esteem3

Enabling Science through European Electron Microscopy

Report on training and education

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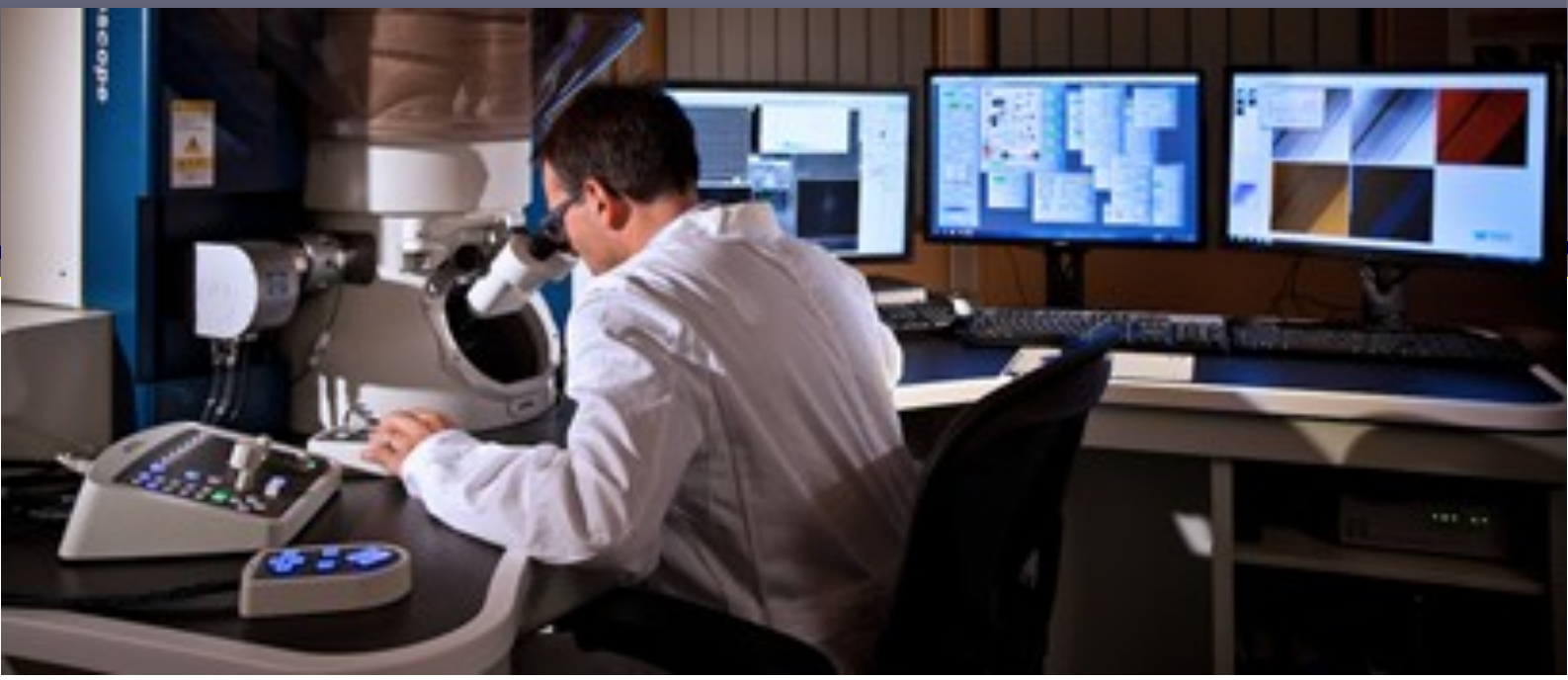

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Revision history log

Version number	Date of release	Author	Summary of changes
V0.1	07/04/2020	Miran Ceh	Preparation of a draft report
V0.2	14/04/2020	Gerald Kothleitner	Additions, revision
V0.3	15/04/2020	Miran Ceh	Unified format, finishing
V0.4	15/04/2020	Lucie Guilloteau	Editing
V0.5	18/04/2020	Miran Ceh	Revision and additional editing
V0.6	22/04/2020	Peter van Aken	Approval of the deliverable

Description of WP2 Education and Training

The WP2 Education and Training is dedicated to the education and training in advanced TEM techniques. Important objectives of the WP2 are:

- Organisation of schools and workshops in order to transfer knowledge about TEM techniques to the scientific community with an emphasis on attracting scientists in the early stages of their careers.
- Organisation of webinars for specific and emerging TEM techniques.
- Dissemination of webcasts related to TEM via the ESTEEM3 website to a broader scientific community.

Schools and workshops as well as webinars are organized within the ESTEEM3 and are open to the entire European research community. This networking activity is divided into two:

Task 2.1: Schools and workshops

This task includes organisation of schools and workshops in order to transfer knowledge about TEM techniques to the scientific community with an emphasis on attracting scientists in the early stages of their careers. The schools are focused on more general education in TEM while the workshops cover more specific topics including practical work. The events organised within this WP cover all aspects of modern TEM and related analytical and computational techniques. The anticipated schools/workshops within specific topics include:

TEM and STEM Imaging:

- EMAT workshop on transmission electron microscopy (ANT)
- TEM-UCA workshop on transmission electron microscopy of nanomaterials (CAD)
- European workshop on quantitative STEM imaging (LJU)
- QEM: Review and new advanced TEM techniques (TOU+ORS)
- The 6th Stanisław Gorczyca European school on electron microscopy and tomography (KRA)

Sample preparation:

- Workshop on advanced TEM specimen preparation (STU)

Spectroscopy:

- ESTEEM-spectroscopy school (GRA)
- Conventional and counting EELS spectroscopy school (CAT)

Diffraction:

- Workshop on electron diffraction for solving engineering problems (TRO)

In situ:

- European workshop on advanced in-situ electron microscopy of ICT structures and quantum devices (CHA)
- School on in-situ TEM (JUL)

Task 2.2: Webinars

Webinars are organised for specific new and emerging TEM and related analytical techniques. Access to webcasts is available through the ESTEEM3 website together with videos of selected lectures from the ESTEEM3 schools and workshops. The following webinars are foreseen to be organized within this task:

- Low-loss EELS modelling and tomography (GRA)

- Preparations and considerations for in-situ microscopy of ICT structure (CHA)
- In-situ techniques (LJU)
- Open software for TEM image simulation (ANT)
- Computer-assisted electron crystallography (CAD)
- Industrial webinars by the SME partners

Schools and workshops until Month 16 (01/01/2019- 30/04/2020)

EMAT Workshop on Transmission Electron Microscopy
June 11 – 21, 2019, EMAT laboratories, University of Antwerp
http://ematworkshop.uantwerpen.be/

The workshop provided a complete hands-on training concerning transmission electron microscopy. During the first week, the basic principles were covered concerning topics such as electron diffraction, high resolution transmission electron microscopy as well as analytical transmission electron microscopy. During the second week, students were offered the choice between one of the following modules:

- Advanced high-resolution transmission electron microscopy
- Analytical techniques in the transmission electron microscope
- In situ techniques in transmission electron microscopy

During the workshop, the students were provided with the unique opportunity to work with the most advanced transmission electron microscopes currently available. All practical sessions were guided by experienced members of the EMAT group.
Practical sessions included:
Week 1:
Sample preparation by ion milling, focused ion beam, real space image formation in the transmission electron microscope, electron diffraction, electron precession, introduction to high resolution transmission electron microscopy, introduction to analytical transmission electron microscopy.
Week 2:

- Module "*Advanced high-resolution transmission electron microscopy*": high resolution transmission electron microscopy, aberration corrected transmission electron microscopy, high annular dark field transmission electron microscopy, exit wave reconstruction, image quantification.
- Module "*Analytical techniques in the transmission electron microscope*": electron energy loss spectroscopy, energy filtered transmission electron microscopy, energy dispersive X-ray spectroscopy, high angle annular dark field scanning transmission electron microscopy, aberration correction for analytical techniques.
- Module "*In situ techniques in transmission electron microscopy*" was organized in collaboration with DensSolutions and covered the following topics: heating, biasing, gas and liquid in-situ transmission electron microscopy.

Number of ESTEEM3 participants: 12 (out of 47)

Name	Affiliation	Module	Country
Yu-Mi Wu	Max Planck Institute for Solid State Research	TEM spectroscopy	Germany
Xu Chen	Stuttgart Center for Electron Microscopy / Max-Planck-Institute for Solid State Research	TEM spectroscopy	Germany
Oleksandr Kryshtal	AGH University of science and technology	TEM spectroscopy	Poland
Xiaonan Luo	University of Oxford	TEM spectroscopy	United Kingdom
Monika Kušter	Jožef Stefan Institute	High Resolution TEM	Slovenia
Ping-Luen Ho	University of Oxford	High Resolution TEM	United Kingdom
Hoel Laurent Robert	Ernst Ruska-Centre, Jülich Research Centre	High Resolution TEM	Germany
Achim Strauch	Ernst Ruska-Centre, Jülich Research Centre	High Resolution TEM	Germany
Ewan Richardson	University of Oxford	High Resolution TEM	United Kingdom
Piotr Szewczyk	AGH University of Science and Technology	In situ TEM	Poland
Maja Koblar	Jožef Stefan Institute	In situ TEM	Slovenia
Alessandro Gradone	University of Bologna - Department of Chemistry & CNR-IMM Section of Bologna	In situ TEM	Italy

20 Speakers

Name	Affiliation	Country
Marc De Graef	Carnegie Mellon University	USA
Joost Batenburg	CWI / University of Leiden	Netherlands
Knut Müller-Caspary	Ernst-Ruska-Centre / Fz Juelich	Germany
Joke Hadermann	University of Antwerp	Belgium
Dirk Van Dyck(*)	University of Antwerp	Belgium
Sara Bals	University of Antwerp	Belgium
Sandra Van Aert	University of Antwerp	Belgium
Tim Pennycook	University of Antwerp	Belgium
Qiang Xu	DENSsolutions	Netherlands
Staf Van Tendeloo	University of Antwerp	Belgium
Armand Béché	University of Antwerp	Belgium
Jo Verbeeck	University of Antwerp	Belgium
Hugo Perez Garza	DENSsolutions	Netherlands
Mingjian Wu	Friedrich-Alexander University Erlangen-Nuremburg	Germany
Thomas Hansen	Technical University Denmark	Denmark

Hosni Idrissi	Universite Catholique de Louvain	Belgium
Marijn van Huis	University of Utrecht	Belgium
Wiebke Albrecht	University of Antwerp	Belgium
Nicolas Gauquelin	University of Antwerp	Belgium
Werner Grogger	TU Graz	Austria

(*) The presentation by Prof. Dirk van Dyck was recorded and will be available on online platform.

EMAT Workshop participants.

Conventional and Counting EELS spectroscopy
July 22 – 25, 2019, CNR-IMM c/o STMicroelectronics, Catania
http://www.beyondnano.it/?q=EELS-2019

The Conventional and Counting EELS spectroscopy school provided an intensive 4-day training school that incorporated lectures, computer laboratories, and microscope practicals and hands-on training on key EELS topics and technology. The practical lessons have been made at the new Beyond-Nano Sub-Ångstom Lab on integrated JEOL GIF/EELS systems. This special Transmission electron microscopy (TEM) is able to reveal details of natural and man-made structures even at sub-nanometer scale. Electron energy-loss spectroscopy (EELS) is the ideal analytical tools to the high spatial resolution provided by TEM in both the conventional and scanned (STEM) imaging modes.
This course reviewed the basic theory and practice of EELS imaging and analysis in the TEM. By the end of the course, participants can expect to know how best to optimize the performance of their EELS hardware as well as their EELS experimental setups in order to capture and extract the maximum amount of information from their TEM samples.

Main Topics:
- Fundamentals of EELS
- Optimization of EELS data acquisition
- Quantification of elemental composition
- Use of EELS signals to form maps of elemental and chemical composition
- Atomic EELS analysis Identification of material phases via EELS fine structure mapping
- Other information provided by EELS and how best to extract it (plasmons, phonons..)
- Advanced data processing
- Detectors for electrons and counting EELS

Number of ESTEEM3 participants: 6 (out of 17)

Name	Affiliation	Country
Alfonso Ibarra	Advanced Microscopy laboratory, Zaragoza	Spain
Monika Kušter	Jozef Stefan Institute	Slovenia
Tianyi Chen	University of Oxford	United Kongdom
Giuseppe Caruso	IMM-CNR	France
Marta Agati	IMM-CNR	France
Gianfranco Sfuncia	IMM-CNR	France

10 Speakers

Name	Affiliation	Country
Stefan Loffler	TU Wien	Austria
Demie Kepaptsoglou	SuperSTEM lab	United Kingdom
Paolo Longo	Gatan Inc, Pleasanton CA	Unites States of America
Katherine E. MacArthur	Ernst Ruska-Centre	Germany
Eiji Okunishi	Jeol Ltd.	Japan
Pavel Potapov	Techical University of Dresden	Germany
Quentin Ramasse	SuperSTEM lab	United Kingdom
Liam Spillane	Gatan Inc, Pleasanton CA	Unites States of America
Daniel Stroppa	Thermo Fisher	Nederland
Nahid Talebi	Max Plank Institute	Germany

Conventional and Counting EELS spectroscopy participants.

ESTEEM-Spectroscopy School
February 4 – 7, 2020, FELMI Institute, Graz University of Technology

The spectroscopy school at the FELMI is a concentrated, four days hands-on laboratory workshop taking participants step-by-step through the many uses of electron energy-loss spectroscopy. The course familiarizes participants with the latest EELS & EFTEM equipment and technologies, the fundamental principles of the technique, critical calibrations to obtain meaningful EELS spectra and with the latest software data processing tools.
Starting with the basics of EELS and EFTEM, the course gradually becomes more sophisticated in the discussed topics, entailing spectrum imaging, electron beam monochromation and even X-ray spectroscopy in combination with DualEELS acquisitions. Ample provision is made for continued discussions, by implementing extended breaks between the lectures, allowing for in-depth discussions. The course is divided up into separate acquisition and analysis labs, taking place at the latest generation microscopes and computer work stations, respectively. By the end of the course, participants have learned how to optimize their experiments in order to capture and extract the maximum amount of information from their samples.

Main topics that have been covered during the school:

- EELS basics
- Angular considerations
- Spectrum detection / Direct Electron Detectors
- STEM EELS and EFTEM spectrum imaging
- Spectrum imaging artefact avoidance / correction
- Scripting with DigitalMicrograph
- Electron beam monochromation
- X-ray spectroscopy

Number of participants: 16

Name	Affiliation	Country
Loukya BODDAPATI	International Iberian Nanotechnology Laboratory	Portugal
Eugenio SOLLA	University of Vigo / Spain	
Khalil EL HAJRAOUI	International Iberian Nanotechnology Laboratory	Portugal
Justyna GRZONKA	Viagens El corte Ingles SA	Portugal
Ren QIU	Chalmers University of Technology	Sweden
Ou JIN	Karlsruher Institut für Technologie	Germany
Bonnie MURPHY	Max-Planck-Institut für Biophysik	Germany
Olivia PFEIL-GARDINER	Max-Planck-Institut für Biophysik	Germany
Sebastian LECH	Akademia Gormiczo-Hutnicza im. Stanislawa Staszica w Krakowie	Poland
Laurence CHEVALIER	CNRS SCTD	France
Joanna GRYBOS	Jagiellonian University	Poland
Ivo KUBENA	Institute of Physics of Materials AS CR, v. v. i.	Czech Republic
Clementine WARRES	NMI Naturwissenschaftliches und Medizinisches Institut an der Universität Tübingen	Germany
Pierre RUTERANA	CIMAP-ENSICAEN	France
Oliver DIESTE BLANCO	European Commission, Directorate-General Human Resources and Security	Germany

Jonathan HAWES	Paul Scherrer Institut	Switzerland

ESTEEM-Spectroscopy School participants.

Additional schools and workshops until Month 16 (01/01/2019- 30/04/2020)

Workshop on Electrochemistry in Liquid TEM and on Orientation/Phase Mapping in Liquid

May 27 – 29, 2019, University of Picardy Jules Verne, Amiens

https://www.eventbrite.com/e/protochips-nanomegas-workshop-at-u-picardie-amiens-fr-tickets-59008062704#

The workshop (supported by the ESTEEM3 consortium) has been successful with more than 30 participants coming from various European countries (France, Germany, Spain, Italy, Czech Republic) including University of Picardy-LRCS local participants. Tutorials (theoretical presentations and laboratory sessions) were focused about the potentials of liquid cell TEM imaging with a special focus on Poseidon EC experiments, as well as on performing nm scale orientation and phase mapping in various materials (metals, alloys, nanoparticles, battery related samples, minerals).
During the 2.5 day workshop it has been demonstrated an electrochemistry in-situ LCTEM experiment and also (one of the first experiments of its kind) in-situ orientation/phase maps of nanoparticles within a Poseidon liquid cell. Participants have learnt to extract useful texture information from orientation/phase maps with ASTAR technique and better understand liquid cell concept and applications with Protochips liquid holders.

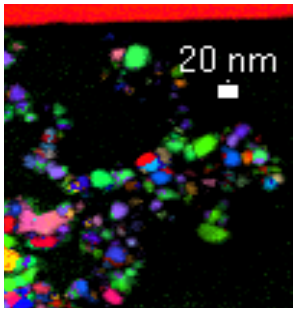
Number of participants: 16

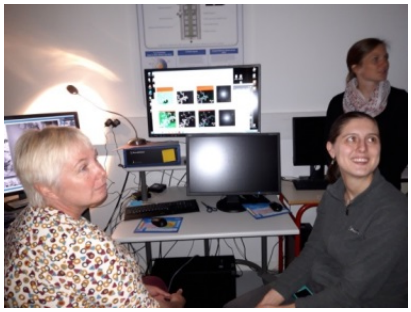
Name	Affiliation	Country
Alberto Azor Lafarga	UCM	Spain
Michael Paul	Forschungszentrum Jülich GmbH	Germany
Stefan Merkens	CIC nanoGUNE	Spain

loic Dupont	UPJV Electron Microscopy Platform / LRCS	France
Carine Davoisne	LRCS	France
Tomas Moravek	TESCAN	Czech Republik
Isabel Gomez Recio	UPMC	France
Raffaello Mazzaro	CNR-IMM	Italy
Ankush Bhatia	Institute of Chemistry and Materials Paris Est	France
Malte Klingenhof	TU Berlin	Germany
Vera Beerman	TU Berlin	Germany
Jesus Gonzalez Casablanca	Rey Juan Carlos University	Spain
Nathalie Ortiz	IPCMS Strasburg	France
Stef Aguy	EDEN France	France
Alejandro Gomez	NanoMEGAS	Belgium
Partha Das	NanoMEGAS	Belgium
Arnaud Demortiere	LRCS-Picardie	France
Arash Jamali	LRCS-Picardie	France
Jean Bernard	ELOISE SARL	France
Kirill Cherednichenko	LRCS-Picardie	France
Zeliang Su	LRCS-Picardie	France
TuanTu Nguyen	LRCS-Picardie	France
Ali Akhavankazemi	LRCS-Picardie	France
Alus Kudu	LRCS-Picardie	France
Garima Shukla	LRCS-Picardie	France
Christian Masquelier	LRCS-Picardie	France

Speakers: 7

Name	Affiliation	Country
Ankush Kashiwar	KIT Karlsruhe	Germany
Muriel Veron	INPG Grenoble	France
Edgar Rauch	SIMAP Grenoble	France
Stavros Nicolopoulos	NanoMEGAS	Spain
Mathias Mosig	Protochips	Germany
Remy Berthier	Protochips	France
Madeleine Dukes	Protochips	United States of America



ASTAR Orientation map of gold particles within water solution using Poseidon Liquid cell.

Advanced Direct Detection EELS Workshop
September 25 – 26, 2019, FELMI Institute, Graz University of Technology

Indirect electron detectors (IDC), as most commonly used in electron microscopic imaging, inherently limit the camera's point spread function (PSF) and its detection quantum efficiency (DQE). Over the last decade, radiation tolerant CMOS active pixel sensors, which directly image high energy incident electrons (direct electron detection, DDC), have been developed, which can now be utilized also for typical materials science applications. These improvements now give access to a wide range of applications including efficient and low-dose spectrum imaging, trace element detection and analysis, and time-resolved EELS. Right now, only limited knowledge is available regarding the best use of these detectors. For instance, in counting mode, where each electron falling onto a pixel can be distinguished and isolated by its charge (fraction), the result is a dramatic increase in the resolution. Other sources of noise typically related to the fiber optic, gain and dark contributions are effectively eliminated and shot noise becomes the only source of noise present.

The Advanced Direct Detection EELS workshop at the Graz University of Technology aimed to familiarize users with this new detection technology and provided instructions regarding best uses for various application scenarios. After short theoretical introductions into the technology, participants have got the opportunity to participate in comprehensive hands-on training and could even provide their own samples to evaluate the information gain.

Main topics that have been covered the workshop:

- Direct Detection Technology
- Counting electrons and advantages for imaging and EELS spectroscopy
- Instruments noise free EELS analysis
- Fast STEM EELS analysis
- Low-dose EELS analysis
- Chemical analysis
- Ultra-High-Energy edges acquisition
- Direct Detection practical sessions – looking at attendee's TEM specimens

Number of participants: 12 (2 within ESTEEM3)

Name	Affiliation	Country
Yi Wang	Stuttgarter Zentrum für Elektronenmikroskopie (StEM), Stuttgart	Germany
Andrey Mazilkin	Institut für Nanotechnologie INT, Karlsruhe	Germany
Xing Huang	Scientific Center for Optical and Electron Microscopy ScopeM, Zürich	Schwitzerland
Marta Rossell	Zentrum für Elektronenmikroskopie, Dübendorf	Schwitzerland
Ingo Lieberwirth	Max Planck Institut für Polymerforschung, Mainz	Germany
Sonia Conesa Boj	Kavli Nanolab, Delft	Netherland
Hongchu Du	Peter Gruenberg Institut / Ernst Ruska Zentrum, Jülich	Germany
Dongsheng Song	Gemeinschaftslabor für Elektronenmikroskopie GFE, Aachen	Germany

Armin Feldhoff	Institut für Physikalische Chemie und Elektrochemie, Hannover	Germany
Emrah Yücelen	Microsoft, Delft	Netherlands
Clementine Warres	NMI Reutlinge, Reutlingen	Germany
Vesna Srot	Stuttgarter Zentrum für Elektronenmikroskopie (StEM), Stuttgart	Germany

Advanced Direct Detection EELS Workshop participants at the microscope.

Webinars until Month 16 (01/01/2019- 30/04/2020)

The University of Antwerp (Belgium), ESTEEM3 partner, has published a webinar on HyperSpy, a multi-dimensional data analysis toolbox.

HyperSpy is a scientific Python library used to analyse a large variety of multidimensional data, with a focus on transmission electron microscopy.
In this webinar functionalities related to analysing electron energy loss spectra (EELS) were addressed, from the more standard background subtraction and simple integration of intensities, to the more advanced model based approach of Oxygen K-edge energy loss near edge structure. The webinar lasts 52 minutes. It is free for viewing and available in open access on Youtube (https://www.youtube.com/watch?v=G_yqv0Vj3ug) and communicated on the ESTEEM3 website.
This project has received funding from Horizon 2020 under both the ESTEEM3 and MAGIMOX projects.