Fourfold Azimuthal Dependence of Terahertz Radiation from (100) Silicon

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Abstract— **A fourfold-azimuthal dependence of terahertz radiation from polished mono-crystalline (100) silicon is observed firstly. This phenomenon is explained by the electric quadrupole-magnetic dipole, which resemble second harmonic generation from (100) silicon.**

I. Introduction

It's known that several properties are needed for efficient terahertz emission from semiconductor surfaces, such as high absorption in near infrared, high electron mobilities, fast recombination rates and short carrier lifetimes. However, mono-crystalline silicon doesn't possess these properties [1], [2]. So silicon is rarely used as terahertz emitters. In order to change the properties of silicon, various methods, such as irradiation induced-defects, disorder needles perpendicular to the surface, vertically aligned silicon nanowire (Si NW) arrays , and argon implanted, is carried out on silicon surfaces [3]-[6]. Although many trials have been implemented to improve terahertz emission from silicon, there are few specific reports of terahertz emission from mono-crystalline silicon.

II. Experimental Setup

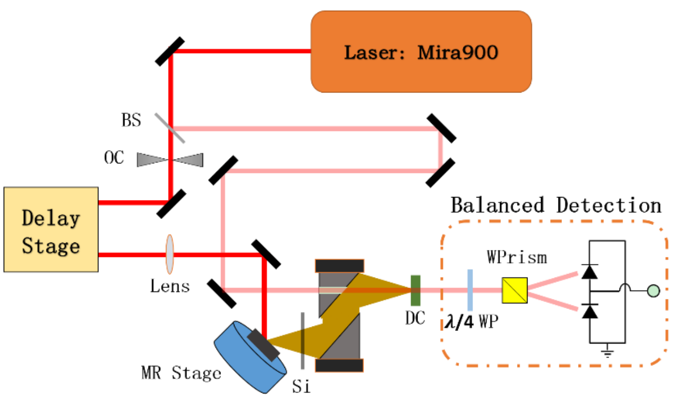

Fig. 1 Schematic diagram of experimental setup. BS, Beam Splitter; OC, Optical Chopper; MR Stage, Motorized Rotary Stage; Si, Silicon used to block pump light; DC, 3-mm thick ZnTe Detection Crystal; WP, Wave Plate; WPrism, Wollaston Prism.

In our work, the azimuthal dependence of terahertz radiation from (100) silicon was studied by a home-built THz-TDS. Fig. 1 shows the experimental setup.

The laser source was a Ti: Sapphire oscillator (Mira900, coherent) generating p-polarized light pulse of 150fs duration, centered at a wavelength of 800nm with a repetition rate of 78MHz. The average pump power was 1.5W, which was directed onto the sample at a 45° angle of incidence and focused to 1.5 mm diameter on the sample. The sample was mounted on a motorized rotary stage, which was controlled by the computer. In the reflecting direction, the generated terahertz from (100) silicon was collected and focused by two parabolic mirrors of effective focal length $f = 76.2mm$ and diameter $D = 50.8mm$. Then the focused terahertz was detected by standard electro-optic sampling techniques in a 3mm thick (110) ZnTe detection crystal, which was followed by a quarter wave plate, Wollaston prism, and balanced photodiodes. The ZnTe crystal had been carefully adjusted so that only p-polarized THz could be detected [7].

III. Preliminary Results

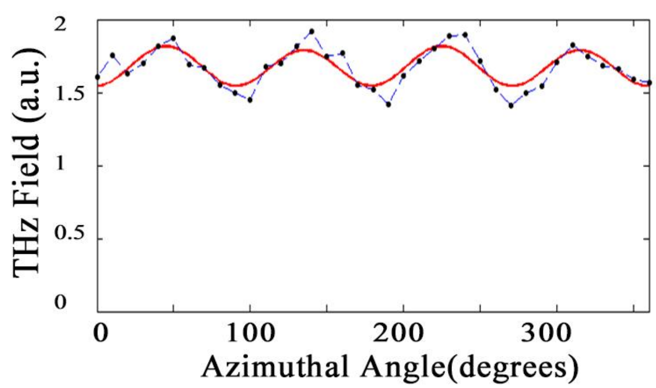

Fig. 2 The azimuthal dependence of THz radiation from (100) silicon with p-type and the resistivity of 1~5 Ω · cm.

A fourfold azimuthal dependence of terahertz radiation from (100) silicon surfaces is shown in Fig. 2. Comparing Fig. 2 with Fig. 3, it is obvious that this azimuthal dependence is very similar with that of second harmonic generation (SHG) [8], which displays the lattice symmetry of silicon. As far as we know, it's the first time that the silicon symmetry was detected in this way. Comparing THz and SHG from (100) silicon, we can conclude that the azimuthal dependence we found should be attributed to the electric quadrupole-magnetic dipole

(EQMD) of (100) silicon. The relation of the fourfold azimuthal dependence and EQMD using THz-TDS have been reported in several materials, such as (100) InAs, a-plane InN and $YBa_2Cu_3O_{7-\delta}$ [9]-[11].

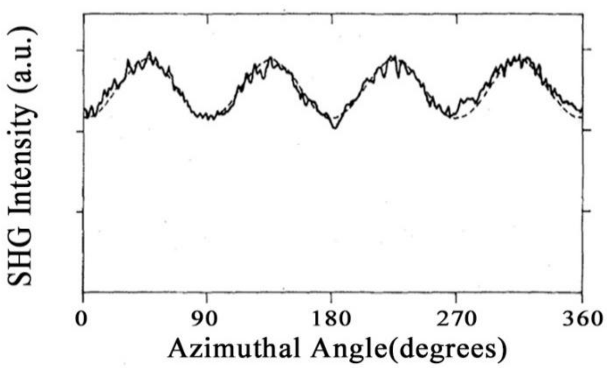

Fig. 3 The azimuthal dependence of SHG radiation from (100) silicon, referring the work of Tom [8].

IV. Future Extensions

Although the azimuthal dependence of THz and SHG from (100) silicon is very resemble, more experimental data and theoretical analysis are needed to prove our results. Firstly, based on the different properties of the radiation from the dipole and EQMD in space, we can distinguish them by a home-built spatial resolution system. Secondly, we can perform a joint measurement of the azimuthal dependence of THz and SHG from (100) silicon, which will give a more powerful evidence for our results.

Acknowledgment

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