 Adv. Opt. Techn. 2022; 11(3–4): 57–58

Editorial

Rüdiger Schmidt-Grund, Chris Sturm and Andreas Hertwig*

Ellipsometry and polarimetry – classical measurement techniques with always new developments, concepts, and applications

https://doi.org/10.1515/aot-2022-0025

Ellipsometry is a matured experimental method, whose roots reach back into the early phase of modern optics itself. It is often attributed to be invented by Paul Drude in the last decade of the 19th century, but similar techniques had already been applied for years before Drude started his work.

The actual term "ellipsometry" is in use since the 1940s. Interestingly, it started in context of a work describing a biological application. It is noteworthy that this was at a time when modern physics of solid phases, especially of semiconducting materials, was expanding rapidly. The ellipsometer was immediately welcomed by the solid state and surface research community as the ability to investigate surfaces, interfaces, and thin layers showed up to be essential. Ellipsometry is a method benefiting much from numerical calculations and modelling concepts. The connection between solid state physics and ellipsometry is an example of a self-strengthening innovation cycle in science and technology. Especially the strong increase in computational power was accompanied with an increase of ellipsometry in research and a rapid expansion of the community. Ellipsometry benefits from microelectronics and digital technology. Vice versa, it enables the development of better electronic devices. The hardware which is the foundation of the digital age would not exist without the development of ellipsometers and their manyfold applications decades earlier.

Ellipsometry is the realisation of polarimetry as a reflection experiment. All polarimetric techniques rely on the measurement of the change in polarisation state of electromagnetic waves upon transmission, reflection, or scattering. Ellipsometry is extremely sensitive towards thin layer properties through its ability to detect phase shifts. In ellipsometry, the change of a probe light's polarization state is measured, giving access to the Jones or Mueller Matrix of a sample. By model analysis of the experimental data by means of transfer-matrix techniques, information on sample structure and the optical response functions (the complex dielectric tensor and even the optical gyration tensor) of the sample's constituting materials can be derived. This way, the properties of very thin layers are accessible, together with structural information of layers and bulk phases. The advantages of ellipsometry and polarimetry are widely known: the relative ease of use as a measurement scheme, combined with unprecedented sensitivity to tiny changes in optical properties and structure, especially of the surface. The short measurement times make ellipsometry suitable for large-scale scanning and imaging as well as routine quality assessment.

The ellipsometry community has always been connected by their common methods, searching for new fields of applications, driven by better theoretical understanding and analysis capabilities. Ellipsometry has made the development from monochromatic to full variable angle-of-incidence spectroscopic measurements and to full Mueller-Matrix representation of the polarimetric data. The current development moves the method from single point measurements and scanning to full imaging. Today, the spectral range has expanded up the edge of soft X-rays to the THz radiation regime without significant gaps. The basic concepts and analysis methodologies are very similar over this wide spectral range, bridging the otherwise very diverse respective research fields as a strong unifying power of the polarimetry community. Contemporarily, data science driven methods and modelling-free approaches are on the horizon, providing new analytical opportunities for the easily obtainable large amounts of difficult to analyse data available today.

With this Special Issue about ellipsometry and related techniques, we hope to bring more attention to this method and advance and propagate it to be used by a broader

***Corresponding author: Andreas Hertwig**, Bundesanstalt für Materialforschung und -Prüfung (BAM), FB 6.1: Oberflächenanalytik und Grenzflächenchemie, Berlin, Germany,
E-mail: andreas.hertwig@bam.de
Rüdiger Schmidt-Grund, Technische Universität Ilmenau, Institut für Physik, Ilmenau, Germany,
E-mail: ruediger.schmidt-grund@tu-ilmenau.de
Chris Sturm, Universität Leipzig, Felix-Bloch Institut für Festkörperphysik, Leipzig, Germany,
E-mail: csturm@physik.uni-leipzig.de

community. We have collected a good mixture of articles: some texts are more in the line of users' tutorial and best practice guides; others are intended to show recent developments of the method. With this collection, we also hope to show the generally rapidly expanding possibilities of ellipsometry and polarimetry to draw attention of new users and previously unrelated communities to this valuable tool.

Bionotes

Rüdiger Schmidt-Grund
Technische Universität Ilmenau, Institut für Physik, Ilmenau, Germany
ruediger.schmidt-grund@tu-ilmenau.de

Rüdiger Schmidt-Grund received his PhD (Dr. rer. nat., 2007) from Universität Leipzig, Germany. From 2007 to 2019 he was workgroup leader for optics within the semiconductor physics group at the Felix Bloch Institute for Solid State Physics of Universität Leipzig. Since 2019 he is scientific senior staff at Institute of Physics at Technische Universität Ilmenau and since his habilitation in 2020 Privatdozent ibid. His research is focused on the dielectric function of a wide variety of materials, especially its ultrafast dynamics studied by fs-time resolved ellipsometry; as well as on microcavities of various dimensions, their topology and emerging coherent light-matter states. He has published over 100 papers with an h-index of 26 (ISI). He is a member of DPG and German Association on Ellipsometry AKE-Paul Drude e.V.

Chris Sturm
Universität Leipzig, Felix-Bloch Institut für Festkörperphysik, Leipzig, Germany
csturm@physik.uni-leipzig.de

Chris Sturm received his doctoral degree in 2011 from Universität Leipzig (Germany). During his stay at the Laboratoire de Photonique et de Nanostructures (LPN/CNRS) in Marcoussis (France) in 2011/2012 and 2013, he continued his research on light-matter coupling in microcavities. In 2014, he returned back to Universität Leipzig. Besides the study of light-matter coupling, his research is focused on the optics of optically uniaxial and biaxial materials and confined systems, especially their dielectric function and related properties like the presence of exceptional points and Voigt waves. He is member of DPG and German Association on Ellipsometry AKE-Paul Drude e.V.

Andreas Hertwig
Bundesanstalt für Materialforschung und -Prüfung (BAM), FB 6.1: Oberflächenanalytik und Grenzflächenchemie, Berlin, Germany
andreas.hertwig@bam.de

Dr. Andreas Hertwig studied Chemistry in Karlsruhe, specialising in Physical and Theoretical Chemistry. He worked on his PhD thesis in 1998 – 2002. In the group of Prof. Horst Hippler, he investigated the ultrafast dynamics of excess electron systems in ionic and polar liquids using femtosecond laser spectroscopy. He then joined the group of Prof. Wolfgang Kautek at BAM in Berlin. His work there was on laser safety and laser surface materials processing using ultrashort laser pulses. Andreas Hertwig was offered a junior scientist position at BAM in 2003 and joined the group of Dr. Uwe Beck. From this point on, his focus was on optical spectroscopic analytics of surfaces and thin films. He is author of numerous articles on spectroscopic ellipsometry and its use in the analytics of complex thin layers. Recently, the focus of his work is on traceability and accuracy in ellipsometry and its use in a standardised way to enable it as a quality assurance tool in the production of thin layer systems. Recent works include the ellipsometric analysis of electronic devices, hybrid metrology, and the use of plasmonic systems in such applications as gas sensing. Andreas Hertwig is member of the board of the AKE, the German society for ellipsometry. He has been co-organiser of several events in this field, including the ICSE-7 in Berlin as the editor of the proceedings.