Enabling Nanoscale Advances

Accurion EP4

Microscopic Thin Film Metrology and Visualization

Park Systems GmbH - Accurion

Park Systems GmbH previously known as Accurion GmbH is a leading provider of high-end, state of the art imaging ellipsometry and active vibration isolation products. Accurion was merged into Park Systems Corporation in 2022 to boost its R&D resources and expand its sales network to better serve its customers.
Park Systems is a world leading manufacturer of nano metrology-microscopy solutions including the atomic force microscopy (AFM), white light interferometry and infrared spectroscopy systems.
It provides complete range of nano metrology and microscopy products for researchers and engineers in the chemistry, materials, physics, life sciences, semiconductor, and data storage industries.

Prior to merger with Park Systems, Accurion was previously known as Nanofilm Technology GmbH, a spin-off from the Max Planck Institute for biophysical chemistry in Goettingen. In 1991, the company began designing the Brewster angle microscope for the characterization of ultrathin films. In 1996, the company's division of active vibration isolation was established. In 2009, Halcyonics GmbH, a specialist in active vibration isolation solutions, merged with Nanofilm Technology GmbH to form Accurion GmbH.

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Accurion EP4

The Microscopic Way of Doing Ellipsometry

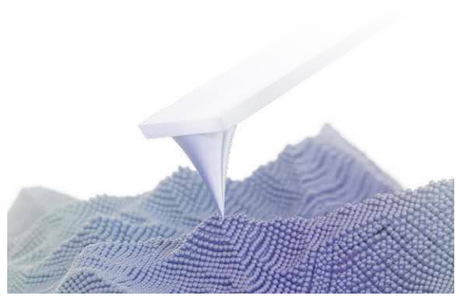
Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

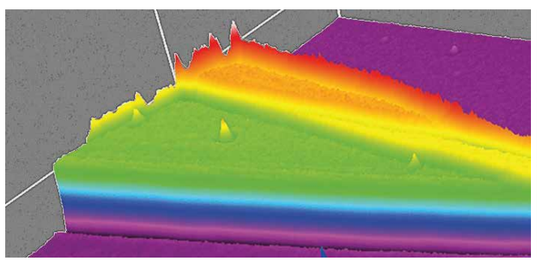
This well established microscopic thin film, surface and materials metrology tool generation uses a combination of ellipsometry and microscopy to enable surface characterization with a lateral ellipsometric resolution down to 1 micron.

The Accurion EP4 offers a variety of unique features that allow the visualization of your surface in real time. You will see in real time the structure of your sample on a microscopic scale. You can measure parameters like thickness, refractive index and absorption. You can receive maps of selected areas. You can combine the instrument with other technologies like AFM, QCM-D, reflectometry, Raman spectroscopy and many more to receive even more information from your samples. The Accurion EP4 is a modular instrument enabling configuration for your specific measurement tasks. The Accurion EP4, equipped with the standard laser can also be operated as a Brewster angle microscope, typically in LB applications.

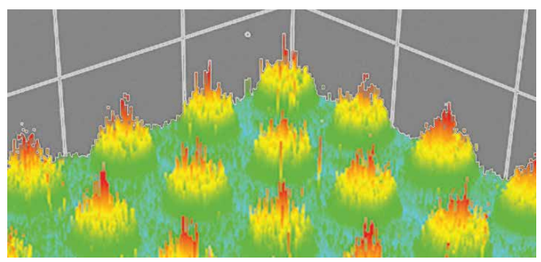
Unique Features:

- Ellipsometry with the highest lateral ellipsometric resolution available on the market: Objects down to 1 micron can be resolved. This feature allows the investigation of structured samples or tiny substrates.
- Real time ellipsometric contrast images providing a fast view of the surface, any defects or structures.
- Patented region of interest (ROI) concept allows the parallel investigation of multiple areas within the selected field of view.
- Spectroscopic imaging ellipsometry in the wavelength range from 190 nm to 2750 nm provides pictures and ellipsometric micro-maps of your samples over a wide wavelength range.
- Optional single shot full field fully focused images (UltraObjektive) in the visible wavelength range allowing the easy investigation of moving samples like growing or moving SAM's, protein interaction or moving monolayers on water surfaces.
- Knife edge illumination allows measurements on thin transparent substrates to avoid background reflection.
- An interesting range of accessories enable the instrument to work in a large variety of applications (SPR or solid/ liquid cells, light guides for liquid/liquid interfaces, microfluidic, temperature control, electrochemistry cells, and many more).
- The technology integration platform allows the adaption of various alternative measurement technologies to receive even more information from your sample.

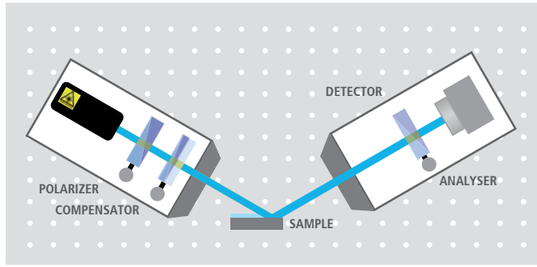


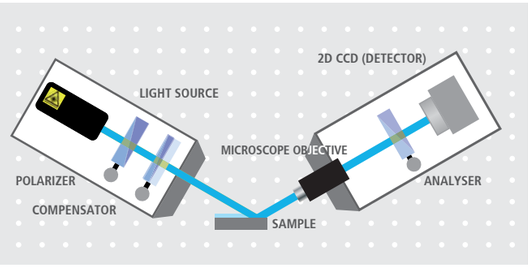


Materials research example: graphene layer



Bio application example: protein spots on glass





Why use ellipsometry?

Ellipsometry analyzes the change of polarization of light reflected from a sample and yields information about thin film layers that are often even thinner than the wavelength of the probing light itself.

The change of amplitude and phase of the p and s components of the light after the reflection from the sample are depending on film properties like thickness, refractive index and absorption. Ellipsometry measures the change of the amplitudes and phases of s- and polarized light by rotating polarization components. The measured values are psi and delta. These values need to be put into a computer based model of the sample materials to calculate the thickness, refractive index, absorption and a variety of sample properties, including morphology, crystal quality, chemical composition or electrical conductivity. Ellipsometry is an established technology to measure multilayer film thickness, refractive index and absorption.

Why use imaging ellipsometry?

Imaging ellipsometry combines microscopy and auto nulling ellipsometry. The microscopy aspect allows the direct visualization of your sample with an ellipsometric contrast image with a lateral resolution as small as 1 micron as well as the measurement of the ellipsometric parameters Delta and Psi with the highest lateral ellipsometric resolution also down to 1 micron.

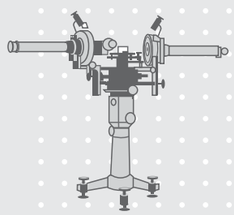
This enables resolving sample areas 1,000 times smaller than most micro spot equipped non-imaging spectroscopic ellipsometers. Imaging ellipsometry permits characterization of local sample parameter variation on a microscopic scale. This technology can measure the same ex-situ applications as non-imaging ellipsometers and many more. It is dedicated to applications where you have lateral structures in the range of 50 mm down to 1 micron. This includes patterned samples or where you have tiny samples like tips of a cantilever.

Comparison non-imaging and imaging ellipsometers

The lateral ellipsometric resolution of non-imaging ellipsometers is determined by the spot size of the light source at the sample surface. Non-imaging ellipsometers reflected light from the spot guided through the analyzing system to the detection system. Spot sizes are in the range 2 mm to 35 µm. All sample structures smaller than the spot size cannot be accurately detected. The instrument will average over all structures within the sampled spot. This can provide incorrect results if your sample is not completely homogeneous.

The enhanced lateral ellipsometric resolution of imaging ellipsometry is a result of the combination of a high numerical aperture objective that images about a million sites on the illuminated sample area onto a high resolution 2 dimensional pixel detector array.
This provides a resolution as small as 1 micron, depending on the wavelength of the illumination light.

Comparison non-imaging and mapping ellipsometers



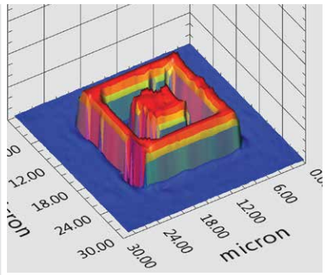
A mapping ellipsometer is a non-imaging ellipsometer with a motorized stage. Psi and delta readings are measured at one spot and then the table is moved to another sample location and the process is repeated until enough data is collected to construct a map of the sample. The lateral resolution is determined by the spot size and the density of the sample grid.
In addition to poor lateral resolution sampling time is directly related to the number of sample sites.
By contrast an imaging ellipsometer can take as many as one million readings in one short exposure with vastly better lateral resolution. The images obtained are maps of Delta and Psi. Compared to a mapping ellipsometer, maps are recorded with much higher lateral ellipsometric resolution. The acquisition time for a map can be much shorter in imaging ellipsometry.

Accurion EP4

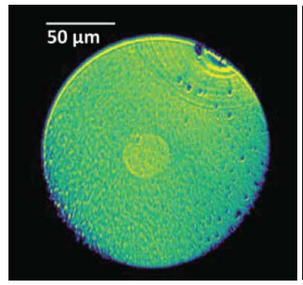
Unique Features

THE HIGHEST LATERAL ELLIPSOMETRIC RESOLUTION

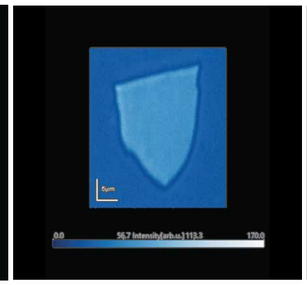
The combination of microscopy and auto nulling ellipsometry allows a lateral ellipsometric resolution as small as 1 micron.



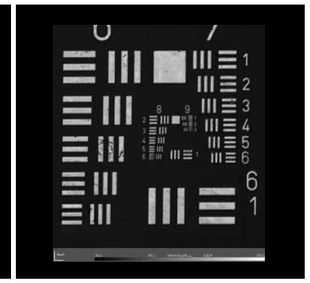
Air | SiO_2 | Si
Thickness map



Air | As_2S_3 (fi ber, core/clad)
Ellipsometric contrast micrograph



Microscopic mapping of 2D materials

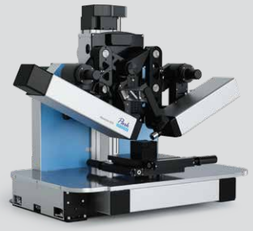


Highest lateral resolution
in the field of ellipsometry

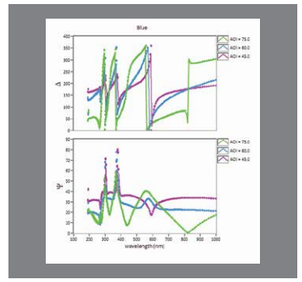
NEW FEATURE

IMAGING ELLIPSOMETRY IN THE WAVELENGTH RANGE OF 190 TO 2750 NM

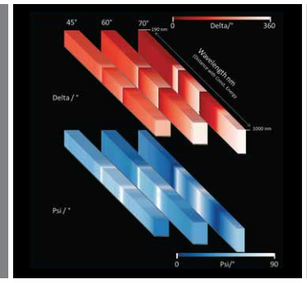
With the use of a grating monochromator now continuous spectroscopic measurements are possible.



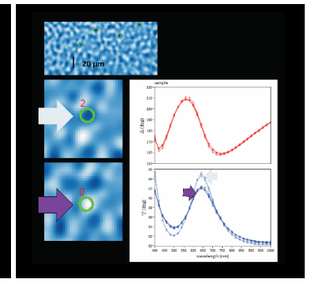
EP4 equipped with a UV
and NIR camera



Spectrocopic micro ellipsometry
at variable angles



i-VASE: Spectroscopic micromaps
at variable angles



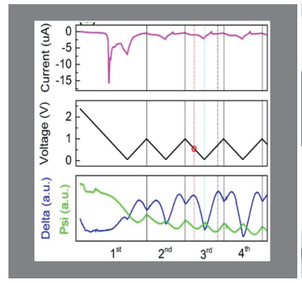
Local Delta and Psi spectra
of mesoporous polymer

NEW FEATURE

TECHNOLOGY INTEGRATION PLATFORM

Implementation of complementary technologies e.g. Raman, AFM etc. provide even more information on your sample

The new adaption platform



Operando imaging ellipsometry

Integration of a
Micro Raman System (Horiba)

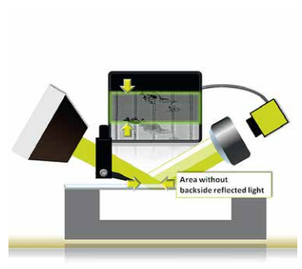
Please contact us for your integration ideas!

NEW FEATURE

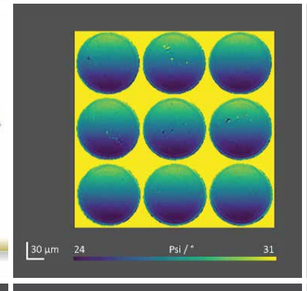
VARIOUS UNIQUE FEATURES

A variety of further new features and accessories enabling ellipsometry for new applications.

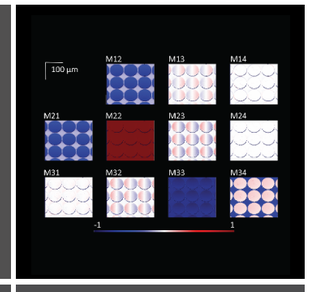
EP4 beam cutter – a nondestructive
way to eliminate backside reflection



Knife edge illumination allows the
investigation of thin transparent substrates



Thickness of thin films on curved surfaces
(Patent: DE 102019 101 650, EP3914899)



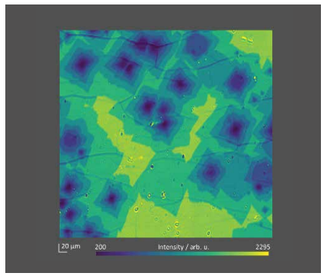
Imaging Mueller Matrix measurement
on curved surfaces

Accurion EP4

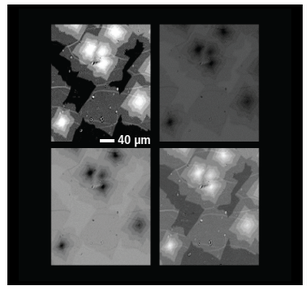
Selected Applications

GRAPHENE, 2D-MATERIALS

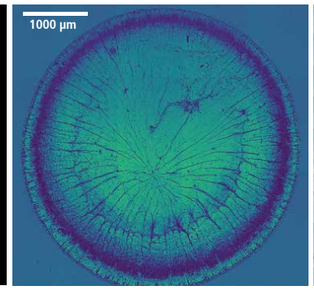
Imaging ellipsometry allows the direct visualization of your 2D-material flakes on various substrates/materials. It is possible to measure thickness and optical properties of different 2D-material layers in the micrometer scale.



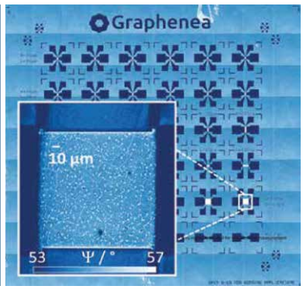
Characterization of complex layer stack of a pixel in parallel including common layer stack modelling



Ellipsometric contrast micrographs of CWD graphene



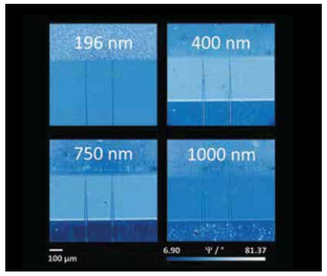
Drying of a sissile droplet of a graphene dispersion



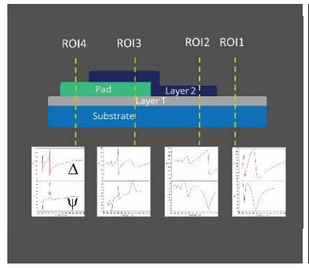
Characterization of Graphene devices

PHOTONICS, DISPLAYS, MEMS

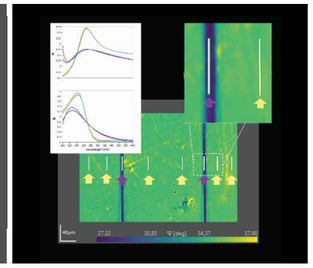
Our technique enables spectroscopic measurements on very small regions of only a few micron, using the patented ROI (region of interest) concept.
Multiple consults can be derived from a single measurement: film thickness, refractive index, composition and contaminations.



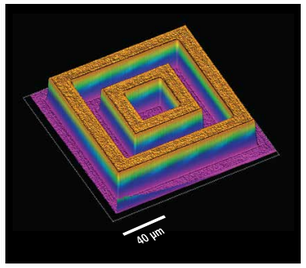
Psi maps of linear waveguides, characterized at different wavelength making use of knife edge illumination



Characterization of complex layer stack of a pixel in parallel including common layer stack modelling



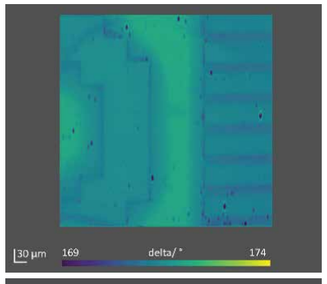
Optical properties of microscopic waveguides



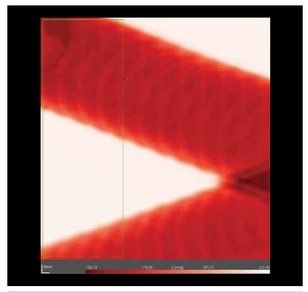
Microscopic maps of oxide layer thickness

SURFACE ENGINEERING

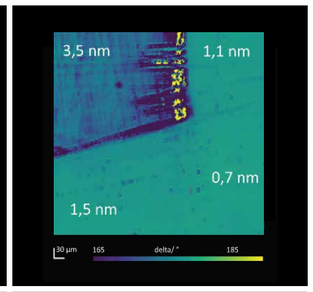
The main attempt of silanization is to form bonds across the interface between mineral/inorganic components and organic components present in paints, adhesives etc., or as the anchor for further steps of surface modifications.



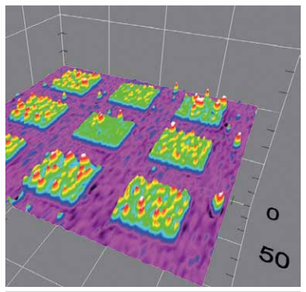
Surface inspection of Silanisation pattern



Film thickness of ALD-printed thin film structures



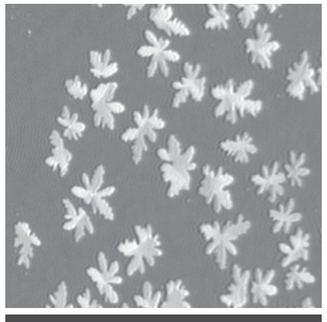
Postsilanisation treatment of (3-Glycidoxipropyl) trimethoxysilane on Silicon



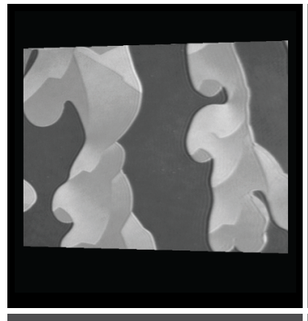
SAM pattern (Hexadecanthiol+PEG-SH) | gold 3D thickness map

AIR/WATER OR LIQUID/LIQUID INTERFACE

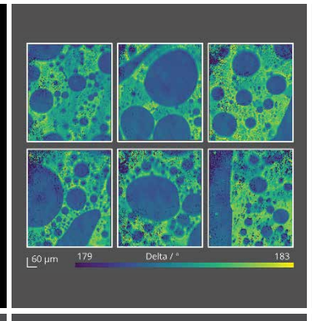
The air/water interface is of elementary interest in biophysics as well as in industrial applications. Brewster angle/LIQUID microscopy (BAM) is a powerful technique that allows for real-time visualization of Langmuir-Blodgett monolayers.



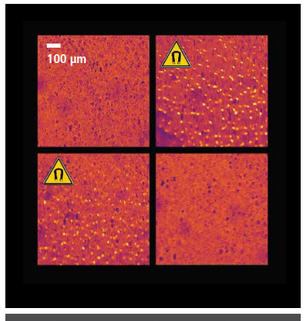
Air | Monopalmitoyl-rac-glycerol | water
BAM image (180 Å²/min · molecule)



Overall focused Brewster angle microscopy with ultraobjective



Microscopic Delta maps of lipid layers at the air/water interface



Effect of magnetic nanoparticles at the oil/water interface – with and without magnetic field

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Selected Applications

BIO INTERFACES

Biological applications demand high sensitivity observation techniques. Additionally, the environment needs to be controllable in order to avoid influencing or damaging the behavior of observed materials.

Imaging Ellipsometry (IE) offers highest sensitivity for thickness or surface coverage of mono- as well as sub-monolayers with microscopic resolution.

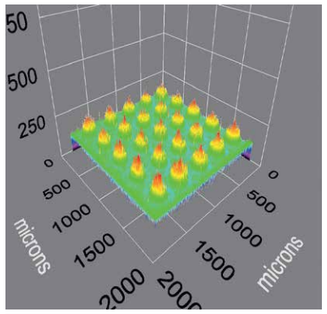
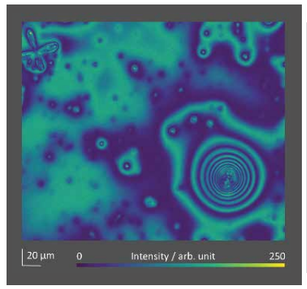
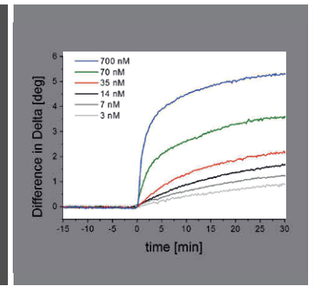


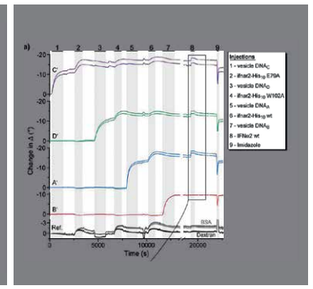
Image scan of protein spots on glass



Monochromatic imaging of biofilm formation



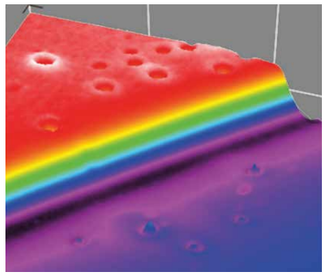
Antigen/antibody interaction: Binding of polyclonal anti-Rabbit IgG to immobilized Rabbit IgG



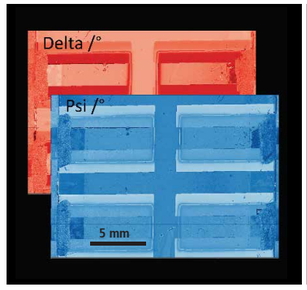
DNA – bar-coding of vesicles for bio chip application

ORGANIC ELECTRONICS, SOLAR CELLS

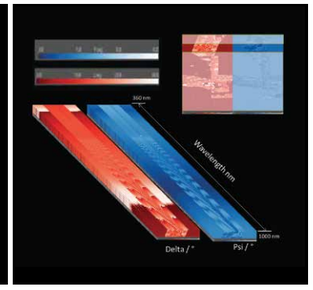
Considering that the optimal parameters play a central role in understanding and tailoring the properties of thin conductive polymers and that microscopic applications such as solar cells or OLEDs are increasingly coming to the fore, imaging ellipsometry is the method of choice to determine these parameters.



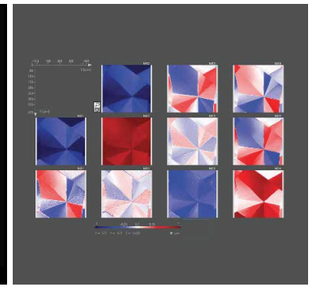
Air | PCBM (spincoated) | Si-3D Delta map



From micro to macro: Stitching of Delta and Psi



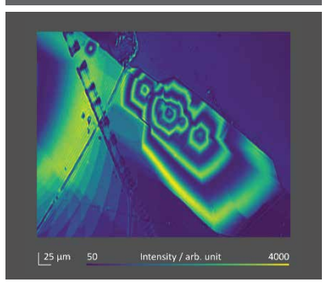
Spectroscopic mapping of Perovskite material



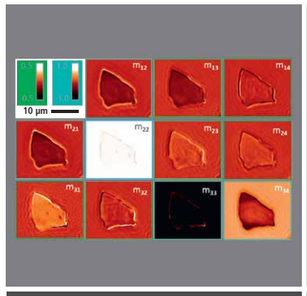
Determining the dielectric tensor of micro-textured organic thin films

ANISOTROPIC FILMS

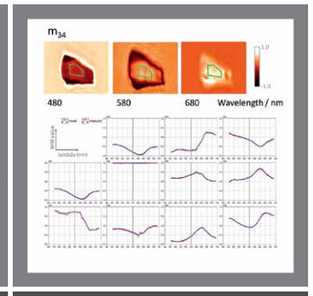
Anisotropic micro crystals show high potential for the applications in e.g. microelectronic devices and flexible electronics.
Most organic single crystals indicate a highly anisotropic optical behavior. Regarding anisotropic samples, the refractive index depends on the polarization of light and direction of propagation.



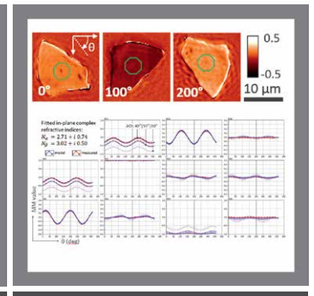
Air | Black Phosphorus | SiO_2 (300 nm) | Si In-plane dispersion function



Micrographs of 3x4-Müller-Matrix, normalized (m_{11} = 1)



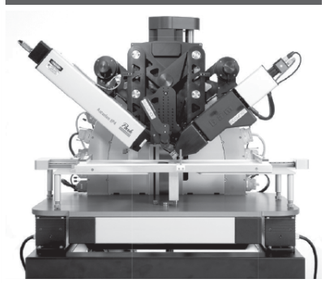
Spectroscopic Mueller-Matrix measurement



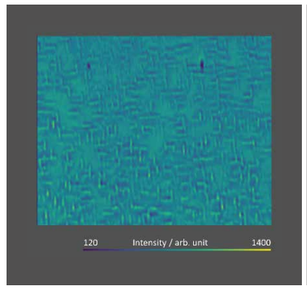
Orientation of optical axes obtained from Mueller-Matrix θ-scan

VARIOUS OTHER APPLICATIONS

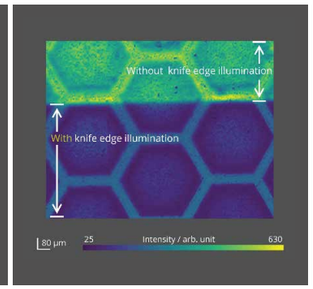
A wide selection of samples with structures can be visualized and measured with the unique technique of imaging ellipsometry.
If you do not find your application in this overview, feel free to contact us for specific information.



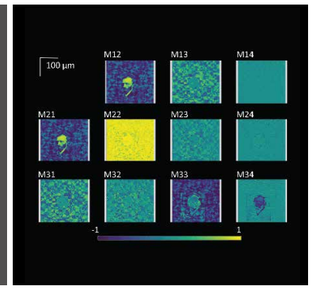
EP4 beam cutter – a nondestructive way to eliminate backside reflection



Spectroscopic Imaging Ellipsometry of self-Assembled SiGe/Si nanostructures



Honeycomb-like coating on glass: improved imaging with knife edge illumination



Optical properties of phase change materials with high lateral resolution

Accurion EP4

The Software

IMPROVED SOFTWARE CAPABILITIES

The Accurion EP4 software is modular. Separate software modules simplify the instrumental operation and enables parallel or offline analysis of collected data on a computer remote from the instrument.

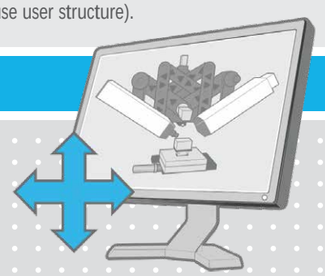
The “EP4Control” software manages the operation of the EP4 system. It is an interactive and easy to use control unit and automatization tool.

The “Server” software manages the documentation of your EP4 measurements including data from accessories and supported complementary measurement technologies. It is a sophisticated data and analysis module to enable a deeper understanding of complex systems.

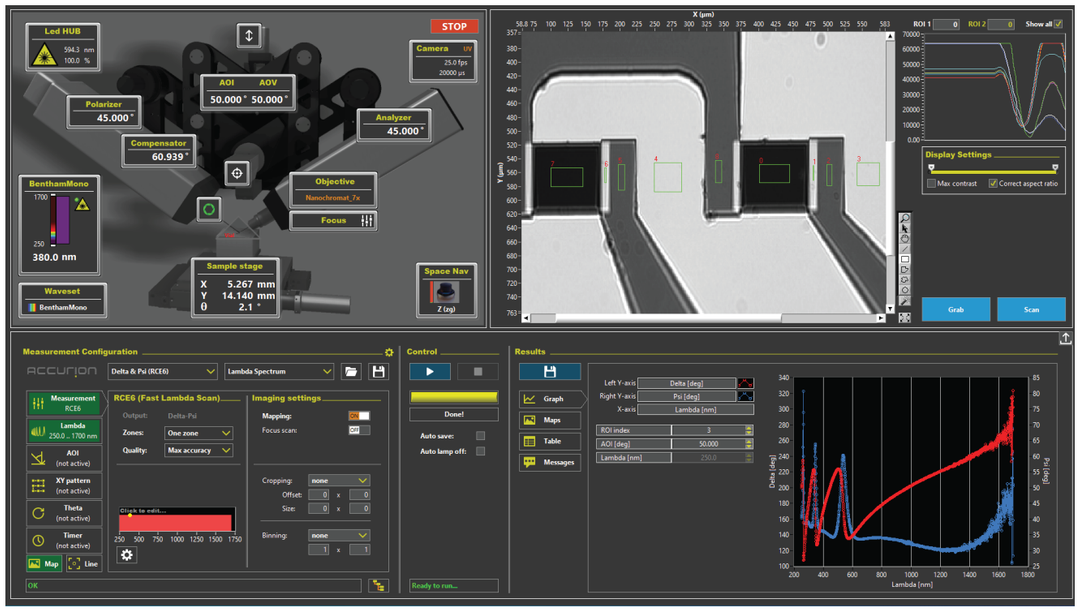
Server

- Organizes all supported data sources including accessories and optional complimentary measurement technologies and interfaces between instruments and software packages.
- Organizes the data storages structure (easy to use user structure).

EP4Control

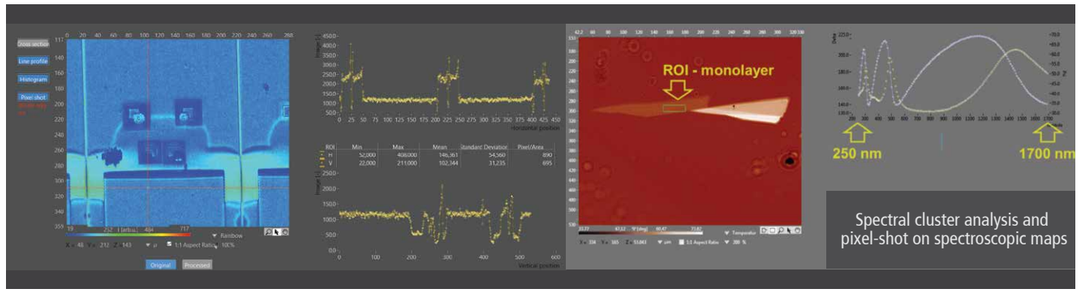


- Including image processing features:background correction (automatic), black level correction, geometric correction, signal tracking (overall brightness correction), default session storage and many more ...
- Operating the instrument (control of moving components, taking images, performing measurements, process automization, …)



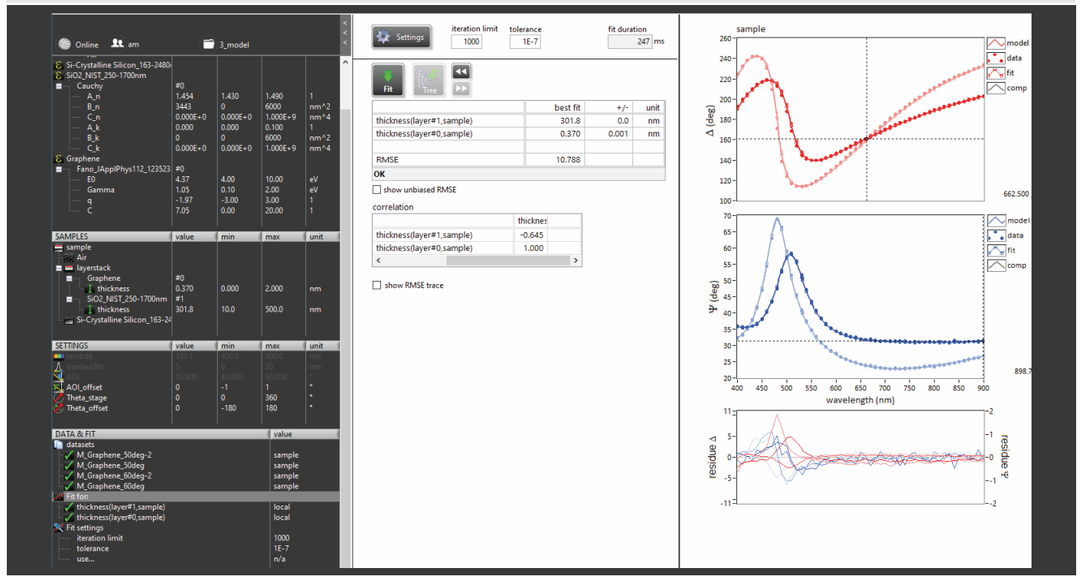
DataStudio

- Processing all data (images, measurement results, kinetics,structure description, etc.).
- Independent from the instrument and allows to analyze your data on your offi ce PC.
- Special features (examples):
  - Batch fitting: calculating delta/psi maps into thickness maps is done automatically in the background while using the instrument (pixel by pixel analysis).
  - Images can be saved continuously also as movies with all information of the measurement parameters



EP4Model

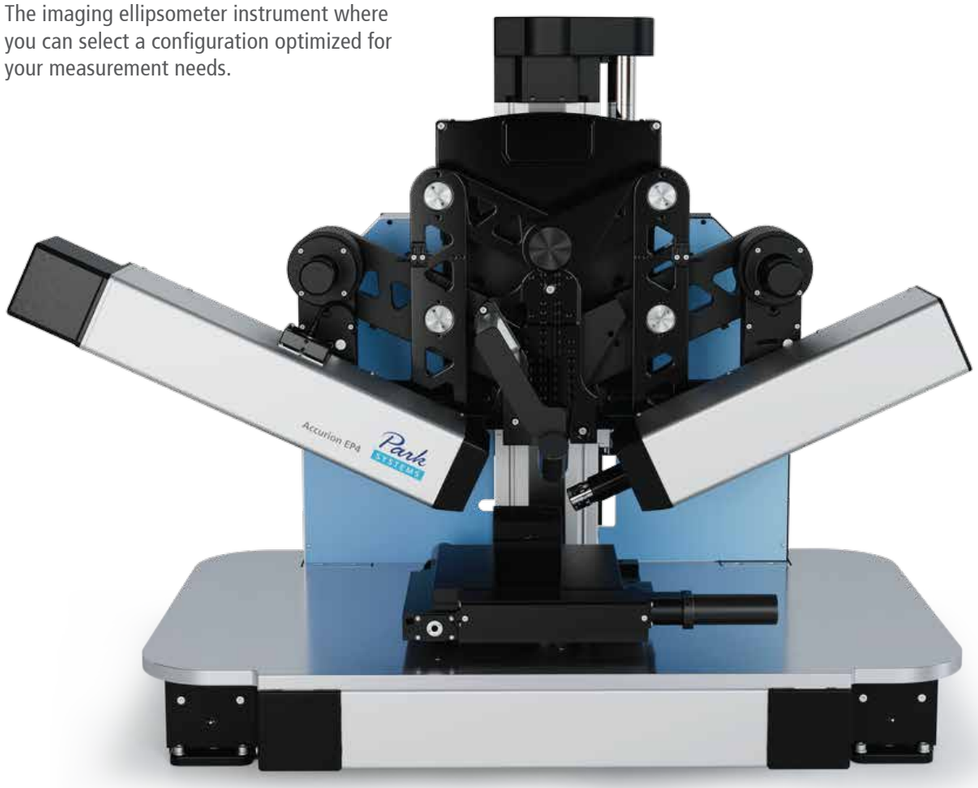
- Analyzing and fitting your measured data with a large selection of dispersion functions.
- Modeling of complex thin film systems and fitting of your measured data with the chosen model.
- Simulation of the fitting to follow the effect of any parameter in the model.
- Modelling of refractive indices (uniaxial, biaxial) and the orientation of optical axes of anisotropic materials (based on 11 elements of a normlized Mueller Matrix).



Accurion EP4

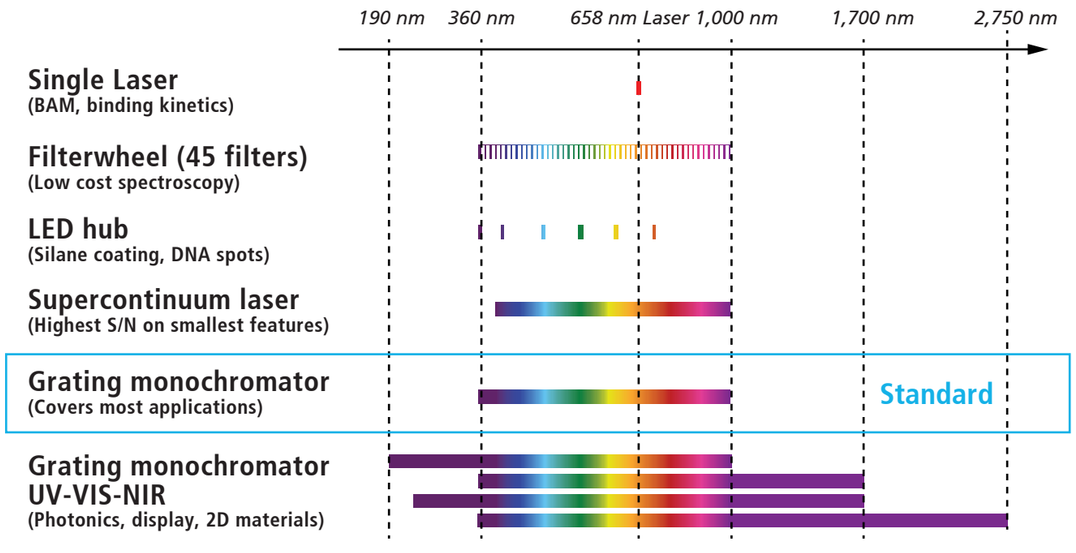
Configuration Possibilities

The imaging ellipsometer instrument where you can select a configuration optimized for your measurement needs.



EP4 CONFIGURATION | WAVELENGTH RANGE

Options - Light Sources (combinations possible)



Light source	Technical description	What is it good for?
OPTIONAL Laser (L) 658 nm, 50 mW	Broadband laser for highest image quality (other laser or multi laser solutions on request)	A laser is required for low reflective surfaces like glass or more in general low reflecting situations. Examples are insulator surfaces directly at the Brewster angle, surfaces close to the nulling conditions or close to the SPR resonance angle. You find these conditions in LB-experiments with LB films, SAMs, sub mono layers or in i-SPREE experiments.
OPTIONAL Xenon lamp with 44 interference filters (Xe-44IF) 360 – 1000 nm	Xenon Arc lamp Filter wheel 44 interference filters, one green broadband filter, one white light position Filters Band width: 6 – 12 nm	The 44 wavelengths enable classical ellipsometric measurements. These includes the thickness of thin transparent films (< 1 nm and 1 µm) and materials with straight forward optical properties.
OPTIONAL Laser driven Xenon light source (LDXe) with Grating Monochromator	Laser-stabilized Xenon Arc lamp Continuous output, 200 – 2000 nm Grating Monochromator Center wavelength precision: < 1 nm includes three gratings: Grating / Band width 250 – 750 nm: 10 nm 400 – 1050 nm: 6 nm 1050 – 1700 nm: 18 nm Gratings with smaller band width are available on request	The higher spectral resolution makes the detection of optical properties like band gaps, excitons or other absorption centers possible. The light source is also essential for instruments with UV- and NIR capability. The high brilliance of the light source offers in general better signal to noise ratio than a classical Xe-lamp with filter wheel.
OPTIONAL Super continuum laser (SCL) 450 – 1000 nm 450 – 1700 nm	Super continuum laser Monochromatic output, no additional monochromator needed Center wavelength precision = 1 nm band width: 2 nm FWHM @ 450 nm 8 nm FWHM @ 1000 nm	One benefit of a super continuum laser is the highest spectral resolution with band width down to 2 nm resulting in a higher coherent length than the other light sources, that enables additional application like the thickness determination of thicker films. Another benefit is the high brilliance that enables a better signal to noise ratio especially on smallest samples.

Imaging optics	Technical description	What is it good for?
Focus scanner	Allows realtime images at variable angles of incident (< 80°) and is compatible with all objectives. Lateral resolution: < 1 micrometer (see chart objectives)	The focus scanner is part of the standard EP4 detection arm. It is also used for focusing of ultraobjectives. In standard objectives, it collects focused images stripes to form an overall focused image. Focus scans take 2 – 5 sec, depending on the required image quality.
OPTIONAL Ultraobjective (add-on, easy to exchange by customer, upgradable)	New Scheimpflug set up for receiving an overall focused image/live video Lateral resolution: 2 micron Usable angle of incident range: 52° – 57°	• Overall focused real time image • Faster measurement; faster mapping • Multi spot array, improved image quality • Good for moving objects / kinetics (e.g. floating Monolayer on water) This is an optional exchange unit you may use in your focus scanner unit

Accurion EP4

Configuration Possibilities

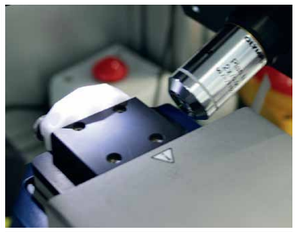
Cameras	Technical description	What is it good for?
Standard camera *New*	High quality, monochrome GigE CCD camera. Wavelength: 360 –1000 nm 1392 × 1040 pixel, 12 bits, max. 25 frames per second (fps)	Usually the CCD is used in 2 × 2 binning mode to improve the signal and is operated at 20 fps.
OPTIONAL NIR camera (only with IR upgrade)	InGaAs FPA, cooled, GigE interface. Wavelength range: 900 – 1700 nm, 320 × 256 pixels, 25 fps fixed	For spectroscopic measurements in the NIR. This camera is added to the standard or the UV camera. Allows measurements e.g. for telecommunication materials, water absorption and many more.
OPTIONAL UV camera (only with UV upgrade)	Back-illuminated CMOS; CameraLink interface. Wavelength: 200 – 1000 nm, 1280 × 1040 pixels, 25 fps	For spectroscopic measurements in the UV. Camera will be operated in 2 × 2 binning mode by default. This camera replaces the standard camera in all configurations that operate < 360 nm. The camera link interface board is included.
OPTIONAL Adaption package for second camera	Switchable mirror or dichroic filter for camera selection (via software). Optical camera adaptation. Mechanical mounts.	For broad range spectroscopy a secondary camera is being used. Optics for both cameras provide a similar, positionadjusted FOV. By this, seamless switching of the camera during spectral measurements is enabled.
OPTIONAL Alternative cameras		The modular software concepts allow integration of various other cameras. Especially all GenICam cameras are supported. Some cameras may require additional PC boards (camera link).

Objective for use with focus scanner	Specification of the EP4, equipped with the following objectives:	What is it good for?
OPTIONAL 2 × objective	Lateral ellipsometric resolution: 10 µm FOV: 2 mm × 2 mm, depends on AOI	Long distance objectives with high numerical apertures. FOV (field of view) is based on standard camera. The FOV is quadratic for this camera at 42° AOI. At different AOI, the FOV becomes rectangular depending on the angle. Resolution is defined at 400 nm. Not applicable for UV !
OPTIONAL 5 × objective	Lateral ellipsometric resolution: 4 µm FOV: 800 µm × 800 µm, depends on AOI	
OPTIONAL 10 × objective	Lateral ellipsometric resolution: 2 µm FOV: 400 µm × 400 µm, depends on AOI	
OPTIONAL 20 × objective	Lateral ellipsometric resolution: 1 µm FOV: 200 µm × 200 µm, depends on AOI	
OPTIONAL 50 × objective	Lateral ellipsometric resolution: 1 µm*) FOV: 70 µm × 70 µm, depends on AOI Only suitable for small samples (approx. 20 × 20mm)	
OPTIONAL Nanochromat	Lateral ellipsometric resolution: 2.5 µm FOV: 600 µm × 600 µm, depends on AOI	UV/IR objective Necessary for all measurements that include wavelength between 250 and 360 nm

*lateral resolution of the microscopic image down to 0.6 µm

Adaptable technologies

Integration of a Micro Raman System

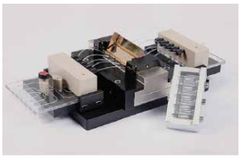


Q-Sense QCM-D E1 module integrated in the imaging ellipsometer

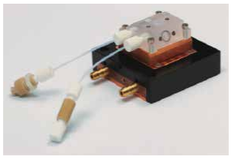
Further adaption of technologies like white light interferometry, reflection spectroscopy and others are possible.

PLEASE FEEL FREE TO CONTACT THE ACCURION TEAM TO DISCUSS THE ADAPTION OF A TECHNOLOGY.

Selected accessories



In situ SPR cell allowing kinetic SPR measurements



Solid-liquid cells for ellipsometry at the solid liquid interface

Light guide enables measurements at liquid/liquid interfaces and solid/liquid interfaces at variable angles between 40° and 72°

Unique accessories	Technical description	What is it good for?
OPTIONAL Knife edge illumination (only combined with spectroscopic option)	Mechanic plate with a sharp edge movable into the light beam to provide an illuminated area in correspondence of the thickness of the transparent substrate.	Unique feature: Allows measurements of thin transparent substrates to avoid backround refl ection. Only for spectroscopic measurements. AOI measurements possible without mechanical adjustment.

Technical specification

Ellipsometer Type	Brewster Angle Microscope (BAM) Imaging Ellipsometer (IE) in PCSA configuration Spectroscopic Imaging Ellipsometer (SIE) in PCSA confi guration
Open Frame-Setup	Rugged aluminum frame construction with integrated multi-axis alignment. Separate electronic control unit.
Imaging Optics	Automatic focus scanner for high-resolution ellipsometric contrast images and maps, 10 × objective (image width – 400 µm, lateral resolution – 2 µm (other objectives with larger field-of-view or higher lateral resolution are available) Ultraobjective for overall focused images (optional): 2 µm lateral resolution, angle of incident range: 52° – 57°.
Motorized Goniometer	Patented software controlled motorized goniometer Angle-of-incidence range: 38 – 90° Angle resolution: 0.001° Absolute angle accuracy: 0.01° Speed of motion: ~ -2.5° / sec.
Z-lift	10 cm travel range, 1 µm repeatability, 0.5 µm resolution
Electronics	Up-to-date monitor and Windows® PC Embedded Linux operating system (internal only) Communication with host PC via dedicated 100 Mbit Ethernet
Power Supply	Voltage: 100 – 240 V ~, 50 / 60 Hz, max. current: 10 A