COST Action CA20116

OPERA

European Network for Innovative and Advanced Epitaxy

International Hybrid Training School

University of Aveiro, Portugal

13th to 17th June 2023

Characterization Techniques for Epitaxial Materials

Organized by:

Paula Ferreira | University of Aveiro, CICECO, PT

Maxim Ivanov | University of Aveiro, CICECO, PT

Paula M. Vilarinho | University of Aveiro, CICECO, PT

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ciceco aveiro institute of materials

cost EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Funded by the Horizon 2020 Framework Programme of the European Union

Welcome to the OPERA International Hybrid Training School on Characterization Techniques for Epitaxial Materials!

We are delighted to have you at the University of Aveiro in Portugal from the 13th to the 17th of June 2023. This training school aims to provide a comprehensive platform for PhD students to explore the intricate world of epitaxial material characterization techniques.

Over the course of this event, you will have the opportunity to engage in insightful discussions, attend lectures by renowned experts in the field, and participate in hands-on workshops that will enhance your understanding of the latest advancements in epitaxial materials characterization. The diverse range of topics covered will encompass various characterization techniques, including spectroscopy, microscopy, and structural analysis, among others.

The University of Aveiro, known for its strong research background and commitment to academic excellence, is the perfect setting for this training school. Nestled in the charming city of Aveiro, with its picturesque canals and vibrant culture, you will find an enriching and inspiring environment to expand your knowledge and network with fellow researchers.

We encourage you to actively participate in all the activities and take advantage of the opportunities for collaboration and knowledge exchange. The OPERA International Hybrid Training School is not only a platform to learn and acquire new skills but also a chance to foster new connections and develop lasting collaborations with like-minded individuals from around the world.

Before finishing, we would the like to thank all who help on the organization of this school, namely Speakers, Technical Staff and Entities, namely the OPERA COST Action 20116, University of Aveiro, FCT (CICECO projects UIDB/50011/2020, UIDP/50011/2020 & LA/P/0006/2020), Dias de Sousa Lda., NenoVision, Demcon TSST and NT-MDT.

Once again, we extend a warm welcome to you and wish you a productive and fulfilling experience at the OPERA International Hybrid Training School on Characterization Techniques for Epitaxial Materials.

We hope you enjoy your stay in Aveiro and contribute to the advancement of this exciting field.

Paula Ferreira, Maxim Ivanov and Paula M. Vilarinho

DAY 1 **Tuesday, 13th June 2023**

14:00 REGISTRATION AT DEPARTMENT OF MATERIALS AND CERAMICS ENGINEERING

14:30 WELCOME (NETPORE meeting room)

- **Paula Ferreira** | University of Aveiro, CICECO, PT - Organizer
- **Maxim Ivanov** | University of Aveiro, CICECO, PT – Organizer
- **Paula M. Vilarinho** | University of Aveiro, CICECO, PT - Organizer
- **Yamina André** | Institut Pascal, Université Clermont Auvergne, FR – Scientific Great Holder of COST OPERA Action 20116

15:00 TRANSMISSION ELECTRON MICROSCOPY OF THIN FILMS AND 2D MATERIALS

Paulo J. Ferreira | International Iberian Nanotechnology Laboratory (INL), Braga, PT

16:30 REFRESHMENT & POSTER SESSION

17:00 THE IMPACT OF MATERIALS GROWTH IN DEVICE PERFORMANCE AND SCALABILITY

Susana Cardoso de Freitas | INESC-Microsystems and Nanotechnologies, Instituto Superior Técnico, Lisboa, PT

18:30 2 minutes PITCH

19:15 DINNER (Students' Restaurant) - FREE

9:00 DIFFRACTION TECHNIQUES

José António de Carvalho Paixão | University of Coimbra, Department of Physics, Coimbra, PT

10:30 REFRESHMENT & POSTER SESSION

11:00 X-RAY METROLOGY OF EPITAXIAL GROUP-III-NITRIDES FOR DEVICE FABRICATION

Lutz Kirste | Fraunhofer Institute for Applied Solid State Physics, Freiburg, DE

12:30 LUNCH BREAK (Students' Restaurant)

14:00 HANDS ON CASE STUDIES USING DIFFRACTION TECHNIQUES

José António Paixão | University of Coimbra, Department of Physics, Coimbra, PT

Lutz Kirste | Fraunhofer Institute for Applied Solid State Physics, Freiburg, DE

15:30 REFRESHMENT & POSTER SESSION

16:00 VISIT TO THE LABORATORIES (XRD+TEM)

18:30 2 minutes PITCH

19:15 DINNER (Students' Restaurant) - FREE

9:00 OPTICAL CHARACTERIZATIONS OF EPITAXIAL MATERIALS: FROM CRYSTAL DEFECTS TO OPTOELECTRONIC PROPERTIES

Charles Cornet | University of Rennes, INSA Rennes, CNRS, Institut FOTON – UMR 6082, Rennes, FR

10:30 REFRESHMENT & POSTER SESSION

11:00 CHARACTERIZATION OF FUNCTIONAL OXIDES THIN FILMS & HETEROSTRUCTURES USING RAMAN

Joaquim Agostinho Moreira | LaPMET – IFIMUP. Faculdade de Ciências da Universidade do Porto, PT

12:30 LUNCH BREAK (Students' Restaurant)

14:00 CHARACTERIZATION TOOLS ON EPITAXIAL GROWTH CONTROL

Armando Lourenço | CICECO, University of Aveiro, PT

Ricardo Silva | CICECO, University of Aveiro, PT

15:30 REFRESHMENT & POSTER SESSION

16:00 VISIT TO THE LABORATORIES (PVD, Optics, Raman, Magnetics)

19:30 REFRESHMENT AND NETWORKING

9:00 ASSESSING NANOSCALE (OPTO)ELECTRONIC PROPERTIES THROUGH ADVANCED SPM

Sascha Sadewasser | International Iberian Nanotechnology Laboratory **(**INL), Braga, PT

10:30 REFRESHMENT & POSTER SESSION

11:00 SCANNING TUNNELING MICROSCOPY AND RELATED SPECTROSCOPIES IN EPITAXY MATERIALS

Lucia Vitalia | University of Basque Country, Centro de Fisica de Materials, San Sebastian, ES

12:30 LUNCH BREAK (Students' Restaurant)

14:00 SCANNING PROBE MICROSCOPY OF EPITAXY OF METAL COMPLEX OXIDES

Alexander Tselev | University of Aveiro, Department of Physics, Aveiro, PT

15:30 REFRESHMENT & POSTER SESSION

16:00 VISIT TO THE LABORATORIES (AFM) + ADVANCED SPM TECHNICAL SESSION I (AFM-in-SEM LiteScope)

DEMCON | TSST NenoVision Dias de Sousa

19:15 DINNER (Students' Restaurant) - FREE

9:00 PIEZORESPONSE FORCE MICROSCOPY IN EPITAXIAL MATERIALS

Vladimir V. Shvartsman | University of Duisburg-Essen, Institute for Materials Science, DE

10:30 REFRESHMENT

11:00 PRATICAL ANALYSIS OF COMBINED AFM AND MICRORAMAN

Timur Nikitin | University of Coimbra, LCBM, PT

Maxim Ivanov | University of Aveiro, CICECO, PT

12:30 LUNCH BREAK (Students' Restaurant)

14:00 ADVANCED SPM - TECHNICAL SESSION II

NenoVision Dias de Sousa

15:30 REFRESHMENT

16:00 ADVANCED SPM - TECHNICAL SESSION II

NT-MDT Spectrum Instruments

19:15 DINNER (Students' Restaurant) - FREE

Organizers

Paula Ferreira | University of Aveiro, CICECO, PT

Paula Ferreira is a Coordinator Researcher at the University of Aveiro, CICECO – Aveiro Institute of Materials. She has been awarded so far over 2000 k€ in career income for engineering research; she has been Principal and Co-Investigator on more than 15 research project awards and 8 projects with industry. She is(has) supervising(ed) or co-supervising(ed) 14 Post-doctoral fellows, 16 PhD, 28 MSc and 30 last year project students and more that 15 initial research fellows. She published over 148 scientific papers, with more than 2810 citations (h-index 33). She participated in over 110 international conferences delivering more than 60 oral presentations. She is/was involved in 4 FCT-CNRS and 1 Pessoa bilateral cooperation agreements and 13 COST actions (1 as working group leader, 1 as science communication coordinator, 5 as participant of the working groups, 5 as member of the management committee and 1 as workgroup leader). She has been collaborating with several Portuguese Researchers and foreigner Researchers within Europe. She participated on the organizing committee of 10 International Scientific Meetings on Materials Science topics. The research interests involve the synthesis, structural and physical characterization, and processing of functional and ordered porous materials for microelectronics and energy applications by bottom-up approaches. She is also interested in sustainable functional bionanocomposites for flexible devices applications. She was awarded as one of the “100 Portuguese Women in Science in 2023”.

Maxim Ivanov | University of Aveiro, CICECO, PT

Maxim Ivanov is a researcher at CICECO - Aveiro Institute of Materials and Department of Materials and Ceramic Engineering (DEMaC), University of Aveiro. He is an expert in nanotechnology and materials/physics science. His main scientific activities imply advanced piezo- and ferroelectric materials, with a particular focus on measuring interface forces arising in epitaxial and multilayer materials. For this purpose, Maxim Ivanov has developed magnetoelectric and non-contact electromechanical methods for Atomic Force Microscopy approach. This yielded a patent and commercialized mode with an industrial partner, NT-MDT (https://www.ntmdt-si.com/resources/applications/hybrid-piezoresponse-force-microscopy). The results obtained by using this method were published in a high-impact journal, for example in Science 367 (6478), 671-676, 2020. Currently, Maxim Ivanov leads the project BioMEMs “Advanced BioMEMs for tissue engineering: applications in hard tissue” bringing the idea to study the interactions of bioactive materials (including molecularly engineered – a natural aspect of epitaxy) with osteoblast cells. He is a member of FEMS and Portuguese Society of Materials (SPM) (ID#1041), MRS and European Material Research Society (EMRS) (ID #11079677), Marie Curie Alumni Association (Spain-Portugal chapter), and DAAD Alumni Association.

Paula M. Vilarinho | University of Aveiro, CICECO, PT

Paula M. Vilarinho holds a PhD in Materials Science and Engineering from the University of Aveiro (UA). She is a Professor in the Department of Materials and Ceramics Engineering (DEMaC) at the UA.

Currently, she is Deputy Director of CICECO-Associated Laboratory, CICECO – Aveiro Institute of Materials, UA. She is a member of the Executive Board of the European Materials Federation (FEMs) and a board member of the Portuguese Materials Society (SPM). She is director of the UA Masters in Additive Manufacturing, member of the Board of DEMaC, UA. She is the leader of the Electroceramic Research Group at CICECO.

Her research includes synthesis, properties and processing of functional materials for electronics, microelectronics and applications as sensors and actuators, energy stores, tunable dielectrics, among others and, more recently, for biocompatible piezoelectric platforms for tissue growth. Sustainability of materials and processes, development of alternative processes leading to the decarbonisation of the industry, namely the ceramic industry and additive manufacturing are also a common denominator of its R & D. She published more than 350 scientific works. Cooperation and knowledge sharing through R&D with industry is common practice. She coordinates several cooperation projects. Exploration the creation of value for her investigation. In parallel, she has always been involved in actions to raise public awareness and understanding of materials science and engineering and its importance. She was distinguished with the “Stimulus to Excellence” award from the Foundation for Science and Technology (FCT), in February 2007. More recently, her profile and scientific career were distinguished in the book Successful Women Ceramic and Glass Scientists and Engineers: 100 Inspirational Profiles ” by Lynnette Madsen, Willey, 2016. Her contribution to Science was highlighted in the “Women in Science” project, a tribute to Portuguese women scientists and a Ciência Viva project (March 2023).

Invited Speakers

Paulo J. Ferreira | International Iberian Nanotechnology Laboratory (INL), Braga, PT

Paulo Ferreira is currently a Full Professor in the Department of Mechanical Engineering at IST, University of Lisbon, Portugal, as well as the Scientific Coordinator of the Advanced Electron Microscopy, Imaging and Spectroscopy Center at the International Iberian Nanotechnology Laboratory (INL), Portugal. He is also an Adjunct Professor at the University of Texas at Austin, USA. Before joining IST and INL in Portugal, he was Robert & Jane Mitchell Endowed Faculty in Engineering and Full Professor at the University of Texas at Austin, USA and the Director of Electron Microscopy at the Texas Materials Institute at the University of Texas at Austin.

He has a Ph.D in Materials Science and Engineering from the University of Illinois, USA and has done his Post-doctoral work at MIT in Materials Science and Engineering.

He concentrates his scientific research in the areas of Materials Science, Nanomaterials and Electron Microscopy applied to alternative energy materials and 2D materials. At the educational level, he teaches graduate courses in Nanomaterials and Nanotechnology, Structure of Materials and Electron Microscopy. In parallel, he has been involved in initiatives with various American and Portuguese institutions in the areas of Education and Higher Education, Systems of Innovation, and Science and Technology.

He is co-author of three books, namely “Materials 2000”, IST Press, 2003, “Investing in the Future: University-Industry Collaborations in USA and Portugal”; and “Nanotechnology for Architects, Designers and Engineers” with co-authors D. Schodek (Harvard University) and Michael Ashby (University of Cambridge, UK).

He is also the author of more than 220 scientific articles published in international journals, conference proceedings and book chapters. Prof. Ferreira has also acted as a special advisor to the Minister of Economics and Innovation, Portugal, on Government Strategy for Science & Technology, and he is part of the Selection Nomination Committee of the Japan Prize. He is also one of Area Directors of the UT Austin-Portugal Program and the Vice-President of the Portuguese Society for Microscopy.

Susana Cardoso de Freitas | INESC-Microsystems and Nanotechnologies, Instituto Superior Técnico, Lisboa, PT

Susana Cardoso de Freitas received the Ph.D. degree in Physics by the Instituto Superior Técnico, Universidade de Lisboa in 2002 and since then is the leader of INESC-MN Spintronics and Magnetic Biosensors Group.

She has extensive experience as principal researcher in collaborative projects developing advanced materials, sensors, and integrated systems in microelectronics. As an Associate Professor in the Physics Department, she is responsible for student coordination and advanced training in spintronics, microelectronics and microfabrication.

She is a co-author of more than 300 articles, 25 book chapters and manages several technology-transfer contracts with industry worldwide related to magnetic sensors. She is a IEEE Distinguished Lecturer for 2023.

José António de Carvalho Paixão | University of Coimbra, Department of Physics, Coimbra, PT

Born in 1965, graduated in 1987 in Physics, got his PhD in Solid State Physics in 1994 at the University of Coimbra (UC), Portugal.

Full Professor of Physics at UC since 2005. Former director of CEMDRX (X-Rays Diffraction Centre for Materials Research), he is currently the Director of CFisUC (Centre for Physics of the University of Coimbra), coordinator of the thematic line on Multifunctional Materials and head of the TAIL-UC (Trace Analysis and Imaging Laboratory) analytical facility.

President of the Portuguese Physical Society (SPF) since 2022.

Has authored or co-authored more than 300 publications indexed in the WoS, mainly in the fields of condensed-matter physics, chemical-physics and chemical crystallography, that have attracted more than 4000 citations. He has been strongly involved in science outreach, having created and steered the Quark!-school on physics for talented high school students. He was the chairman of the IPhO2018-International Physics Olympiad, that took place in Lisbon in 2018.

He is an expert on diffraction techniques applied to condensed matter (XRD, synchrotron radiation, elastic and inelastic neutron scattering). He has served as Portuguese representative in the European Synchrotron Radiation Facility (ESRF) council and Science Advisory Committee.

Current research topics include, multiferroic materials, exotic superconductivity, chiral magnets and topological insulators.

Lutz Kirste | Fraunhofer Institute for Applied Solid State Physics, Freiburg, DE

Lutz Kirste received his Dipl. Min. and Ph.D. degrees with honors from the RWTH Aachen University and the University of Freiburg, Germany, in 1998 and 2003, respectively.

Since 2001, he has been a research associate at the Fraunhofer Institute for Applied Solid State Physics in Freiburg, Germany, and head of the structural and chemical analysis group.

His research focuses on the structural and chemical characterization of compound semiconductor and diamond thin films and substrate materials by X-ray diffraction and secondary-ion mass spectrometry.

Since 2022 he is deputy head of the epitaxy department. From 2014 to 2020, he was a guest lecturer at the University of Freiburg, where his teaching was on high-resolution X-ray diffraction of thin films. (Publications: >200, citations: > 3700, h-index: 33 (according to Google Scholar)).

Charles Cornet | University of Rennes, INSA Rennes, CNRS, Institut FOTON – UMR 6082, Rennes, FR

Charles Cornet (Prof., Hab.) is head of the "Optoelectronics, Heteroepitaxy and Materials" (OHM) research team at Institut FOTON (France). After studies of fundamental physics in University Paris-Saclay, he pursued a PhD thesis on optoelectronic properties of semiconductor quantum dots within European networks of excellence.

In 2007 he became Ass. Prof. at Institut FOTON, focusing on the monolithic integration of III-V semiconductors on Silicon. In 2017, he took the responsibility of the OHM research team, whose activities focus on materials and devices for photonics and energy applications, including group III-V, group IV semiconductors and hybrid perovskites.

In 2020 he obtained a full professor position at Institut FOTON (INSA Rennes). Specialist of growth, structural, and optoelectronic properties of III-V semiconductors and their integration on Si, C.

Cornet authored or co-authored more than 100 publications/proceedings, one book, one book chapter and more than 150 contributions in international conferences. He is presently working on III-V/Si hybrid combination of materials for non-linear photonics and energy harvesting applications, such as solar hydrogen production or photovoltaics.

Joaquim Agostinho Moreira | LaPMET – IFIMUP. Faculdade de Ciências da Universidade do Porto, PT

Joaquim Agostinho Moreira completed his Habilitation in October 2013 at the Faculty of Sciences, University of Porto. He obtained his PhD in 2000 from the same institution. His doctoral studies were conducted at the Faculty of Sciences, University of Porto, between 2000 and 2007. In 1995, he completed his Master's degree in Optoelectronics and Lasers at the Faculty of Sciences, University of Porto. Additionally, he holds a Bachelor's degree in Physics - specializing in Solid State Physics and Materials Science - which he obtained in 1992 from the Faculty of Sciences, University of Porto.

Currently, Joaquim Agostinho Moreira serves as an Assistant Professor at the Department of Physics and Astronomy, University of Porto.

He has published over 150 articles in international scientific journals and has received one award and/or honor for his work. His research primarily focuses on Condensed Matter Physics within the field of Physical Sciences. Throughout his professional career, he has collaborated with 118 colleagues, co-authoring scientific papers with them.

Armando António Cardoso Dos Santos Lourenço | University of Aveiro, CICECO, PT

Armando Lourenço completed his undergraduate studies in Physics at the University of Porto in 1990. He further pursued his passion for research and obtained his Ph.D. in Physics from the same institution in 1995. Following his doctoral studies, he began his academic career as a Guest Assistant Professor at the University of Aveiro from 1995 to 1996. Since then, he has been serving as an Assistant Professor at the University of Aveiro. Throughout his career, Dr. Lourenço has supervised 7 Master's and 1 PhD. students, nurturing their scientific growth and fostering their research endeavors. His research output is commendable, with 39 articles published in scientific journals, 10 articles in conference proceedings and 1 patent.

Some selected publications include:

"The growth of (110) YBaCuO thin films and their characterization by optical methods", Habermeier, H.-U.; Lourenço, A.A.C.S.; Friedl, B.; Kircher, J.; Köhler, J., Solid State Communications 77 9 (1991): 683-687.

“Giant Strain and Induced Ferroelectricity in Amorphous BaTiO3 Films under Poling”, Pegah Mirzadeh Vaghefi, Ali Baghizadeh, Armando A.C.S. Lourenço, Vitor S. Amaral and Andre L. Kholkin, Materials 2017, 10, 1107; doi:10.3390/ma10091107

“Effect of lattice mismatch on the magnetic properties of nanometer-thick La0.9Ba0.1MnO3 (LBM) films and LBM/BaTiO3/LBMheterostructures”, P. Mirzadeh Vaghefia, A. Baghizadehb, M. Willingerc, A.A.C.S. Lourenco, V.S. Amaral, Applied Surface Science 425 (2017) 988–995, http://dx.doi.org/10.1016/j.apsusc.2017.06.252 0169-4332

“Ultrathin Mg metalic oxygen barrier diffusion applied to Si-based components and microelectronics devices”, Armando Santos Lourenço and Erwan Yann Rauwel, WO/2011/070398, PCT/IB2009/055667.

Ciência ID: 7B15-5AE1-EB22

ORCID ID: 0000-0002-4874-1575

Scopus Author ID: 7005749861

Ricardo Silva | University of Aveiro, CICECO, PT

Ricardo Silva received his PhD in Materials Science and Engineering at University of Aveiro in 2017. His doctoral thesis focused on novel heterostructures fabrication based on atomic layer deposition (ALD) approaches for supercapacitors electrodes materials.

His current research focuses on developing organic-inorganic hybrid thin films by atomic/molecular layer deposition (ALD/MLD) for energy transfer and conversion, as well as rational design of interfaces and multifunctional materials based on carbon nanotubes and metal oxides.

Sascha Sadewasser | INL, Braga, PT

Dr. Sascha Sadewasser is the Principal Investigator of the Laboratory for Nanostructured Solar Cells at INL – International Iberian Nanotechnology Laboratory.

The group of Sascha works on the development of advanced solar cell materials and devices implementing nano- and microstructures. Additionally, scanning probe microscopy methods, especially Kelvin probe force microscopy, are developed and applied for the characterization of the optoelectronic nanostructure of solar cell materials. The group also works on 2D chalcogenide materials and other energy-related materials.

Sascha Sadewasser holds a Diploma (1995) in Physics from the RWTH Aachen, Germany and a PhD (1999) from the Washington University St. Louis, MO, USA. After 2 post-docs in Berlin (Hahn-Institute) and Barcelona (Centro Nacional de Microelectrónica), he became group leader and later deputy department head at the Helmholtz-Zentrum Berlin, Germany. After his Habilitation in Experimental Physics from the Free University of Berlin, Germany (2011) he joined INL in 2011.

Sascha has published more than 130 peer-reviewed papers (incl. Nature Communications, Physical Review Letters, and Advanced Energy Materials), with about 3600+ citations (h-index 35, web of science). He has published 5 book chapters and 2 books and has been granted 3 patents.

He has participated in and coordinated several European and international collaboration projects and is a member of several scientific committees and evaluation boards.

Lucia Vitali | University of Basque Country, Centro de Fisica de Materials, San Sebastian, ES

Lucia Vitali is an Ikerbasque research professor and visiting professor at the University of Basque Country UPV/EHU in San Sebastian, Spain since 2009. With expertise in experimental physics, her research focuses on the field of experimental surface science, specifically in the areas of scanning tunneling microscopy (STM) and spectroscopy (STS), inelastic electron tunneling spectroscopy (IETS), and the growth of metals and molecules on metallic and semiconducting substrates.

In 2000, Lucia Vitali served as a research associate and group leader at the Max-Planck Institute for Solid State Research in Stuttgart. Prior to that, she held the position of research associate at the Institute for Experimental Physics at Karl-Franzens University in Graz, Austria. She obtained her Ph.D. in experimental physics from Karl-Franzens University in Graz in 1997, following a postgraduate fellowship at the same university.

Lucia Vitali's contributions to the field have been recognized through grants, awards, and leadership roles. She leads the "Spectroscopy at Atomic Scale" group and has participated in numerous granted projects. Her outstanding research achievements during her Ph.D. studies led to the prestigious Max-Auwaerter prize awarded by the Max-Auwaerter Foundation in Balzers. She was also honored with the Auwärter prize in 2002 for her exceptional work on adsorbate on surfaces during her Ph.D. studies.

Lucia Vitali is actively involved in teaching and is affiliated with the Master in Nanoscience program at UPV/EHU. She is fluent in English, proficient in German, and has a good command of Spanish and Italian.

Alexander Tselev | University of Aveiro, CICECO, PT

Alexander Tselev obtained his Ph. D. degree in Materials Science in 2000 from Dresden Technical University (Germany).

Currently, he is a Principal Researcher at the University of Aveiro in Portugal. Before joining the University of Aveiro in 2016, he was a Joint Faculty Research Assistant Professor at the Oak Ridge National Laboratory and the University of Tennessee in the USA (2009-2015).

He has co-authored to date about 140 articles in peer-reviewed journals, co-edited 1 book, and holds one patent.

His works were cited multiple times on major science news WWW-portals. His most recent research was focused on the development and applications of various scanning probe microscopy modalities for nanoscale functional characterization of materials and devices. He has made major contributions to near-field microwave microscopy, piezoresponse force microscopy, and scanning tunneling microscopy of complex oxides.

His current research includes also the physics of nanoscale phase transitions and heat transport, materials for information storage and energy storage and conversion.

In 2017, he was a recipient of Tan Chin Tuan Exchange Fellowship in Engineering from Nanyang Technological University, Singapore. Alexander Tselev is a Senior Member of IEEE.

Vladimir V. Shvartsman | University of Duisburg-Essen, Institute for Materials Science, DE

Dr. Vladimir V. Shvartsman is a highly accomplished researcher and lecturer in the field of Materials Science, currently affiliated with the University of Duisburg-Essen's Institute for Materials Science in Germany. He completed their Habilitation in Materials Science at the University of Duisburg-Essen in 2015. His habilitation thesis focused on the "Investigation of polar structures in relaxor ferroelectrics by piezoresponse force microscopy," showcasing their expertise in understanding the intricate properties of these materials. In 2000, Dr. Shvartsman obtained a Ph.D. in Physical Chemistry from the L.Ya. Karpov Institute of Physical Chemistry in Moscow, Russia. Prior to their Ph.D., he graduated with distinction in Solid State Physics from the Moscow Engineering Physical Institute in 1995.

Dr. Shvartsman has been a lecturer and senior researcher at the Faculty of Engineering, Institute for Material Science at the University of Duisburg-Essen since November 2009. From 2005 to 2009, Dr. Shvartsman worked as a researcher at the Department of Physics, Applied Physics at the University of Duisburg-Essen. He also gained valuable experience as a postdoctoral researcher at the Department of Ceramic and Glass Engineering, University of Aveiro in Portugal from 2001 to 2004. His research journey began in 1995, where he worked as a Ph.D. student, junior researcher, and researcher at the Laboratory of Oxide Materials, L.Ya. Karpov Institute of Physical Chemistry in Moscow, Russia, until 2001. His research interests revolve around functional materials with properties such as ferroelectricity, piezoelectricity, and electrocaloric effects. He has specialized in investigating the nanoscale properties of these functional materials using advanced scanning probe microscopy techniques. Additionally, his research explores multiferroic materials, focusing on the coupling between polar and magnetic subsystems to uncover the magnetoelectric effect and discover new types of magnetoelectric materials. Furthermore, he excel in synthesizing and characterizing composite functional materials, contributing to the development of materials with tailored properties for various applications.

Dr. Shvartsman has authored more than 200 papers in peer-reviewed journals and has contributed to five book chapters. His research has been widely recognized, with an h-index of 42 and a significant number of total citations exceeding 5000. In addition to his research endeavors, Dr. Shvartsman has supervised and co-supervised numerous Ph.D. students, nurturing the next generation of researchers in the field.

Timur Nikitin | University of Coimbra, LCBM, PT

Dr. Timur Nikitin is a researcher at the Laboratory for Molecular Cryospectroscopy and Biospectoscopy (LCBM), Coimbra Chemistry Research Centre, Department of Chemistry, University of Coimbra.

He obtained his Ph.D. degree in Chemistry from the University of Helsinki, Finland, where he studied optical and structural properties of different nanomaterials, including silicon nanocrystals embedded in silica, and carbon nanotubes, by Raman spectroscopy and other optical methods.

His current research interests focus on the areas of FTIR matrix isolation of light-induced conformational changes of organic species, including the modeling of IR spectra by quantum chemical calculations, and Raman spectroscopy of various nano- and epitaxial materials.

Responsible of the visits to the laboratories

Rosário Soares | University of Aveiro, CICECO, PT

Diffraction techniques laboratory

Ana Violeta Girão | University of Aveiro, CICECO, PT

Electron microscopy laboratory

Marta Ferro | University of Aveiro, CICECO, PT

Electron microscopy laboratory

Rute Ferreira | University of Aveiro, CICECO, PT

Photoluminescence laboratory

Armando Lourenço | University of Aveiro, CICECO, PT

PVD and magnetic properties laboratory

Alexander Tselev | University of Aveiro, CICECO, PT

Atomic force microscopy laboratory

Substrate provided by Demcon TSST for the demonstration.

Agenda

	13th June	14th June	15th June	16th June	17th June
9h00		Diffraction techniques José António Paixão	Optical characterization Charles Cornet	Assessing nanoscale (opto)electronic properties through advanced SPM Sascha Sadewasser	Piezoresponse force microscopy in epitaxial materials Vladimir Shvartsman
9h30					
10h00					
10h30		**refreshement & poster session**	**refreshement & poster session**	**refreshement & poster session**	**refreshement**
11h00		X-ray Metrology of Epitaxial Group-III-Nitrides for Device Fabrication Lutz Kirste	Characterization of functional oxides thin films & heterostructures using Raman Joaquim Agostinho	Scanning tunneling microscopy and related spectroscopies in epitaxy materials Lucia Vitali	Pratical analysis of combined AFM and microRaman Maxim Ivanov & Timur Nikitin
11h30					
12h00					
12h30		**Lunch**	**Lunch**	**Lunch**	**Lunch**
13h00					
13h30					
14h00		Hands on case studies using diffraction techniques José António Paixão & Lutz Kirste	Characterization tools on epitaxial growth control Armando Lourenço & Ricardo Silva	Scanning probe microscopy of epitaxy of metal complex oxides Alexander Tselev	Advanced SPM Technical session II
14h30	**Welcome**				
15h00	TEM for thin films and 2D Materials Paulo J Ferreira				
15h30		**refreshement & poster session**	**refreshement & poster session**	**refreshement & poster session**	
16h00		Visit to the laboratories	Visit to the laboratories	Visit to the laboratories + Advanced SPM Technical session I	**refreshement**
16h30	**refreshement & poster session**				Advanced SPM Technical session II
17h00	The impact of materials growth in device performance and scalability Susana Cardoso de				
17h30					
18h00					
18h30	**2 minutes PITCH**	**2 minutes PITCH**			
19h15	**Dinner**	**Dinner**		**Dinner**	**Dinner**
19H30			**refreshment and networking**		

Lecture 1

Transmission Electron Microscopy of Thin Films and 2D Materials

Paulo J. Ferreira[1,2,3]

[1]*INL – International Iberian Nanotechnology Laboratory, Braga, Portugal*

[2]*Mechanical Engineering Department and IDMEC, Instituto Superior Técnico, University of Lisbon, Lisboa, Portugal*

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This lecture will first cover some of the basic principles of transmission electron microscopy, including which microscopes to use for a particular study, an overview of the various lenses, apertures and stigmators available, as well as the difference between TEM and STEM imaging modes. Subsequently, the sample preparation of thin films and 2D materials by FIB/SEM and dry hot transfer, respectively will be discussed. Finally, a myriad of advanced TEM/STEM techniques applied to thin films and 2D materials coupled with EDS/EELS and DPC will be presented, in addition to multislice computational methods.

Lecture 2

The impact of materials growth in device performance and scalability

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Magnetic field sensor innovation - in particular, related with magnetoresistive MR sensors, was driven by the technological push from computers and information storage in the early 1990's. Presently they have a mature and transversal level of implementation in the market, from automotive to biomedical domains. The impressive technological progress in thin film preparation and characterization, combined with nano-microfabrication tools offer presently large spectra for device design. The materials discussed in my lecture include several varieties of thin films: oxide films as tunneling barriers, ultrathin amorphous and crystalline films, ultrathin textured layers with grain size control, magnetically soft layers or antiferromagnetic films – all combined onto multilayer stacks, typically thinner than 40nm in total.
The detection principles, sensor design, simulations and experimental validation will be discussed for exciting applications where MR sensors bring added value over other competing technologies.
During the lecture, I will show examples where spintronic sensors are useful tools for precision sensing, including integration with microelectronics ASIC, microfluidics, optical and MEMS micromachined actuators.

Lecture 3

Diffraction techniques

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A brief introduction to diffraction techniques used for condensed matter and materials science studies, focusing on the X-Ray Diffraction methods that are most useful in the study of thin films.

Topics to be covered:

- Properties of X-rays, sources of X-rays

- Interaction of X-rays with matter. Kinematic and dynamical theory of X-Ray Diffraction. Electron and neutron diffraction.

- X-ray diffraction methods: PXRD, SCXRD, GIXRD, HRXRD, XRR e SAXS. Examples.

- RXRS and other techniques using synchrotron radiation.

Lecture 4

X-ray Metrology of Epitaxial Group-III-Nitrides for Device Fabrication

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Wide bandgap semiconductor heterostructures such as group-III-nitrides are of great technological interest for the realization of electronic and optoelectronic devices such as high electron mobility transistors (HEMTs), Schottky diodes, micro-electro-mechanical systems (MEMS), RF filters, light emitting diodes (LEDs), lasers, UV detectors and others. The devices typically consist of layered structures deposited on a substrate by epitaxy (e.g., metal organic chemical vapor deposition (MOCVD), molecular beam epitaxy (MBE), hydride gas phase epitaxy, atomic layer deposition (ALD), sputtering, etc.). The structural properties of the epitaxial layers largely determine the characteristics of the devices. Therefore, the precise control of the layers´ growth and process parameters is essential for the production of devices with defined properties.

This lecture will focus on how high-resolution X-ray diffraction (HRXRD) and X-ray reflectivity (XRR) can be used for non-destructive, fast, non-contact, and accurate measurement of the layers´ structural parameters. In detail, it will be shown how the state of strain, composition, thickness, density, roughness, texture and perfection of the layers can be determined using X-ray metrology. The lecture will also cover the structural characterization of substrates for the epitaxy of group-III-nitride-based devices, since the substrate properties also have a major influence on the epitaxy process. Foreign substrates (e.g., SiC) but also homo-substrates (e.g., GaN and AlN) are discussed. Bragg diffraction imaging techniques such as laboratory Lang topography, synchrotron white beam topography, and synchrotron rocking curve imaging are reviewed. The methods of structural analysis presented in this lecture will take epitaxial nitride semiconductors as an example, but they are to a large extent applicable to other material systems as well.

Lecture 5

Hands on case studies using diffraction techniques

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Brief description of practical examples on the use of X-ray diffraction on the characterization of epitaxial materials.

Lecture 6

Optical characterizations of epitaxial materials: from crystal defects to optoelectronic properties

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Materials for light harvesting or photonic applications are at the heart of many recent technological developments and innovation, to address the main issues of the XXIst century, such as health care, clean water, sanitation, affordable and clean energy, environmental sensors, climate action, computing or communication. In this context, epitaxy is often considered as the ultimate technology for growing materials with dedicated physical properties, and especially optical ones. It however comes with the inevitable formation of several different crystal defects.

In this contribution, the link between crystal defects and optoelectronic properties of semiconductors will be first presented. We will then review the different optical characterization tools commonly used with epitaxial materials, both for light emission or light harvesting. Prospects will be given on the development of single photons characterization tools, in the context of the recent development of quantum technologies.

Lecture 7

Characterization of functional oxides thin films and heterostructures using Raman spectroscopy

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This lecture will address relevant applications of the Raman spectroscopy in the study of structure and distortions in functional oxides thin films and heterostructures.
The lecture will review the main concepts and instrumentation associated with Raman spectroscopy and Raman imaging, and the relevant models to interpret the Raman spectra. Detailed description of the Raman spectrometer and its capabilities existing at LaPMET – IFIMUP will also be presented. The lecture will continue with the presentation of representative examples of the characterization of functional oxide thin films and heterostructures using this technique, focusing on the effect of substrate on the overall Raman signal, domain structures and domain wall mapping, strain-induced phase transitions, and investigations using multiple wavelength measurements.

Lecture 8

Characterization tools on epitaxial growth control

Armando Lourenço

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Brief introduction on thin film PVD (Physical Vapour Deposition), with special focus on PLD (Pulsed Laser Deposition) and RF Sputtering
Deposition and characterization of oxide ($YBa_2Cu_3O_{7-x}$, $La_{0.7}Ba_{0.3}CuO_3$, HfO_2 and $BaTiO_3$) and metallic ($Co_{60}Fe_{40}$) thin films

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Atomic layer deposition (ALD) is gaining attention as a thin film deposition method, uniquely suitable for depositing uniform and conformal films on complex three-dimensional (3D) geometries. The indifference of ALD to substrate shape facilitates the use of ALD in highly different fields of technology. The present work describes the basics principles of ALD and summarizes the two-reactant ALD processes to grow inorganic materials (e.g., metal oxides) as well as their application fields.

Lecture 9

Assessing nanoscale (opto-)electronic properties through advanced scanning probe microscopy

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The presentation will give a brief introduction into atomic force microscopy (AFM) and a detailed introduction into the working principles and operation modes of Kelvin probe force microscopy (KPFM). These methods comprise light-matter interaction through surface photovoltage imaging and time-resolved KPFM.

Several application examples will be discussed. A range of applications for the nanoscale characterization of thin-film solar cells based on Cu(In,Ga)Se_2 (CIGSe) absorbers will be presented. These polycrystalline materials exhibit outstanding power conversion efficiencies, despite a large abundance of grain boundaries, with typical grain sizes in the range of 1 micrometer. The understanding of the electronic properties of grain boundaries has been largely supported by their AFM and KPFM characterization. These studies rely on polycrystalline CIGSe thin films, as well as on epitaxially-grown CIGSe with individual grain boundaries.

Another class of epitaxial growth is van-der-Waals epitaxy, which is used for the growth of two-dimensional (2D) materials. We studied the nanoscale optoelectronic properties of beta-phase In2Se3 and compare findings from KPFM with those of photodetector devices based on this material.

Lecture 10

Scanning tunneling microscopy and related spectroscopies in epitaxy materials

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Since its invention, the scanning tunneling microscope (STM) has established itself as a fundamental tool for interdisciplinary research. STM has proven essential in the characterization of surfaces and adsorbates allowing for a correlation of the structures to their electronic and vibrational properties at the nanoscale. Our understanding of nanoelectronics and quantum information processes had advanced by manipulating atoms and molecules. Its contribution to nanoscience is such that we now understand chemistry, physics, and nanotechnology from a surface science perspective.

In this lecture, I will start with a description of how the electron tunneling effect between a sharp tip and a surface allows for imaging and how these images can be related to surface topography. I will provide an overview of the principal operations of this instrument for local spectroscopic techniques such as elastic and inelastic electron tunneling spectroscopy, surface potential measurements, and atomic manipulation as well as how they can be applied to characterize epitaxial growth, surface chemistry, and quantum physics.

Lecture 11

Scanning probe microscopy of epitaxy of metal complex oxides

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This lecture will highlight epitaxial growth of complex metal oxides with perovskite structure with the use of pulsed laser deposition (PLD). After a short introduction into this class of materials and their potential applications in the form of epitaxial thin films, the focus will be placed on film growth modes and their signatures revealed with atomically resolved scanning probe microscopy (SPM) supported by in-situ surface diffraction and spectroscopic techniques: reflective high-energy electron diffraction (RHEED) and x-ray photoelectron spectroscopy. Specifically, two major growth modes—step-flow and layer-by-layer—will be illustrated in detail.

Lecture 12

Piezoresponse Force Microcopy of nanosized ferroelectric materials

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Piezoresponse force microscopy (PFM) has now become an indispensable tool for the study of ferroelectrics and related materials. It allows mapping ferroelectric domains with high spatial resolution in bulk ceramics and single crystals, thin films, and nanostructures (nanoparticles, nanofibers, etc.). The possibility of applying an electrical field or mechanical stress in situ makes it possible to directly visualize the processes of polarization switching and propagation of domain walls, study interaction of domain walls with defects, and measure the conductivity of domain walls. PFM can also be used to prove ferroelectricity in materials where it cannot be done with traditional methods. This lecture will introduce the basic principles of PFM and the mechanisms of PFM contrast formation, review some recent results of PFM in nanostructured ferroelectric materials, and discuss the pitfalls in interpreting PFM results.

Lecture 13

Synergistic Insights at the Nanoscale: A Comprehensive Approach with AFM and Micro-Raman Techniques

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This lecture is devoted to the introduction to the coupled use of the two very powerful surface techniques. The lecture will focus on a comprehensive analysis of the surface properties of epitaxial, thin-filmed, nanostructured, bulk, soft, and bioinspired materials by using these techniques. The method of complementary analysis will be discussed as well as the advantages and disadvantages of each method solely and an approach to overcome the imperfection of the methods.

Dr. Timur Nikitin, an expert in micro-Raman spectroscopy, will provide insights into the nuances of micro-Raman studies of specific samples, whereas Dr. Maxim Ivanov, a specialist in Atomic Force Microscopy, will provide his perspective on the same issues complemented with a scanning probe microscopy perspective.