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ALTECH 2024 – Analytical Techniques for Precise Characterization of Nano Materials

Luca Boarino, Fernando Araujo de Castro, Georges Favres, Adrian Jonas, and Burkhard Beckhoff

In the present issue of *physica status solidi (a)* readers will find 12 articles presented by participants of ALTECH 2024 ("Analytical techniques for accurate nanoscale characterization of advanced materials"), held as Symposium L at the 2024 E-MRS Spring Meeting. The ALTECH symposium series brings together scientists and engineers from metrology institutes, research labs, and industry to share advances in nanoscale analysis. Nanostructured materials are central to many technologies and accurate characterization at the nanometer scale is essential for controlling their properties and performance. ALTECH 2024 focused on emerging methods and instruments for nanoscale analysis, including *in situ* and multimodal techniques. The contributions in this Special Issue illustrate a broad range of innovative approaches and applications in nanoscale metrology. The 2024 E-MRS Spring Meeting took place in Strasbourg from 27 to 31 May. The Symposium was organised by NPL, PTB, CEA and INRIM - four major European national metrology institutes.

Advanced materials often exhibit unique properties due to their extremely small size. These functional nanomaterials are vital components in a wide range of modern technologies, including those involved in energy conversion and storage, quantum devices, sensors and power electronics. To drive innovation and understand the potential health and environmental impacts, it is essential to accurately characterize these materials at the nanoscale. The ability to measure the relevant properties of advanced materials with nm resolution in three dimensions over large areas and traceable to SI units is crucial for nanoscale metrology.

Collectively, the 12 contributions in this Special Issue span a rich array of analytical techniques - from X-ray spectroscopy and scattering, through optical nanoscopy, to advanced scanning prove microscopy (SPM) - all applied to the accurate characterization of nanomaterials. The papers highlight emerging experimental methods such as in situ/operando XAS, reverse-tip SPM, AI-based analysis as well as metrological developments of calibration standards for C-AFM and SMM, and EXAFS-based thermometry. Each article addresses specific challenges yet together they advance the common goal of improving nanoscale measurement precision and reliability. These advances are valuable not only for fundamental research but also for industrial applications requiring rigorous nanoscale quality control.

The importance of the area of metrology for nanomaterials and nanotechnologies has attracted a broad community to ALTECH 2024, which was the 4th most attended symposium from EMRS Spring Meeting 2024 (from a total of 23 symposia). During 5 days of conference, 179 papers were presented (12 invited, 72 oral, 95 posters), with contributions from 24 different countries. In addition to presentations from world leading scientists and engineers, the symposium also pro-actively sought to provide a platform for PhD students and early career scientists to interact. Demonstrating its commitment to scientific recognition, ALTECH provided six prizes for best poster presentations, two of which were kindly sponsored by EXSA. They also supported emerging talent by granting two EMRS Young Researcher Awards. We thank all authors for their high-quality contributions and the ALTECH organizing committee for assembling this stimulating set of works. We are confident that readers will find in these papers both technical insights and inspiration, and that the demonstrated methodologies will help future developments in nanoscale materials characterization.

We would also like to acknowledge the support of the European Union through the European Metrology Programme for Innovation and Research (EMPIR) and European Partnership on Metrology projects 20IND09 PowerElec, 19ENV08 AEROMET II, 20FUN06 MEMQuD and 21GRD01 OpMetBat, as well from the European Metrology Network on Advanced Manufacturing. These projects have received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 and Horizon Europe research and innovation programme.

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Luca Boarino is Technology Director at INRiM (Istituto Nazionale di Ricerca Metrologica). He started his work on phothermal spectroscopy in semiconductors, porous silicon and on gas doping in silicon nanostructures. His research interests are related to nanofabrication, self-assembly and silicon nanowires. Between 1998 to 2007 he contributed to clarify the interaction mechanisms between silicon nanostructures and nitrogen dioxide. Since 2009 he is founder and responsible of the Nanofacility Piemonte INRiM, a nanofabrication laboratory by electron and ion beams. He is the Italian representative of VAMAS, the Versailles Project on Advanced Materials Standardisation. He is author of more than 190 international publications.

Fernando Araujo de Castro is Department Head of Science at the National Physical Laboratory, UK, leading work on metrology for advanced materials semiconductors. He is also a visiting Professor at the Advanced Technology Institute, University of Surrey, the UK representative of VAMAS, the current Chair of the European Metrology Network on Advanced Manufacturing, providing high level coordination of metrology in Europe. His research interests include innovation in measurement techniques, emerging semiconductor materials, SPM optical techniques, best practice standards.

Georges Favres was the Director of the LNE Nanotech Institute at the Laboratoire National de métrologie et d'Essais (LNE), in France. He is involved in numerous networks initiatives dealing with Advanced Materials characterisation/metrology, standardisation, safety regulation topics. Currently, he is Development Manager for FX-CONSEIL, École Polytechnique, France.

Adrian Jonas joined the X-ray Spectrometry group at the Physikalisch-Technische Bundesanstalt (PTB) in 2022. Prior to this, his research at the University of Berlin focused on time-resolved X-Ray absorption spectroscopy using laser-produced plasma sources. At PTB, he specializes in the operando characterization of battery materials and the development and application of polarization-dependent resonant inelastic X-Ray scattering instrumentation.

Burkhard Beckhoff leads the X-ray Spectrometry group at the Physikalisch-Technische Bundesanstalt (PTB). The group's primary objective is to establish traceable characterization techniques for advanced materials at both the nano- and microscales. Utilizing calibrated instrumentation, X-ray spectrometry enables elemental and species analysis along with complementary dimensional information. Further work focuses on qualifying operando analysis methods for batteries and developing calibration samples for external methods.

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