in-situ sensors

In-situ layer thickness measurement by spectral reflectance

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Outline

- measurement principle
- single wavelength measurement
- spectral reflectance measurement
- measurement of OLED processes
- summary and outlook

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- **measurement principle**
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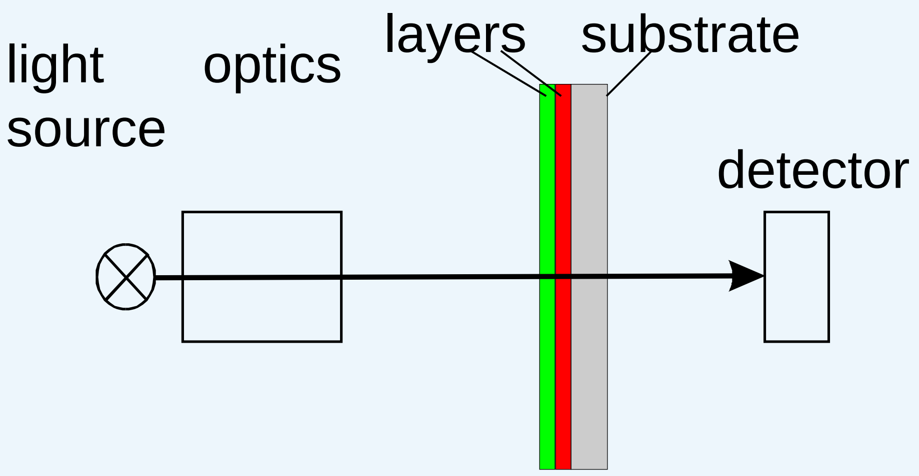
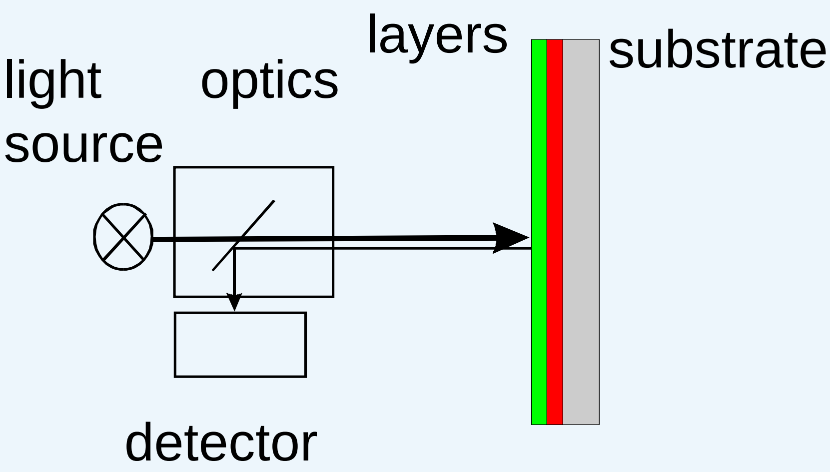
Established measurement technique: Optical transmission measurement

- yields thickness of deposition layers
- **disadvantages:**
  - needs two view ports
  - not applicable to non-transparent substrates

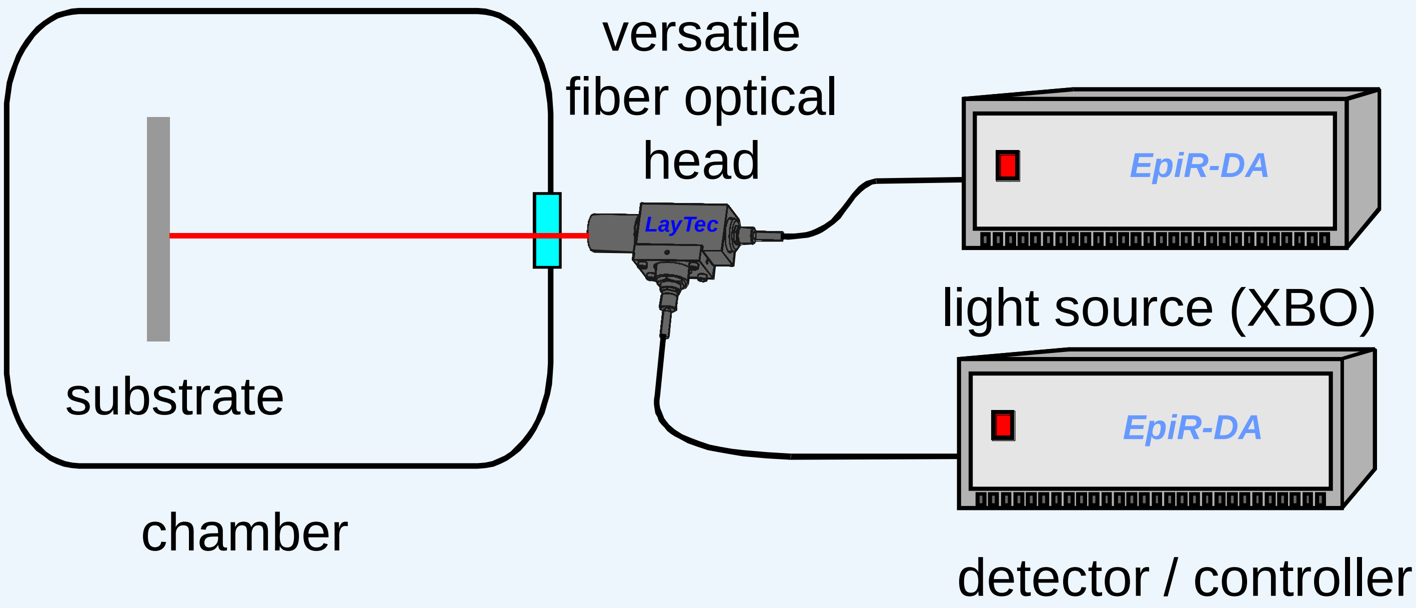


Reflectivity measurement

- white light is irradiated to the sample
- reflected light is detected and spectrally resolved
- **advantages:**
  - most robust geometry: normal incidence (only one view port is needed)
  - applicable to non-transparent substrates
  - other geometries possible on request



Reflectometer set-up



- versatile set-up allows measurement on various deposition systems
- all you need is a quartz glass view port for normal incident

Information from reflectance

Spectrum of reflected light is influenced by:

- thickness d of each layer
- refractive index n(λ) of substrate
- absorption k(λ) of the substrate
- refractive index n(λ) of each layer
- absorption k(λ) of each layer

Reflection spectra can be used:

- as fingerprints for run to run comparison
- for quantitative measurement of d, n and k
- for feedback control

Process types and reflectometry options

	single chamber	cluster tool	in-line	roll-to-roll
thickness gauging	single wavelength reflectometry is sufficient	spectral reflectometry required	spectral reflectometry required	spectral reflectometry required
deposition control	time control (EPD)	time control (iterative EPD)	source rate control	source rate control

- single chamber: allows permanent measurement during deposition
- other set-ups: only „single shot“ measurement at certain steps are possible

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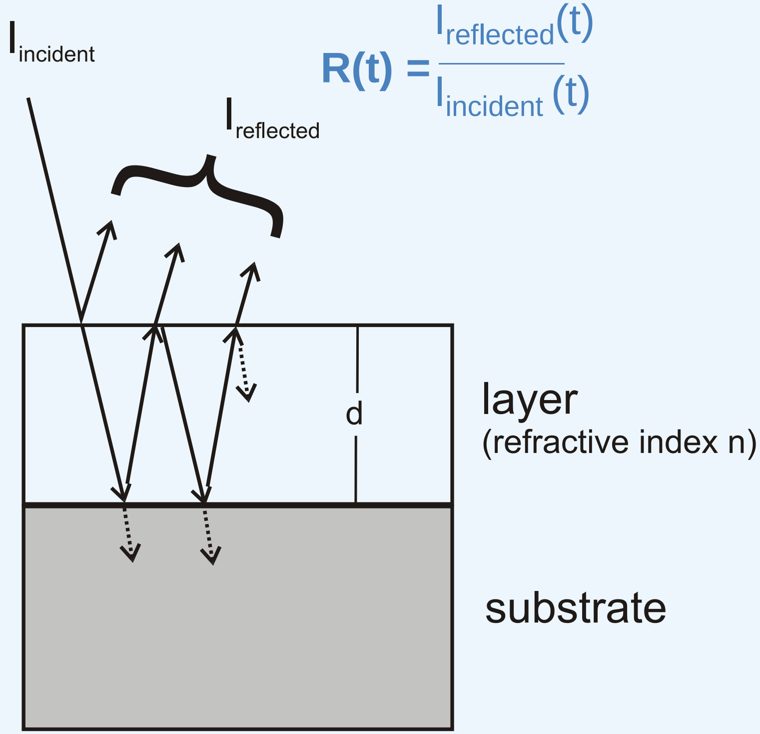
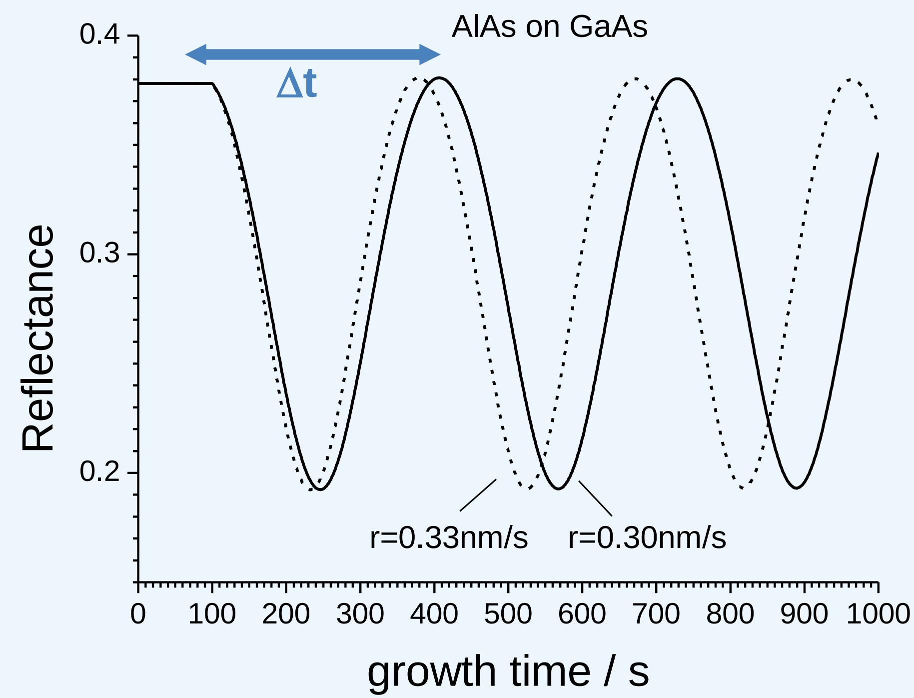
Single wavelength measurement

$$R(t) = \frac{I_{reflected}(t)}{I_{incident}(t)}$$





long oscillation period Δt
➔ **small growth rate r** (and vice versa)

Δt = oscillation period

$$\mathbf{r} = \frac{\lambda / n}{2 * \Delta t}$$

- spectral detection enables to choose most adequate detection wavelength

In-situ single-wavelength reflectance

- yields growth rate and (indirectly) layer thickness
- necessary: permanent measurement during deposition
- straight forward if $nd > \lambda$
- requires more sophisticated analysis for $nd < \lambda$

Process types and reflectometry options

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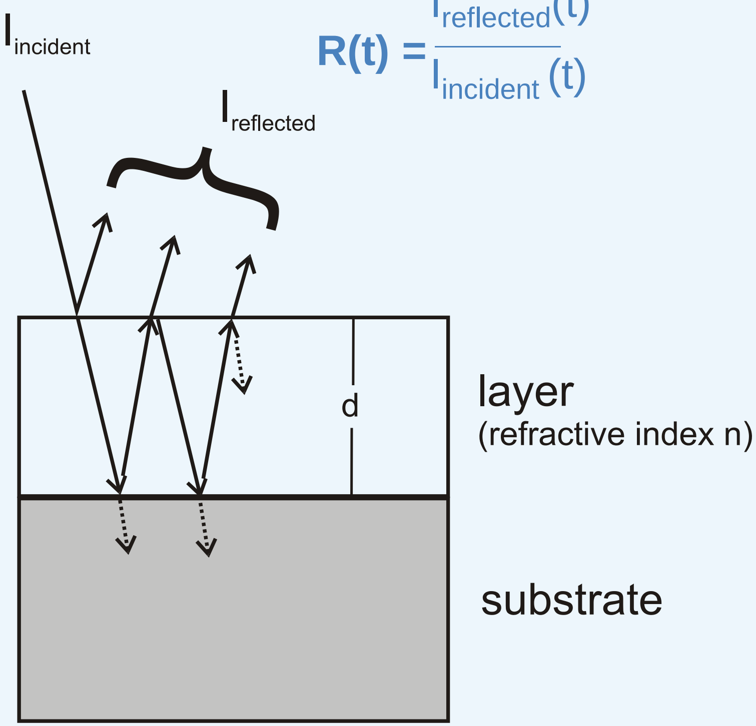
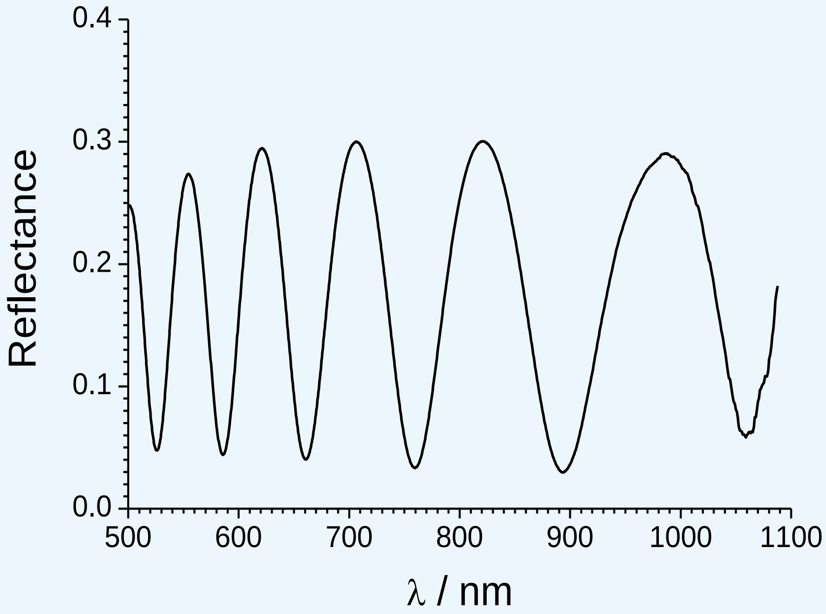
Spectral reflectance measurement

$$R(t) = \frac{I_{reflected}(t)}{I_{incident}(t)}$$



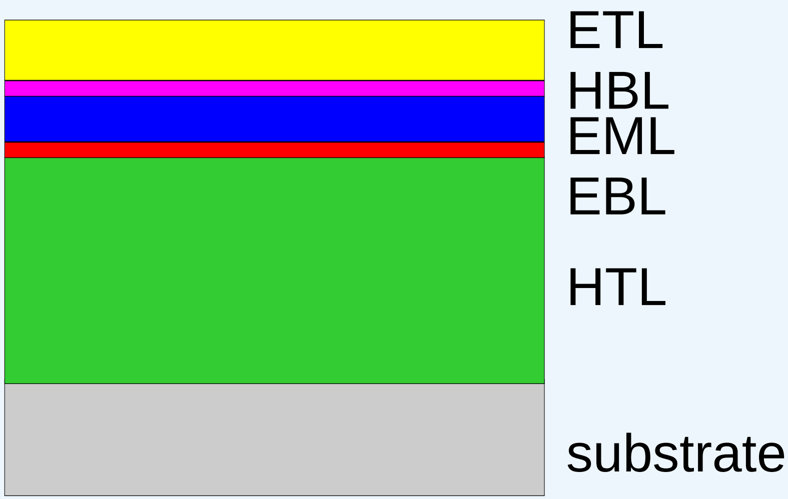


long oscillation period Δt
➔ **small growth rate r** (and vice versa)

$$d = \frac{1}{2n(\lambda)\left(\frac{1}{\lambda_{m+1}} - \frac{1}{\lambda_m}\right)}$$

In-situ spectral reflectance after each deposition step

- yields layer thickness directly
- yields spectral optical properties (for optical coatings)
- straight forward if *nd* > λ
- requires more sophisticated analysis for *nd* < λ



ETL: electron transport layer

HBL: hole blocking layer

EML: emitting layer

EBL: electron blocking layer

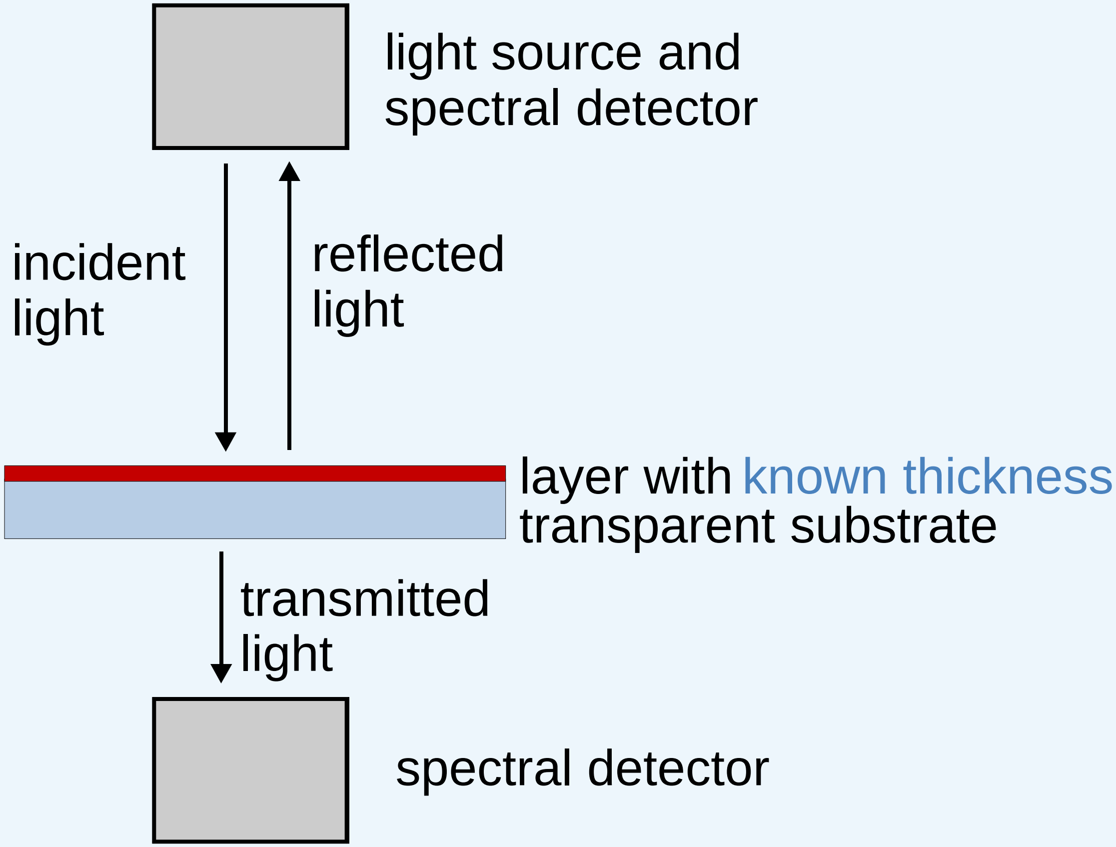
HHL: hole transport layer

Laboratory set-up

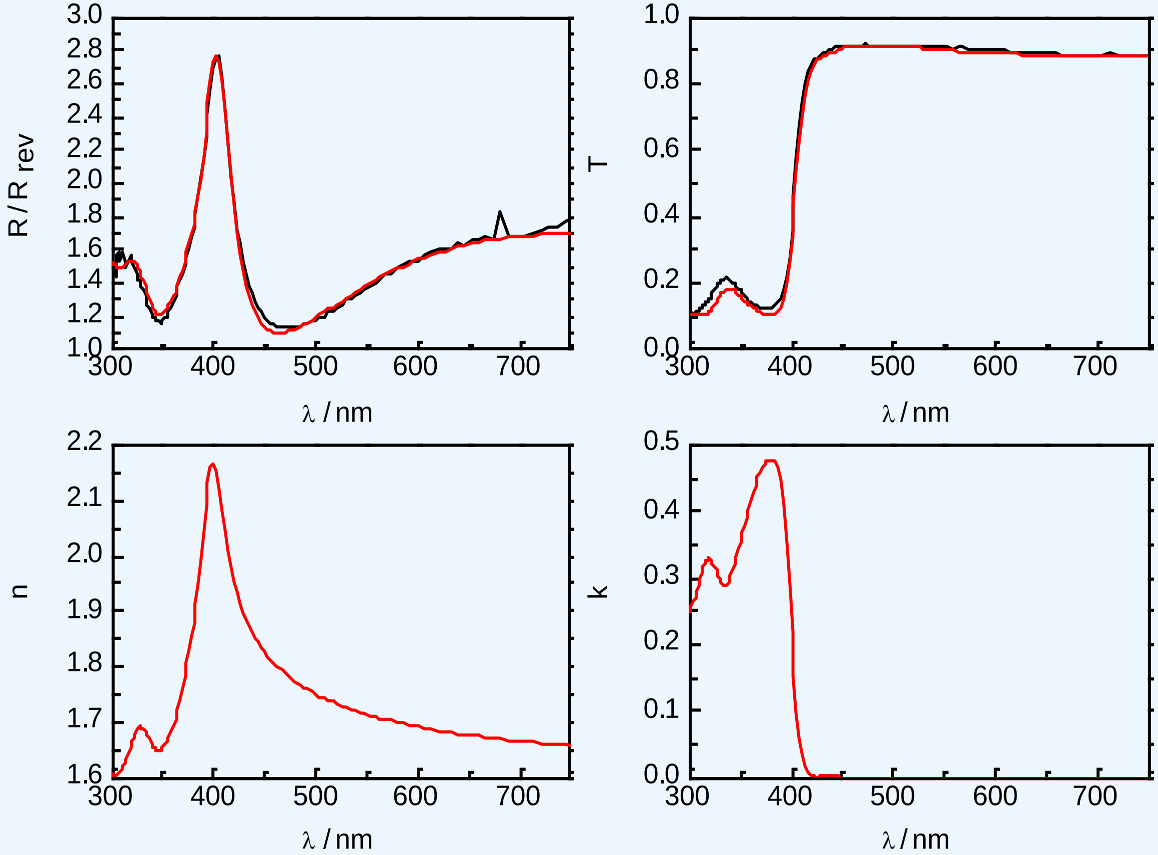
- analysis of reflectance and transmittance spectra of single layers gives n(λ) and k(λ)

↓

- n, k dispersion database for all used materials



Single layer dispersion from laboratory measurements

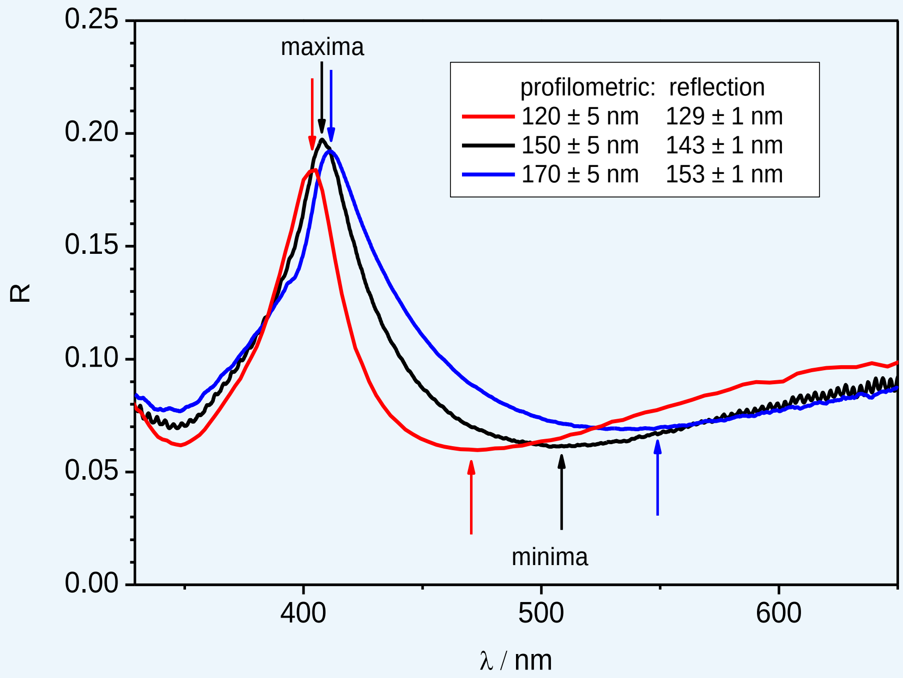


black: measured

red: fitting results

Single layer: HTL

- spectral reflectance of three HTL layers with thicknesses of: 120, 150 and 170 nm
- thickness can be „seen“ directly
- quantitative analysis uses n,k data base



thickness: profilometry vs. reflectance

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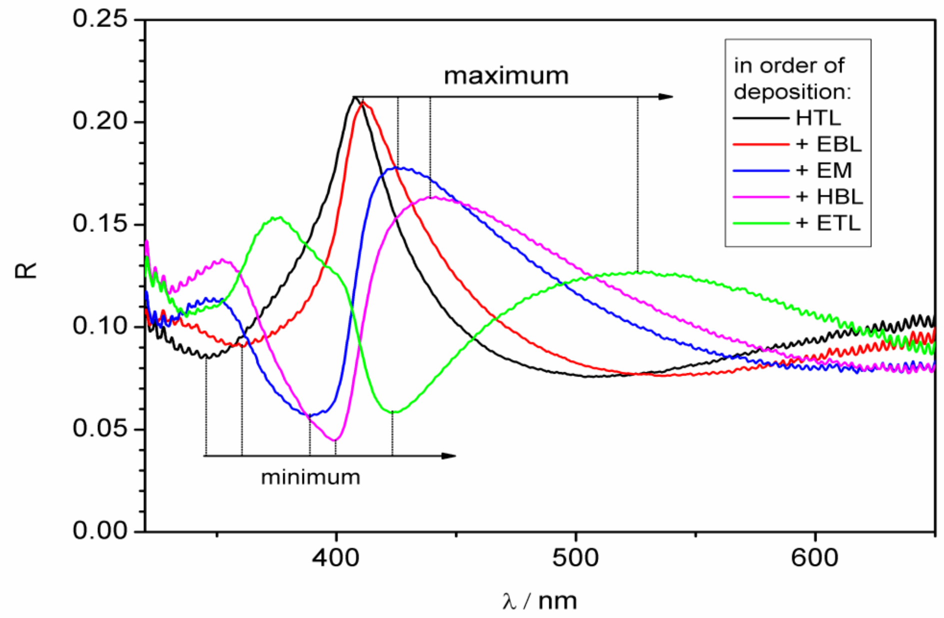
Full OLED structure on glass

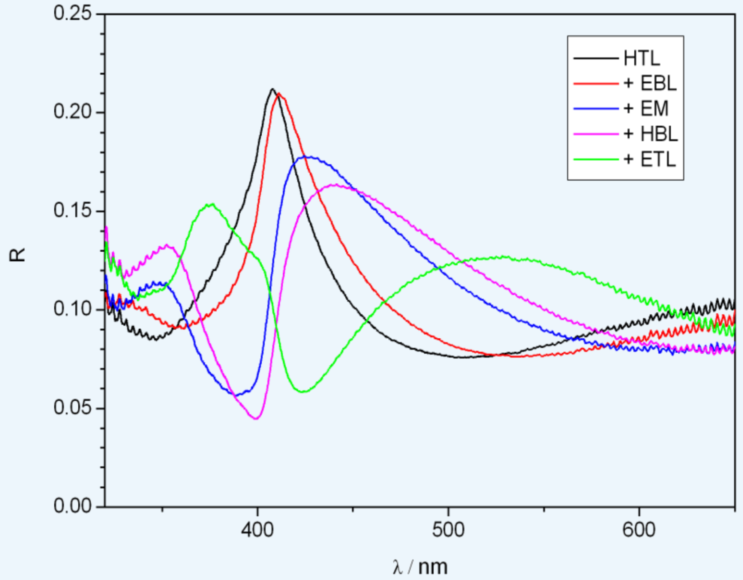
- all OLED layers are clearly resolved
- signal-to-noise ratio is excellent
- quantitative analysis of thickness (all layers) by using n, k data base



all functional layers (HTL, EBL, EM, HBL and ETL) give a characteristic spectrum

Full OLED structure on glass

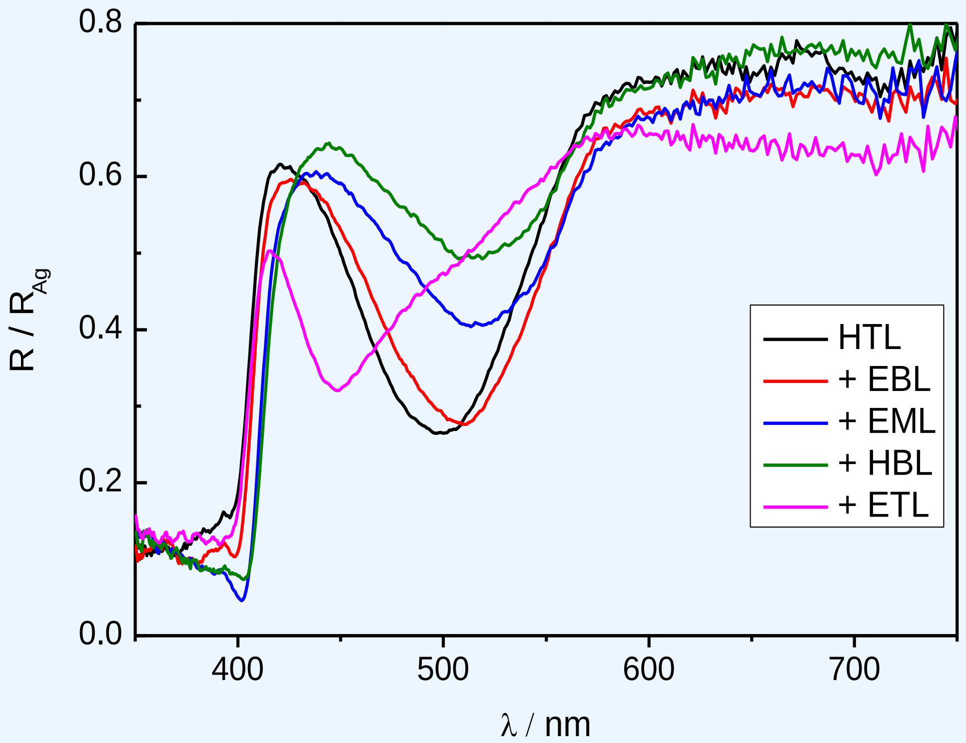
	d_{refl} / nm	d_{prof}/ nm
HTL	143 ± 1	150 ± 5
+ EBL	7 ± 1	10 ± 5
+ EM	30 ± 1	24 ± 5
+ HBL	9 ± 1	10 ± 5
+ ETL	37 ± 1	39 ± 5



all functional layers (HTL, EBL, EM, HBL and ETL) give a characteristic spectrum

Measurement on metal foil

- spectra exhibit maxima and minima due to layer thickness
- dispersion of measurement on glass substrate cannot be used



substrate: silver coated aluminium foil

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Real-time spectroscopic reflectance in OLED in-line tool

real-time spectroscopic reflectance (300nm-800nm)

- film thickness (10…250nm; accuracy: up to ±0.5nm)
- optical film properties (refractive index, absorption spectra)

measurement on Al/Ag foil:

- high sensitivity even at low film thickness
- n and k are different from values on glass substrates

Real-time spectroscopic reflectance in OLED in-line tool

Next steps:

- quantitative measurement of n and k on metal foil (in progress)
- concept for roll-to-roll specific measurement mode and software
- correlation: optical film properties $\leftrightarrow$ film composition/doping

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Some gems
need a little
extra help to
sparkle
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