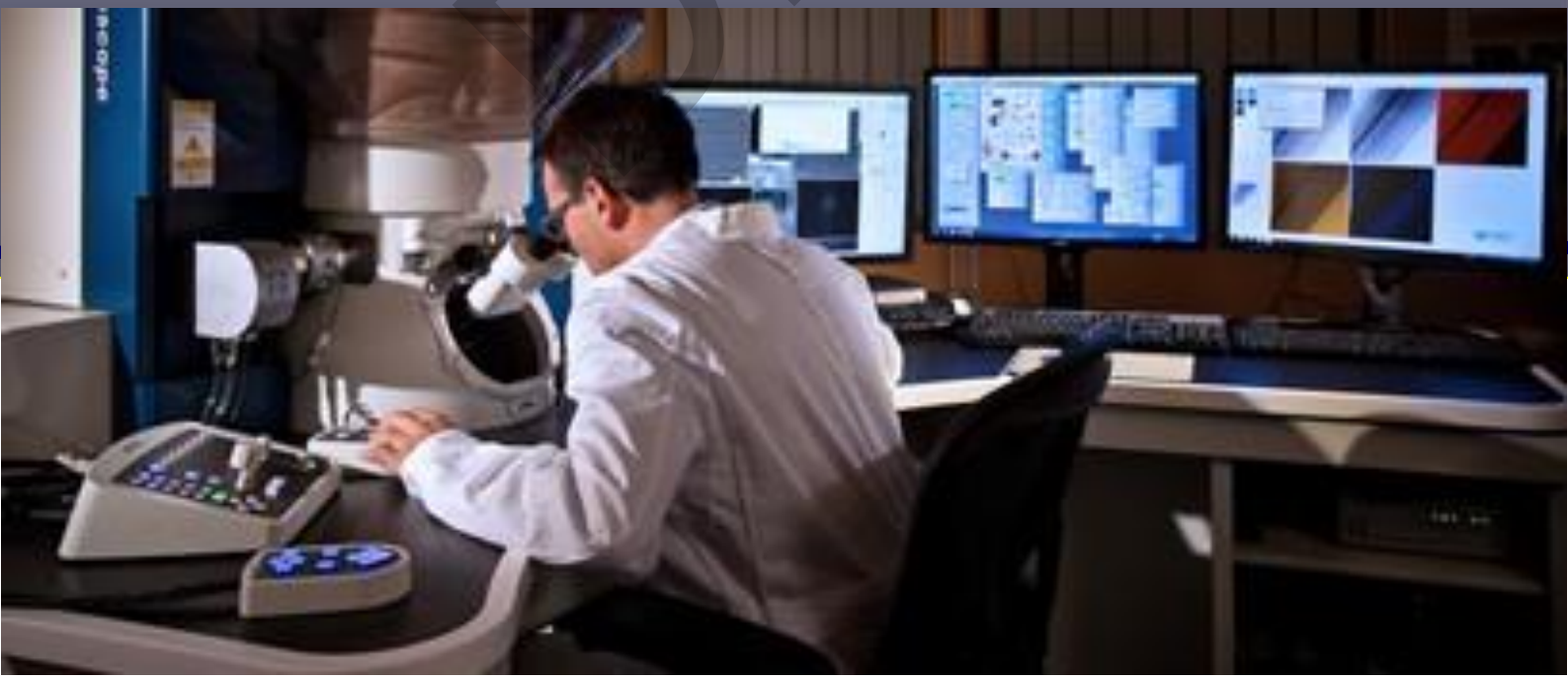
esteem3

Enabling Science through European Electron Microscopy

Report on training and education

Deliverable D2.2 – version 1

Estimated delivery date:	M40 April 2022
Actual delivery date:	29th April 2022
Lead beneficiary:	LJU and GRA
Person responsible:	Gerald Kothleitner and Miran Ceh
Deliverable type:	☒ R ☐ DEM ☐ DEC ☐ OTHER ☐ ETHICS ☐ ORDP
Dissemination level:	☒ PU ☐ CO ☐ EU-RES ☐ EU-CON ☐ EU-SEC



THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT NO **823717**

Grant Agreement No:	823717
Funding Instrument:	Research and Innovation Actions (RIA)
Funded under:	H2020-INFRAIA-2018-1: Integrating Activities for Advanced Communities
Starting date:	01.01.2019
Duration:	54 months

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Revision history log

Version number	Date of release	Author	Summary of changes
V0.1	26/04/2022	Miran Ceh	Preparation of a draft report
V0.2	26/04/2022	Peter A. van Aken	Revision and approval of deliverable
V1	27/04/2022	Aude Garsès	General review

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 40 (01/05/2020-30.04.2022)

Due to a very unfortunate Covid-19 situation no schools and no workshops have been organized during the reporting period of the project (month 17 to 40) because of imposed travel restrictions and other preventive measures in the EU. This is why the consortium partners have agreed to reschedule still remaining schools and workshops, as proposed in the ESTEEM3 proposal, which will be carried out during the following accepted dates:

Partner	School/workshop	Date
TOU+ORS	QEM: Review and new advanced TEM techniques	May, 8-20, 2022
TRO	Workshop on electron diffraction for solving engineering problems	June, 20-26, 2022
KRA	The 6th Stanisław Gorczyca European school on electron microscopy and tomography	July, 5-8, 2022
CAD	TEM-UCA workshop on transmission electron microscopy of nanomaterials	September, 11-16, 2022
STU	Workshop on advanced TEM specimen preparation	October, 24-28, 2022
CHA	European workshop on advanced in-situ electron microscopy of ICT structures and quantum	2023
LJU	European workshop on quantitative STEM imaging	2023
JUL	School on in-situ TEM	2023

The consortium partners are aware that it is extremely important to organize such schools and workshops with participants present on-site, especially since many of the ESTEEM3 events include practical, hands-on the equipment courses. However, to assure the realization of planned activities the partners have also agreed to organize these events on-line as well as in hybrid mode, if it will be necessary.

Webinars until Month 40 (01/05/2020-30.04.2022)

The Chalmers University of Technology has organized a webinar with the title *Considerations for in-situ mechanical, electrical and optical measurements of ICT materials in electron microscopes*

In this webinar, using semiconductor nanowires as examples, some of the considerations for in-situ mechanical, electrical and optical measurements of ICT materials in electron microscopes were discussed. Different approaches of transferring nanoscale samples into in-situ electron microscopy sample holders were explained and compared. The means by which reliable electrical contacts can be established for in- situ electron microscopy studies were also discussed. Since the treatment and modelling of electrical contacts in data analysis for reliable interpretation of the results is extremely important, the correct approaches were presented on individual III-V

nanowires. In-situ electron microscopy continues to play an important role in the research and development of ICT materials. The considerations presented at the webinar should help to develop reliable and streamlined measurement setups and protocols for the in-situ electron microscopy study on ICT materials, including semiconductor nanostructures.

Webinar was presented on April 9, 2021, by Lunjie Zeng, researcher at Chalmers University of Technology, Sweden.

Website: https://www.esteem3.eu/Webinars

The University of Cadiz has organized a webinar with title *Computer-assisted electron crystallography*

Crystallography is the mathematical language to describe crystal structures. When we know this language, and with the help of a computer, we can easily interpret atomic resolution images, obtain useful information from electron diffraction patterns and build complex nanostructures. Modelling allows us to simulate Scanning/Transmission Electron Microscopy data or perform DFT calculations. During this webinar the computer tools present at the TEMserver (http://temserver.uca.es) were explained with a basic introduction to matrix crystallography.

The webinar was presented on April 23, 2022 by Prof. José Antonio Pérez-Omil of the University of Cadiz). The webinar had 54 attendees from the following countries: United Kingdom, Turkey, Netherlands, Germany, Spain, Italy, France, Argentina and Belgium. The webinar was transmitted on-line using the capabilities of the ICTS-ELECMI platform.

Website: https://www.youtube.com/watch?v=xGm60BtA36I

The SME DENSsolutions has organized the following short webinars (30min to 1hour) during the reporting period of the deliverable

Webinar title: In-situ Biasing and heating of semiconductor nanowires
Time: July 22nd, 2020

Webinar title: Liquid phase electron microscopy: From the lab to the microscope and back again
Time: July 29th, 2020

Webinar title: The use of in-situ TEM techniques and Lorentz microscopy to study magnetostructural transitions
Time: August 5th, 2020

Webinar title: Time-resolved TEM to study the assembly of macromolecular and hybrid structures in solution
Time: August 12th, 2020

Webinar title: Investigating the phase changes in conductive polymers and ferroelectric oxides by in-situ biasing TEM
Time: August 19th, 2020

Webinar title: Liquid phase (S)TEM: A developing toolbox to visualize bio-nano mechanisms
Time: September 9th, 2020

Webinar title: Liquid phase electron microscopy, fundamentals, application to study membrane proteins in whole cells, and future look
Time: October 20th, 2020

Webinar title: Disentangling the correlation between electronic and structural phase transitions in VO_2
Time: October 22nd, 2020

Webinar title: Structure-property correlations in hafnia-based RRAM Devices
Time: November 11th, 2020

Webinar title: Formation and catalytic behaviour of nanoparticles via in situ TEM
Time: November 24th, 2020

Webinar title: In-situ TKD with hearing and biasing
Time: December 1st, 2020

Webinar title: Direct observation of chemical dynamics in Pt catalyst during CO oxidation by operando electron microscopy
Time: December 16th, 2020

Webinar title: Redox dynamics of active metal catalysts studied by Operando TEM
Time: January 14th, 2021

Webinar title: In Situ Electron Microscopy Study of High-Temperature Dynamics in Metal-Intercalated Layered Materials
Time, January 27th, 2021

Webinar title: In-situ heating correlative studies for additively manufactured and irradiated materials
Time: March 9th, 2021

Webinar title: Interpretable electrical biasing of ferroelectric material
Time: March 24th, 2021

Webinar title: Cation migration dominated kinetic stability of layered cathodes
Time: April 27th, 2021

Webinar title: Phase transitions in perovskite thin films
Time: May 19th, 2021

Webinar title: Diffusion in single nanoparticles measured in situ using electron tomography
Time: May 25th, 2021

Webinar Title: Chemical environment induced re-dispersion of Ag nanoparticles
Time: June 30th, 2021

Webinar Title: Using In Situ TEM to explore structural transformations in 2D material $CoSe_2$
Time: July 21th, 2021

Webinar Title: Atomic diffusivities in amorphous and liquid Cu-Zr metallic glasses: TEM studies
Time: September 22nd, 2021

Webinar Title: Latest developments in Climate: Introducing the Vaporizer and time-delay calibration
Time: October 20th, 2021

Webinar Title: Liquid Structural Biology: Protein reconstruction and dynamics in liquid state
Time: November 17th, 2021

Webinar Title: Exploring the critical role of temperature during pyrolysis of ZIF-67 nanoparticles via in situ TEM
Time: December 22nd, 2021

Webinar Title: The love-hate relationship of electron beam sample interactions in Liquid Phase EM
Time: February 16th, 2021

The SME NanoMEGAS has organized the following webinars during the reporting period of the deliverable

Webinar title: Advance TEM Tools
Time: 13th May, 2020
Speakers:
- Dr. Edgar Rauch, CNRS, France, Orientation and Phase Mapping with a TEM
- Dr. Muriel Veron, CNRS, France, Application of Orientation and Phase Mapping in Metallurgy
- Prof. Christian Kubel, KIT, Germany, In-Situ Orientation and Phase Mapping in Tem

Introduction and application examples in Orientation and Phase mapping analysis by ASTAR technique in Transmission Electron Microscope. ASTAR can provide sample properties details in nm scale for variant materials like alloys, metals, ceramics, nanoparticles, etc. The under-study sample is scanned by a precessed beam in electron diffraction mode using smallest possible pseudo-parallel beam, and the series of acquired diffraction patterns data, are merged together, and processed towards the crystal orientation and /or phase identification (indexing) of know phases. Sample properties are further identified as like grain boundaries, grain size distribution, twins identification, texture analysis, grains overlapping, dislocations, etc.
Number of Participants: >200

Webinar title: Advance Characterization Techniques in TEM by Precession Electron Diffraction
Time: 18th June, 2020
Speakers:
- Dr. Partha Ghosal, DMRL, India, Advance Characterization of Materials using PED/ACOM
- Dr. Partha P. Das, Applications Scientist, NanoMEGAS SPRL, Belgium, Electron Diffraction Tomography/Micro-ED and ePDF with TEM

Precession electron diffraction (PED) method is a well know technique to enhance diffraction quality data in Transmission Microscope (TEM). PED is applied in several advance techniques in TEM leading to improved results. Precession enhanced Automated Crystal Orientation mapping in TEM, and Electron crystallography by Precession Electron diffraction tomography method, are some of the methods that described in this webinar. Moreover, introduction of Pair Distribution function method for characterization of amorphous and nanocrystalline materials is described in detail.
Number of Participants: >200

Webinar title: Introduction to Precession Electron Diffraction Mapping with TEM
Time: 2nd June, 2020
Speaker:

- Dr. Jing Lu, Applications Scientist, NanoMEGAS USA, An Introduction to Scanning PED, ASTAR Mapping & Strain Applications for TEM

Orientation and Phase mapping, and stain analysis method can be applied in TEM by scanning the sample with a smallest possible probe towards the best possible spatial resolution collecting series of electron diffraction patterns. The data quality of those patterns is dramatically enhanced by using beam precession while scanning. The acquired data are proceeded by fully automated software to obtain final Orientation and Phase maps (ASTAR software) and/or Strain maps (TopSPIN software). In both methods precession is essential to obtain reliable and reproducible results, in TEM. In this webinar, introduction of both methods together with the benefits of precession use is discussed, and application examples are described.
Number of Participants: >200

Webinar title: Introduction to Precession Electron Diffraction Mapping with TEM
Time: 16th June, 2020
Speakers:

- Prof Simon Billinge, Columbia University, USA**,** Local Structure at the Nanoscale
- Dr. Partha P. Das, Applications Scientist, NanoMEGAS SPRL, Belgium, Structural Characterization in TEM by 3D/Micro-Ed

Pair distribution function using electron diffraction data by TEM, provides useful information and can characterize amorphous or nanocrystalline materials. The PDF diagram gives information for the interatomic distance for the amorphous or nanocrystalline materials, leading to material characterization. The PDF method is described on this webinar, together some advanced examples. In the second part of this webinar, Electron crystallography by 3D electron diffraction tomography method and Micro ED is discussed using beam precession.
Number of Participants: >200

Webinar title: Advanced TEM Applications in Material Science using ASTAR and PED
Time: 17th June, 2020
Speaker:

- Prof Greg Thompson, University of Alabama, USA, The Use of Precession Electron Diffraction for in situ Cross-correlative Microscopy

Precession enhanced Orientation and Phase mapping method can be further applied in situ, to determine material properties in different conditions and study dynamical phenomena. In this webinar, Automated crystal Orientation mapping is combined with Cross-correlative Microscopy and is situ studies are shown.

Webinar title: ASTAR: Phase & Orientation mapping at nm scale by 4D - SPED in TEM.
Time: 2nd December, 2020
Speakers:

- Dr. Edgar Rauch, CNRS, France, ASTAR: Introduction to Automated Crystal Orientation Mapping in TEM.
- Dr. Muriel Veron, CNRS, France, ASTAR: Applications of orientation and phase mapping in TEM.
- Romain Gautier, CEMES-CNRS. Coupling in-situ TEM and ACOM-ASTAR to characterize Grain Boundaries motion
- Arnaud Demortiere, CNRS, France, ACOM-ASTAR a tool to characterize sodiation mechanism inside individual crystals of Na-ion battery materials

Based on beam precession method that consist a breakthrough in electron diffraction, various applications have been developed. The Automated crystal Phase/Orientation Mapping application, called “ASTAR”, offers 1-5 nm spatial resolution maps (for FEG-TEM) for any material, is using Precession electro diffraction method to acquire data by scanning the beam over the sample. Method introduction and applications in several materials, and precession benefits are described during this webinar. In situ examples by heating, or in liquid in TEM is also shown, to determine dynamical properties of the materials.
Number of Participants: >100

Webinar title: ASTAR: Novel features and advanced results applied to a variety of challenging materials.
Time: 9th December, 2020
Speaker:

- Dr. Edgar Rauch, CNRS, France, ASTAR V2:New tools in Automated Crystal Orientation Mapping in 4D-SPED
- Dr. Muriel Veron, CNRS, France, ASTAR V2: Demonstration of ASTAR analysis in challenging materials.

Automated crystal orientation and phase mapping (ACOM) is a well-known technique in TEM that can provide information in materials in a scale of 1-5nm when FEG-TEM is used. Advance tools of ASTAR software dedicated for ACOM analysis, provides further details of the sample properties, like grain boundaries maps and size measurement, grain size distribution, twins identification, texture analysis, grains overlapping, dislocations, etc. Those advanced tools and applications in several materials are discussed in detail in this webinar.
Number of Participants: >100