Exploration of mid-infrared thermal radiation mechanisms at longitudinal-optical phonon energy via u-GaAs/Au mesa-type surface stripe structures

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Light emission or absorption at terahertz (THz) – tens of THz frequency range had been investigated through inter-sub-band transitions in quantum wells and resonant tunneling of electrons. Because of smaller interaction energy width with the radiation field in phonon system than that in electronic system, greater optical gain of oscillation at room temperature is observed and operation of THz radiation at higher temperatures is possible using phonons. THz emission based on surface phonon polaritons (SPhPs) has been explored using various micro/nano structures although careful selections of emission direction and geometric conditions are indispensable. Unlike SPhPs, we have reported thermal radiation at 8.5THz resonant with longitudinal optical (LO) phonon from undoped (u-) GaAs/Au surface micro stripe structures [1]. Here, we will discuss distinctive characteristics of LO resonant thermal radiation by adopting narrow window of less than 1μm stripe structures under the condition of improving LO phonon coherence.

In this study, photolithography process was performed on undoped GaAs substrates followed by chemical etching to fabricate mesa height of stripe lines, followed by the deposition of metal on stripe patterns. Infrared emission measurements were observed for the polarization perpendicular to the stripe and parallel to the stripe using a Fourier transform IR spectrometer at 450 – 630 K.

The origin of LO phonon resonant thermal emission of radiation (LORE) comes from electric dipoles formed by coherently oscillating polarization charges at GaAs/As interface. One main factor affecting LORE intensity is the magnitude of the electric dipole, which is fundamentally concerned with the GaAs emission window. This also becomes a reason for greater LORE in in narrow emission window with low mesa-type (mesa range, H = 0 ~ 0.7 μm) structures, in which the formation of higher electric flux around the mesa region is involved (Fig.1). On the other hand, LORE intensity significantly decreases at high mesa structures (H > 1μm), especially at wide emission window. This phenomenon is due to the reabsorption of emitting radiation causing the extension of the effective radiative lifetime, which in turn increases the nonradiative LO phonon annihilation process [2]. This extended longer radiative lifetime is exhibited as a decrement in FWHM (Fig. 2). In addition, LORE intensity of 0.62μm of GaAs width is found to be decreasing due to smaller dipole moment by narrower emission width and its drop in FWHM suggests that radiative lifetime becomes longer in smaller dipole-occupied volume.

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[1] Y. Ishitani, *et al.*, Appl. Phys. Lett.**113**,192105 (2018) [2] Hnin Lai Lai Aye *et al* IR Phys.Techno.**134**,104924 (2023)

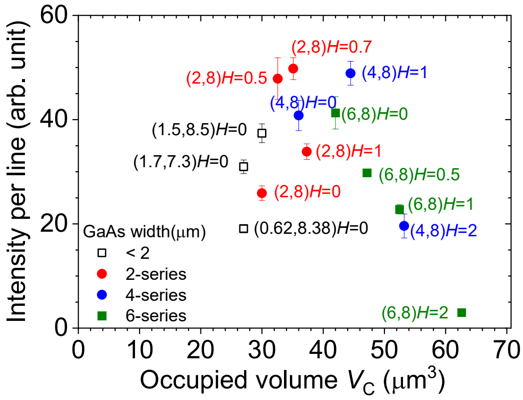

Fig.1 Emission intensity vs effective volume of the dipole. The utilized photo-mask size and mesa height are indicated.

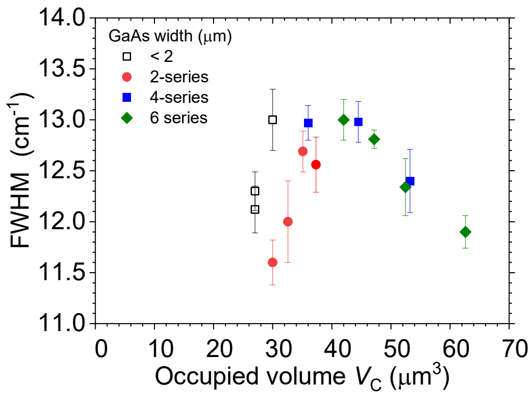

Fig.2 Emission line width relative to the effective dipole-occupied volume.