Terahertz radiation generated by acoustic waves in InGaN/GaN Multiple Quantum Wells

Abdul Mannan[1], I. Kawayama[1], K. Yamahara[1], F.R. Bagsican[1], H. Murakami[1], A. Hangleiter[2], T. Langer[2], H. Bremers[2], U. Rossow[2], D. Turchinovich[3], M. Tonouchi[1].
[1]ILE, Osaka Univ. Japan. [2]TU Braunschweig, Germany. [3]Bielefeld Univ. Germany.
E-mail : mannan-a@ile.osaka-u.ac.jp

InGaN/GaN multiple quantum wells (MQWs) are widely studied for light emitting diodes (LEDs) and laser diodes (LDs). However, the lattice mismatch and miscibility between GaN and InN, the diffusion and segregation of indium in MQW due to high-temperature growth, change the potential distribution in MQW, results in degradation of the optical properties of devices. Therefore, if a nondestructive evaluation method of the potential change in the MQW structure can be realized, it can greatly contribute to the improvement of LDs and LEDs with MQWs. We have been conducting research using laser-induced terahertz (THz) emission as an evaluation method for semiconductor surfaces and interfaces [1, 2]. In this study, we observed THz emissions from InGaN/GaN MQWs excited by a femtosecond (fs) laser and investigated generation mechanism of THz waves based on detailed characterization of the THz emissions with the aim of developing it as an evaluation method of MQW in the future.

Sample schematic is shown in Figure 1(a), a 2μm thick GaN as buffer layer was grown on a 200μm sapphire substrate, followed by 10 pairs of InGaN quantum well width (Lz) with GaN barrier of 7.2nm and subsequently covering MQW with capping layer of 180nm. Optical excitation was done using second-harmonics of 800nm wavelength, with pulse width of 100 fs and repetition rate of 80MHz. The samples were pump with excitation laser incident at an oblique angle of 45° and p-polarized THz emission was detected at an angle 45° from InGaN/GaN MQW. THz emission was detected using low-temperature grown gallium arsenide (LT-GaAs) dipole antenna. Figure 1(b) clearly shows the waveform of THz emission from the MQW with two main peaks. In previous research, THz emission mechanism from InGaN/GaN MQW upon excitation of fs laser is explained [3]. Recent research has proven GaN a promising candidate for acoustic transducer in THz frequency domain [4, 5]. Based on previous studies, these two peaks were attributed to acoustically generated THz emission in GaN capping layer and dynamical screening-induced THz emission in MQW structure. The THz emission by dynamically screening is shown as first peak labeled at time delay T_1 = 15.6 p.s. whereas acoustically generated THz pulse labeled at time delay T_2 = 36.8 p.s. The time difference between THz emission pulses ΔT = 21.2 p.s. correspond to the travelling time of acoustic pulse (sound wave) in GaN material [5].

Detailed THz emission mechanism from InGaN/GaN MQW will be discussed based on power dependence, wavelength dependence of excitation laser and THz emission imaging.

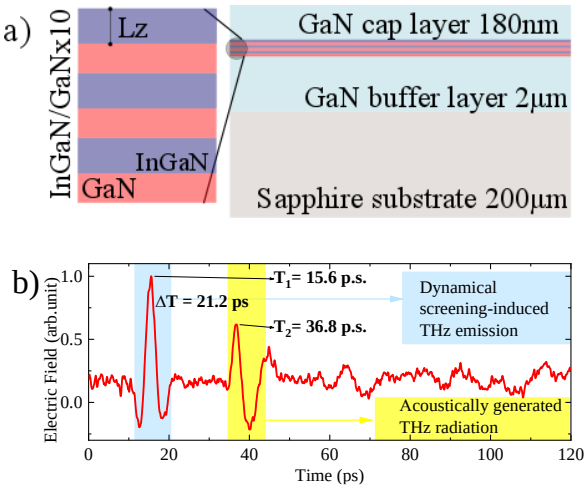

Figure 1 (a) Schematic structure of InGaN/GaN MQW and (b) waveform of THz emission from MQW

Acknowledgements
This work was supported by JSPS KAKENHI Grant Numbers 17H05338, JP18KK0140, JP18K18861.

References

[1] Y. Sakai et al., APL Photonics 2, 041304 (2017).
[2] T. Mochizuki et al., Journal of Applied Physics 125, 151615 (2019).
[3] D. Turchinovich et al., Phys. Rev. B. 68, no. 24, pp. 1–4, 2003.
[4] A. A. Maznev, et al., Appl. Phys. Lett. 112, 061903 (2018).
[5] Armstrong, Michael R. et al, Nature Physics vol. 5, pp. 285–288 (2009).