Impact of optical absorption for THz radiation in GaSb/InAs heterostructures

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***Abstract*—Terahertz radiation characteristics were investigated for InAs/GaSb/InAs heterostructures by varying the thickness of the GaSb hot-electron injection layer between 5 and 50 nm. Monotonic increase in the radiation intensity was observed as the GaSb injection layer thickness was reduced. Enhanced radiation compared to InAs film without the GaSb injection layer occurred only for the GaSb layer thickness of 5 nm. We also studied the radiation intensity by introducing InGaSb injection layer, and found the superior enhanced radiation occurred even for the layer thickness of 20 nm.**

I. Introduction

TERAHERTZ time domain spectroscopy (THz-TDS) is becoming a growing technique due to its hopeful applications such as medical diagnosis, non-destructive inspection and so on. Photoconductive (PC) antennas excited by femtosecond laser pulses are commonly used for those applications.

We have proposed that the use of InAs thin-film structures grown on a cost-effective GaAs substrate as a pulse optical source for THz-TDS systems. It can eliminate the formation of electrodes and the precise optical-alignment since it relies on the photo-Dember effect. We reported that InAs thin films grown on a GaAs substrate exhibited comparable THz radiation intensity with a p-InAs bulk substrate which is known as the best THz emitter among III-V bulk semiconductors[1]. We recently proposed a use of an InAs/GaSb/InAs heterostructure for hot-electron injection leading to an enhanced THz radiation[2]. We report on the radiation characteristics of the heterostructure by varying the thickness of the GaSb hot-electron injection layer between 5 and 50 nm. We also studied the radiation intensity for InGaSb injection layer as a superior electron injector for enhanced terahertz radiation.

II. Results

In order to investigated the relationship between GaSb film thickness and radiation intensity, we grew InAs/GaSb/InAs heterostructures by molecular beam epitaxy for the GaSb thickness between 5 and 50 nm. The structure consists from a low-temperature grown InAs buffer layer (150 nm), a 1-µm-thick InAs radiation layer, a GaSb hot-electron injection layer, and a 1-nm-thick InAs cap layer. THz-TDS measurements were used to measure the radiation intensity. The optical excitation was done by femtosecond laser pulses producedby a mode-locked Ti:sapphire laser. The excitation wavelenght was 800 nm, the pulse width was 100 fs. The laser power was 75 mW and was focused into 1 mm in diameter.

We also grew an InAs/$In_{0.2}Ga_{0.8}Sb$/InAs heterostructure. The InGaSb layer used in place of the GaSb injection layer increases the optical absorption and decreases the energy band offset with respect to the 1-µm-thick InAs radiation layer.

Figure 1 shows the radiation intensity of the THz emission from two kinds of heterostructures, one from the InAs/GaSb/InAs (squares) and the other from InAs/$In_{0.2}Ga_{0.8}Sb$/InAs (circle). The broken line shows the intensity from a 1-µm-thick InAs thin film. The radiation intensity increased as the GaSb thickness decreased, and showed the strongest one for the GaSb thickness of 5 nm. In the structure, the optical absorption takes place in the GaSb while terahertz radiation is produced in the InAs by hot-electorons with an excessive energy which is brougth by the large conductionn band discontinuity between GaSb and InAs. By using an InGaSb injection layer, it increases the optical absorption, but decreases the band discontihuity. As shown in Fig. 1, enhanced radiation observed for the InGaSb injection layer indicates that the increase in the absorption is crucial for the radiation enhancement.

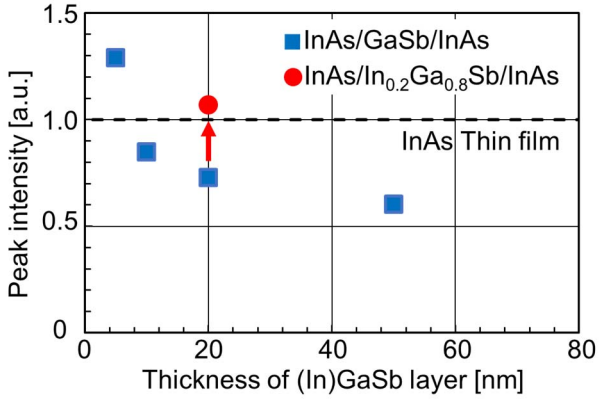

Fig. 1. The THz radiation intensity from two kind of heterostructure, one of the InAs/GaSb/InAs(square) and the other InAs/$In_{0.2}Ga_{0.8}Sb$/InAs(circle). The broken line shows the peak intensity from a 1-µm-thick InAs thin film.

III. Summary

The thickness dependence of the terahertz radiation intensity for InAs/GaSb/InAs heterostructures were studied. The strongest THz radiation was obtained for the GaSb thickness of 5 nm. The enhanced radiation even for the injection layer thickness of 20 nm indicates that the increase in the absorption by the introduction of InGaSb layer has higher impact than the band discontinuity for the enhanced radiation.

References

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