ENABLING SCIENCE AND TECHNOLOGY THROUGH EUROPEAN ELECTRON MICROSCOPY

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esteem3

JOINT RESEARCH ACTIVITIES

Joint Research Activities (JRA) focus on the development of the advanced Transmission Electron Microscopy (TEM) methods required for the solution of key problems in materials and nanoscience. The JRA have been selected to enable potentially disruptive scientific and technological projects that enhance overall service provision. JRA have been structured to tackle key problems in technologically important materials.

DEVELOPMENT OF ADVANCED TEM TECHNIQUES AND METHODOLOGIES

Imaging, diffraction and metrology are key tools that enable quantitative measurements of material structures at atomic spatial resolution. We have used spectroscopies in TEM to probe electronic, chemical and optical properties of materials below nanometer spatial resolution, for applications in nano- and material science and photonics. One main achievement was the development of new technologies for quantitative time-resolved, coincident and phase-resolved spectroscopy in the TEM.

In addition, we have shown how electric fields can be measured in working devices. Indeed, we found that the charge distributions are not always as expected and the information helps the microelectronics industry with their modeling and design of new components.

TEM SOLUTIONS FOR MATERIALS PROBLEMS

Different TEM characterization and specimen preparation techniques have been implemented for the study of materials systems in Information and Communications Technologies (ICT), energy, health and transport. This provides information on properties and performance characteristics of novel materials and material combinations that are necessary for understanding and improving materials to engineering readiness for European industry.

ICT

- **Applications** in semiconducting and magnetic materials, functional complex oxides and photonic materials.
- **One main achievement**: A better understanding of new transport properties such as the study of magnetically doped topological insulators (TI) and the first measurement of a large band-gap opening at the Dirac point of a TI with an unambiguous magnetic origin.

ENERGY

- **Applications** in photocatalysis, electrocatalysis, clean energy, energy storage and advanced energy systems.
- **One main achievement:** Development of new materials for energy applications and optimization of advanced electron microscopy techniques for a better understanding of these complex materials.

HEALTH

- **Applications** in medicine, bio-inspired materials science, biotechnology and pharmaceuticals.
- **One main achievement**: Development of new routines for electron-transparent sample preparation of organic/inorganic, biological, and bioinspired composites, and pharmaceuticals.

TRANSPORT

- **Applications** in the aerospace and automotive industries.
- **One main achievement:** Developing sample preparation procedures and applying analytical TEM and FIB-SEM tomography techniques for 3D visualization and phase identification of microstructural elements in nickel-based and aluminum alloys.

DATA ACQUISITION AND ANALYSIS IN TEM

ESTEEM3 partners helped to bring 4D STEM with event-based detectors, a significant innovation in this area, from basic research to a competitive product through active cooperation between vendors and users. Interfacing open-source software supported by ESTEEM3 with the software from the detector vendor Amsterdam Scientific Instruments through the quasi-standard CSR format allows scientists to use their CheeTah T3 detector like any other 4D-STEM detector. It will be natural to support this format in more software and detectors from different vendors. This will help to make such detectors mainstream in the future.

TRANSNATIONAL ACCESS

ESTEEM3 provided free Transnational Access (TNA) to 15 leading European state-of-the-art TEM research infrastructures, facilitating and extending TNA services of the most powerful atomic-scale characterization techniques in advanced electron microscopy research to a wide range of academic and industrial research communities.

APPROX. 500 TNA PROJECTS ACCEPTED

85% OF TNA USERS ESTIMATED THAT THEIR EXPERIMENT WAS **SUCCESSFUL**

86% OF PROJECTS FROM THE EU

MORE THAN 6000 UNITS OF ACCESS ACCEPTED AMONG WHICH

- **46%** TEM
- **18%** SAMPLE PREP.
- **36%** DATA ANALYSIS

NETWORKING ACTIVITIES

ESTEEM3 developed and hosts Networking Activities (NA) with regular events held throughout Europe. It included:

- **INTEGRATION AND SUSTAINABILITY:** Focused on increasing the quality and integration of the TA service provided by the consortium.
- **EDUCATION AND TRAINING:** ESTEEM3 strives to disseminate knowledge and expertise through an extensive education and training component. It delivers advanced TEM instruction to schools and advanced workshops, webinars and other contemporary, internet-supported means of education with input from leading experts in the field. There is also an education hub on the official website with open access to all.
- **OUTREACH:** Increase the awareness and promotion of ESTEEM3 activities in general and of the free-to-use transnational access offer in particular, including the dissemination of information to industry and to non-specialist scientific communities as well as to the general public.

SUSTAINABILITY

THE CONSORTIUM SUCCEEDED IN:

- Establishing a strategic leadership in electron microscopy to guide future developments and promote advanced electron microscopy to the wider research community.
- Providing transnational access for the academic and industrial research community in physical sciences to some of the most powerful characterization techniques available at the nanoscale.
- Providing training in innovative methods in electron microscopy and a forum for discussing emerging cutting-edge electron microscopy techniques.

Eight partners of ESTEEM3 created the e-DREAM (European Distributed REsearch Infrastructure for Advanced Electron Microscopy), a not-for-profit initiative formed to promote cooperation between European-level advanced electron microscopy infrastructure providers, collaborative research and transnational user programs.

This collaboration led to 2 Horizon Europe Infrastructure projects:

- ReMade-at-ARI for "Recyclable Materials development at Analytical Research Infrastructures" (2022-2026).
- IMPRESS for "Interoperable electron Microscopy Platform for advanced RESearch and Services" (2023-2027).

e-DREAM constitutes a step stone towards creating a legal structure.

14 WORKSHOPS AND SCHOOLS ORGANISED

50 PUBLIC DELIVERABLES

MORE THAN 500 PUBLICATIONS

TNA SUCCESS STORIES

MHPs-MOFs-LEDs

The project "Metal-halide perovskites (MHPs) in metal-organic frameworks (MOFs) for light-emitting diodes (LEDs)" proposed by Dr Sean Collins from the University of Leeds (UK) was granted access to the International Laboratoire de Physique des Solides (LPS) at the CNRS (France). The project focused on developing new materials for durable, high-efficiency lighting. Through the ESTEEM3 access, we were able to obtain cathodoluminescence (CL) measurements in the scanning transmission electron microscope from individual nanocrystals within the MOF glass matrix. The ability to achieve nanometer spatial resolution in CL with the sample cooled to liquid-nitrogen temperature was crucial to record emission spectra from individual grains within the composite. The CL results showed narrow-band red-light emission in $CsPbI_3$ crystals, providing direct evidence of the targeted crystal phase and optoelectronic properties in the glass composite.
Among the successful outcomes, Dr Sean Collins and Dr Luiz Tizei published an article arising from this access with colleagues from the University of Cambridge and the University of Queensland in the journal "Science" entitled "Liquid-phase sintering of lead-halide perovskites and metal-organic framework glasses"

CeramECS

The CeramECS "Glass-ceramic and ceramic materials for energy conversion and storage" project, carried out by Prof. Federico Smeacetto and by PhD student Elisa Zanchi, from the Politecnico di Torino (Italy), focuses on the advanced microscopy characterization of innovative ceramic coatings based on in-situ modified MnCo spinels. The project was granted access to the facilities and expertise of the International Centre of Electron Microscopy for Materials Science (IC-EM) at the AGH-UST in Krakow. The application of a ceramic protective coating on the steel interconnects of Solid Oxide Cell stacks is a widely employed solution to limit the steel-oxidation rate and chromium evaporation.
Thanks to ESTEEM3 transnational access, it was possible to unravel the effect of the simultaneous addition of Cu and Fe on the microstructural properties of in-situ modified MnCo-based spinel coatings for solid oxide cell interconnects. This work provides the first comprehensive assessment of simultaneous Cu and Fe addition into the Mn–Co spinel dual-phase structure and lays the groundwork for future research into the tuning of Mn-based spinel properties. This TNA project led to the joint publication (POLITO and AGH) of two manuscripts in the Journal of the European Ceramic Society.

UNIVERSITY OF LEEDS

LPS ORSAY

ORSAY LPS

ESTEEM 3 FACILITIES

KRAKOW IC-EM

AGH

Politecnico di Torino

esteem3

ESTEEM3 (Enabling Science and Technology through European Electron Microscopy) is an EU-funded project integrating activity for electron microscopy providing access to the leading European state-of-the-art electron microscopy research infrastructures, facilitating and extending transnational access services of the most powerful atomic-scale characterization techniques in advanced electron microscopy research to a wide range of academic and industrial research communities for the analysis and engineering of novel materials in physical, chemical, and biological sciences.

DURATION
1 January 2019
30 June 2023

CONSORTIUM
15 Laboratories
5 SMEs

BUDGET
10 M€

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