Park SYSTEMS

Accurion EP4
Imaging and Non-Imaging Ellipsometry compared

Why use ellipsometry?

Ellipsometry is tailor-made for the optical characterization of thin-film coatings on reflective surfaces like glasses, wafers and mirrors. It has evolved into a must-have tool in research facilities and the high-tech industry's quality control. Today, no computer chip is made without an ellipsometer being involved!

Ellipsometry is highly sensitive to any variations of the sample surface. It excels at the thickness measurement of transparent or semi-transparent thin films with nanometric accuracy and sub-Angstrom precision. Applicable thin films range from single atomic/molecular layers up to multi-layer stacks with a total thickness of several microns.

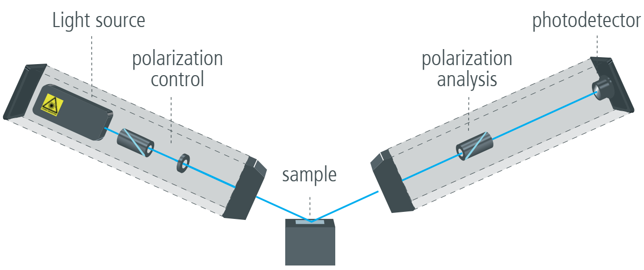


Fig. 1: Setup of a non-imaging ellipsometer using a simple photodetector.

As an all-optical tool, ellipsometry allows for a true non-contact and non-destructive sample characterization without the need for special treatment – no dyes, no cutting, no vacuum.

Ellipsometry is easy and safe to operate, since it uses low-intensity and low-energy spectroscopic light sources in the ultraviolet, visible and infrared spectral range – no high-power lasers, no X-rays.

Why use imaging ellipsometry?

Imaging ellipsometry integrates ellipsometry with optical microscopy. This evolves ellipsometry from a single-spot probe into an area-resolving imaging technique. It therefore enables thin-film metrology on micro-structured and/or inhomogeneous samples, which are below the resolution limit of non-imaging ellipsometers (see next page).

The technique intrinsically provides a high contrast visualization of the thin-film sample, which is elusive in conventional ellipsometry. This unique capability allows to identify the most suitable measurement spots on the sample and to define regions of interest, from which the data shall be collected.

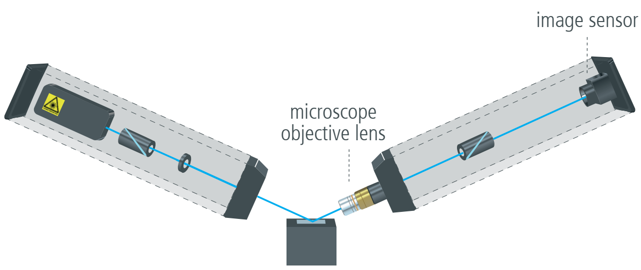
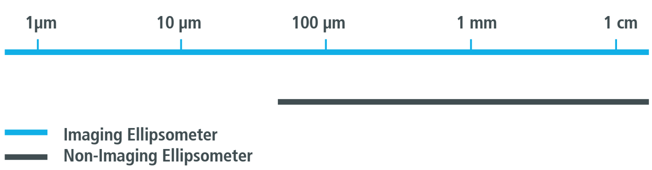


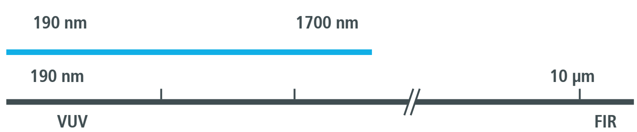
Fig. 2: Imaging ellipsometer with integrated objective lens and image sensor.

On nominally homogeneous samples, imaging ellipsometry easily reveals unintended anomalies such as defects, contamination and damage. It enables fast, high contrast imaging and inspection of ultra-thin layers, even for mono-atomic/monomolecular thin films.

Spatial resolution



Wavelength range



Imaging vs. non-imaging ellipsometry

The key difference between imaging and non-imaging ellipsometry refers to the spatial resolution, which is the smallest sample feature that can be measured by a respective instrument. Imaging ellipsometry has an enormous advantage in this regard, as it allows for the characterization of micro-structures that are many times smaller than the best-case scenarios of non-imaging ellipsometers.

The spatial resolution of a non-imaging ellipsometer is determined by the spot size of the probing beam at the sample surface (typically 0.035 to 2 mm). The instrument collects all the light reflected from this single spot and delivers it to the detection system (Fig. 1). Thus, non-imaging ellipsometers average over all features within the probed spot. This can provide incorrect results if your sample is not completely homogeneous on that scale.

In contrast to that, an imaging ellipsometer is an optical microscope that obtains a 2D image of the illuminated sample area using an optical lens system and a digital image sensor (Fig. 2). The spatial resolution is determined by the imaging system and pixel size of the detector, rather than by the spot size of the probing beam. The imaging system crops an area from within the illuminated spot, and the 2D detector provides a highly resolved image of it. Therefore, imaging ellipsometry reaches microscopic spatial resolutions down to 1 µm.

Since each pixel of the sensor provides an ellipsometry measurement, an imaging ellipsometer effectively yields more than a hundred thousand ellipsometry measurement in parallel! This enables the simultaneous measurement of different sample features, area-selective masking and statistical analysis that is elusive in non-imaging ellipsometers.

Imaging vs. mapping ellipsometers

A mapping ellipsometer is typically referred to as a non-imaging ellipsometer with a motorized sample stage. It measures one sample spot at a time and moves the sample stage in between the measurements until enough data is collected to create a sample map. Therefore, the maximum spatial resolution of a mapping ellipsometer is still determined by the instrument's spot size of the probing beam.

In practice though, the spacing of the measurement points is typically much larger than the spot size, as the overall measurement time scales linearly with the number of sampling points. Mapping ellipsometers are therefore primarily used for the acquisition of low-resolution maps on large area samples (sparse sampling).

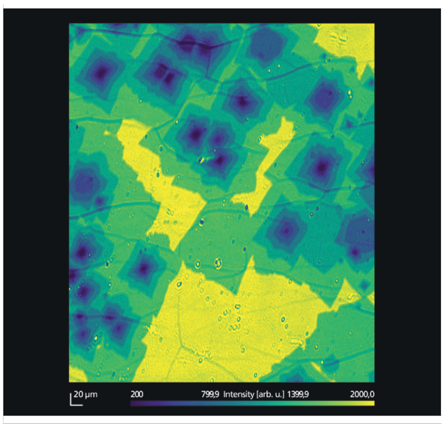
By contrast, an imaging ellipsometer can take more than a hundred thousand readings within one measurement with vastly better spatial resolution. All measurement locations within the field of view are measured in one shot. This creates a local, high-resolution map of the probed sample site, without the need to move the sample stage.

Additionally, an imaging ellipsometer provides large-area mapping as well if it is combined with a motorized sample stage. In practice, this is used to acquire a super image of the sample by means of image stitching, which covers a large area whilst maintaining the high spatial resolution.

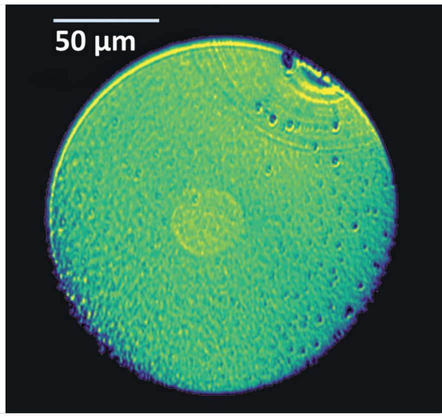
Key advantages of imaging ellipsometry

- Thin film characterization on micro-structured and inhomogeneous samples
- Enables layer thickness measurements on micro-structures too small for conventional ellipsometry
- Allows for area-selective measurements including only regions of interest within the probed sample spot
- Simultaneous acquisition of multiple sample areas - more than a hundred thousand readouts in parallel
- High-contrast visual inspection of thin films by ellipsometric contrast microscopy
- Simple detection of layer-structure anomalies, defects, contamination and damage

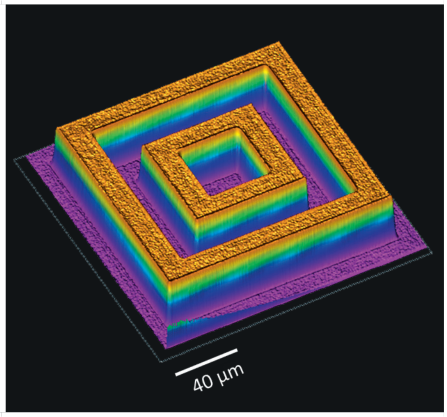
Application Examples of Imaging Ellipsometry



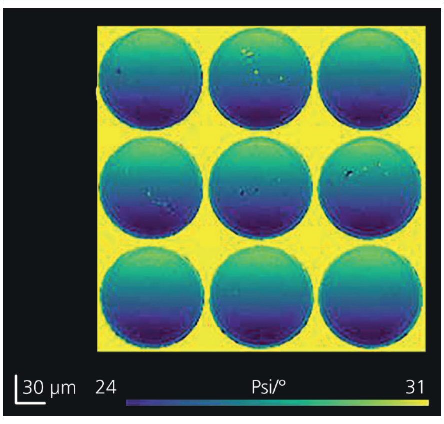
Ellipsometric contrast micrographs
of CVD graphene



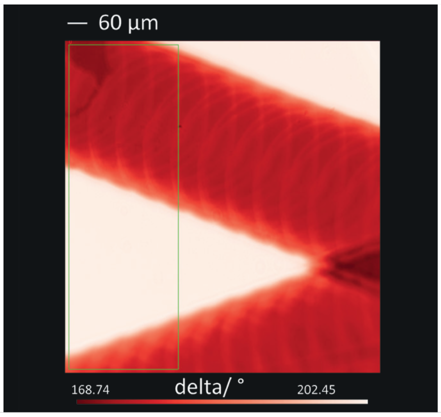
Ellipsometric contrast micrograph
of an optical fiber (As_2S_3 core/clad)



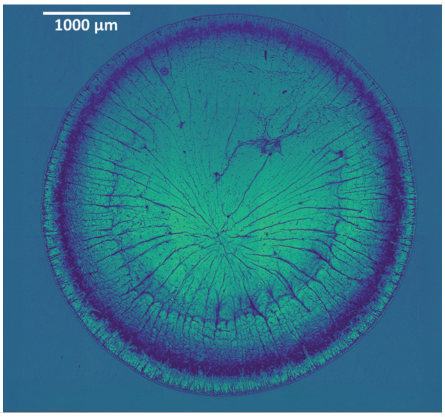
Microscopic maps
of oxide layer thickness (SIO_2)



Psi map of thin films
on curved micro lenses



Delta map of
ALD-printed thin film structures



Characterization of
drop cast graphene thin film

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