Analysis of governing thermal radiation efficiency via GaAs/Au micro-stripe structures

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As terahertz (THz) frequencies, covering from 300GHz to 30THz in general, can be able to detect smaller objects and realize precise positioning, THz wave can be applied not only for high-speed communication but also for medical science and security applications. Moreover, having the advantage of smaller interaction energy width with light in the phonon system, optical gain of oscillation at room temperature is focused on a narrower energy range than that of electronic system. Previously, we have reported radiation emission at 8.5 THz with line width of 0.4 THz at 628 K using metal-GaAs surface micro-stripe structures, where electric dipoles resonating with the longitudinal optical (LO) phonon are formed.[1, 2] Since this dipole has been found to be based on polarization charges generated at metal-GaAs interfaces, this time, we discuss how emission efficiency is determined by structural parameters including the effect on phonon lifetime.

In this study, undoped GaAs wafers were adopted to fabricate metal/GaAs microstructures by the method of photolithography. Mesa-height structures were created by adjusting the etching rate followed by the deposition of metal on the sample surface. IR emission and absorption measurements were observed using a Fourier transform IR spectrometer at 450-630 K and at room temperature respectively. Fig.1 shows emission efficiency plotting integral area of emission intensity per stripe normalized by the estimated dipole moment as a function of the volume associated with the electric dipole. Phonon scattering occurring in high mesa structures determines decreased efficiency regardless of increasing dipole-occupied volume. In Fig.2, emission spectrum line width is analyzed as half width at half maximum (HWHM) per occupied volume, and is decided in consecutive order of periodic structure. It is estimated that the LO phonon lifetime in the local region of metal/GaAs/metal-structure is dominated by two factors of window width and mesa height or occupied volume. The smaller width for higher mesa possibly indicates the extension of LO phonon lifetime by reabsorption, and lower emission efficiency indicates the LO phonon decomposition during the extended lifetime.

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[1] Y. Ishitani, *et al*., Appl. Phys. Lett. **113**, 192105 (2018)
[2] Hnin Lai Lai Aye *et al*., Phys. Stat. Sol. A, 2200583 (2022)

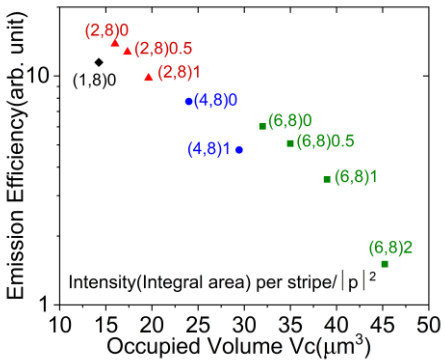

Fig.1 Emission efficiency as a function of dipole occupied volume. The photo-mask pattern of (window width, metal width) is denoted in the unit of μm. The mesa height is denoted beside the size of the mask pattern.

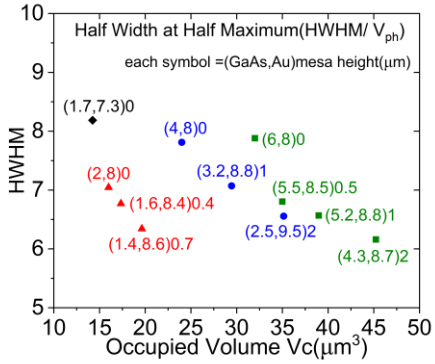

Fig.2 HWHM per occupied volume showing LO phonon lifetime dependent on scattering rate. The measured value of (window width, metal width) is denoted in the unit of μm.