Large-Area Layer Counting of 2D Materials via Visible Reflection Spectroscopy

Hutzler, A.[1], Matthus, C.D.[1], Rommel, M.[2], Jank, M.P.M.[2] and Frey, L.[1,2]

[1] Chair of Electron Devices, University of Erlangen-Nuremberg, Germany, [2] Fraunhofer Institute for Integrated Systems and Device Technology, Germany

Two-dimensional (2D) materials are highly promising because of their unique electrical, optical, and mechanical properties. These properties can be adjusted by variation of the number of layers. In order to determine the structure-property relations of these materials, various characterization methods, like scanning electron microscopy, transmission electron microscopy, Raman spectroscopy, and atomic force microscopy are applied [1]. However, most of these techniques are restricted to small area measurements (e.g. nm up to m^2) and the evaluation of data is not always straightforward.

A further characterization technique is visible reflection spectroscopy. The current approach is to calculate the optical contrast of layered crystals on top of thin-film systems from measured reflectance spectra. This method has the advantage of being remarkably faster than most of the techniques named above. In order to determine the number of layers, distinct maxima or minima of the optical contrast to subjacent layer stacks are utilized. However, typically this optical contrast is a non-linear function of the number of layers [2]. Additionally, the measurable absolute reflectance and thus the contrast is limited by the sensitivity of the detector [3]. In this presentation, we demonstrate that the spectral position of distinct minima of the reflectance is even better suited for determining the number of layers. This is, because the wavelength where the minimum occurs shifts highly linearly with increasing number of layers on appropriate layer stacks. The calculation is done by utilizing the analytical model of our former work [3] which was proven experimentally for graphene. Furthermore, this method is applicable for large area (several mm^2) characterization of different 2D materials as well.

Figure 1 shows the calculated reflectance spectra of graphene oxide (GO, complex refractive index according to [4]) with up to 25 layers on a layer stack consisting of a 54 nm Si_3N_4 layer on a 11 nm SiO_2 layer on silicon substrate. The linear dependency of the minimum wavelength λ_{min} on the number of GO layers is shown in the inset yielding a wavelength shift of 3.6 nm per GO layer. In Figure 2 (a) a micrograph of drop casted GO flakes on the previously mentioned layer stack is shown. Figure 2 (b) shows the corresponding thickness map which was calculated by utilizing the reflectance spectra of a raster scan across an area of 2.25 mm. The thickness is determined by evaluating the spectral position of the reflectance minima for each raster point.

Acknowledgements

Financial support by the DFG via the Research Training Group GRK1896 "In situ microscopy with electrons, X-rays and scanning probes" is gratefully acknowledged.

References

[1] D. Bing, Y. Wang, J. Bai, R. Du, G. Wu, L. Liu, *Opt. Commun.* **406** (2018), 128-138

[2] Z. H. Ni, H. M. Wang, J. Kasim, H. M. Fan, T. Yu, Y. H. Wu, Y. P. Feng, and Z. X. Shen, *Nano Lett.* **7** (9) (2007), 2758-2763

[3] A. Hutzler, C. D. Matthus, M. Rommel, L. Frey, *Appl. Phys. Lett.* **110** (2017) 021909

[4] Stefan Schöche, Nina Hong, Mohammadreza Khorasaninejad, Antonio Ambrosio, Emanuele Orabona, Pasqualino Maddalena, Federico Capasso, *Appl. Surf. Sci.* **421** (2017) 778 - 782

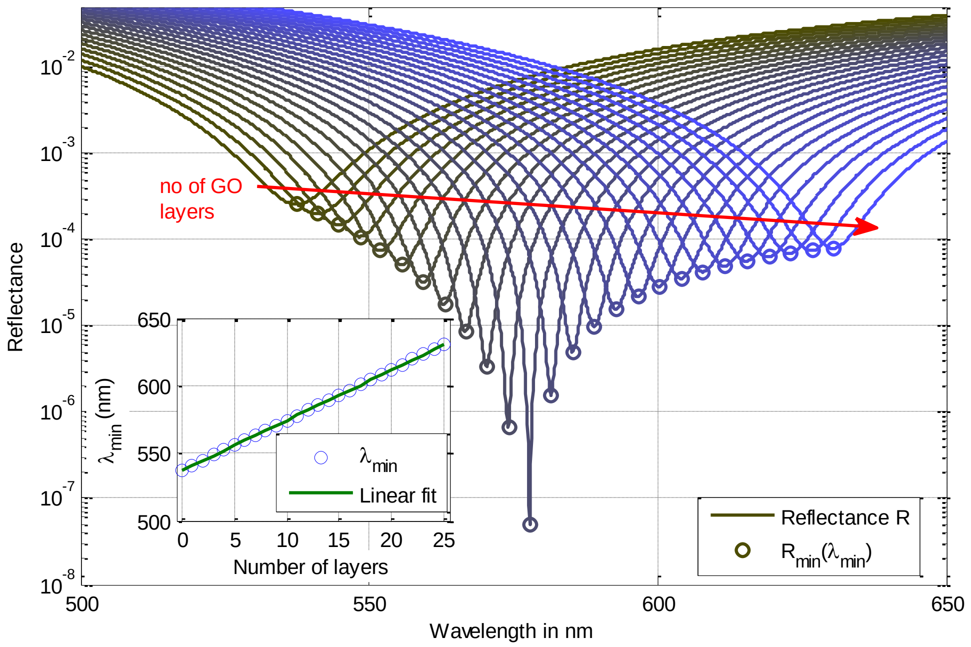
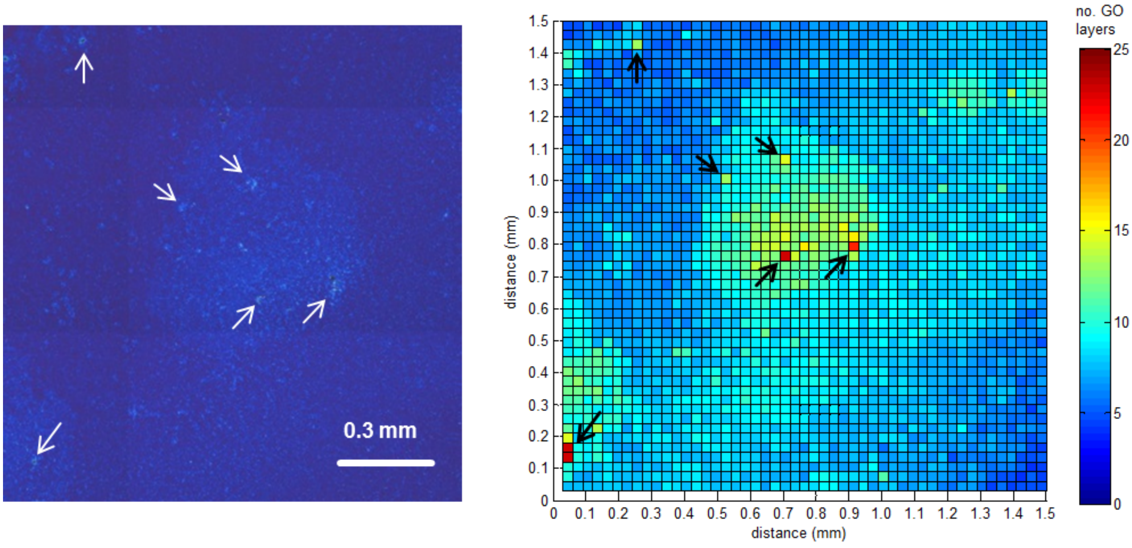


Figure 1. *Calculated reflectance spectra and corresponding minima of GO flakes with 0-25 layers on 54 nm* Si_3N_4 *on 11 nm* SiO_2 *on silicon substrate. Inset shows the linear wavelength shift with increasing number of GO layers.*



(a)

(b)

Figure 2. *a) optical micrograph of drop casted GO b) corresponding 50 x 50 pt thickness map of the area of 1.5 mm x 1.5 mm, remarkable features are indicated by an arrow in both subfigures. The point resolution is restricted to the spot diameter of 30 m in this particular case. The reflectance spectra from these areas are mean values of smaller features contained therein. This resolution can be enhanced by utilizing different objective lenses which project a smaller spot size onto the specimen.*