European Vision with a Focus on Access

The ESTEEM3 initiative coordinates an integrated network of the leading European Transmission Electron Microscopy installations, enabling them to pool their resources and know-how. We spoke to the coordinator of the project **Prof. Dr Peter A. van Aken** of the Max Planck Institute for Solid State Research in Stuttgart.

TRANSMISSION ELECTRON MICROSCOPY

The advances in Transmission Electron Microscopy (TEM), which allow materials to be studied at the atomic level, are invaluable for research and development in physical, chemical, and biological sciences, and the ever-increasing demand for highly specialized materials in practical applications for many industries and small-to-medium-sized enterprises (SMEs) developing materials for a particular end-use.

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.

ESTEEM3 also delivers a programme of education and training to heighten awareness of the European TEM technology and capabilities available to industry, small businesses, and academia.

THE ROLE OF ESTEEM3

"Europe is at the forefront of electron microscopy technology, offering world-class instrumentation and installations equipped to support industry and research," according to Prof. Dr. Peter A. van Aken, ESTEEM3 Coordinator, "and our vision at ESTEEM3, while continuing to support ongoing research and encourage dissemination of the latest findings, includes a drive to connect those working in materials, whether in industry, small businesses, or academic research, with the network of European centres of excellence offering state-of-the-art high-resolution electron microscopy equipment and services."

The partner laboratories, distributed throughout Europe (see map), are brought together by the ESTEEM3 initiative to innovate, collaborate and share the latest knowledge and techniques in this domain.

He continues, "Building on the achievements and the knowledge gleaned from the first incarnation of ESTEEM in 2007, and through ESTEEM2 in 2012, ESTEEM 3 can call on 16 years of experience in serving the needs of the end-users".

The term of the current project runs four and a half years, from January 2019 until the end of June 2023.

Following the Mid-Term Review by the European Commission in 2020, where the reviewers declared the results and progress of the ESTEEM3 project to be "excellent", Prof. Dr. Peter A. van Aken is understandably delighted by the interest the project has attracted, and the successes recorded by the initiative.

He concludes, "So far, ESTEEM3 has provided access to more than 350 projects, which demonstrates the high level of demand for access to TEM infrastructures in Europe and indicates the confidence in ESTEEM3 as a firmly established and trusted network to support the European electron microscopy community."

ESTEEM3 partner laboratories, distributed throughout Europe.

By connecting a network of centres of excellence in state-of-the-art electron microscopy throughout Europe, the findings of the latest research can be disseminated among the laboratories, thus ensuring that the highest standards of service and the most up-to-date advances in electron microscopy are deployed throughout. As cutting-edge services are made accessible to industry, research and SMEs, the scope of applications is expanding rapidly as more end-users become aware of the services available to them.

The 14 ESTEEM3 member laboratories and SMEs such as Attolight, CEOS, DENS solutions, Quantum Detectors and Nanomegas have developed Joint Research Activities, which have resulted in over 250 scientific publications so far.

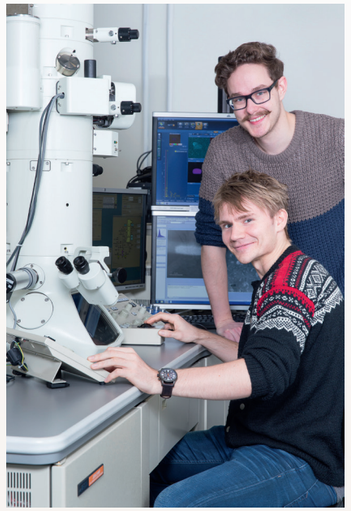
ESTEEM3 OBJECTIVES

The overall objective of ESTEEM3 is to be the best in the world and the key European multi-site research and user infrastructure platform for advanced characterisation of materials using TEM.

ESTEEM3 activities are divided into three main areas of : 1. Transnational Access (TA), 2. Joint Research Activities (JRA), and 3. Networking Activities (NA).

1 TRANSNATIONAL ACCESS

As an ongoing European project, ESTEEM3 provides transnational access for the scientific community to the leading European state-of-the-art electron microscopy research infrastructures.



The ESTEEM3 protocol means that highly sophisticated equipment and the services of highly trained staff are made available, free of charge, to serve industrial developers and small to medium-sized enterprises, all having access to the latest electron microscopy facilities, and the services personnel qualified to assist them with the methodologies and experimental techniques to support their requirements.

European and international researchers are provided with ultrahigh-resolution electron microscopy instrumentation at the forefront of technology with world-class facilities so that challenging materials problems can be solved at unprecedented spatial and energy resolution, and researchers from various disciplines can interact and develop collaborations.

The procedure to apply for transnational access follows a simple peer review process, based on merit and scientific priorities. The user, whether an individual or a team, presents a description of the work they intend to carry out on the ESTEEM3 website. The application is then assessed by the Transnational Access Proposal Committee (TAPEC), which is composed of world-renowned scientists in microscopy and materials science.

Users are supported throughout the process, from assistance with preparing their requests, to the selection of appropriate methodologies and protocols.

2 JOINT RESEARCH ACTIVITIES (JRA)

Joint Research Activities (JRA) focus on the development of the advanced TEM methods required for the solution of key problems in materials and nanoscience. Importantly, these JRA will strengthen TA capabilities within the ESTEEM3 consortium by providing a higher level of overall service to all TA users both from academia and industry. The JRA have been selected to enable potentially disruptive scientific and technological projects that will enhance overall service provision. In addition, we have structured a JRA to tackle key problems in technologically important materials.

- **THE DEVELOPMENT OF NEW TECHNIQUES IN TEM**

The ESTEEM3 project strives to foster the development of new techniques at the leading edge of Electron Microscopy and to maintain Europe's position as the world leader in the field.

- **THE STUDY OF NEW MATERIALS**

Facilitating the use of TEM as it becomes an invaluable research tool in an ever-expanding range of applications, such as ICT, energy, health, and transport. (See panel "TEM Applications")

- **AUTOMATION and BIG DATA**

The advancement of routines for instrument control data acquisition data processing and machine learning with a reduced level of human intervention will be developed using automated and smart workflows, as well as open software for the design and interpretation of experiments.

3 NETWORKING ACTIVITIES (NA)

In addition to the initiative to facilitate access for industries and small to medium enterprises (SMEs) to world-class electron microscopy facilities and services, ESTEEM3 develops and hosts Networking Activities, with regular events being hosted throughout Europe.

- **Integration and Sustainability** is 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 in 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.
- **The Outreach** component strives to increase the awareness and promotion of the 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 and the general public

TEM APPLICATIONS

TEM is an invaluable research tool in the four main categories of:

ICT: with increasing demand for highly-engineered semiconducting and magnetic materials, functional complex oxides, and photonics materials.

Energy: for the assessment and development of materials for electrodes in batteries, nanocomposite solar cells, and steel and superalloys for use in power plants.

Pharmaceutical Industry: for research into materials such as pharmaceutical nanoparticles.

Transport: including the aeronautics, aerospace, and automotive sectors, where there is a need for high-performance materials, such as complex metallic alloys.

In addition, there are applications in an ever-widening range of disciplines, including the study of polymers for the Chemical Industry, the analysis of rocks and unlithified materials in Geology, and applications in Archaeology, for instance, the requirement to preserve and protect substrates of cultural heritage materials, such as paintings and textiles.

Materials Development at the Atomic Level

By means of a state-of-the-art synthesis technique "molecular beam epitaxy", we can create novel materials by layering atoms. This technique gives rise to unprecedented physical properties between any two layers of specific atoms. One of the most exciting examples is the existence of interfacial superconductivity between two non-superconducting dissimilar layers, for example, a metallic layer and an insulating layer. Such intriguing properties are confined to the range of one to two nanometres, and the underlying physics and chemistry can be determined with atomic-resolution imaging and spectroscopy using scanning transmission electron microscopy. These techniques can be used not only to image the atoms of the materials but also to reveal the chemical properties of the individual layers, e.g. by elemental mapping of each atomic column.

Mapping Electrical Properties of Nanodevices *in situ*

A collaboration with the European semiconductor company STMicroelectronics resulted in a technique to study electric fields in commercial nanodevices under working conditions, by means of operando electron holography. A sample preparation protocol was developed to allow nanodevices to be extracted from production lines and thinned to electron transparency while still retaining their electrical connectivity and functionality. This technique enabled the electric potential of the devices to be mapped quantitatively in situ, so that electrical properties, such as capacitance and surface charge density, could be determined. This exciting development opens up further possibilities to study more complex devices.

ESTEEM3

Enabling Science and Technology through European Electron Microscopy

Project Objectives

The European H2020-INFRAIA project ESTEEM3 (Enabling Science Through European Electron Microscopy) is an 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.

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Project Partners

The ESTEEM3 project has a total of 20 international partners. A full list of details of the project participants can be found here: https://www.esteem3.eu/consortium

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To keep abreast of news and developments and to join our community, subscribe to our newsletter at https://www.esteem3.eu/Newsletters for further details about results, training events, transnational access, etc. The latest information is available on our website or social media (LinkedIn: https://www.linkedin.com/company/esteem3/ or Twitter: https://twitter.com/Esteem3Project).

Prof. Dr. Peter A. van Aken

Prof. Dr. Peter A. van Aken leads the Stuttgart Center for Electron Microscopy of the Max Planck Institute for Solid State Research and is Coordinator and Principal Investigator of the European project ESTEEM3 (Enabling Science Through European Electron Microscopy). Prof. van Aken's research mission is the advancement of the in-depth microscopic understanding of materials with respect to their functionalities and structure–property relationships.

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