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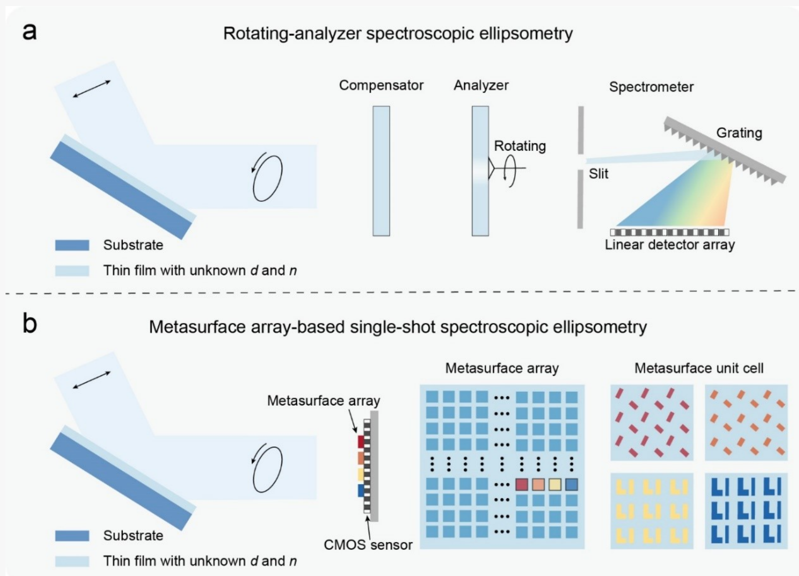
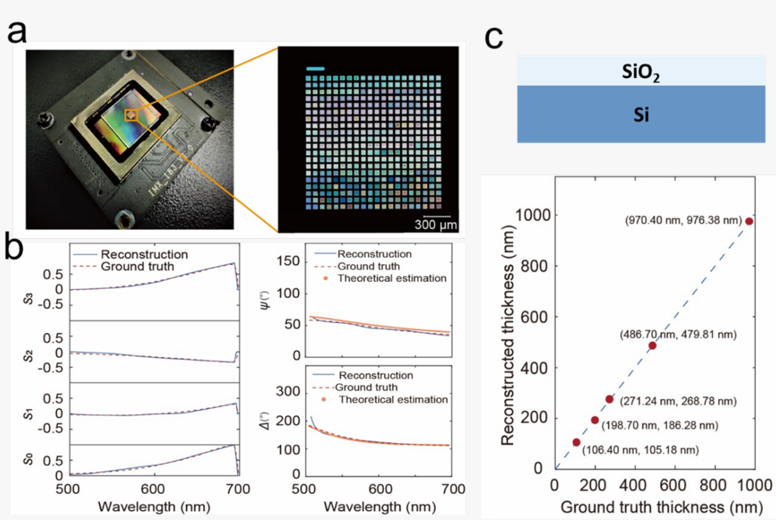
Metasurface-based miniaturized spectroscopic ellipsometer

USA, April 11, 2024 /EINPresswire.com/ -- Spectroscopic ellipsometry has been widely adopted for the measurement of thin film thickness as well as its optical constant. However, conventional ellipsometers are rather bulky. Scientists from Tsinghua University in China recently demonstrate a compact metasurface array-based spectroscopic ellipsometry system, which allows single-shot spectropolarimetric detection and accurate determination of thin film properties.



a, Schematics of a conventional spectroscopic ellipsometry system. b, Schematics of a metasurface array-based single-shot spectroscopic ellipsometry system.



The metasurface array-based system for single-shot spectroscopic ellipsometry measurement.

Spectroscopic ellipsometry is widely adopted in semiconductor processing, such as in the manufacturing of integrated circuits, flat display panels, and solar cells. However, a conventional spectroscopic ellipsometer, as shown in Fig.1a, typically modulates the polarization state via mechanical rotation of the compensator or analyzer. For spectral detection, it either requires wavelength scanning or the use of a multi-channel spectrometer. The resulting system is often bulky, complex, and require multiple measurements.

In a new paper (https://doi.org/10.1038/s41377-024-01396-3) published in Light Science &

Applications, a team of scientists, led by Professor Yuanmu Yang from Tsinghua University, China and co-workers have proposed and experimentally demonstrated a compact metasurface array-based system for single-shot spectroscopic ellipsometry measurement, as shown in Fig.1b.

The proposed system utilizes a silicon-based metasurface array to encode the full Stokes polarization spectrum of light reflected from the thin film. Subsequently, the polarization and spectral information is decoded based on the intensity signals collected by a CMOS sensor using convex optimization algorithms. It can reconstruct the full Stokes polarization spectrum of the thin film, which then further allow the determination of film thickness and refractive index. This approach significantly simplifies conventional spectroscopic ellipsometry systems and enables single-shot thin film parameter measurements.

The schematic of the metasurface array-based spectroscopic ellipsometer is shown in Fig. 2a. The spectropolarimetric detection section of the ellipsometer is composed of a metasurface array integrated onto a commercial CMOS sensor, resulting in an extremely compact system. The metasurface array consists of 20 × 20 optimized elements designed to support anisotropic and spectrally-diverse response, ensuring accurate reconstruction of the full Stokes polarization spectrum. In this work, five SiO2 thin films with thicknesses ranging from 100 nm to 1000 nm deposited on a silicon substrate were selected as samples for testing. The fitted thicknesses and refractive index dispersions of the tested thin films closely matched the ground truth obtained from a commercial spectroscopic ellipsometer, with errors of only 2.16% and 0.84% for thickness and refractive index measurements, respectively.

The research team proposed and experimentally demonstrated a metasurface-array for single-shot integrated spectroscopic ellipsometry system. This system allows accurate determination of thin film thickness and refractive index through a single measurement without any mechanical moving parts or dynamic phase modulation elements. The metasurface array also holds promise for spectropolarimetric imaging, which may further allow the non-destructive characterization of spatially-inhomogeneous thin films.

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