Technologies for the optical characterization of materials at terahertz frequencies

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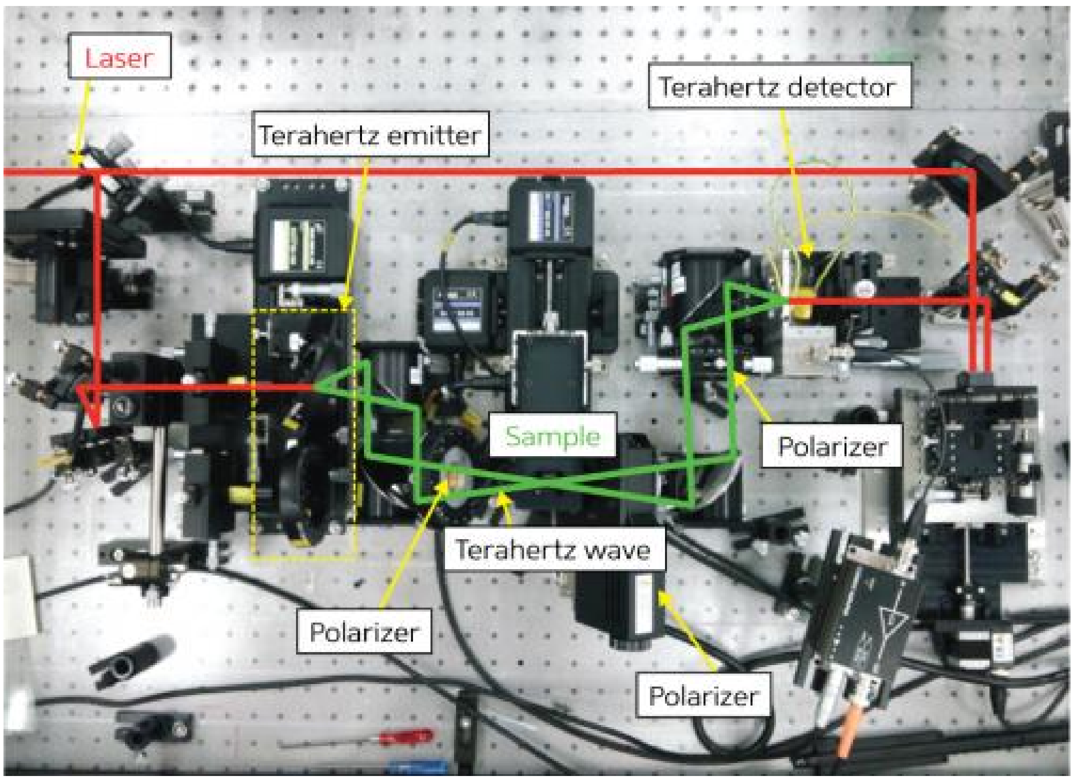

Figure 1: The 'ultra-broadband' terahertz time-domain spectroscopic ellipsometry system. Credit: Masatsugu Yamashita, RIKEN Center for Advanced Photonics

The noncontact measurement of material properties using light is used in a wide variety of applications, from airport security scanners to medical x-ray imaging and various analytical techniques. Some of the most interesting information is contained in what is known as the terahertz region of the frequency spectrum, but developing broadband spectroscopic techniques for the terahertz regime has proved difficult. Masatsugu Yamashita, Chiko Otani and colleagues from the RIKEN Center for Advanced Photonics and Canon Inc. have now developed a spectroscopy system that operates across an unprecedented range of terahertz and infrared frequencies.

Terahertz light, while potentially very useful for probing material properties, is difficult to handle using optical instruments because it is easily absorbed by many materials. Time-domain terahertz spectroscopy is already widely used to measure the optical properties of materials. Measurement of the polarization of light reflected from the sample in comparison to a reference mirror, or ellipsometry, provides even more information. Yamashita and his colleagues combined the two methods for use over a wide range of terahertz frequencies (Fig. 1).

Precision was a crucial aspect of the system, explains Yamashita. "Conventional terahertz reflection time-domain spectroscopy suffers from positioning error between the sample and the reference mirror, which prevents precise measurement of phase information."

Achieving the necessary micrometer precision across a broad frequency range required the use of as few light emitters and detectors as possible, and the use of broadband emitter and detector materials. The researchers used crystals of gallium phosphide or gallium selenide as light emitters, covering an unprecedented frequency range of 0.5–30 terahertz. For detection, Yamashita's team used a film of gallium arsenide, prepared at low temperature to extend its broadband characteristics. The thin film of gallium arsenide was transferred to an optically neutral substrate to avoid unwanted terahertz wave absorption.

The researchers demonstrated the excellent performance of the system across almost the entire operating frequency range. Although some unwanted light absorption in the detector and other optical components remains, which prevents the system's use at certain frequencies, Yamashita is confident that these issues can be overcome by using thinner detector films or different optical components.

Once refined, the 'ultra-broadband' terahertz time-domain spectroscopic ellipsometry system could have some significant industrial applications. "An important application of the system," says Yamashita, "is the contactless and nondestructive characterization of carrier transport properties in semiconductors and the conducting polymers used in optoelectronic devices such as mobile-phone displays. This would be indispensable for improving device performance."

More information: Yamashita, M., Takahashi, H., Ouchi, T. & Otani, C. "Ultra-broadband terahertz time-domain ellipsometric spectroscopy utilizing GaP and GaSe emitters and an epitaxial layer transferred photoconductive detector." *Applied Physics Letters* 104, 051103 (2014). DOI: 10.1063/1.4862974

Provided by RIKEN

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