Raman Scattering and Terahertz Spectroscopic Characteristics of Longitudinal Optical Phonons in *i*-GaAs/*n*-GaAs Epitaxial Structures

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***Abstract*— We have investigated longitudinal optical phonons (LO) characteristics in *i*-GaAs/*n*-GaAs epitaxial structures. The LO phonons and LO phonon-plasmon coupled modes were observed in the Raman scattering spectra, whereas only the coherent LO phonon was detected in terahertz spectroscopy. We conclude that the initial polarization is responsible for emission of the coherent-LO-phonon terahertz wave.**

I. INTRODUCTION

COHERENT longitudinal optical (LO) phonons have an ability of emitting monochromatic terahertz waves. We reported on the intense terahertz wave of the coherent LO phonons from the 200-nm-thick *i*-layer of an *i*-GaAs/*n*-GaAs epitaxial structure [1]; however, the terahertz wave of the coherent LO-phonon-related mode from the 3-μm-thick *n*-layer is not observed: The volume effect does not work.

In the present report, we clarify the above phenomenon using the sample with a thinner *i*-layer (the minimum thickness: 50 nm). We measured the Raman scattering spectra for comparison. We discuss the emission mechanism of the terahertz wave of the coherent LO phonon from the viewpoint of the initial polarization $\boldsymbol{P}$ formed by a built-in electric field $\boldsymbol{E}$.

II. SAMPLES AND EXPERIMENTAL PROCEDURE

The samples were grown on (001)-oriented semi-insulating GaAs substrates by metal organic vapor phase epitaxy. The *i*-layer thicknesses were 50, 100, and 200 nm. The *n*-layer thickness and doping concentration were 3 μm and 3×10^{18} cm^{-3}, respectively. The strengths of $\boldsymbol{E}$ in the *i*-layer were evaluated to be 84, 49, and 27 kV/cm for the samples with the *i*-layer thicknesses of 50, 100, and 200 nm, respectively, using a photoreflectance measurement of Franz-Keldysh oscillations. In the Raman measurement, the photon energy and power of the excitation laser were 1.96 eV and 5.2 mW, respectively. The penetration depth of the laser beam is 233 nm; therefore, the laser beam sufficiently excites the *n*-layer. The time-domain terahertz waves were measured using an optical gating method. The humidity was below 10%. The duration time of the laser pulse and repetition were 60 fs and 90 MHz, respectively, and the pump-beam energy and power were 1.57 eV and 30 mW, respectively. The penetration depth of the pump beam is 710 nm. All the measurements were carried out at room temperature.

III. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 1(a) shows the Raman spectrum of each sample. The band peaking at 8.8 THz results from the LO phonon. The band at 7.85 THz is assigned to the lower branch of the LO-phonon plasmon coupled (LOPC) mode, taking account of the doping concentration of the *n*-layer. The appearance of the LOPC band is reasonable because the laser beam excites the *n*-layer.

The Fourier power spectra of the terahertz wave are shown in Fig. 1(b). Only the coherent LO phonon band is observed though the pump beam excites the *n*-layer. We explain the present results in terms of the generation mechanism of the coherent LO phonon [2]. The coherent LO phonon connects with the initial polarization $\boldsymbol{P}$ produced by the built-in electric field $\boldsymbol{E}$ through the electric susceptibility tensor $[\chi]$: $\boldsymbol{P} = [\chi]\boldsymbol{E}$. The initial polarization $\boldsymbol{P}$ is released by the ultrafast screening of the built-in electric field $\boldsymbol{E}$ caused by the surge current of photogenerated carriers, generating the coherent LO phonon. The coherent LO-phonon polarization produces the terahertz wave. The disappearance of the LOPC band in the terahertz wave is, therefore, attributed to the absence of the built-in electric field $\boldsymbol{E}$ in the *n*-layer. The present findings indicate the fundamental difference between Raman scattering and terahertz-wave emission processes: The terahertz-wave emission of the coherent LO phonon requires the release of the initial polarization $\boldsymbol{P}$ by the ultrafast screening of the built-in electric field $\boldsymbol{E}$.

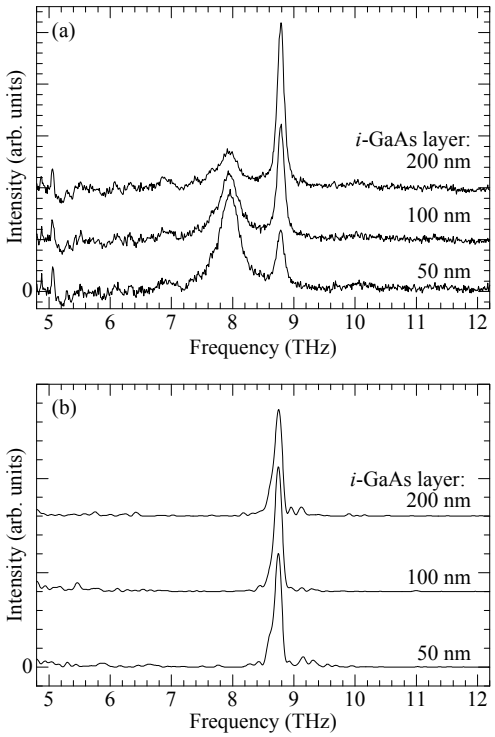

Figure 1: (a) Raman spectrum and (b) Fourier power spectrum of the time-domain terahertz wave of each sample.

REFERENCES

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