Optical Properties of Hybridized Nanostructures

UNIVERSITY OF NEBRASKA-LINCOLN

P2-50

D. Schmidt[1,*], C. Müller[2], K. B. Rodenhausen[3], S. Schöche[1], T. Hofmann[1], O. Inganäs[2], E. Schubert[1], and M. Schubert[1]

[1] *Department of Electrical Engineering and Nebraska Center for Materials and Nanoscience, University of Nebraska-Lincoln, U.S.A.*

[2] *Biomolecular and Organic Electronics, Center of Organic Electronics, IFM, Linköping University, Sweden*

[3] *Department of Chemical and Biomolecular Engineering and Nebraska Center for Materials and Nanoscience, University of Nebraska-Lincoln, U.S.A.*

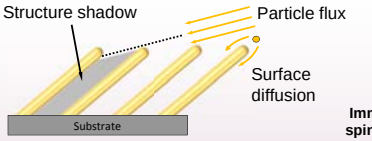
*schmidt@huskers.unl.edu

ellipsometry.unl.edu

Our Message

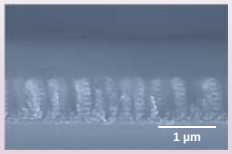
- **Glancing angle deposition is utilized to grow achiral and chiral metallic sculptured thin films.**
- **Generalized Ellipsometry (GE) is employed to determine optical and geometrical properties of highly anisotropic thin films in different environments.**
- **Optical properties can be altered and tuned by infiltration of (conducting) polymers in void spaces between nanostructures.**
- **Minute amounts of chemical molecules dramatically change the overall film birefringence. Consequently, due to an extreme sensitivity to a changing environment such sculptured thin films can be used as agent-free chemical sensors.**

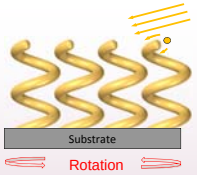
Hybridized Sculptured Thin Films



A collimated particle flux, generated by electron beam evaporation impinges at a glancing angle onto the substrate and results in self-organized, randomly distributed but highly coherent slanted **nanocolumns**.

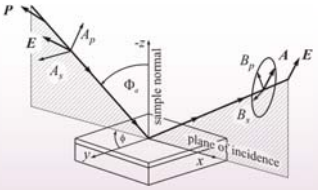
Immerse in liquids or spin coating polymers





Introducing continuous substrate rotation,, sculptured thin films in shapes of hollow core **nanocoils** can be engineered.

Generalized Ellipsometry



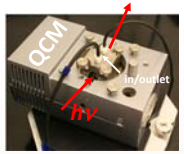
Ellipsometry measures the polarization state change of an electromagnetic wave upon reflection off a sample surface.

If the sample is anisotropic, generalized (Mueller matrix) ellipsometry allows for determination of complete and accurate sets of optical constants.

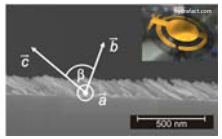
The 4x4 real-valued Mueller matrix connects the incident and emergent Stokes vector components, which are linear combinations of different polarization states.

$$\begin{bmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{bmatrix}_{out} = \begin{pmatrix} M_{11} & M_{12} & M_{13} & M_{14} \\ M_{21} & M_{22} & M_{23} & M_{24} \\ M_{31} & M_{32} & M_{33} & M_{34} \\ M_{41} & M_{42} & M_{43} & M_{44} \end{pmatrix} \begin{bmatrix} I_P + I_S \\ I_P - I_S \\ I_{45} - I_{-45} \\ I_{RC} - I_{LC} \end{bmatrix}_{in}$$

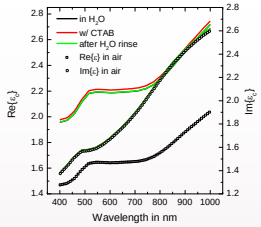
Infiltration of Liquids and Chemicals



QCM liquid cell with optical windows

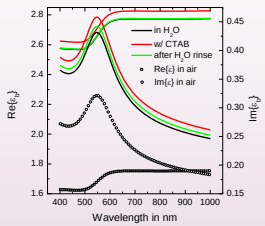


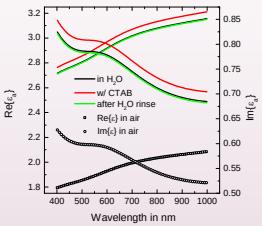
slanted columnar thin films are deposited directly on a QCM crystal



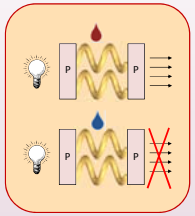
Principal optical constants of a slanted columnar thin film deposited on a QCM crystal:

- in air
- immersed in nanopure H_2O
- after adsorption of CTAB (2.5 mM)
- after desorption (H_2O rinse)



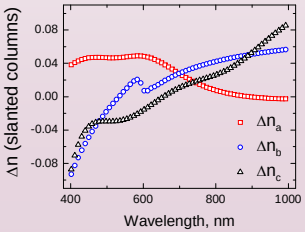


Agent-free Chemical Sensing

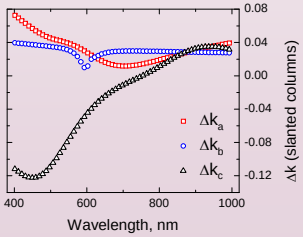


Light from an LED, for example, passes through the sample, which is in between crossed polarizers (P). Different chemicals or reagents modify the film birefringence, which can be detected by darkening or brightening of sensing device.

Change of n_i and k_i along major polarizability axes i = ***a***, ***b***, ***c*** upon changing ambient from nanopure water to ethanol (n_{H_2O} – n_{EtOH} = 0.002, at 633 nm).

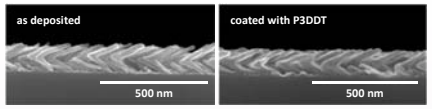


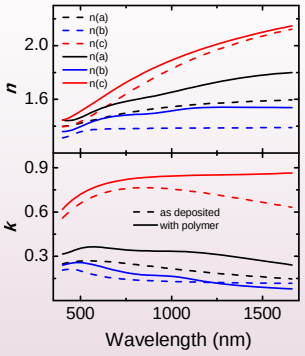
Difference between immersion in water and ethanol (Δn = 0.002, $k = \Delta k$ = 0)

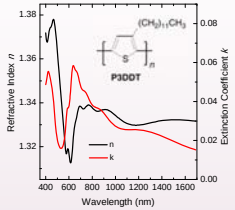


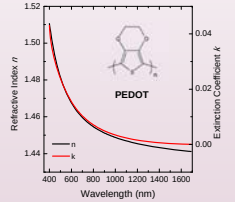
Infiltration of Conducting Polymers

Titanium Chevron





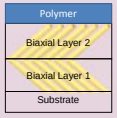




as grown	Layer 1	Layer 2
Thickness *d*	47.7 nm	69.5 nm
Inclination *θ*	57.5°	62.5°

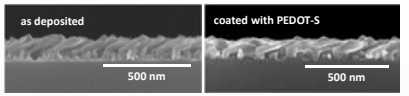
w/ polymer	Layer 1	Layer 2	Polymer
Thickness *d*	47.7 nm	69.5 nm	3.6 nm
Inclination *θ*	57.5°	62.5°	---

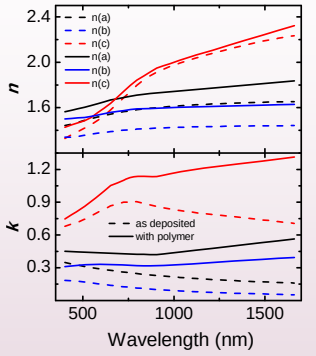
Optical Model



New set of optical constants with identical structural parameters for chevron

Titanium L-Shape





as grown	Layer 1	Layer 2
Thickness *d*	59.7 nm	56.2 nm
Inclination *θ*	54.1°	68.2°

w/ polymer	Layer 1	Layer 2	Polymer
Thickness *d*	62.5 nm	48.7 nm	3.1 nm
Inclination *θ*	64.7°	68.1°	---

Structural parameters for L-shape have to be changed slightly for optimum results

ICSE-V, International Conference on Spectroscopic Ellipsometry, Albany, NY, May 2010

Funding: CAREER, MRSEC, COE, JAWF