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Fabrication and characterization of GaP two dimensional photonic crystals for terahertz-wave generation

K. Saito[1], T. Tanabe[1], Y. Oyama[1], K. Suto[2], T. Kimura[2], J. Nishizawa[2]
1. Department of Materials Science, Tohoku University, Aoba-yama 6-6-11-1021 Sendai 980-8579, Japan,
2. Semiconductor Research Institute, 519-1176 Aoba, Aramaki, Aoba-ku, Sendai 980-0845, Japan
phone: +81 795 7330, fax: +81 795 7329, email: a6td5303@stu.material.tohoku.ac.jp

Abstract- We have fabricated GaP crystal based two-dimensional photonic crystals (2D-PCs) for THz wave applications. We demonstrated THz wave generation from the fabricated 2D-PCs. The enhancement of THz power was observed at around 1.1 THz.

I. Introduction

One of the methods for generating coherent terahertz (THz)-wave is based on an excitation of phonon-polariton in crystals [1-5] using the difference frequency mixing (DFM) between two infrared lasers. The THz wave can be achieved by the excitation of transverse optical phonon. GaP is attractive material for THz wave generation because of its transparency in both near-infrared and THz region, and high nonlinear optical coefficient. We have reported THz-wave generation with high output power (peak power of 1.5W) from bulk GaP crystals under non-collinear phase matching condition. We also have confirmed the enhancement of THz wave conversion efficiency in GaP waveguides with the size of terahertz wavelength due to the confinement of THz wave into the waveguide structure [6].

We focus on photonic crystals (PC) in THz region, which is one of the structures that enable to confine THz waves effectively. PCs are artificial periodic structures that allow for photonic band gaps (PBG) and device designing for many applications. In these structures, electromagnetic waves are confined via Bragg reflection and decreased their group velocity. These properties make it possible to enhance the nonlinear optical effect such as THz wave generation.

In this presentation, we have developed GaP PCs in THz region. We have also measured transmission characteristics and demonstrated THz wave generation in GaP PCs.

II. Experimental

The PC was fabricated using reactive ion etching in parallel plate discharge plasma. Figure 1 shows the fabricated GaP photonic crystal slab waveguide. Air holes were etched in a semi-insulating 200 μm thick GaP wafer to a depth of 75 μm. Air holes were arranged in a triangular lattice with a lattice constant *a* of 200 μm. The radius of air holes *r* was 80 μm. The sample was cut into rectangle with 10 mm wide in <110> direction × 5 mm long in <110> direction.

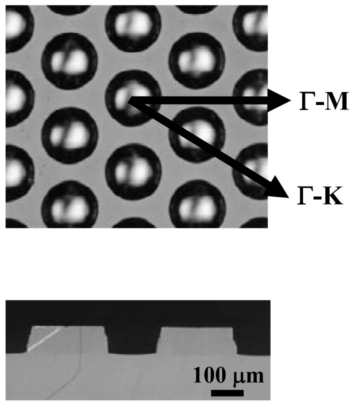

Fig. 1. Structure of the fabricated GaP PC slab waveguide

The schematic of the experimental setup used for the THz wave generation is shown in Fig. 2. The 1064-nm fundamental beam of a Q-switched Nd:YAG laser was used as the signal light for the DFM, and the 355 nm third harmonic beam was used to pump a β-BaB_2O_4 (BBO)-based optical parametric oscillator (OPO). The OPO was tuned in the 1059-1063 nm range. THz-wave generation was carried out under collinear phase matching condition. The generated THz-wave was detected by a liquid helium cooled Si bolometer. We used two types of waveguides: the PC patterned and non-patterned one, respectively.

III. Results

Figure 3 shows the THz power generated from the GaP slab waveguides. Dashed line is the THz power from non-patterned GaP substrate. THz wave generated in the frequency range from 0.3 to 1.3 THz. In the case of the GaP slab waveguide structure, THz waves generate under the modal phase matching condition. THz output characteristics depend on the propagation modes of THz wave in the waveguide. For the PC patterned GaP waveguide (solid line),

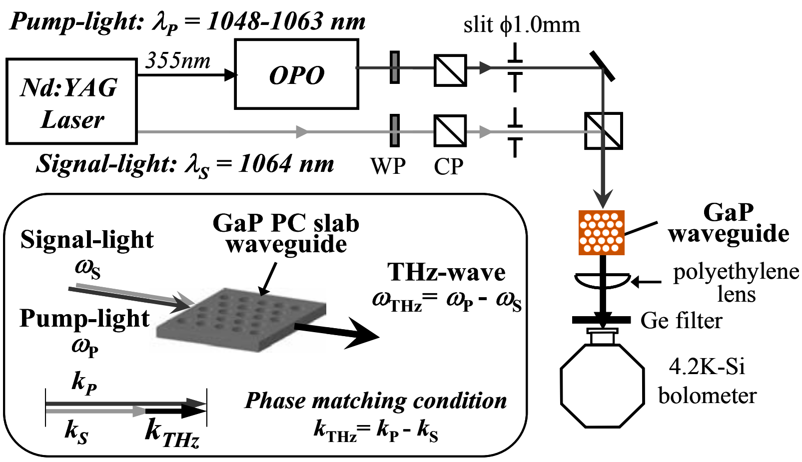

Fig. 2. Schematics of the experimental set-up used for THz-wave generation in GaP waveguides

increment of THz power was appeared at around 1.1 THz.

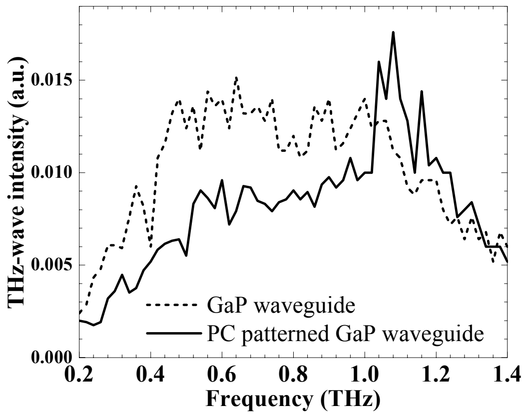

Fig. 3. THz wave output power from GaP waveguides

Figure 4 shows the in-plane transmission characteristics of PC patterned waveguide. The propagation of THz wave was parallel to ΓM direction. The polarization of the THz wave was TE polarization. To obtain the transmission spectrum, we measured that of the non-patterned GaP substrate as reference spectrum.

Several low transmission regions were appeared in this spectrum. One region from 0.4 to 0.6 THz is corresponding to the photonic band gap. Other region at around 0.9 THz and 1.2 THz are corresponding to the photonic bands in which the electromagnetic wave cannot excite due to the existence of their anti-symmetric modes. In particular, THz transmission increased at round 1.1 THz. The enhancement of THz wave generation is possible due to the higher transmission features at around 1.1 THz. Some photonic band structure with low group velocity exists in this frequency region. These photonic bands affect the THz conversion efficiency.

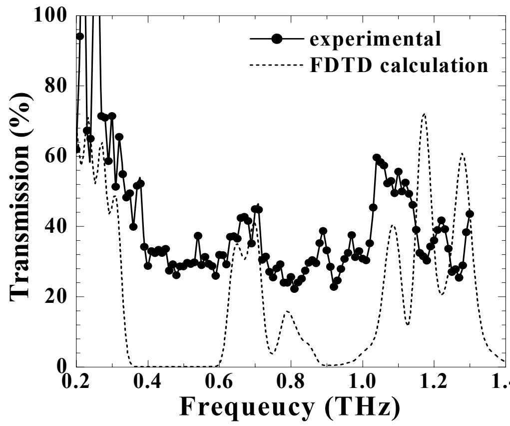

Fig. 4. THz transmission spectrum of the PC waveguide

IV. Conclusion

In conclusion, we have fabricated GaP crystal based two-dimensional photonic crystals (PCs) for THz wave applications. We demonstrated THz wave generation from the fabricated GaP PC waveguide.

References

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