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Imaging Ellipsometry: a Tool for Studying Microstructured Surfaces

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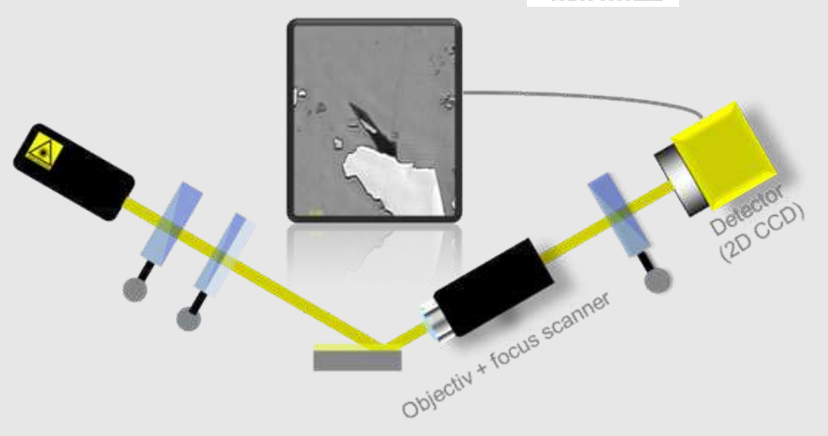
▪ Imaging Ellipsometry

Imaging ellipsometry, **combines** the power of **ellipsometry** with **optical microscopy**. It achieves the highest lateral resolution in the field of ellipsometry and offers a very sensitive imaging technology for thin films. Typical application is the characterization of microstructured thin films.
The ep4 is the latest microscopic imaging spectroscopic ellipsometer with unique measurement capabilities. It can provide real-time ellipsometric enhanced contrast images, and maps of the ellipsometric angles Δ and Ψ. These data can be transferred into d and the optical properties by computerized optical modeling.

For an introduction to our technology please visit our technology page



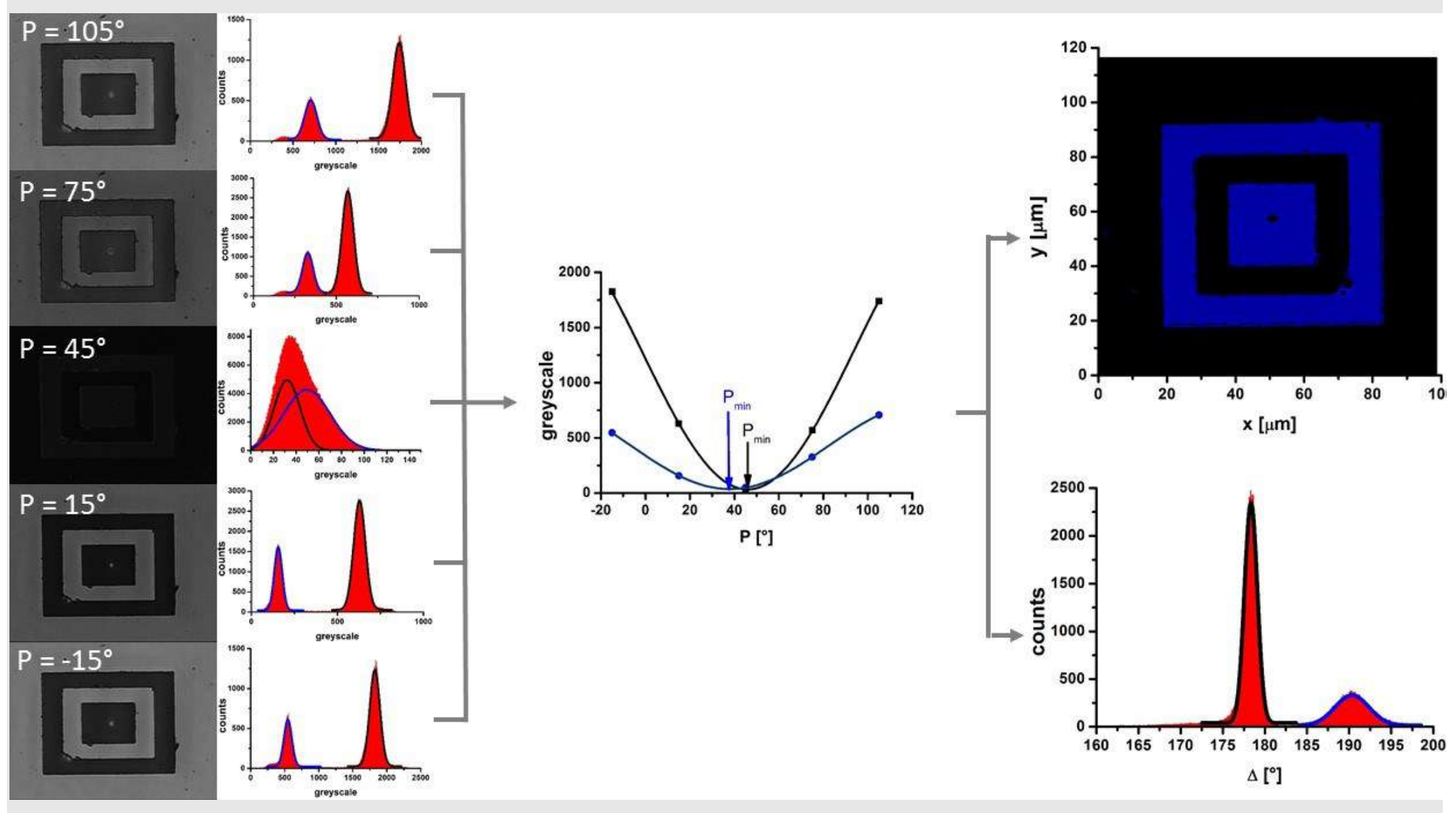
Setup of an imaging ellipsometer including objective and 2D CCD.

For additional information, please visit our EP4 page

Imaging spectroscopic ellipsometer nanofilm_ep4.

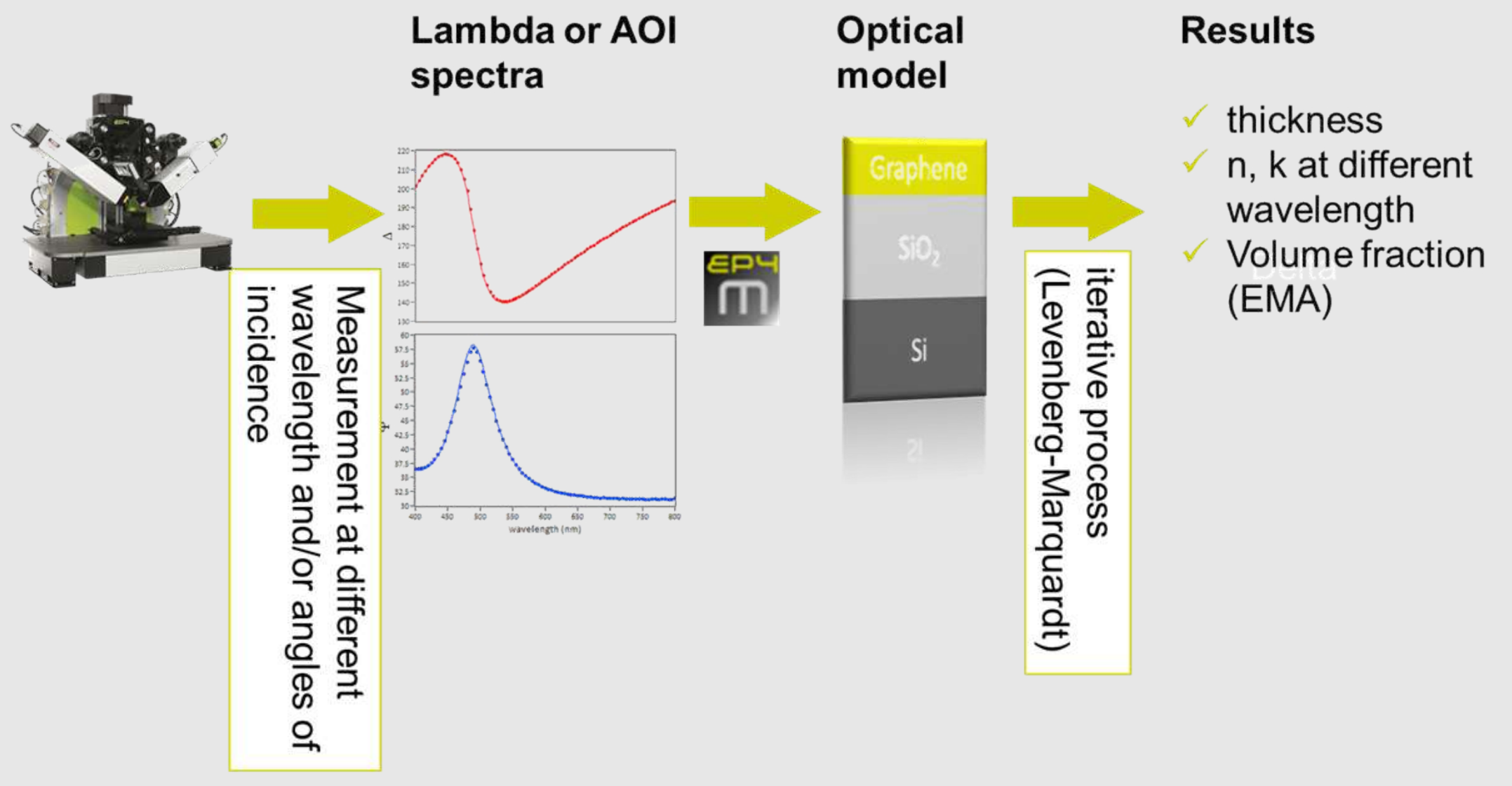
▪ Microscopic Mapping

- ✓Microscopic mapping offers the highest lateral resolution in the field of ellipsometry (down to 1 µm).
- ✓Each pixel works as a single detector.



▪ Optical Modeling

- ✓Fitting of optical- and metrological parameters for ultrathin films.
- ✓Effective medium approach (EMA) also offers information about chemical composition

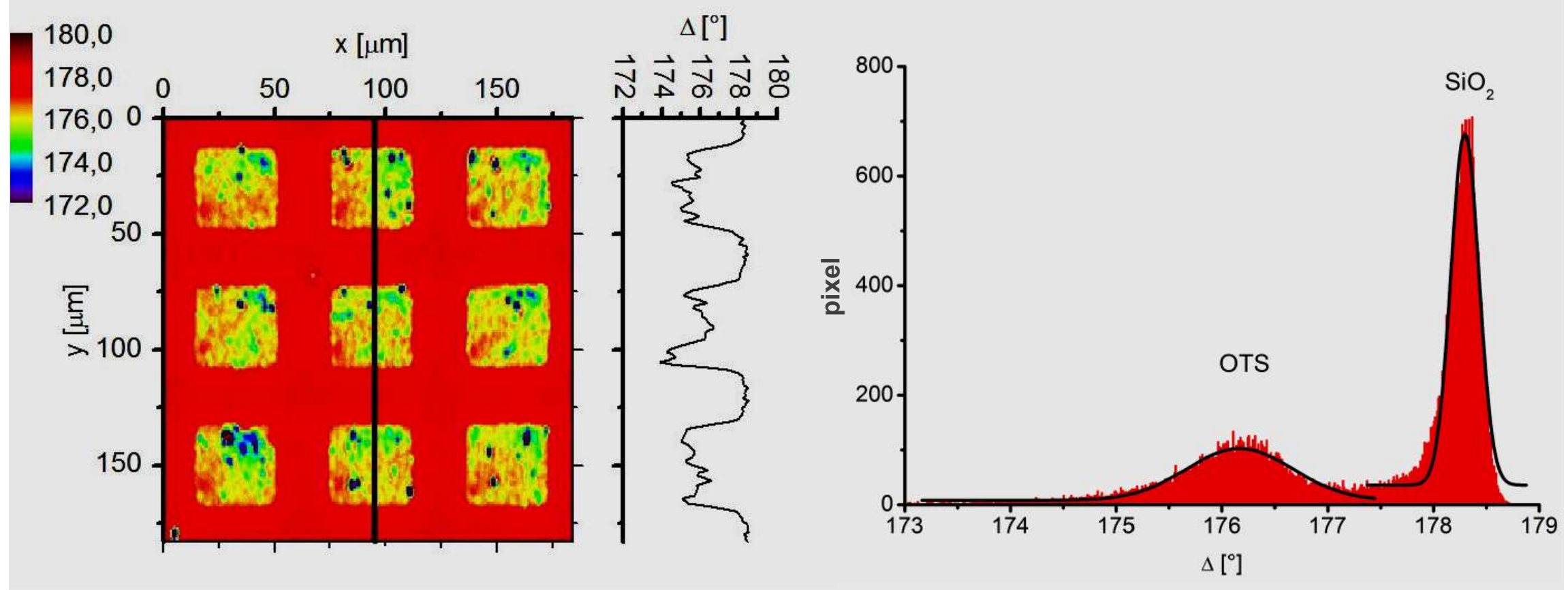


Results
- ✓ thickness
- ✓ n, k at different wavelength
- ✓ Volume fraction (EMA)

The Drude equation combines the reflection coefficients of p- (r_p) and s-polarized (r_s) with the ellipsometric angles Δ and Ψ. Hence r_p and r_s depend on complex refractive index and thicknesses of the investigated layers conclusions on n and k and thickness can be done. By varying wavelength and angle of incidence more independent values are obtained to improve the results.

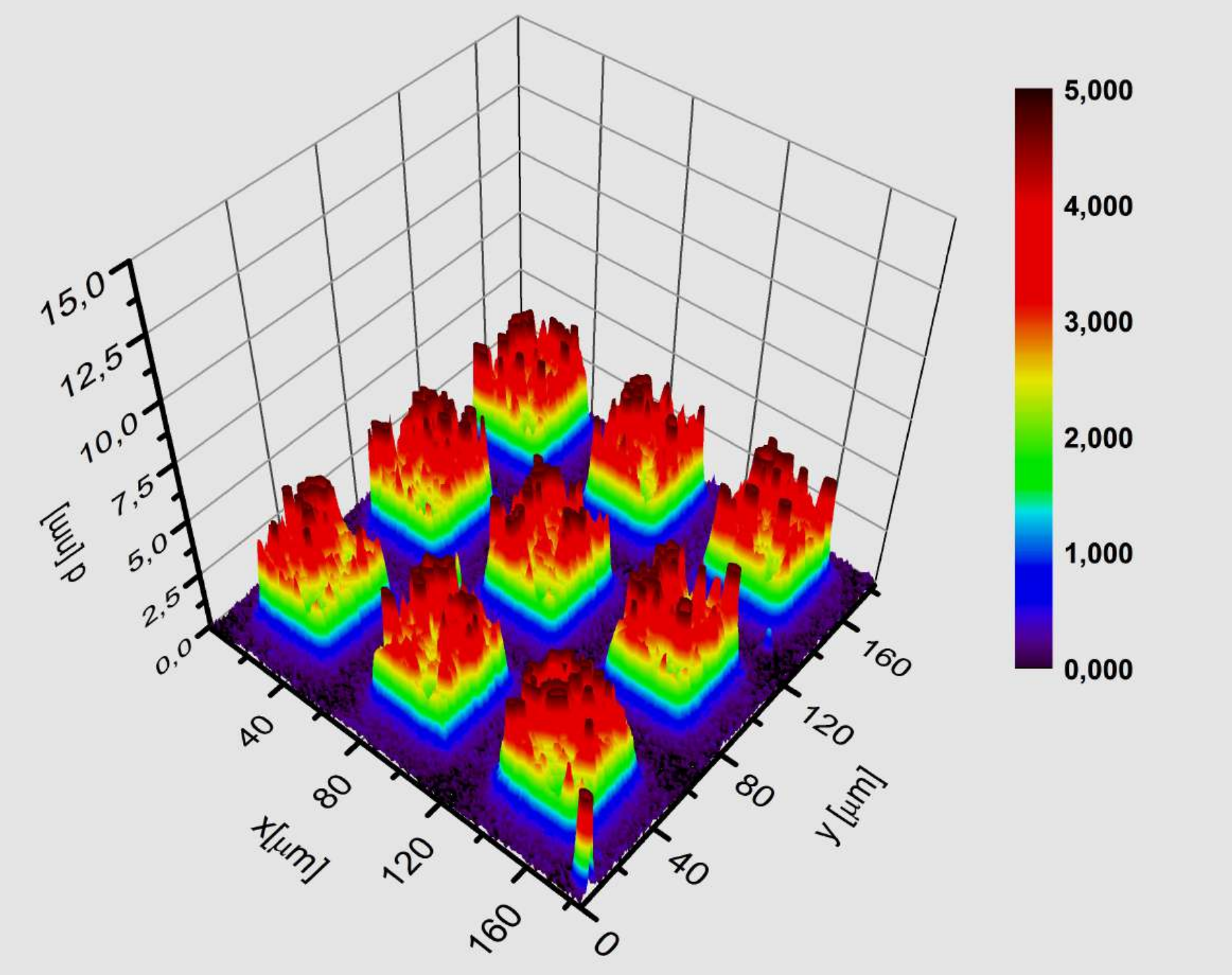
▪ Microcontact Printing

- ✓Pattern of OTS on SiO_2 surfaces by using microcontactprinting method on SiO surfaces [1].
- ✓Fast recording of Δ-maps (λ = 658 nm, AOI = 50°) using 10x objective on 25 postions of 4 samples.



Left: Cropped Δ-map and line-profile of sample micropatterned with OTS (c = 5 mM) on SiO_2/Si(100). Right: Correlating histogram of the Δ-map inclusive Gaussian fit for substrate and patterned SAM layer

- ✓Calculate Δ-maps into thickness-maps by interpolation using dispersion für SiO_2 and Si(100) from database.



3D-plot of thickness-map (c (OTS)=5 mM) on SiO_2/Si(100) .

- ✓Quantitative study (n=100) of the pattern formation regarding the ink concentration.

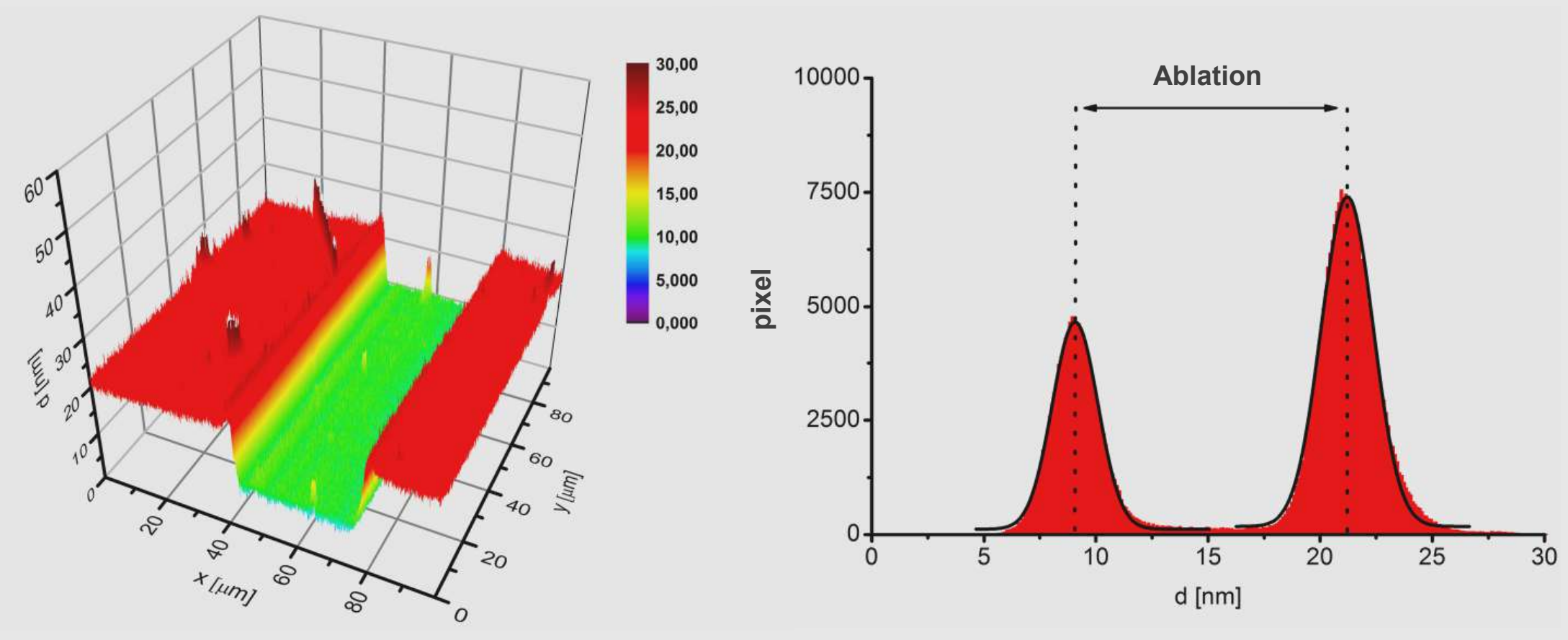
c (OTS) [mM]	ø d (SiO_2) [nm]	σ d (SiO_2) [nm]	ø d (OTS) [nm]	σ d (OTS) [nm]
5	2.39 ± 0.25	0.21 ± 0.06	6.36 ± 2.15	1.19 ± 0.80
1	2.01 ± 0.24	0.16± 0.04	3.30 ± 0.88	1.48 ± 0.80

Results of quantitative histogram analysis (Gaussian Fit) of 100 thickness-maps varying the ink concentration.

Literature: [1] Kumar, Amit, Hans A. Biebuyck, and George M. Whitesides. "Patterning self-assembled monolayers: applications in materials science." Langmuir 10.5 (1994): 1498-1511.

▪ Laser Ablation

- ✓Microstructured PMMA layer on SiO_2/Si(100) formed by laser ablation (pulsed argon ion laser (λ = 193nm)).
- ✓Variation in fluence and number of pulse by laser ablation on the sample.
- ✓Recording Δ-maps (λ = 500 nm, AOI = 50°) using 50x objective on 12 postions of the sample.
- ✓Calculate Δ-maps into thickness-maps by interpolation using dispersion for SiO_2 , Si(100) and PMMA from database.

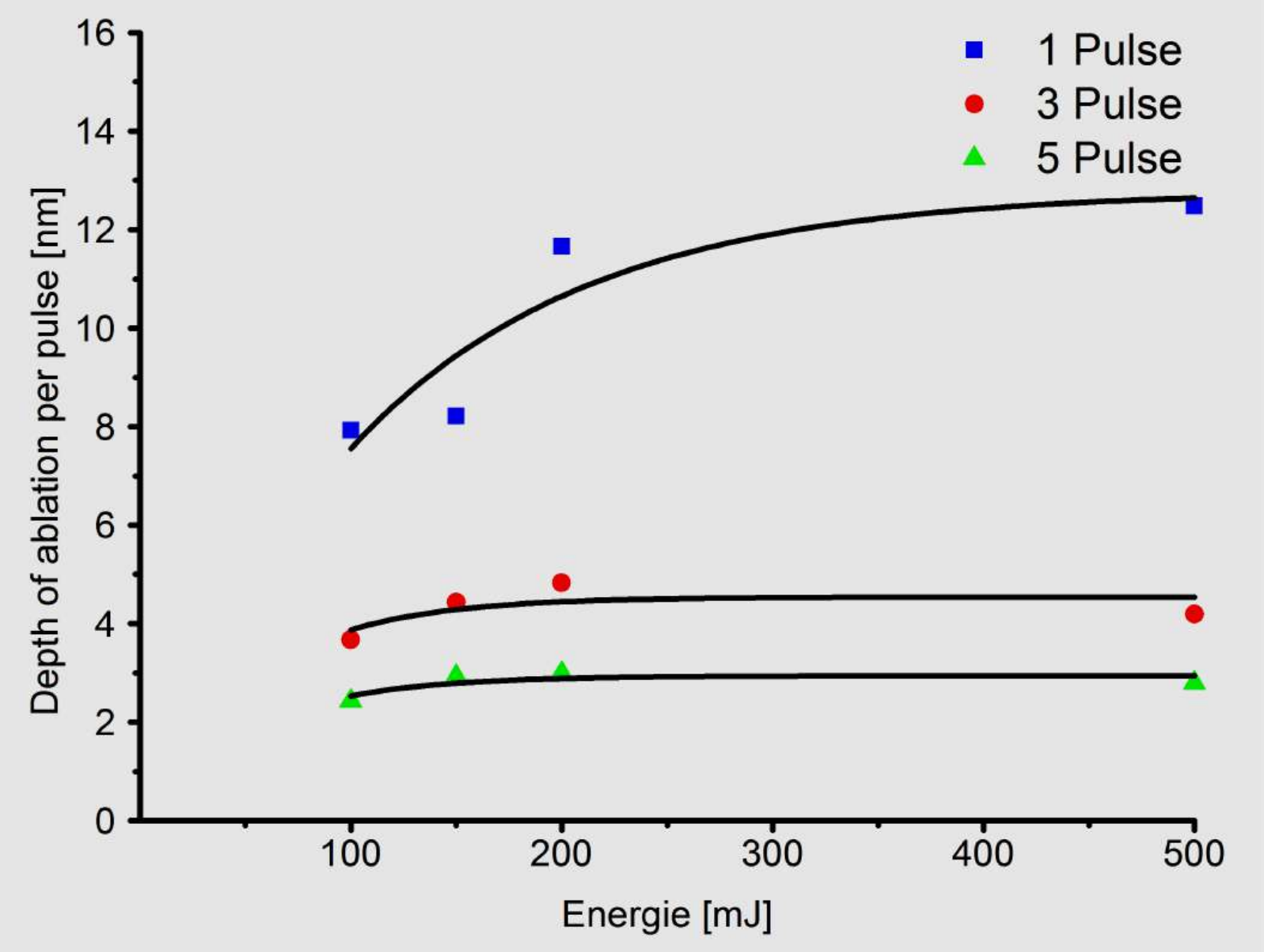


Left: d-map (3D-Plot) of microstructured thin PMMA layer (d = 21.9 nm) on SiO_2/Si(100) Right: Correlating histogram of the thickness-map inclusive depth of ablation for PMMA using Gaussian fit analysis.

- ✓Determination of the depth of ablation regarding fluence and number of pulse using Gauss Fit Histogram Analysis of thickness-maps.

Energy / Pulse	100 [mJ]	150 [mJ]	200 [mJ]	500 [mJ]
1	7.83	8.21	11.66	12.49
3	11.03	13.30	14.49	12.58
5	12.14	14.65	14.96	14.00

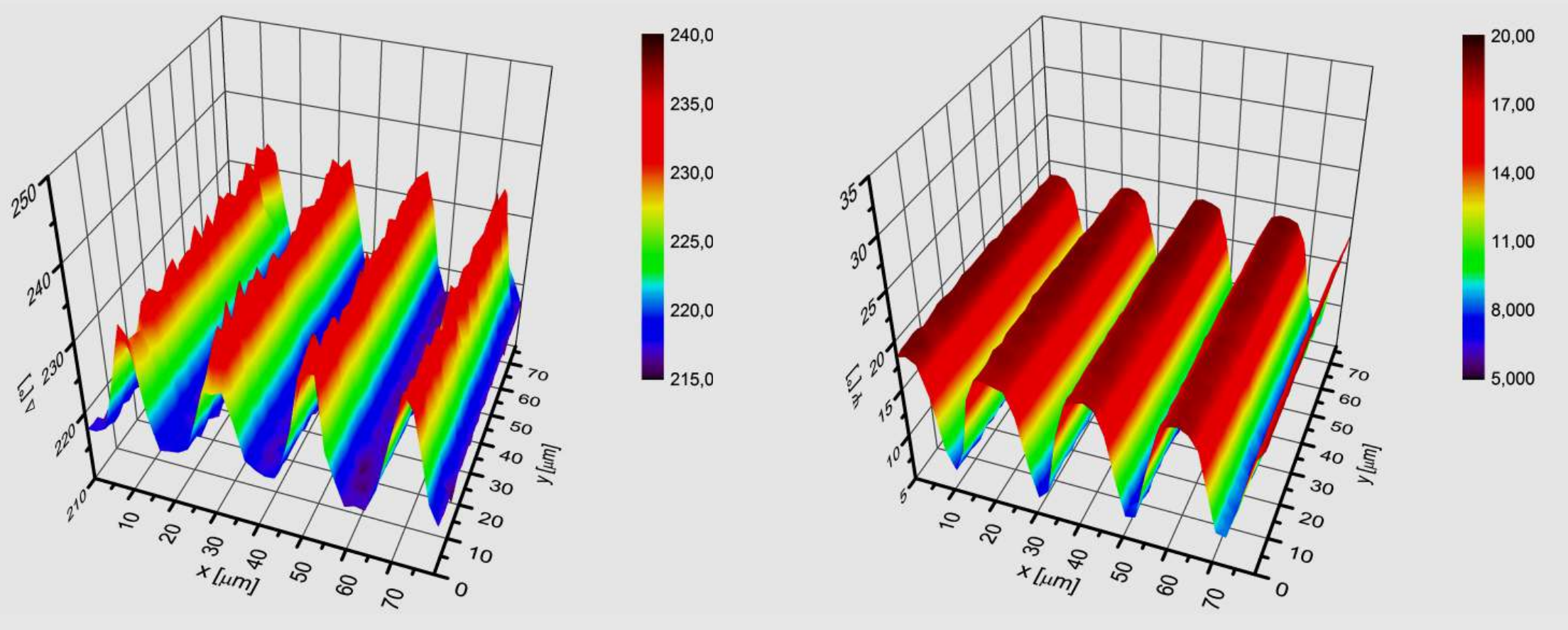
Calculated depth of ablation depending on pulse and energy obtained by histogram analysis of thickness-maps.



Exponential plot of the depth of ablation per pulse depending on the energy.

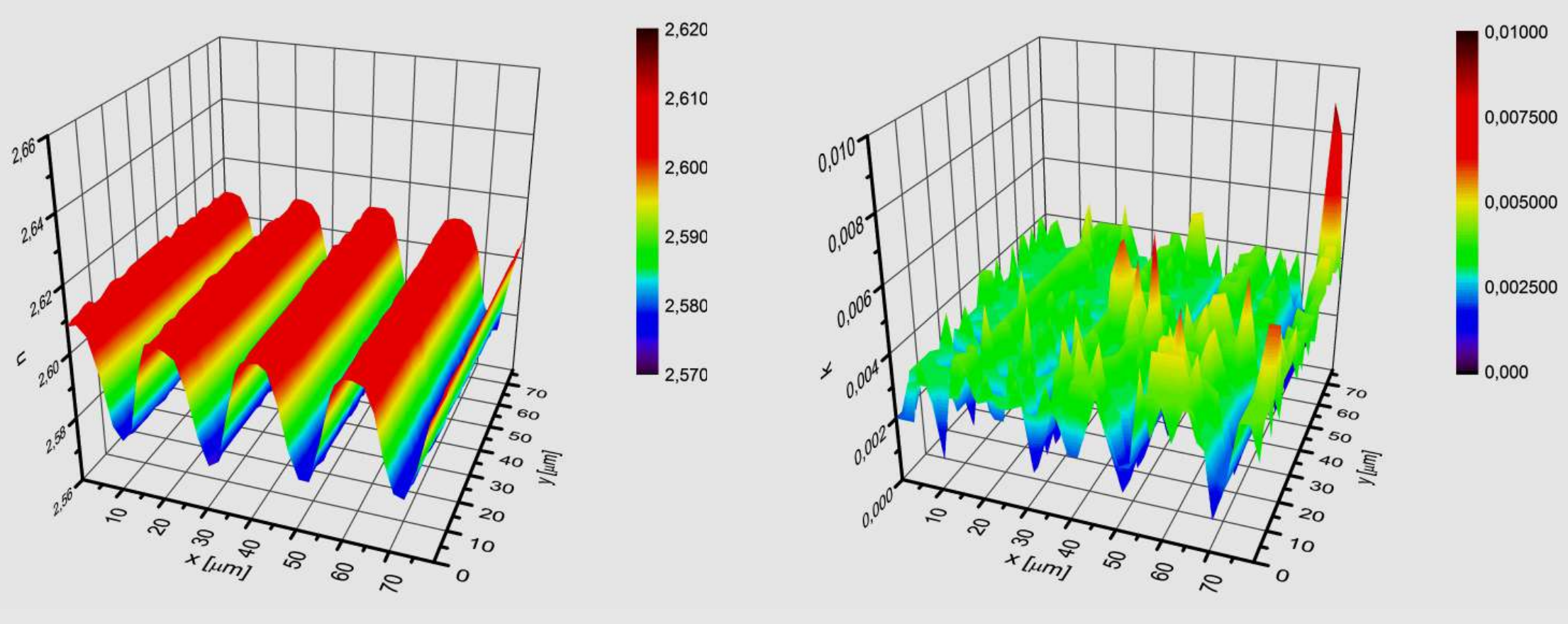
▪ Holographic Interferometry

- ✓Formation of photoinduced diffraction grating in amorphous As_2S_3 thin film on transparent subtrate by holographic interferometry [2].
- ✓Mapping the photoinduced changes of refractive index (λ= 658 nm, AOI = 50°, 10x) regarding expose time.



Δ-map (left) and Ψ-map (right) of microstructured amorphous As_2S_3 thin film on glass (d = 949.4 ± 0.1 nm) with proper-exposed gratings.

- ✓Determine the thickness by Spectrosopic Ellipsometry (380-800 nm) using Tauc-Lorentz-Model.
- ✓Calculate n+k values for each pixel using point to point method with fixed thickess (constant, measured by AFM).



Obtained n-map (left) and k-map (right) of microstructured amorphous As_2S_3 thin film on glass (d = 949.4 ± 0.1 nm) with proper-exposed gratings.

- ✓Gaussian Fit Analysis of n+k-maps regarding photoinduced changes in the optical parameters depending on the exposure time.

Exposure	d [nm]	Δ n	k
Under	966.2 ± 0.2	0.018 ± 0.003	0.0056 ± 0.017
Ideal	949.4 ± 0.1	0.032 ± 0.0005	0.0041 ± 0.007
Over	909.9 ± 0.1	0.022 ± 0.0004	0.0040 ± 0.017

Results of quantitative histogram analysis of the n+k-maps with different exposure time.

Literature: [2] Röling, C., et al. "Imaging ellipsometry mapping of photo-induced refractive index in As_2S_3 films." Journal of Non-Crystalline Solids 365 (2013): 93-98.