S8-O1
Dual-mode Terahertz Time-Domain Spectroscopy for Versatile Characterization of Semiconductors

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Electrical characterization of semiconductors has long been critical for their quality assurance. Conventionally, these characterizations heavily rely on contact methods, such as Hall effect measurement[1]. Whilst mature, its contact nature greatly hinders the throughput and real-world applicability.

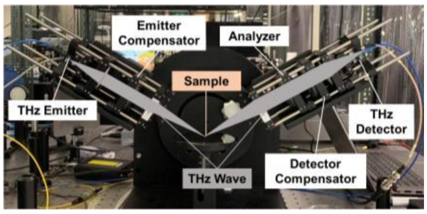

Fig. 1 Photo of the dual-mode THz spectrometer setup, allowing switching between transmission and ellipsometry modes

Contactless methods, for instance, terahertz (THz) spectroscopy, has been intensively investigated for electrical characterization of semiconductors. Much literature has demonstrated sensing of a broad variety of semiconductors with THz spectroscopy, including bulk substrates, thin films, stratified structures[2]. However, these measurements utilize single topology, and are dependent on task-specific designs.

Thus, in this work, we proposed a dual-mode THz time-domain spectrometer, aiming to cater a greater variety of semiconductors. Attributed to its versatility, this instrument is capable of seamless switching between transmission (T-mode) and ellipsometry (E-mode) modes. In addition, a unified modeling based on optical transfer matrix method is developed, to extract the complex refractive indices of specific layer in given structures under both modes. Moreover, computational and instrumentational robustness of this method is discussed. Results are benchmarked against Hall effect measurement, to showcase its versatility and robustness.

Sample: n-type GaN on sapphire	**Sheet Resistivity** (Ω/sq)	**Concentration** (cm^{-3})	**Mobility** ($cm^2V^{-1}s^{-1}$)
THz Spectroscopy (T-mode)	9.332 ± 0.040	$(2.27 \pm 0.30) \times 10^{20}$	147.5 ± 11.0
Hall Measurement	9.075	2.80×10^{20}	123.3

Sample: ITO on glass	**Sheet Resistivity** (Ω/sq)	**Concentration** (cm^{-3})	**Mobility** ($cm^2V^{-1}s^{-1}$)
THz Spectroscopy (T-mode)	37.40 ± 0.32	$(2.03 \pm 0.39) \times 10^{20}$	53.1 ± 11.1
Hall Measurement	36.61	2.32×10^{20}	46.1

Sample: 2DEG in HEMT	**Sheet Resistivity** (Ω/sq)	**Concentration** (cm^{-2})	**Mobility** ($cm^2V^{-1}s^{-1}$)
THz Spectroscopy (E-mode)	350.5 ± 1.3	$(1.023 \pm 0.003) \times 10^{13}$	1741.7 ± 3.7
Hall Measurement	320.9	1.01×10^{13}	1930.0

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