Laser terahertz emission microscope for semiconductor R&D

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Abstract

Photocarriers excited with a femtosecond laser travel with the internal electric field, and terahertz (THz) electromagnetic waves are then emitted. We have been developing a unique technique called laser-THz emission microscope (LTEM), which measures the locally excited THz waves and analyses the spatiotemporal behavior of the photocarriers. This time, we proved that LTEM is effective as a technology to support the development of 3D integrated circuits and wide bandgap semiconductor devices.

Background & Results

TSV is an important element for the development of 3D integrated circuits, and its in-depth internal analysis is becoming more and more difficult. There are still many unknown properties of wide bandgap semiconductors as well, and it is important to evaluate their physical properties at the wafer scale.

The present study is expected to provide an integrated metrology solution that enables non-contact testing in the semiconductor manufacturing process, not only for the evaluation of through-silicon vias (TSV) and wide-gap semiconductors. Maximizing production yield is essential for saving energy and minimizing waste, and as R&D and production become increasingly complex due to 3D and miniaturization, the LTEM, which enables non-destructive, non-contact analysis and inspection, will be an important innovation to solve this problem.

Significance of the research and Future perspective

Japanese semiconductor industry needs breakthrough semiconductor development technologies that are far superior to catch-up technologies. One of the most important keys to solving this problem is the development of new analysis technologies. LTEM provides a unique technology for visualizing the spatiotemporal dynamics of photocarriers. For the practical application of LTEM, it is important to demonstrate how it can be used to solve problems. Here, we examined the usefulness of LTEM for TSVs and multiple quantum well (MQW) structures.

In TSVs, as shown in Fig. 1, metal electrodes are fabricated through the Si wafer. When a photoelectric charge is excited in a part of it, THz radiation is emitted reflecting the direction of the charge movement. In addition, the excited THz waves travel into the Si along the electrodes and are reflected at the backside and are again emitted as terahertz waves from the surface. The time variation of these signals is expected useful to analyze the propagation inside, i.e., the MOS structure in three dimensions.

Figure 2 shows the MQW structure. Unlike TSV, the charges are excited inside the MQW embedded in the GaN layer. As the charge moves through the quantum well, the strain at the interface between GaN and InGaN is released, which excites acoustic phonons. The acoustic phonons emit the THz waves at the surface, resulting in the complex THz waves as show in Fig.3. The thickness of the GaN layer on the surface can be estimated with a resolution of 10nm on a wafer scale.

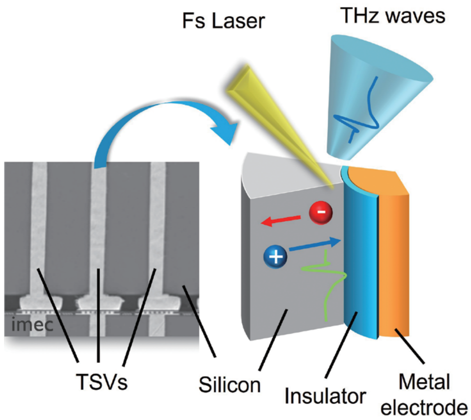

Fig.1

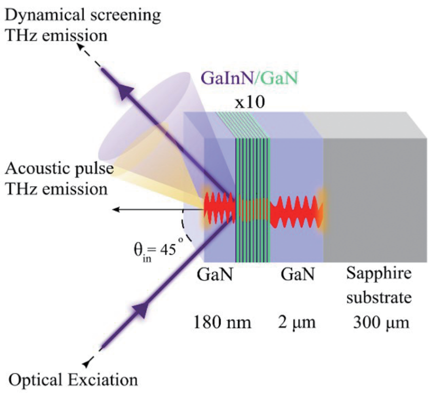

Fig.2

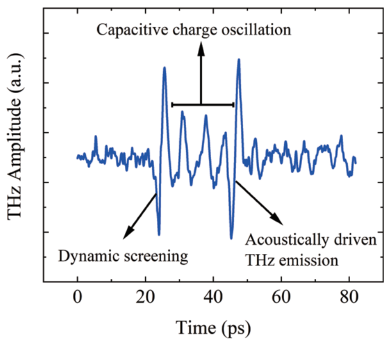

Fig.3

Patent	
Treatise	Jacobs, K. J. P. et al. Characterization of through-silicon vias using laser terahertz emission microscopy. Nat Electron. 2021; 4: 202–207. doi: 10.1038/s41928-021-00559-z Mannan, A. et al. Ultrafast Terahertz Nanoseismology of GaInN/GaN Multiple Quantum Wells. ADVANCED OPTICAL MATERIALS. 2021; 9(15): 2100258. doi: 10.1002/adom.202100258
URL	https://www.ile.osaka-u.ac.jp/research/THP/
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