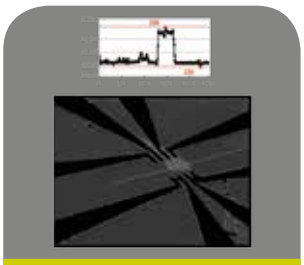
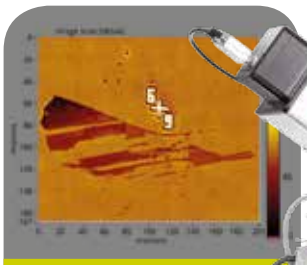
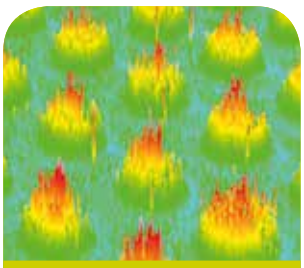
ACCURION
solutions for science

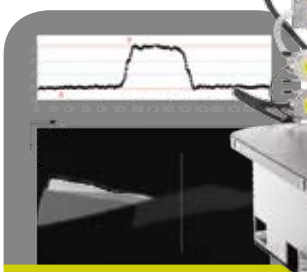
NANOFILM_EP4

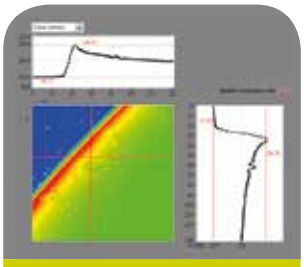
YOUR THIN FILMS VISUALIZED.


Graphene

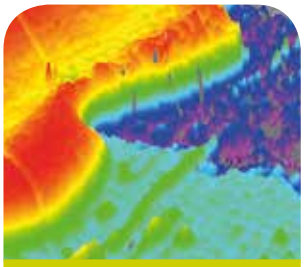

Graphene


Protein spots on glass


Graphene

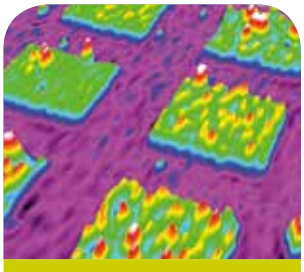

PCBM on SiO_2


SAM


Solar cell on PET


Transparent substrate


Liquid/liquid interface


SAM pattern


PMMA film on Si-Wafer


Monolayer

THE NEXT GENERATION IN IMAGING ELLIPSOMETRY: nanofilm_ep4

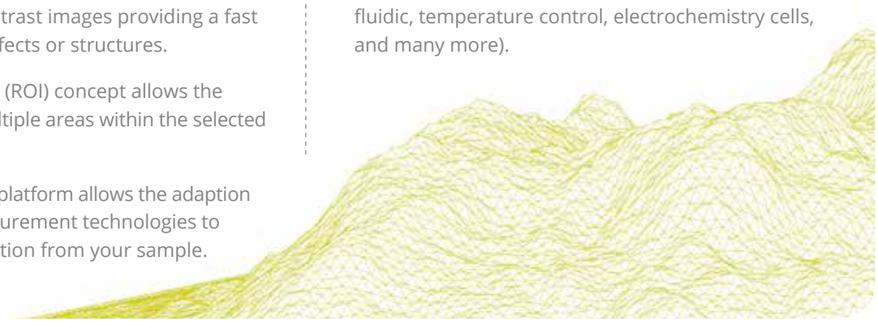
Supported by:
Federal Ministry of Economics and Technology
on the basis of a decision by the German Bundestag

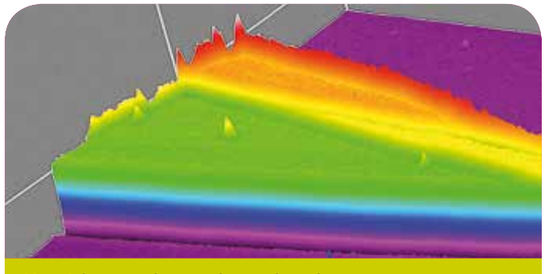
This new Microscopic thin film, surface and materials metrology tool generation uses a combination of auto nulling ellipsometry and microscopy to enable surface characterization with a lateral resolution as small as 1 micron.

The nanofilm_ep4 uses 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 nanofilm_ep4 is a modular instrument enabling configuration for your specific measurement tasks.

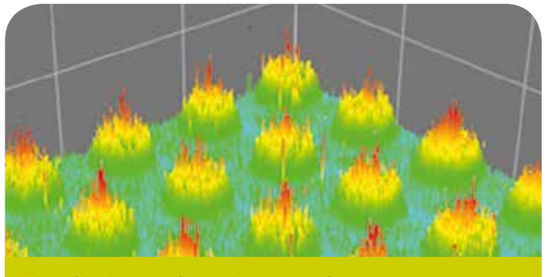
UNIQUE FEATURES:

- Ellipsometry with the highest lateral resolution available on the market: Objects as small as 1 micron can be resolved. This feature allows the investigation of structured samples or tiny substrates.
- Imaging ellipsometry in the wavelength range from 250 nm to 1700 nm provides pictures of your samples over a wide wavelength range. Continuous spectroscopic measurements allows the acquisition of an image at the selected wavelength.
- 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.
- The technology integration platform allows the adaption of various alternative measurement technologies to receive even more information from your sample.
- Optional single shot full field fully focused images 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 guide for liquid/liquid interfaces, micro-fluidic, temperature control, electrochemistry cells, and many more).



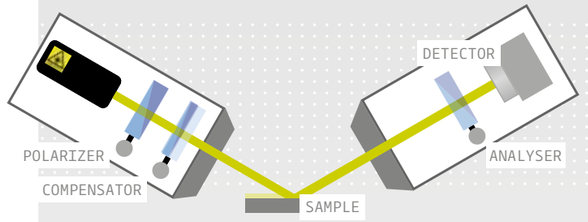


Materials research example: graphene layer



Bio application example: protein spots on glass

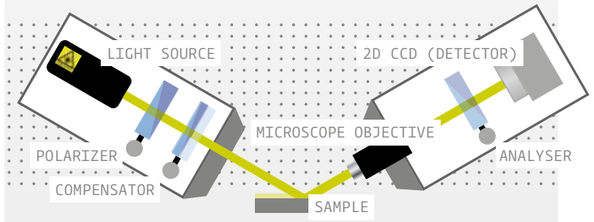
WHY USE ELLIPSOMETRY?



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 dependent on film properties like thickness, refractive index and absorption. Ellipsometry measures the change of the amplitudes and phases with the changing state of 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.

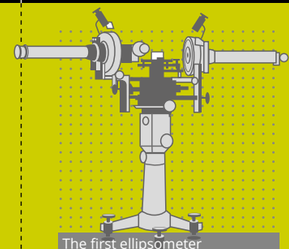
This enables resolving sample areas 1,000 times smaller than most micro spot equipped non-imaging spectroscopic ellipsometers. Imaging ellipsometry permits characterization of local sample parameter variation on a microscopic scale. This technology can measure the same ex-situ applications as non-imaging 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. With the new integrated knife edge illumination you are also able to measure the surface of transparent substrates without disturbing backside reflections.

COMPARISON NON-IMAGING AND IMAGING ELLIPSOMETERS:

The lateral resolution of non-imaging ellipsometers is determined by the spot size of the light source at the sample surface. Non-imaging ellipsometers collect reflected light from this single spot and deliver it to the detection system. These spot sizes are in the range of 2 mm to 35 microns. All sample structures smaller than this resolution 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 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:



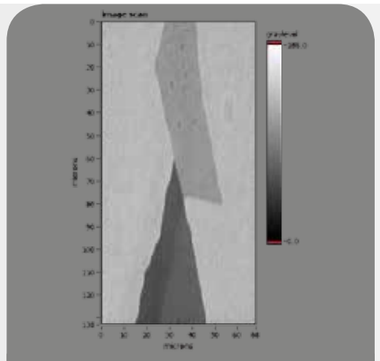
The first ellipsometer by Paul Drude, 1889

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.

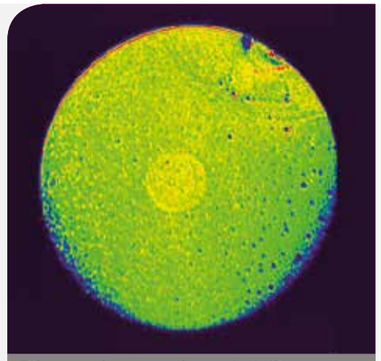
By contrast an imaging ellipsometer can take as many as one million readings in one short exposure with vastly better lateral resolution. The images obtained are maps that are acquired and presented much faster and with much higher resolution than any mapping ellipsometer.

ELLIPSOMETRY WITH THE HIGHEST LATERAL RESOLUTION

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

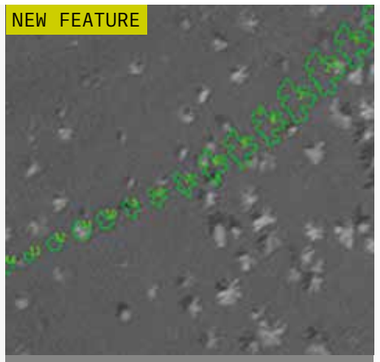


Ellipsometric contrast image graphene



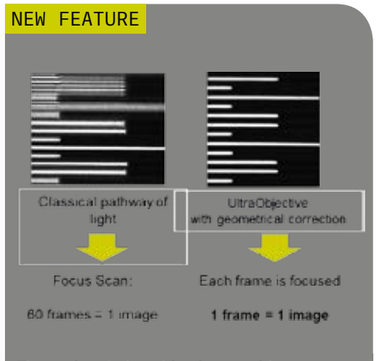
Ellipsometric contrast image As_2S_3 fiber at 550 nm, AOI 40, 20 × objektive

NEW FEATURE



In detail: region of interest with variable shape

NEW FEATURE

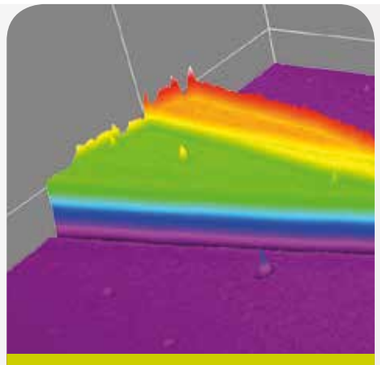


The optional ultraobjective provides overall focused images in real time

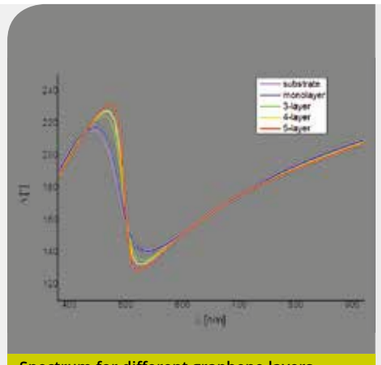
NEW FEATURE

IMAGING ELLIPSOMETRY IN THE WAVELENGTH RANGE OF 250 TO 1700 NM

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

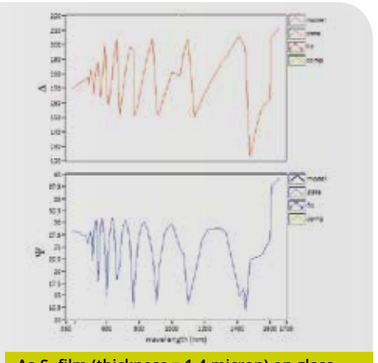


3D Delta map graphene on SiO_2 Si_100



Spectrum for different graphene layers, according to left image

Graphene on SiO_2 Psi map at 1480 nm with Nanochromat



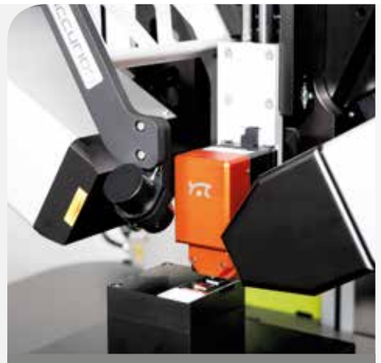
As_2S_3 film (thickness = 1.4 micron) on glass NIR spectra with Nanochromat, AOI 50

NEW FEATURE

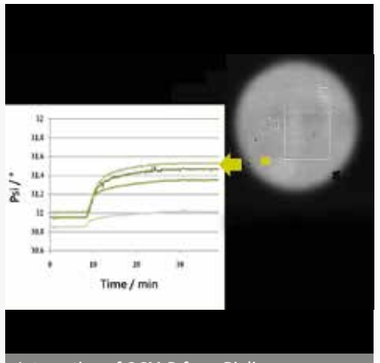
TECHNOLOGY INTEGRATION PLATFORM

Adaption of further technologies provide even more information from your sample.

The new adaption platform



Integration of the Nanosurf NaniteAFM



Integration of QCM-D from Biolin
Adsorption of nanoparticles (20 nm) at SiO_2

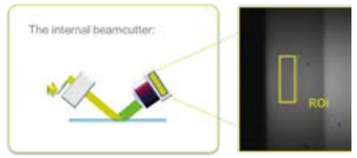
PLEASE CONTACT US FOR YOUR INTEGRATION IDEAS!

NEW FEATURE

VARIOUS UNIQUE FEATURES

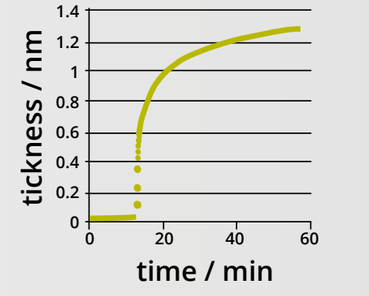
A variety of further new features and accessories enabling ellipsometry for new applications.

New mechanical set-up: the instrument is now adjustable to any samples (incl. water)



Knife edge illumination allows the investigation of thin transparent substrates

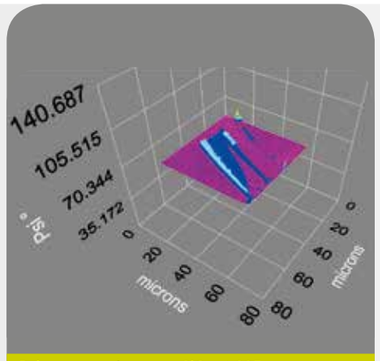
Light guide enables measurements at liquid / liquid interfaces (Cetylpyridiniumromid at the tulouene/water interface)



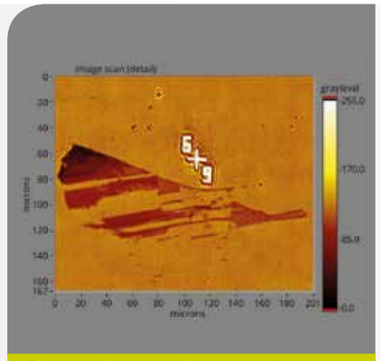
SPR measurements: buffer|BSA|gold

GRAPHENE

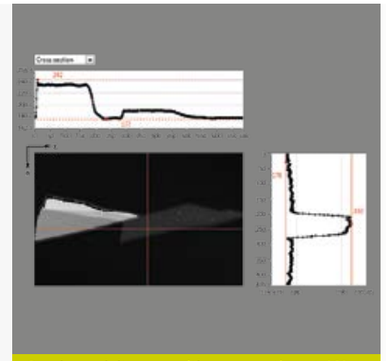
Imaging ellipsometry allows the direct visualization of your graphene flakes on various substrates/materials. It is possible to measure thickness and optical properties of different graphene layers in the micrometer scale.



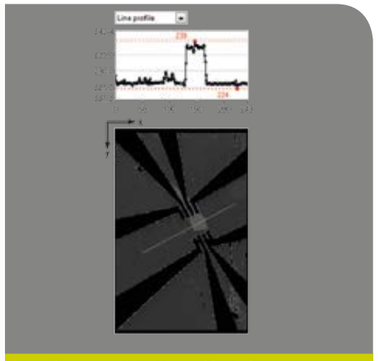
Psi map graphene on SiO_2 at 295 nm, 50 × objektiv



Ellipsometric contrast image graphene SiO_2 Si at 520 nm, AOI 42, 20 × objective



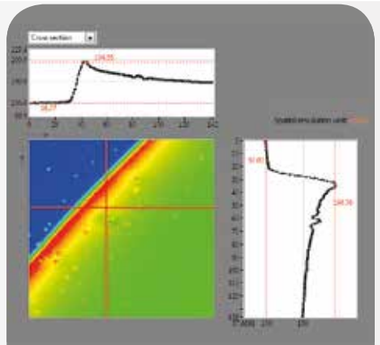
Graphene delta map with cross section at 460 nm, AOI 60, 10 × objective



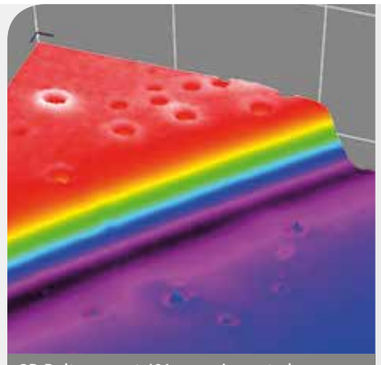
Graphene on SiO_2 Si: profile Delta map at 440 nm, AOI 60, 10 × objective

SOLAR CELLS

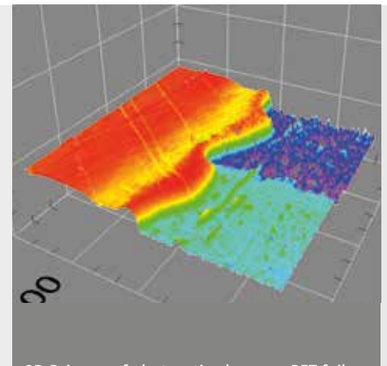
We visualize expected and unexpected structures or non-uniformities of your material on a microscopic scale. It is possible to measure thickness, optical properties and determine band gap energies as function of location on the sample. Using the knife edge illumination allows the investigation of organic solar cells on transparent foils like PET foils.



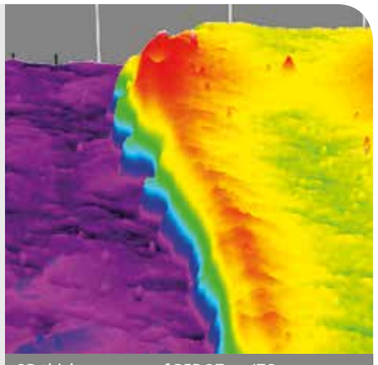
Cross section thickness map spin-coated PCBM on silicon



3D Delta map at 401 nm spin-coated PCBM on silicon



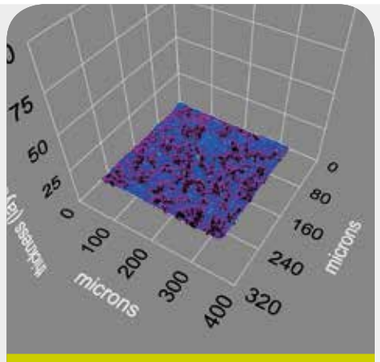
3D Psi map of photoactive layer on PET foil (with knife edge illumination)



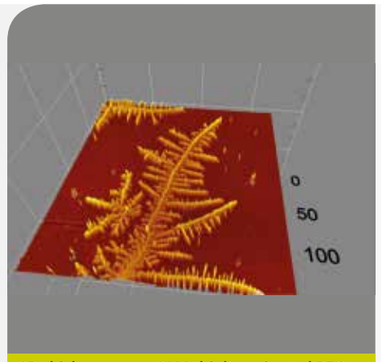
3D thickness map of PEDOT on ITO coated PET foil

SELF-ASSEMBLED MONOLAYER (SAM)

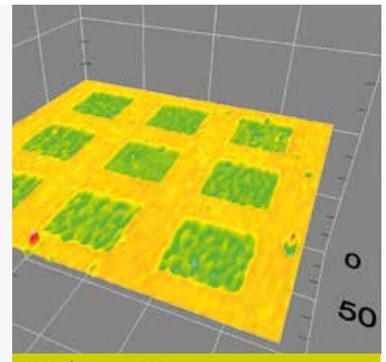
Imaging ellipsometry allows the real time visualization of lateral patterned SAMs of molecules with different chain lengths, head groups or different packing densities. You can measure the thickness of different areas of your SAMs in parallel. Thickness differences of only 0.2 nm on different positions on your pattern can easily be detected.



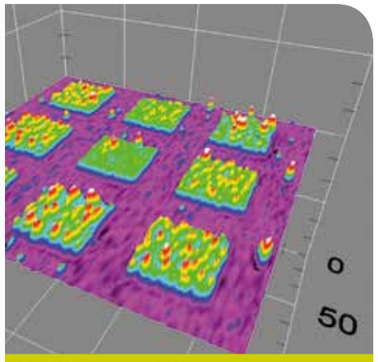
3D Thickness map of OTS on SiO_2 Si



3D thickness map SAM thiolterminated PEG on gold at 450 nm, AOI 60



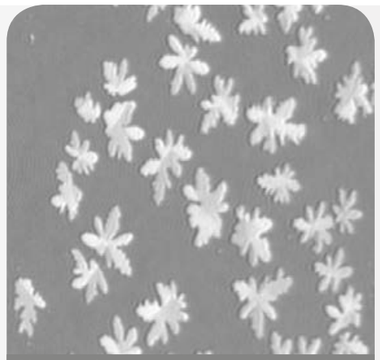
3D Delta map SAM pattern (Hexadecanethiol, PEG-SH) at 401 nm, AOI 65



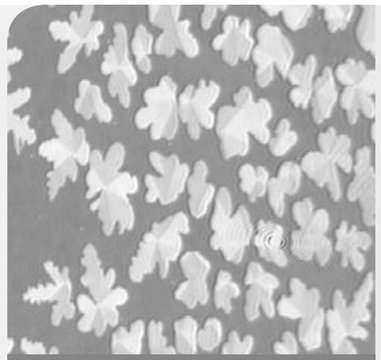
3D thickness map SAM pattern (Hexadecanethiol, PEG-SH) at 401 nm, AOI 65

MONOLAYER

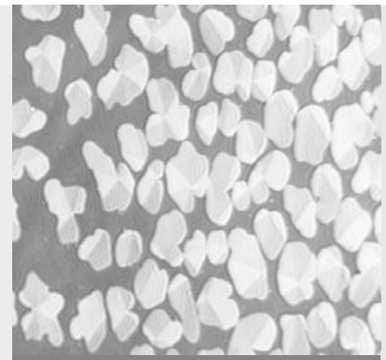
Using the unique ultraobjective allows the investigation of floating monolayers or any kind of moving or growing film with an overall focused real time image. You can see anisotropy of domain texture and structure as well as you can determine the thickness of the monolayers in the nanometer scale. The following images are showing monopalmitoyl-rac-glycerol at the air-water interface, compression speed = 180 Å2/min · molecule.



Monopalmitoyl-rac-glycerol at the air-water interface, compression speed = 180 Å²/min · molecule



SP = 4.2; A = 37.23 (SP = surface Pressure – mN / m A = mean molecular area – Å²/molecule)



SP = 4.4; A = 36.8 (SP = surface Pressure – mN / m A = mean molecular area – Å²/molecule)

SP = 4.4; A = 36.9 (SP = surface Pressure – mN / m A = mean molecular area – Å²/molecule)

PROTEIN INTERACTION

Imaging ellipsometry can perform kinetic measurements of protein binding. All proteins within the field of view can be measured in parallel.

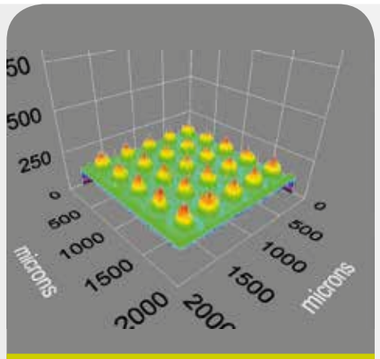
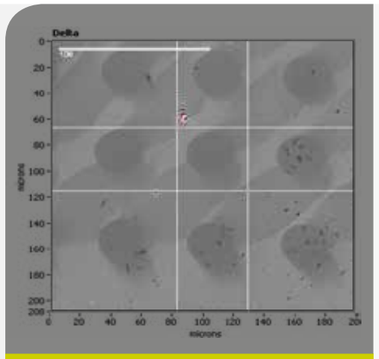
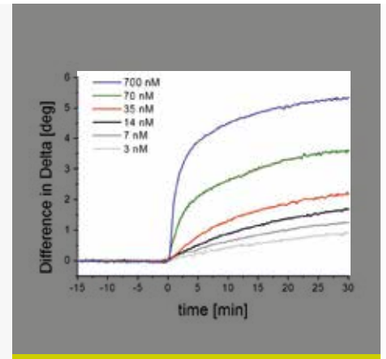


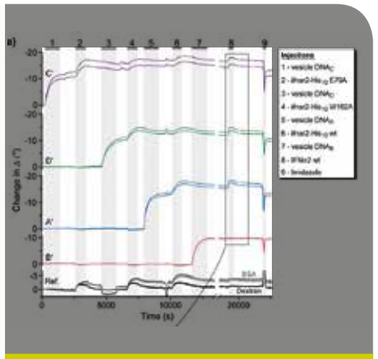
Image scan of protein spots on glass



Delta map protein spots



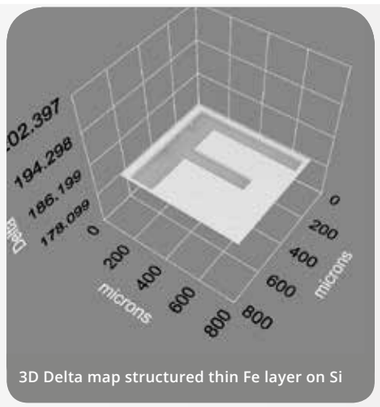
Antigen/antibody interaction: Binding of polyclonal anti-Rabbit IgG to immobilized Rabbit IgG



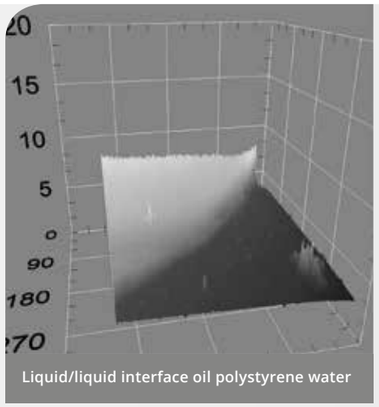
DNA – bar-coding of vesicles for bio chip application

VARIOUS FURTHER APPLICATIONS

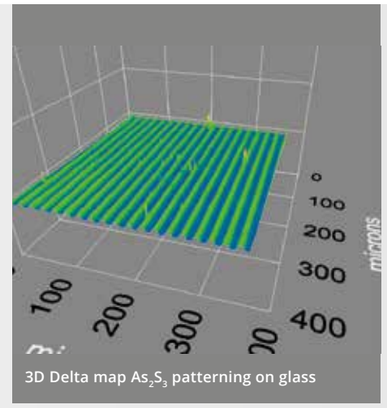
A wide selection of samples with structures can be visualized and measured with the unique technique of imaging ellipsometry. If you do not find your application in this overview, feel free to contact the Accurion team for specific information.



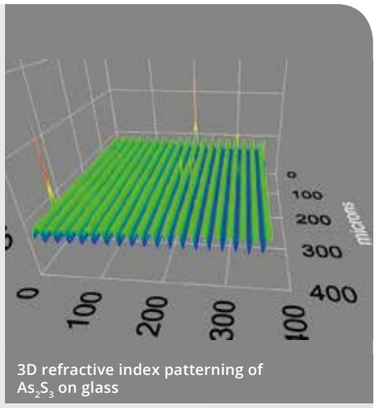
3D Delta map structured thin Fe layer on Si



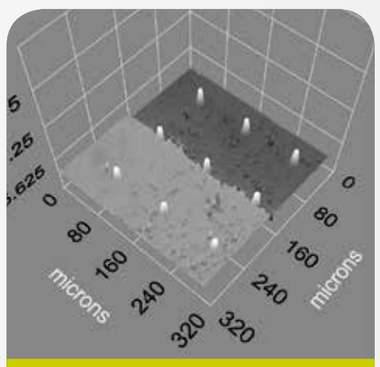
Liquid/liquid interface oil polystyrene water



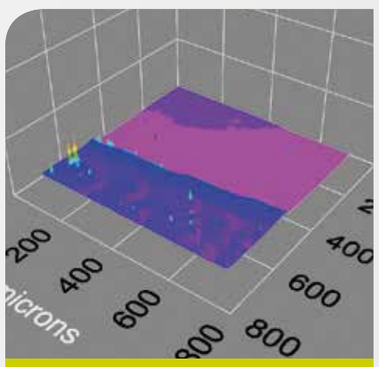
3D Delta map As_2S_3 patterning on glass



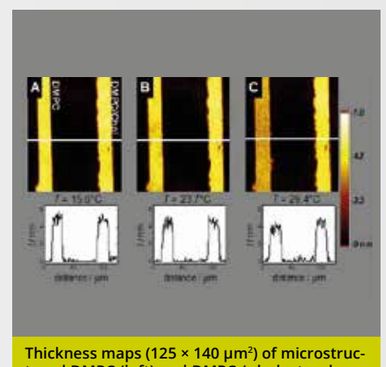
3D refractive index patterning of As_2S_3 on glass



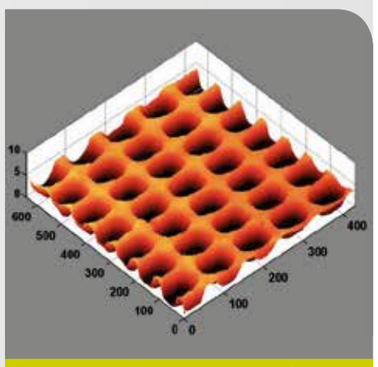
3D ellipsometric contrast image taC on silicon



3D thickness map taC on silicon



Thickness maps (125 × 140 µm²) of microstructured DMPC (left) and DMPC / cholesterol (40 mol % cholesterol, right) bilayers



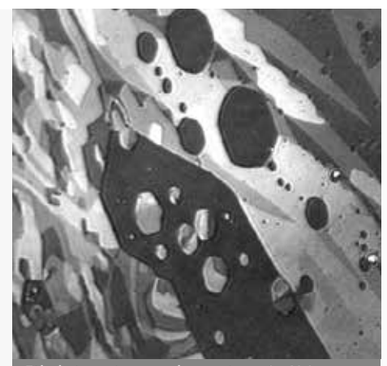
Photopattern of supported phospholipid membrane

BREWSTER ANGLE MICROSCOPY

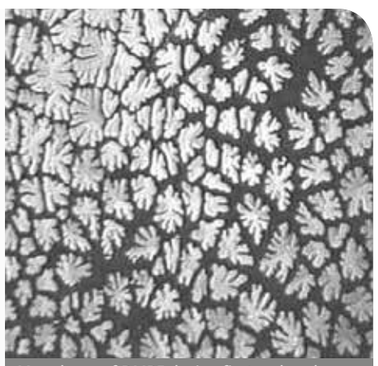
Brewster angle microscopy is a subset of the imaging ellipsometer. The instrument can be used to visualize monolayer at the air/water interface with typical LB accessories like troughs etc.

The nanofilm_ep4 with ultraobjective and KSV / NIMA trough

Monopalmitoyl-rac-glycerol at the air-water interface, surface pressure 4.22 mN/m



Ethyl stearate monolayer at π < 1mN / m. Field-of-view ca. 600 µm.



Monolayer of DMPE during first-order phase transition

IMPROVED SOFTWARE CAPABILITIES

The nanofilm_ep4 software is modular. Separate software modules simplifies the instrument 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 modeling tool.

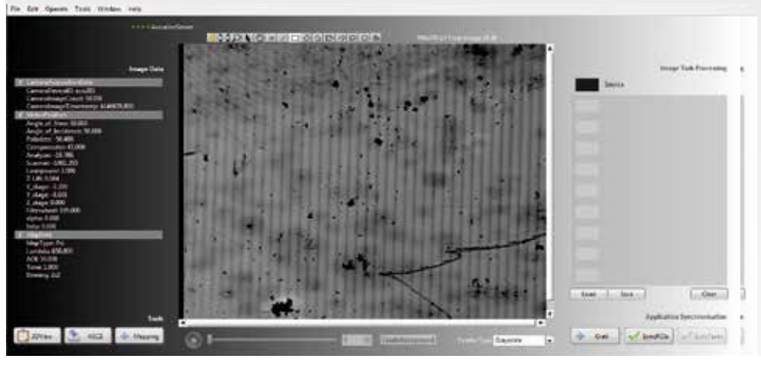
The new “AccurionServer” software manages the documentation of your ep4 measurements including data from accessories and supported complementary measurement technologies. It is a sophisticated data and analysis module to enable a deeper understanding of complex systems.

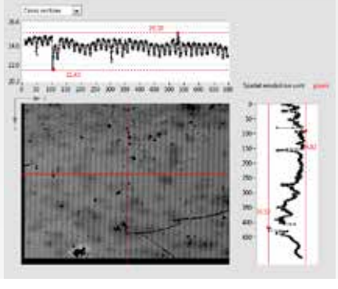
AccurionServer

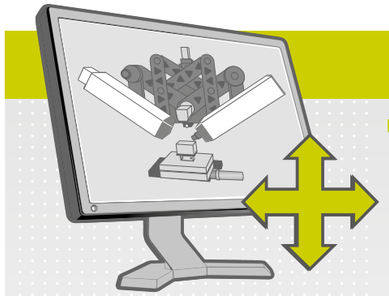
- Organizes all supported data sources including accessories and optional complimentary measurement technologies and interfaces between instruments and software packages.
- Organizes the data storages structure (easy to use user structure).

AccurionDataStudio

- Processing all data (images, measurement results, kinetics, structure description, etc.).
- Independent from the instrument and allows analyzing your data on your office PC.
- **Special features (examples):**
  - Batch fitting: calculating delta/psi maps into thickness maps 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.

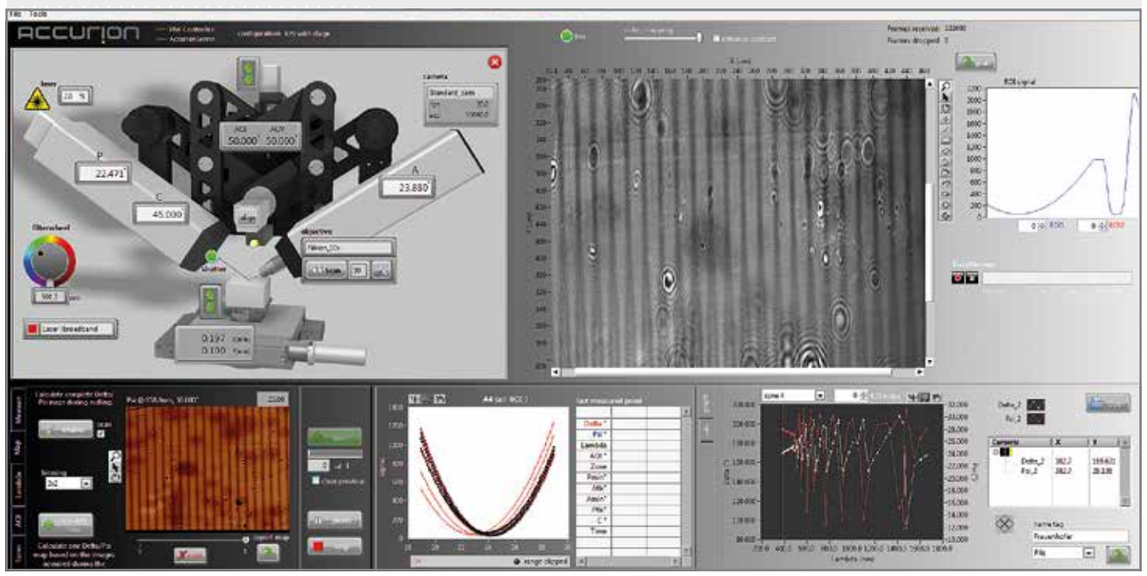






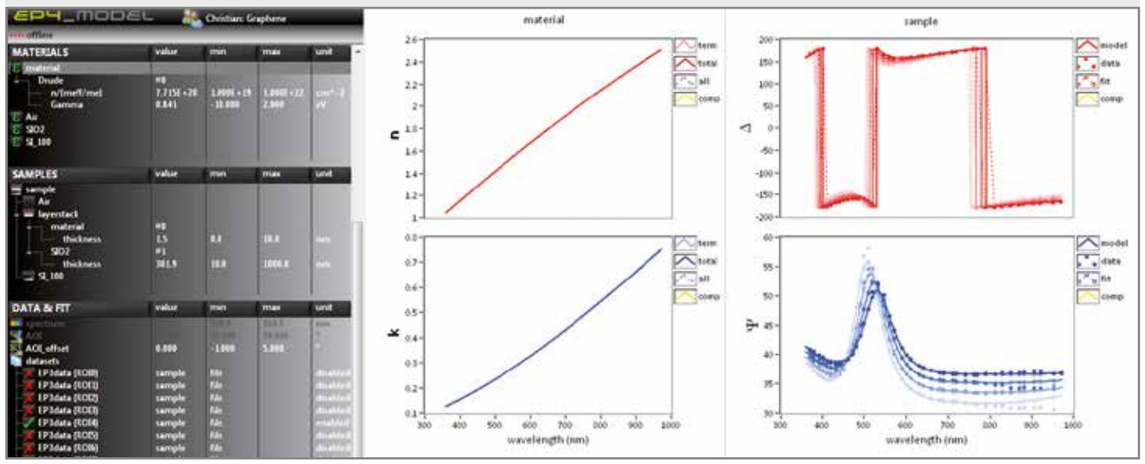
EP4Control

- 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, ...)



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.



CONFIGURATION POSSIBILITIES

The new imaging ellipsometer nanofilm_ep4 is a modular instrument where you can select a configuration optimized for your measurement needs

INSTRUMENT BASE	TECHNICAL DESCRIPTION	WHAT IS IT GOOD FOR?
Alignment Sensor *New*	Detects tilt and z-position of sample. **Detection:** 0.001° in both tilting axes **Z-axis resolution:** up to 1 micron Automatic Z-detection and detection of alignment in 2 tilt directions	Automatic measurement of the height of the sample surface allows automatic Z-tracking and positioning, which keeps the images in focus (BAM,...) The new align sensor provides free space for add-ons (e.g. AFM, Raman, ...).
Instrument Alignment *New*	Angular adjustment of entire optical head instead of sample alignment **Precision:** 0.001° in 2 tilt axes	Adjustable to any samples (incl. water). Independent from the position of the sample. **Compared to ep3:** z and focus adjustment after movement of the sample not necessary.
Mini breadboard *New*	Small breadboard between the optical arms with several M4 / M6 threads.	Provides freedom to the customer to integrate own ideas or external instruments with ep4 (additional illumination, microscope, AFM, Raman, temperature sensor, ...)
Gantry with integrated Z-lift *New*	Vertical travel range > 100 mm 1 µm repeatability.	To drive the optical head up&down to accommodate sample's surface position. Long travel distance enables a large variety of accessories like sample stages, troughs, cells, etc.

LIGHT SOURCE	TECHNICAL DESCRIPTION	WHAT IS IT GOOD FOR?
OPTIONAL **Lasers**	A selection of different lasers are available as a first and only light source in your single wavelength instrument. It can also been selected as a second light source on request for your spectroscopic instrument.	Lasers might be useful for applications where a lot of light will be absorbed, by the sample (e.g. water). E.g.: 658 nm laser for SPR experiments 480 nm laser for LB experiments on water
OPTIONAL **LDLS** (laser driven light source) *New*	Laser-stabilized Xenon Arc lamp Continuous output between 200 and 2000 nm	Stable light source, low noise (typ. 0.1 %). Higher SNR, improved precision. Life time 10,000 hours, practically no bulb changes and adjustments anymore.
OPTIONAL **Spectroscopic measurement package** (LDLS is the standard light source) *New*	**Grating monochromator for various wavelength ranges:** 250 – 750 nm (UV-VIS) 250 – 1000 nm (UV-VIS) 360 – 1000 nm (VIS) 360 – 1700 nm (VIS-NIR) 250 – 1700 nm (UV-VIS-NIR) **Center wavelength precision:** < 1 nm **Bandwidth:** 250 – 500 = 5 nm 500 – 1,100 = 6 nm 1100 – 1700 = 12 nm	Allows continuous spectroscopic measurements. The grating selection depends on the camera as part of the selected wavelength extension module.
OPTIONAL **Knife edge illumination** (only combined with spectroscopic option) *New*	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 background reflection. Only for spectroscopic measurements. AOI measurements possible without mechanically adjustment.

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*	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

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. 40 frames per second (fps)	Usually the CCD is used in 2 × 2 binning mode to improve the signal and operated at 20 fps.
OPTIONAL **NIR camera** (only with NIR upgrade)	InGaAs FPA, cooled, GigE interface. **Wavelength range:** 900 – 1700 nm, 320 × 256 pixels, 50 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) *New*	Back-illuminated CMOS; CameraLink interface. **Wavelength:** 200 – 1000 nm, 1280 × 1040 pixels, 30 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** *New*	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, position adjusted 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).

OBJECTIVES FOR USE WITH FOCUS SCANNER	TECHNICAL DESCRIPTION	WHAT IS IT GOOD FOR?
OPTIONAL **2 × objective**	**Lateral 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 532 nm. Not applicable for UV !
OPTIONAL **5 × objective**	**Lateral resolution:** 4 µm **FOV:** 800 µm × 800 µm, depends on AOI	
OPTIONAL **10 × objective**	**Lateral resolution:** 2 µm **FOV:** 400 µm × 400 µm, depends on AOI	
OPTIONAL **20 × objective**	**Lateral resolution:** 1 µm **FOV:** 200 µm × 200 µm, depends on AOI	
OPTIONAL **50 × objective**	**Lateral resolution:** 0.6 µm **FOV:** 70 µm × 70 µm, depends on AOI Only suitable for small samples (approx. 20 × 20mm)	
OPTIONAL **Nanochromat** *New*	**Lateral resolution:** 2.5 µm **FOV:** 600 µm × 600 µm, depends on AOI	**UV/IR objective** Necessary for UV to NIR measurements.

ADAPTABLE TECHNOLOGIES

ep4 with adapted Nanosurf NaniteAFM

QCM-D Quartz Crystal Microbalance from Q-Sense-Biolin integrated in the imaging ellipsometer

Further adaption of technologies like Raman spectroscopy, 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

Titanium solid-liquid cell

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

TECHNICAL SPECIFICATION

Ellipsometer Type	Auto-nulling imaging ellipsometer in PCSA configuration
Open Frame-Setup	Rugged aluminum frame construction with integrated multi-axis alignment of the entire optical unit. 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°.
Light Sources	Laser Driven XE Lamp, laser on request. Continuously tunable grating monochromators in various selectable wavelength ranges.
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:** ~ 5° / sec.
Z-lift	12 cm travel range, 1 µm repeatability, 0.5 µm resolution
Camera Detector	monochrome GigE CCD camera with variable exposure time and gain control 1392 × 1040 pixel, 12 bits, max 40 frames per second
Sample Alignment Sensor	Accuracy 0.001 deg. in tilt axis, resolution z-detection 1 micron
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

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