Material evaluation, Sensing, Semiconductor device

Terahertz ellipsometry with high precision for 6G materials and wide bandgap semiconductors

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Abstract

We have developed a highly precision terahertz time-domain ellipsometry with a novel rotating analyzer. We succeeded in increasing the detection sensitivity by more than 10 times, making it possible to evaluate the dielectric constant, dielectric loss, and complex refractive index in the terahertz region and Beyond 5G region with high accuracy. It is possible to evaluate the conduction characteristics of 6G materials and wide-gap semiconductors (GaN, SiC, Ga2O3) non-destructively and without contact.

Background & Results

Beyond 5G and 6G are being developed at a rapid pace as next-generation communication standards, and these communication bands correspond to the sub-terahertz frequency range. Wide-gap semiconductors such as GaN, SiC, and Ga_2O_3 are also expected to be used as power devices and high-frequency devices. By terahertz ellipsometry and terahertz time domain spectroscopy, it is possible to evaluate the conductivity properties (carrier concentration, mobility, scattering time, etc.) of these advanced materials and the dielectric constant and refractive index in the high frequency region.

Significance of the research and Future perspective

Conductive property evaluation of wide-gap semiconductors has been performed by electrical evaluation such as Hall measurement and CV measurement up to now. Terahertz waves corresponds to electromagnetic waves with a frequency range of 0.1 – 10 THz. Optical evaluation using terahertz waves has made it possible to evaluate electrical conduction characteristics such as carrier concentration, mobility, and scattering time in a non-destructive, non-contact method without the need to fabricate electrodes. By increasing the measurement accuracy more than 10 times with the newly introduced rotating analyzer method, we have succeeded in evaluating the carrier concentration of 10^{15} -10^{20} cm^{-3}. In the measurement of mobility, it is possible to measure the anisotropy of the sample, and we plan to support the evaluation of in-plane anisotropy and out-of-plane anisotropy in the future. In 6G material evaluation, it is possible to evaluate characteristics such as dielectric constant and dielectric loss in the sub-terahertz region, and it is also possible to evaluate characteristics of artificial substances such as metamaterials as well as insulating substrates and absorbers. Accurate evaluation of conductivity and permittivity characteristics in the ultra-high frequency range, which is the next-generation communication band, is essential for new device development, and we expect that the above technology we have developed will be used.

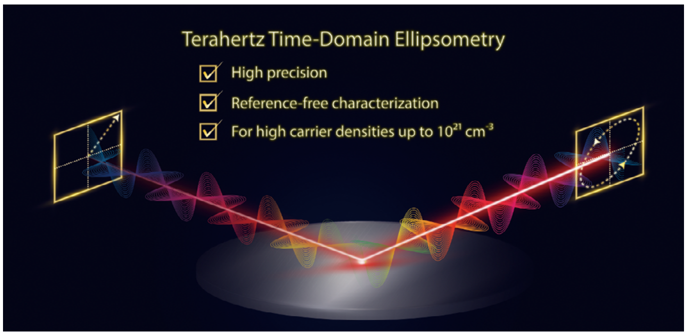
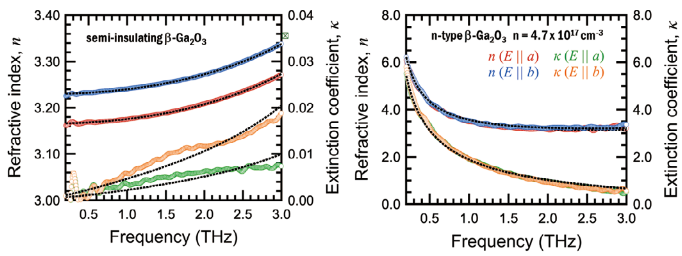


Image of high precision Terahertz time-domain ellipsometry



Refractive index spectra for wide bandgap semiconductor of β-Ga_2O_3 in Terahertz range

Patent	Japanese Patent Application No. 2021-106147
Treatise	V.C. Agulto, M. Nakajima, et al. Scientific Reports 11, 18129 (2021). doi: 10.1038/s41598-021-97253-z V.C. Agulto, M. Nakajima, et al. Applied Physics Letters 118, 042101 (2021). doi: 10.1063/5.0031531 M. Ota, M. Nakajima, et al. Nature Physics 18, 1436 (2022). doi: 10.1038/s41567-022-01767-w
URL	https://resou.osaka-u.ac.jp/ja/research/2021/20210915_2 https://resou.osaka-u.ac.jp/ja/research/2021/20210126_3 https://resou.osaka-u.ac.jp/ja/research/2022/20221021_1
Keyword	terahertz wave, non-destructive non-contact evaluation, semiconductor, 6G, beyond 5G