Spectroscopic imaging ellipsometry

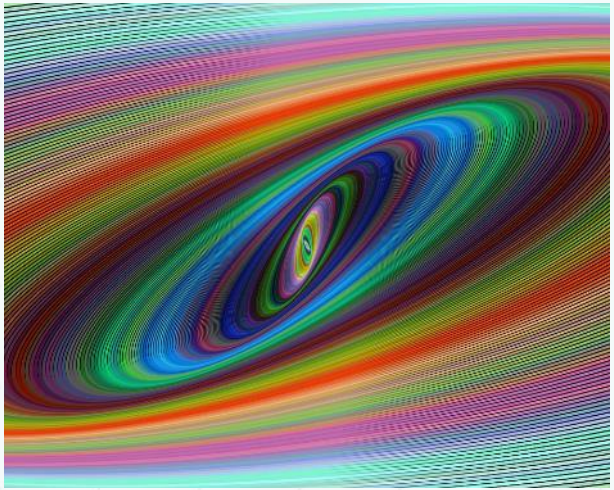
Wout Knoben
January 25, 2018

Surfix

- What is Surfix?
  - WUR spin-off (Organic Chemistry)
  - founded in 2011
  - currently 12 employees
  - located at Wageningen Campus (Plus Ultra)
- What does Surfix do?
  - custom nanocoating development
  - service provider
  - (mainly) life science applications
  - biosensors, microfluidics

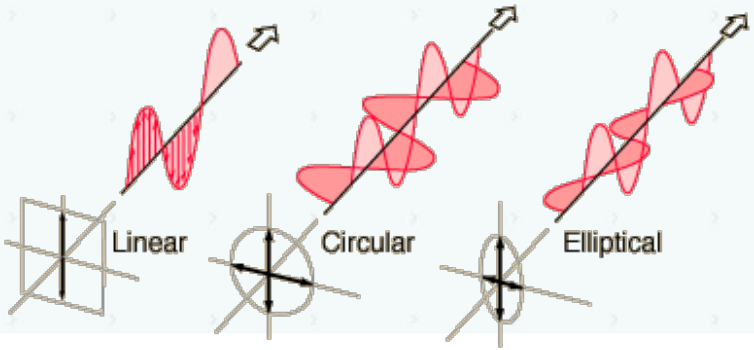
Outline

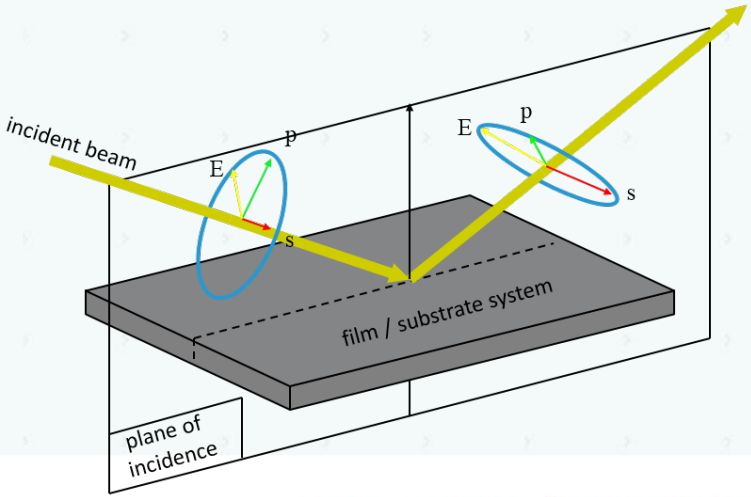
- Introduction to ellipsometry
  - basics
  - spectroscopic imaging ellipsometry
  - measurement and modeling
- Accurion EP4 system
- Application examples
  - solid interfaces
  - liquid interfaces
- Questions & remarks



Introduction to ellipsometry

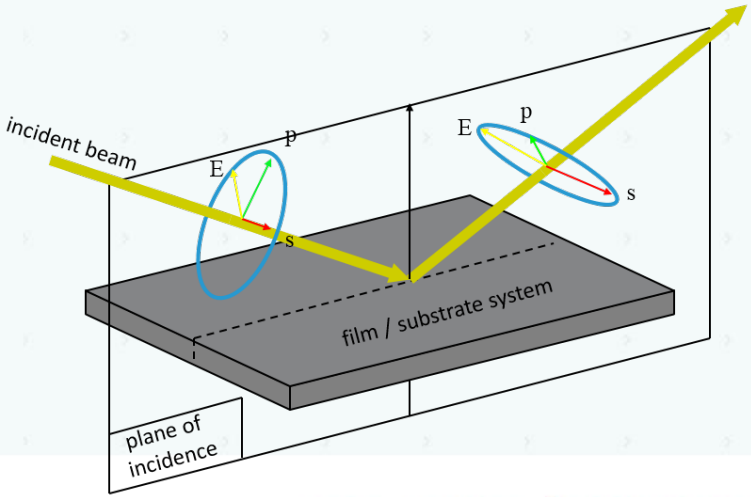
- optical characterization technique for thin films
- based on reflection of polarized light
  - special cases: linear, circular polarization
  - plane of incidence
  - p- and s-polarization





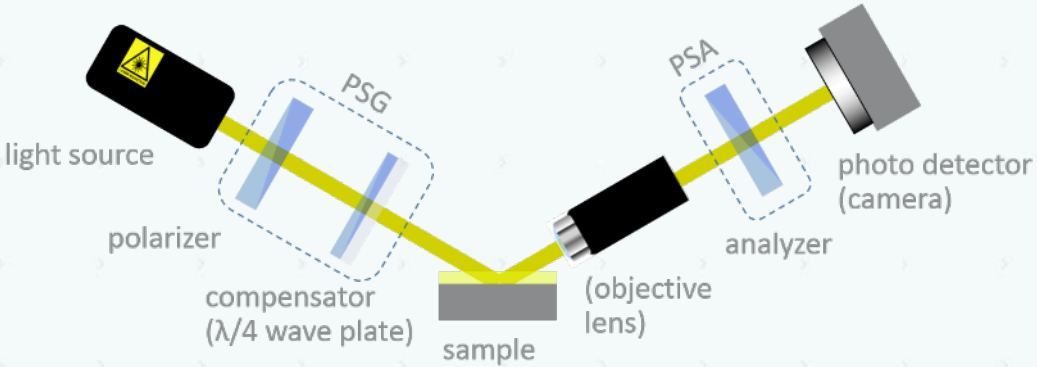
Introduction to ellipsometry

- reflection can change phase and/or amplitude of light
- reflectivity is different for p- and s-polarized light
- ellipsometry measures these **relative** differences
- measured parameters:
  - change in amplitude ratio (ψ)
  - difference in phase shift (Δ)
- Ψ and Δ depend on
  - angle of incidence, wavelength
  - sample properties:
    - optical properties (n, k)
    - layer thickness
    - roughness, porosity
    - …



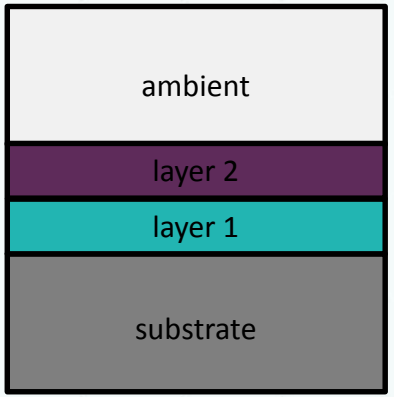
Imaging ellipsometry

- What do you need to measure Ψ and Δ?
  - light source (multiple λ: spectroscopic)
  - photodetector (objective + camera: imaging – no scanning!)
  - polarization state generating/analyzing elements



Measurement and modeling

- What do you do with Ψ and Δ?
  - measurement result: plot of Ψ, Δ vs. wavelength and/or angle of incidence
  - calculation of useful physical parameters (e.g. thickness) requires modeling
  - input: layer structure and optical properties of sample
    - database
    - literature
    - reference samples, other measurement techniques
  - example:
    - substrate: silicon
    - layer 1: silicon dioxide (2 nm)
    - layer 2: polymer film (known n, unknown thickness)
    - ambient: air
  - fit model to measured data to find polymer thickness

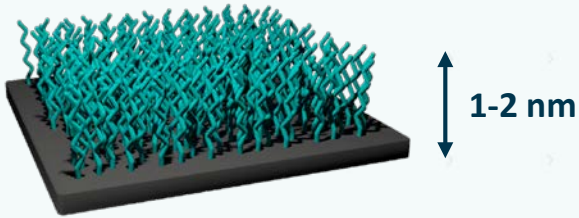


Accurion EP4 system

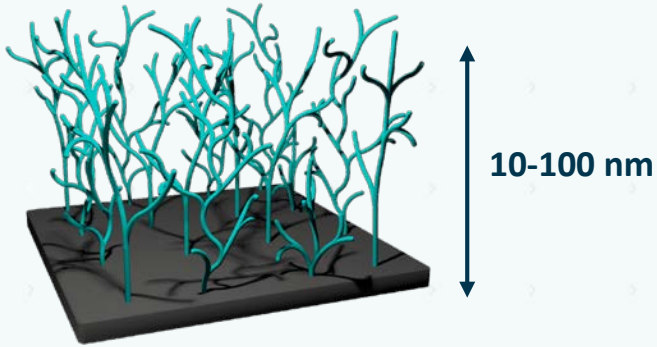
- light source
  - Xe lamp with filters (no laser)
  - 46 wavelengths (300-1000 nm)
- imaging
  - field of view
    - max: 2x2 mm^2 (resolution 10 μm)
    - min: 70x70 μm^2 (resolution <1 μm)
  - contrast imaging (real-time)
  - region-of-interest
  - pixel-by-pixel mapping
- liquid interfaces
  - Langmuir trough

Application example

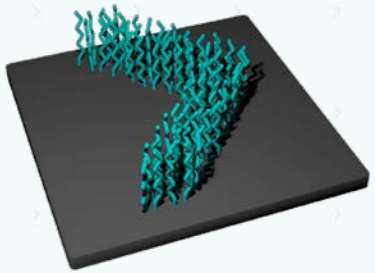
- patterned nanocoatings on glass
  - molecular monolayer (2D) or polymer film (3D)
  - photochemical process enables patterning
  - hydrophobic nanocoating: wettability patterns for liquid control



2D nanocoating



3D nanocoating



patterning

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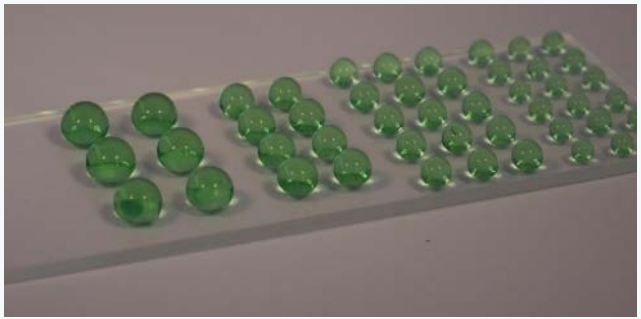

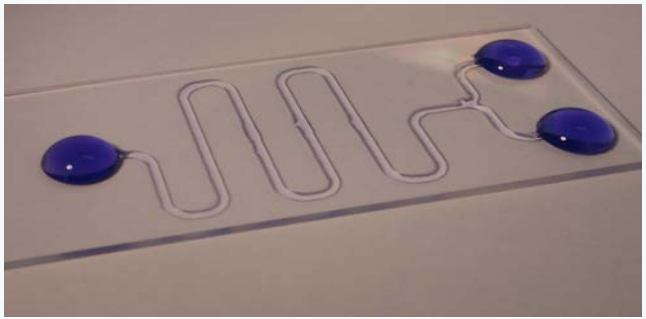

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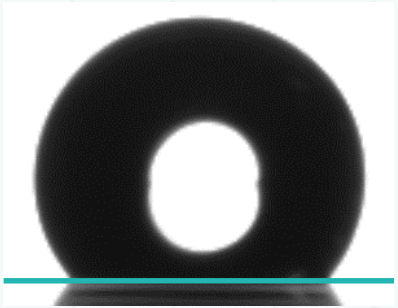
  - hydrophobic nanocoating: wettability patterns for liquid control
- characterization methods
  - **water contact angle**: functionality
  - XPS, IR: chemical elements/groups
  - microscopy: patterns, functionality
    - optical, condensation
    - fluorescence
  - ellipsometry: patterns, thickness, structure
  - SEM, AFM: patterns, structure, thickness



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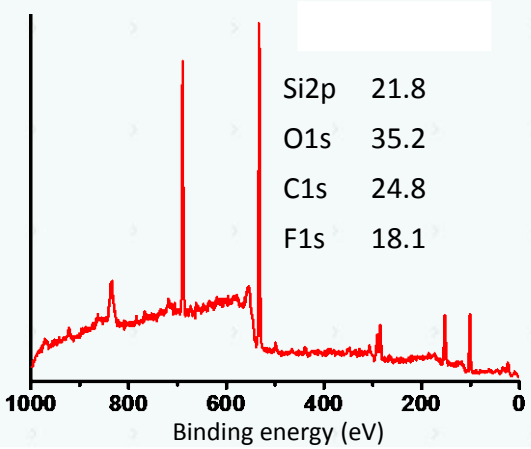

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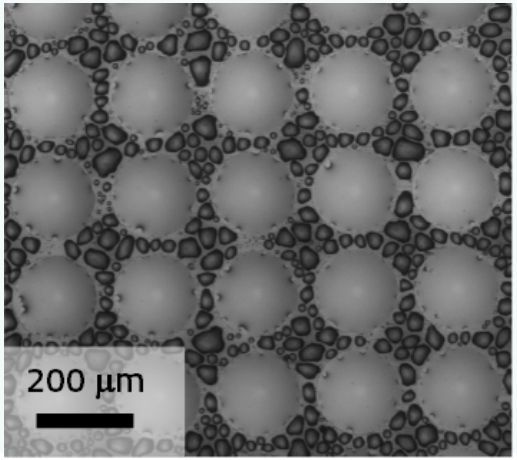

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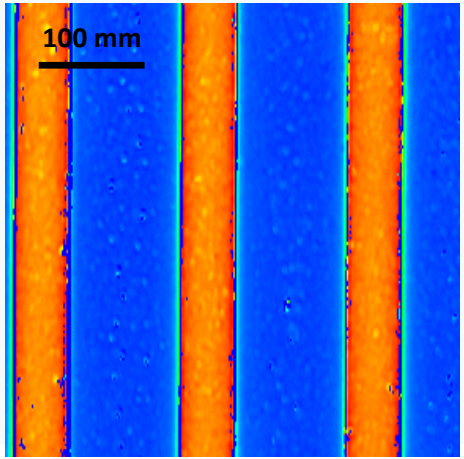
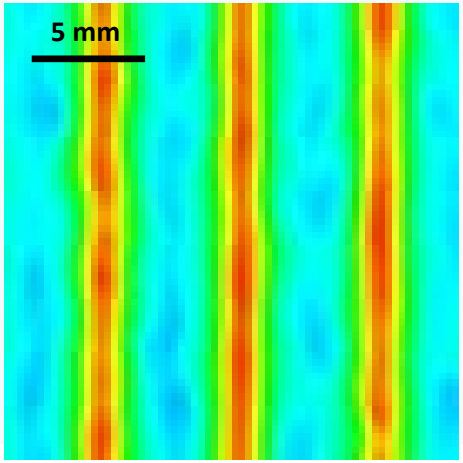
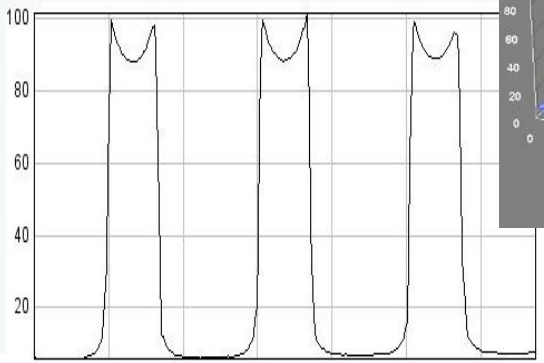
  - thickness
  - structure

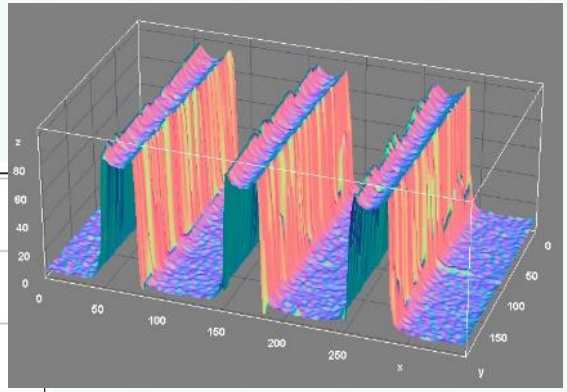




Application example

- patterned nanocoatings on glass
  - molecular monolayer (2D) or branched/crosslinked polymer film (3D)
  - photochemical process enables patterning
  - wettability patterns for liquid control
- ellipsometry
  - patterns (Ψ, Δ)
  - **thickness**
  - structure





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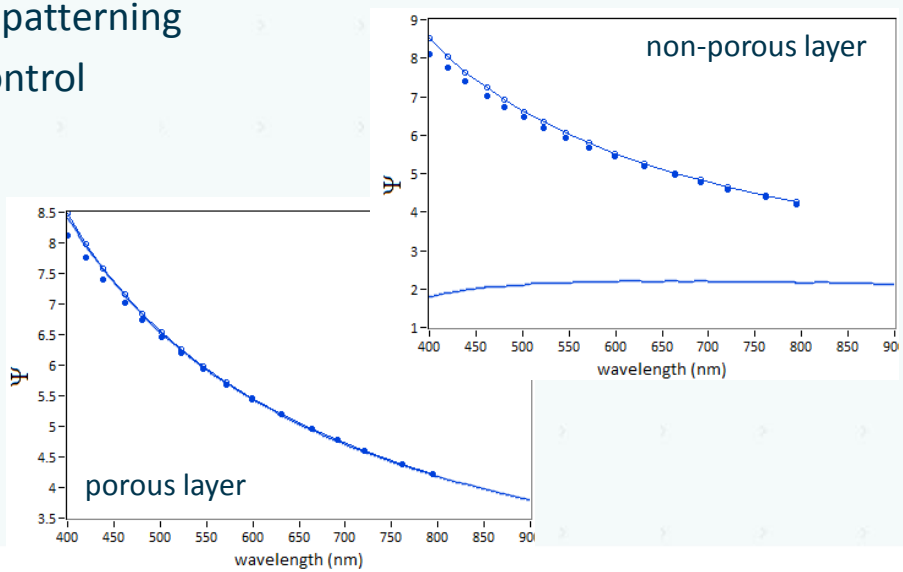
  - photochemical process enables patterning
  - wettability patterns for liquid control
- ellipsometry
  - patterns
  - thickness
  - **structure**



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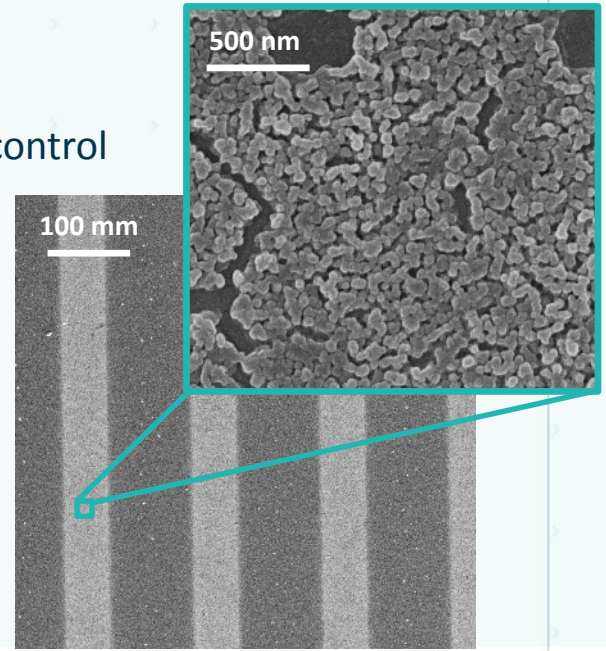

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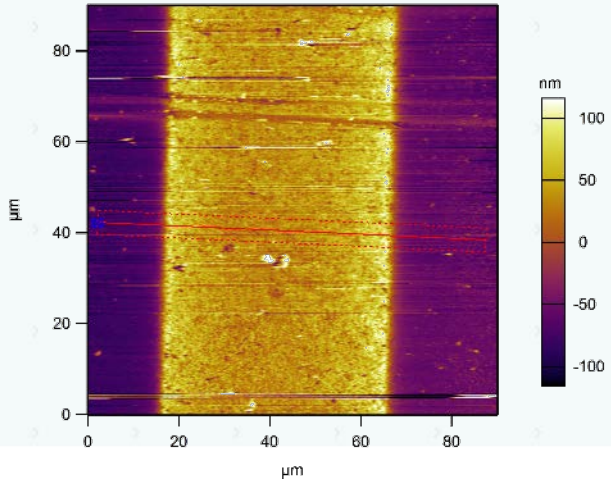
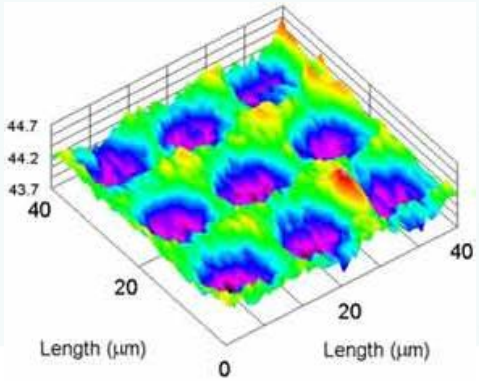
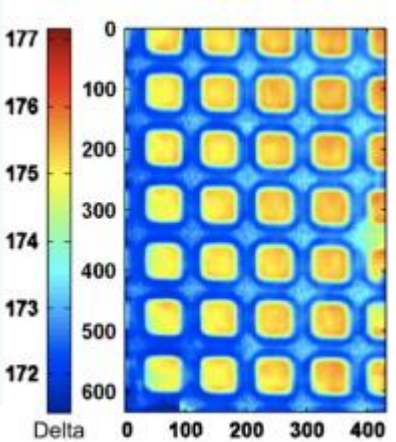
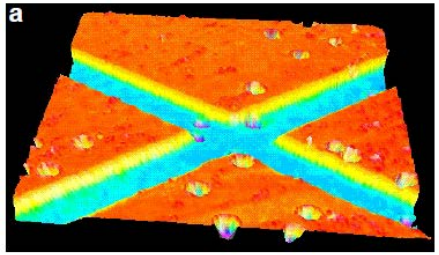


Application examples

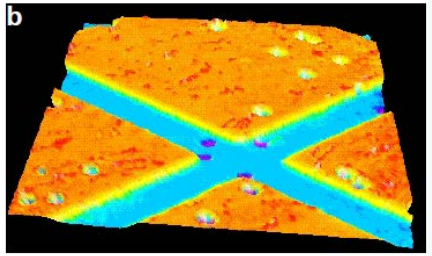
- Solid interfaces
  - self-assembled monolayers
  - layer-by-layer polyelectrolyte adsorption
  - polymer brushes
  - protein binding (biosensing)







25 °C

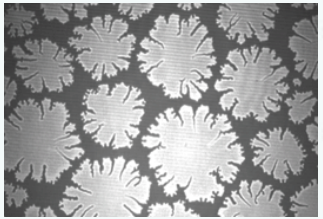


30 °C

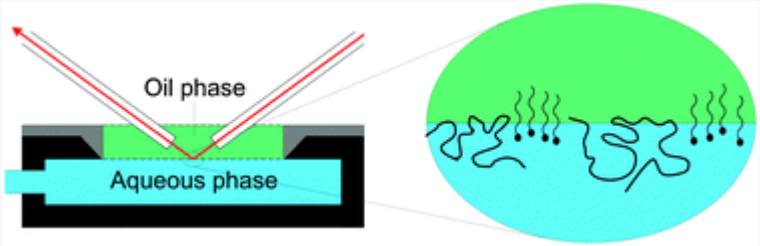
images: www.accurion.com

Application examples

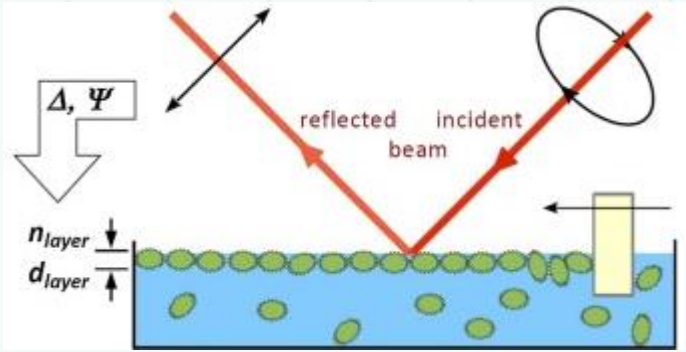
- Liquid interfaces
  - emulsions (water/oil)
  - foams (water/air)
  - surfactants, proteins, nanoparticles
  - adsorption, (re)organization
  - advanced Brewster angle microscope



schuman – soft matter 10 (2014) 7353 (BAM)



day – phys chem chem phys 12 (2010) 4590



muth – colloids surfaces B 140 (2016) 60

Summary & conclusions

- benefits of imaging ellipsometry
  - non-invasive
  - ambient conditions
  - fast
  - versatile
- limitations
  - reflective samples
  - parallel layers
  - layer thickness from <1 to several 100 nm
  - accurate modeling requires knowledge of optical properties or other supporting data, especially for multilayer samples

Thanks!