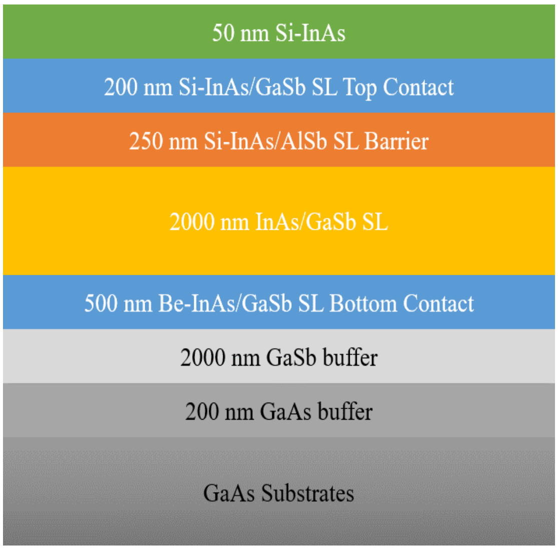

Fig. 1 Schematic of the device structure.

III. RESULTS

Fig. 2 shows the dark current of a 130um device based on GaAs from 77K to 300K which were measured in low temperature probe station by semiconductor device analyzer. Dark current measured at 77K shows a small photovoltaic shift, which is due to the imperfections in the cold shield used for the measurement. Fig. 3 shows the calculated resistance area product (R0A) as a function of temperature, from this Arrhenius plot the activation energy (E_a) can be estimated. The linear fits yield an activation energy of 98 meV at high temperature region, which indicates the dark current is dominated by generation-recombination component.

The optical response was measured by Fourier transform infrared spectrometer and calibrated by a blackbody resource at 700℃ under three different bias as shown in Fig. 4. The device shows the peak responsivity is ~0.5 A/W at 4.1 µm at 77K under -0.1V, the 50% λc is ~6.1 µm and the 100% λc is ~6.6 µm.

The specific detectivity D* was estimated using:

$$D^* = \frac{R_\lambda \sqrt{A}}{(2qI + \frac{4k_B T}{R})^{1/2}} \qquad (1)$$

where q is the electronic charge, k_B is Boltzmann's constant, T is the temperature of the device, R is the resistance under the bias, R_λ is the responsivity, I is dark current and A is the area of device. A peak detectivity D* of 1.3×10^{11} cmHz$^{1/2}$/W was calculated at 4.1 µm at 77 K under 0V as shown in Fig. 5.

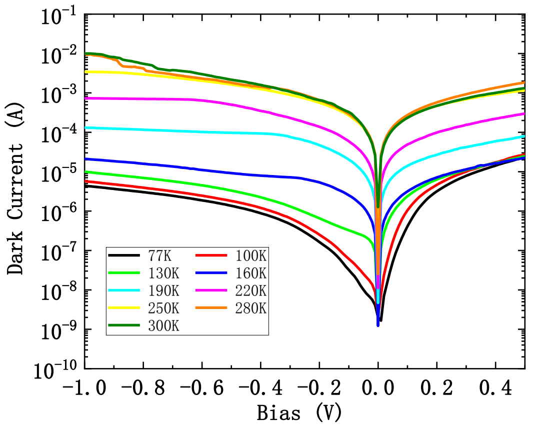

Fig 2. Dark current of the 130µm diameter GaAs based PiBN device as a function of temperature.

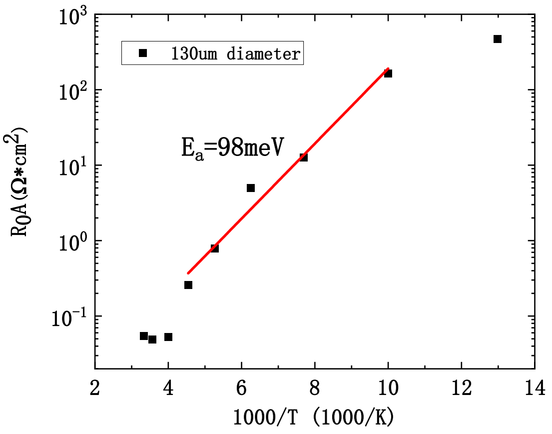

Fig .3 Arrhenius plot of the R_0A product

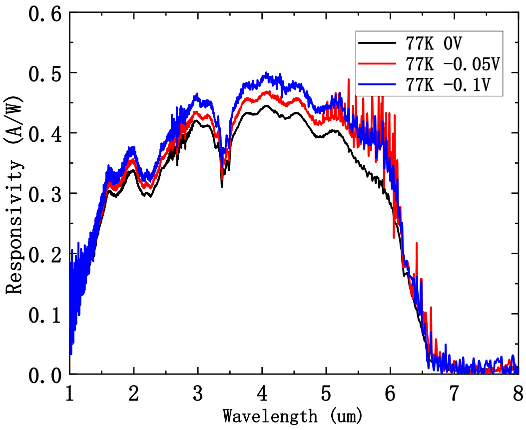

Fig .4 Optical response of detector measured at 77K under reverse bias of 0V, -0.05V and -0.1V.

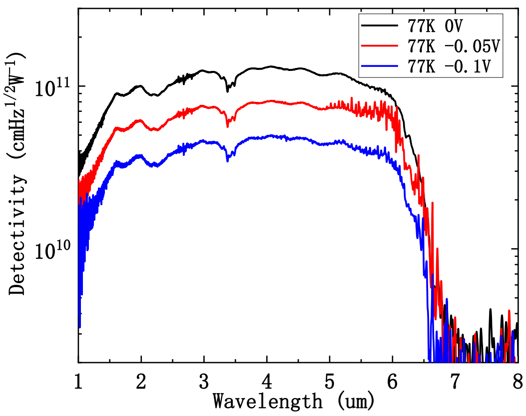

Fig.5 The specific detectivity of the device at 77 K under reverse bias of 0V, -0.05V and -0.1V.

CONCLUSION

In summary, we demonstrated a PiBN InAs/GaSb T2SL photodetector grown on GaAs substrate. The device has a peak responsivity of 0.44A/W and a peak specific detectivity of 1.3×10^{11} cmHz$^{1/2}$/W at 4.1um at 77K under 0V.

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REFERENCES

[1] E. A. Plis, "InAs/GaSb Type-II Superlattice Detectors," *Advances in Electronics*, vol. 2014, pp. 1-12, 2014.

[2] B. F. Andresen, P. Klipstein, G. F. Fulop, and P. R. Norton, ""XB n " barrier photodetectors for high sensitivity and high operating temperature infrared sensors," Proc. of SPIE 2008.