Numerical simulation on the effect of the thickness of the absorbing layer on the spectral response characteristics for GaAs-based blocked impurity band (BIB) terahertz detectors

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***Abstract*—the effect of the thickness of the absorbing layer on the spectral response characteristics for Gallium Arsenide (GaAs) blocked-impurity-band (BIB) terahertz detector has been investigated in detail. It is found that Response bandwidth (BW_R) is approximately a linear function of h_{Abs}, and the relationship between the Response bandwidth (BW_R) and h_{Abs} has been given in this work.**

Keywords—Numerical simulation, Gallium Arsenide (GaAs), Blocked-impurity-band (BIB), Terahertz, spectral response

I. INTRODUCTION

Terahertz (THz) radiation is commonly known as the electromagnetic wave with frequency lying between 0.3 to 10THz. Looking back the history, it is found that the development of THz technologies was suspended for a long time due to the lack of THz detectors with high performances, and thus numerous applications related to THz imaging and spectrum detection were also suppressed. With the rapid development of processing technologies for the materials and devices, the performances of THz detectors have achieved the tremendous breakthrough, which brings new opportunities for the applications of THz detection technologies. Nowadays, the research and development of THz detectors with high performances are still the core power driving the further development of THz technologies.

Blocked-impurity-band (BIB) detector is a novel THz detector. Compared with other THz detector, BIB detector possesses the advantages including high detection sensitivity, and large array size, and wide response spectrum, etc. among them, Silicon (Si)-based BIB detector with 6THz cut-off frequency is the most mature, and widely used BIB detectors. Germanium (Ge)-based BIB can achieve 1.4THz cut-off frequency due to the shallower bonding energy of impurity level in Ge material. It is worthwhile to mentioning that Gallium Arsenide (GaAs)-based BIB detector can further expand the cut-off frequency to 0.7THz, and thus attract lots of attention from the numerous application fields including security inspection, drug monitoring, and astronomical observation, etc.

In spite of lots of attractive application opportunities, the development of GaAs-based BIB detector [1] is still on the initial stage due to the immature material and device processing technologies. Reichertz et al. from UC Berkeley [2] has reported the performances of GaAs-based BIB detector obtained by the epitaxial method. It is reported that GaAs-based BIB detector can operate only when the temperature lower than 4.2K, and have the dark current level of nA. Most importantly, the broadening property of impurity band cannot be observed by photoconductivity spectrum, which brings the obstacle for the further study of spectral response characteristics of GaAs-based BIB detector. In order to fill this gap, the effect of the thickness of the absorbing layer on the spectral response characteristics for GaAs-based BIB detector has been investigated In this paper.

II. STRUCTRAL AND PHYSICAL MODELS

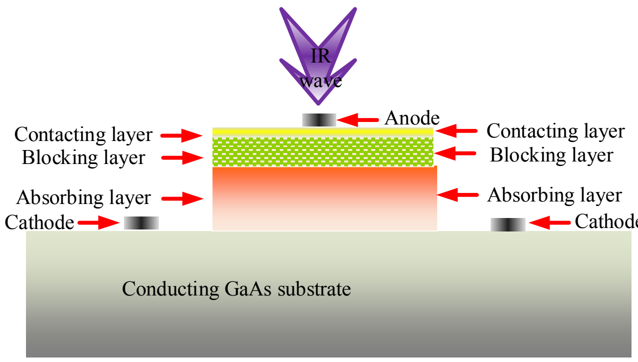

Fig. 1. Schematic of structral model for GaAs-based BIB detector.

Figure 1 shows the schematic of structural model for GaAs-based BIB detector. From the bottom to the top, the

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structure is composed of conducting GaAs substrate, cathode, absorbing layer, blocking layer, contacting layer, and anode, respectively. The anode is formed upon the contacting layer for the purpose of the electron conduction collection, and the cathode is formed upon the conducting GaAs substrate exposed by deep-silicon etching for the hopping conduction collection.

III. Results and Discussions

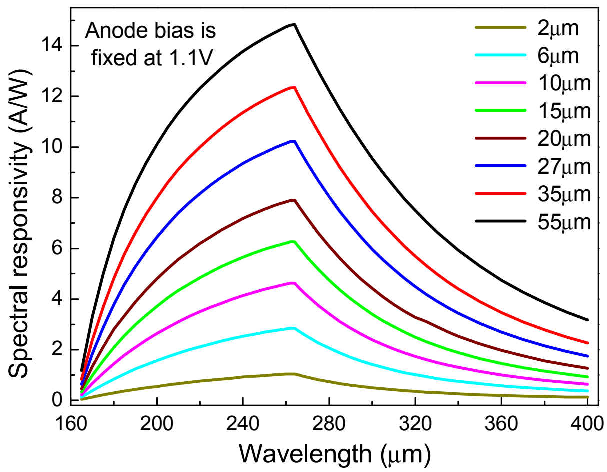

Fig. 2. Spectral responsivity versus wavelength with the anode bias fixed at 1.1V and the thickness of the absorbing layer (h_{Abs}) increasing from 2μm to 98μm in 8μm steps.

Figure 2 shows the spectral responsivity versus wavelength with the anode bias fixed at 1.1V and the thickness of the absorbing layer (h_{Abs}) increasing from 2μm to 98μm in 8μm steps. It is found that spectral responsivity covering wavelength from 165 to 400μm monotonically increases with the increased h_{Abs} due to the increase of the absorbing optical path for the incident THz wave. Figure 3 presents the normalized spectral responsivity versus wavelength with the anode bias fixed at 1.1V and the thickness of the absorbing layer (h_{Abs}) increasing from 2μm to 98μm in 8μm steps.

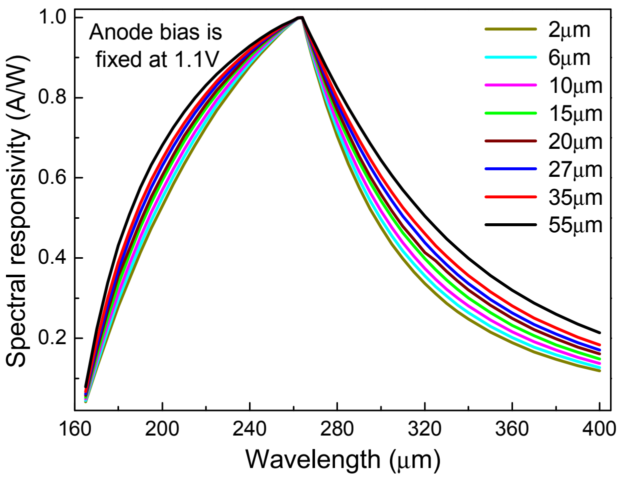

Fig. 3. Normalized spectral responsivity versus wavelength with the anode bias fixed at 1.1V and the thickness of the absorbing layer (h_{Abs}) increasing from 2μm to 98μm in 8μm steps.

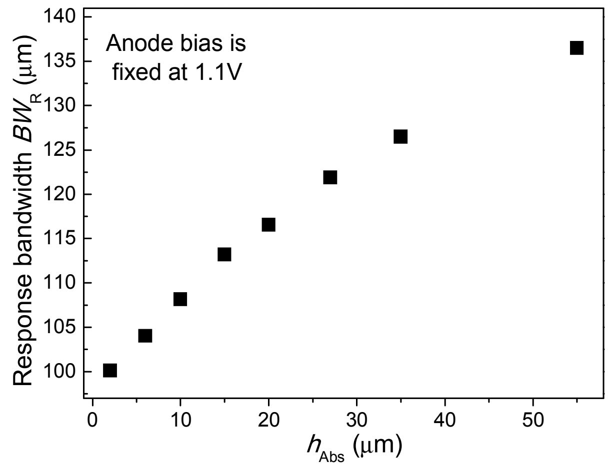

Fig. 4. Response bandwidth (BW_{R}) as a function of h_{Abs} with the anode bias fixed at 1.1V.

Figure 4 Response bandwidth (BW_{R}) as a function of h_{Abs} with the anode bias fixed at 1.1V. It is found that Response bandwidth (BW_{R}) is approximately a linear function of h_{Abs}, and the relationship between the Response bandwidth (BW_{R}) and h_{Abs} can be expressed by:

$$BW_{\mathrm{R}} = 101.28583 + 0.68641 h_{\mathrm{Abs}},$$

and the fitting results are also presented in Fig. 5, according to which, the perfect match can be observed between the simulation and fitting results.

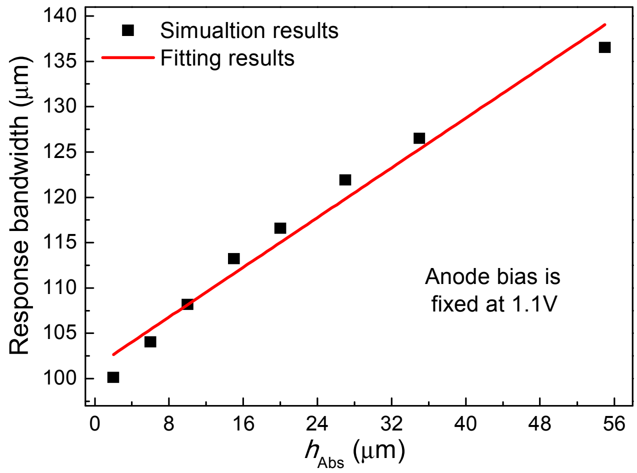

Fig. 5. Fitting result of response bandwidth (BW_{R}) versus h_{Abs} with the anode bias fixed at 1.1V.

IV. Conclusion

In this work, effect of the thickness of the absorbing layer on the spectral response characteristics for GaAs-based BIB detector has been investigated in detail.

References

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