A Wide-Band Wavelength-Tunable Terahertz Detector Using a Graphene Transistor

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Abstract—**We report on a novel type of wavelength-tunable terahertz (THz) detector based on a graphene transistor. We have demonstrated that the graphene under a magnetic field has the ability to detect THz waves in a wide range of 1.6-33THz. Further enhancement of the detection performance will be discussed.**

I. Introduction And Background

THZ spectroscopy is a strong tool for identifying the contents of a container and characterizing their physical/chemical properties. Time-domain spectroscopy and Fourier transform spectroscopy are widely used for such THz spectroscopic measurements. Though these are useful methods, they require an expensive femto-second laser and scanning interferometer, respectively. Alternatively, a solid-state THz spectrometer, *i.e.*, a wavelength-tunable THz detector is strongly desired. We have previously developed a wavelength-tunable THz detector using a GaAs/AlGaAs chip[1] and a carbon nanotube[2]. Their detection ranges, however, are restricted to a far-infrared region (<5THz).

In this work, we present a graphene-based THz detector with wide-band wavelength-tunability. The detection mechanism is based on unique Landau-level formation of Dirac fermions of the graphene, which is in strong contrast to that of conventional semiconductors. Using this property, we have achieved wide-band wavelength-tunable THz detection, ranging from far-infrared to mid-infrared region (1.6-33THz).

II. Results

We used a single-layer graphene on a SiO_2/Si chip, and fabricated a graphene transistor with current electrodes made from Cr/Au and a back-gate electrode. The graphene device was immersed into a 4.2K cryostat and a magnetic field B was applied perpendicular to the graphene surface. Conductivity changes with THz irradiation were measured using a lock-in amplifier, where the THz wave was chopped at 17Hz.

Figure 1 displays THz detected signals a s a function of the magnetic field for three different frequencies of 1.6, 4.2, and 33THz. The data show that sharp resonance peaks appear and that the peak position depends on the frequency of the THz wave. For comparison, we made similar measurements on a conventional GaAs/AlGaAs device. For this device, we observed the signal only for the 1.6-THz irradiation and no any signal for 4.2 and 33THz.

The above results can be reasonably explained in terms of Landau-level formation of Dirac fermions[3]. The THz absorption causes carrier transitions between the following level indexes: 1→2 for 1.6THz, 1→2 for 4.2THz, and -1→2 for 33THz. In contrast, for the GaAs/AlGaAs, the Landau level separation energy for B=0-5T is 0-8.5meV. This energy range is insufficient to absorb the THz waves with higher photon energy (17.6 and 134meV), corresponding to 4.2 and 33THz.

The bandwidth of the graphene detector observed here is determined by that of a THz source in our facility, and will be able to extend to the range from sub-THz to 100THz. We have recently succeeded in mapping electric potential distribution in the graphene device[4], and have found a fluctuating feature in space. For the purpose of the enhancement of the detection performance, we are now studying local properties of the THz response and its relation with the potential fluctuation.

Our next target is to develop an array-type THz spectrometer by disposing many small graphene devices in the presence of the gradient in the magnetic field. Another interesting application is to utilize the graphene device as an on-chip near-field THz imaging detector[5].

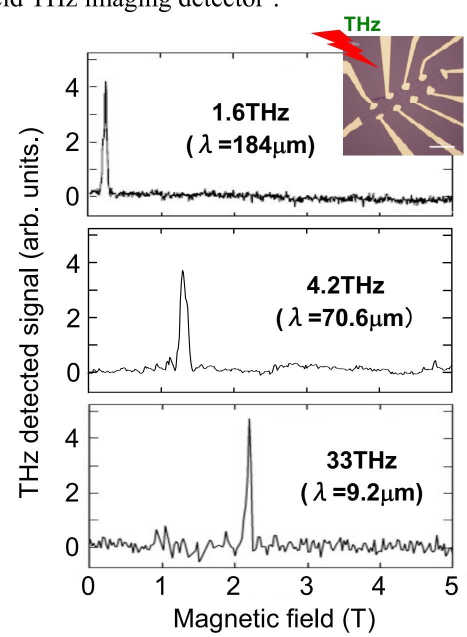

Fig. 1. ***THz detected signal (conductivity changes) versus magnetic field. The inset shows a photograph of the graphene device used.***

References

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