solutions for science

NANOPTICUM

GRAPHENE - WHAT CAN WE LEARN FROM IMAGING ELLIPSOMETRY TODAY AND WHAT WILL BE POSSIBLE IN THE FUTURE?

Literature Summary:

- Albrektsen O. et al. (2012) High resolution imaging of few-layer graphene
- Matković A. et al. (2012) Spectroscopic imaging ellipsometry and Fano resonance modeling of graphene.

Theses on imaging ellipsometry:

- U. Wurstbauer (2010) Graphene on various substrates

Dear Sir/Madam

Graphene may be the most promising material discovered in recent years. From our experience, Imaging ellipsometry is a very helpfull tool ~~in~~ for the characterization of graphene layers. This is especially true for graphene flakes and christalites. For this reason we focus the current nanopticum issue completely on graphene applications.

The new generation of imaging ellipsometry systems will have options that make surface inspection more effective and exciting. For example these options provide much faster Delta and Psi maps, fast spectral mapping methods, and spectra with a spectroscopic resolution down to 1 nm. Additional features and options provide expanded spectral range into the UV and NIR, regions of interest that can be selected even after the mesurement and many more (The next nanopticum will be completely focused on the new nanofilm_ep4).

In our series about Ph.D. theses on imaging ellipsometry, we highlight the thesis of Ulrich Wurstbauer, who was the first, to bring imaging ellipsometry and graphene together – at a Friday afternoon in November 2007 ;-).

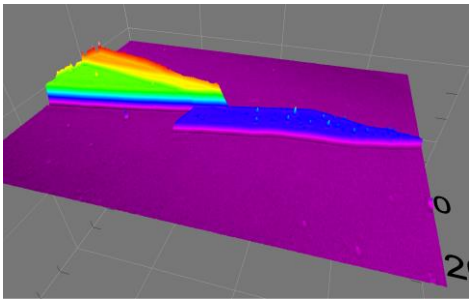
Our literature summary includes two current papers that apply imaging ellipsometry to the field of graphene research.

We hope, you enjoy our current issue of the Nanopticum.

Best regards

Yours,

Accurion team



Graphene flake on $SiO_2|Si$, recorded with the new nanofilm_ep4

June 2013

25th - 26th June, Graphene Commercialisation & Applications 2013 London, UK
www.graphene-applications-summit.com/

30th June – 5th July, Conference on Colloid Chemistry: Moscow, Russia
www.icc2013.ru

8th - 12th July, European Conference on Organised Films, Cork, Ireland
www.ecof13.org

1st – 9th September, Conference on Colloid and Surface Science, Sofia, Bulgaria
www.ecis2013.org

26th - 27th September, Accurion - Inhouse conference on imaging ellipsometry and Brewsterangle microscopy II, Göttingen, Germany

14th – 17th October, V2013, Industrie-ausstellung & Workshop-Woche Vakuum-beschichtung und Plasmaoberflächentechnik, Dresden, Germany
www.v-workshopwoche.net

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Literature Summary:

HIGH RESOLUTION IMAGING OF FEW-LAYER GRAPHENE

Albrektsen et al. successfully demonstrate how imaging ellipsometry can be applied to obtain high-resolution thickness maps of few-layer graphene (FLG) samples, with the results being thoroughly validated in a comparative study using several complementary techniques. The thickness map, revealing distinct terraces separated by steps corresponding to mono- and bilayers of graphene, is extracted from a pixel-to-pixel fitting of ellipsometric spectra using optical constants (n=2.7 and k=1.2) derived by fitting slab model calculations to averaged Ψ and Δ spectra collected in large homogenous sample areas. An analysis of reflection spectra and contrast images acquired by ORM confirm the results by quantifying the number of graphene layers and retrieving the FLG optical constants using a simple Fresnel-law-based slab model. The morphology results are further corroborated with AFM and Raman images, the latter unambiguously verifying that the thinnest part of the FLG consists of a graphene bilayer and providing additional information of electronic origin that might help identifying subtle FLG features, such as the presence of impurities, variations in stacking order, or rolling and folding at the FLG edges.

Albrektsen O., Eriksen R.L., Novikov S.M:, Schall D., Karl M., Bozhevolnyi S.I., Simonsen A. C. (2012) High resolution imaging of few-layer graphene. *J. Appl. Phys.* **111**, 064305.
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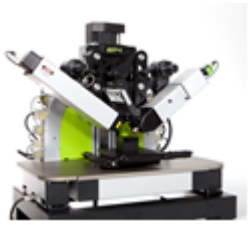
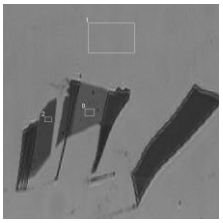


The new nanofilm_ep4



- Ellipsometric contrast micrograph with one, two and more layers of graphene and regions of interest, used in the paper from Matković et al,

SPECTROSCOPIC IMAGING ELLIPSOMETRY AND FANO RESONANCE MODELING OF GRAPHENE

Matković et al. have examined the optical properties of exfoliated graphene on an Si/SiO_2 substrate using spectroscopic imaging ellipsometry in the visible range (360–800 nm). Measured spectra were analyzed by an optical model based on the Fresnel coefficient equations. The optical model was supported by correlated Raman and atomic force microscopy measurements. The complex refractive index of graphene was obtained by inversion of the measured ellipsometry data. The Fano line-shape was used to parameterize the optical properties. Measurements were highly reliable due to the numerous advantages of the spectroscopic imaging ellipsometric technique combined with the proper choice of substrate and experimental set-up. Thickness maps of the graphene sample were obtained from spatially resolved imaging ellipsometry spectra with a spot size of 1 μm. The data showed the presence of a water layer on the surface of the sample, and the thickness was mapped showing the distribution of water over graphene in ambient conditions.

Matković A, Beltaos A., Milićević M., Ralević U., Vasić B., Jovanović D., Gajić R. (2012) *J. Appl. Phys.* **112**, 123523.
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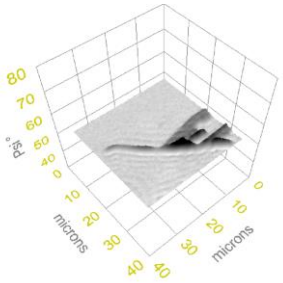

- Psi map of a graphene flake

Theses on Imaging ellipsometry
GRAPHENE ON VARIOUS SUBSTRATES.

(Wurstbauer, Ulrich (2010), Dissertation Universität Regensburg)

Ulrich Wurstbauer reports imaging ellipsometry studies. Samples, with a graphene monolayer on silicon dioxide were measured angle and wavelength dependent, the optical dispersion relation was modeled with a comprehensive algorithm basing on the Drude model. Both, the values for extinction and refraction indices for incident wavelengths from 350 nm to 1000 nm increase with increasing wavelength. Furthermore, graphene flakes were detectable also on the crystalline GaAs-based substrates by imagine ellipsometry.
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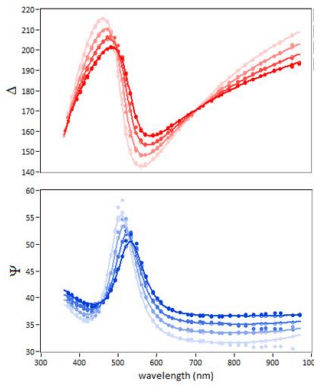
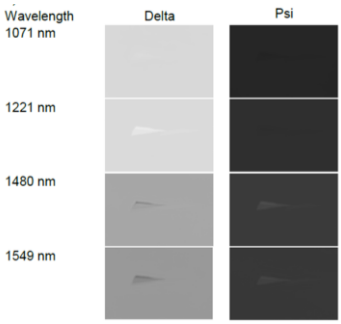


- Wavelength spectra of Delta and Psi at different angles of incident

New application:
FIRST GRAPHENE DELTA AND PSI-MAPS IN THE NIR.

Using our new NIR-upgrade, we measured the first delta and Psi-maps of a small graphene flake in the NIR. An application note with more details will come soon.



- Delta and Psi maps in the NIR.