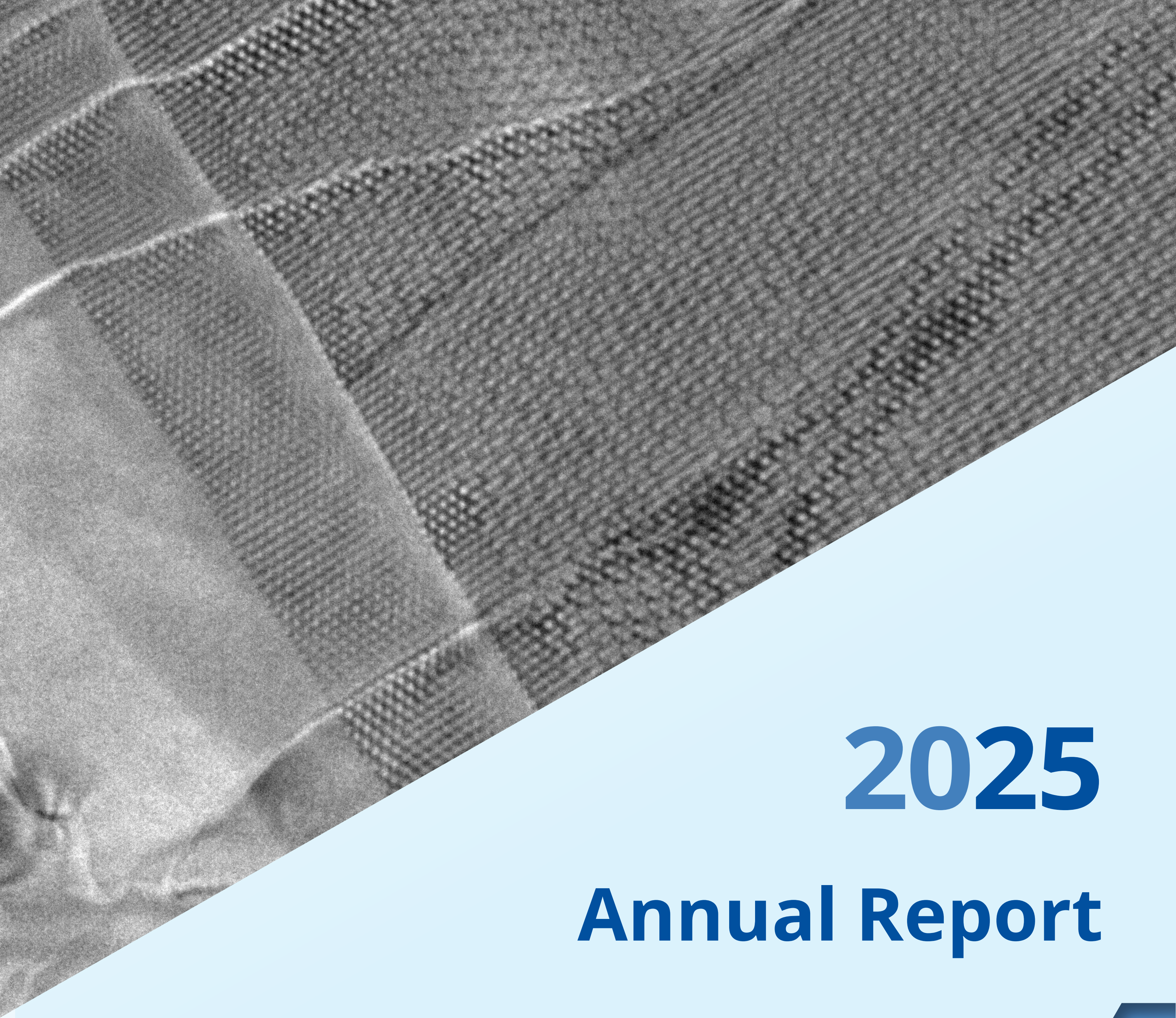


2025

Annual Report

TEM GEMINI CENTRE

DEPARTMENT OF PHYSICS, NTNU
MATERIALS PHYSICS TRONDHEIM,
SINTEF INDUSTRY

All pictures and figures in the report without photo credit are taken/made by people in the TEM Gemini Centre.
Tykket på NTNU Grafisk Senter. Utforming av Anna Eiriksson og Stine Bratlie.

2025 has been an important and successful year for the TEM Gemini Centre. The installation of the new GrandARM 2 microscope within the NORTEM II project marks a major milestone for the Norwegian science community. At the same time, we have maintained high activity on our existing instruments, training a new generation of users and sustaining strong scientific output in terms of publications and graduated candidates. The collaboration between NTNU and SINTEF continues to provide a safe, robust, and efficient environment for advanced transmission electron microscopy (TEM). The GrandARM 2 investment demonstrates not only national strategic commitment, but also the competence and reliability of the NORTEM host institutions (NTNU, SINTEF and UiO) in operating complex scientific infrastructures.

With the arrival of the GrandARM 2, the Trondheim node now hosts four TEM instruments. A systematic and longterm infrastructure management strategy remains essential. While NTNU owns and runs the facility, SINTEF contributes as a key scientific user and collaborator, ensuring operational stability and complementary expertise. This partnership enables advanced TEM studies to support both fundamental research and industrial innovation nationally and internationally. Looking ahead, proactive project acquisition and continued engagement with emerging research directions will be critical to fully exploit the potential of the upgraded infrastructure. TEM plays an increasingly central role in the national initiative on emerging technologies: in quantum materials, functional materials, and device development, the ability to visualise structure at the atomic scale is indispensable.

NTNU is now a partner in the EU projects Impress and RIANA, and a member of the e-DREAM network. In 2025, these consortia, led by Trieste and Jülich, submitted an ESFRI roadmap application under the initiative Microscopy Europe, with NTNU as a contributing partner. The Centre also participates in a wide portfolio of projects, ranging from fundamental research to industry driven innovation. We remain involved in SFI PhysMet, and in December 2025 the new SFI FAST- Future Aluminium Structures - was funded, with Randi Holmestad as Centre Director. Research activities in magnetic materials and data analysis continue to expand. Two new projects, MAD and NIMSKY, started in 2025, and the newly granted Nordic project NEMI, following NordTEMhub, will begin next year.

A highlight of the year was the inauguration of the GrandARM 2 on 2–3 December. The event included an official opening and a scientific seminar with international speakers, attracting around 100 participants from NTNU, SINTEF, and collaborating institutions. In June, we coorganised the The Trondheim International Summer School on Aluminium Alloy Technology (ISSAAT), which gathered 60 participants from academia and industry.

In 2025, the Centre had 36 hands-on operators, 15 users through operators, and supported 74 projects. The research conducted at the facility resulted in 46 journal publications. The breadth of journals and topics reflects the versatility of TEM as a scientific tool. For PhD theses and ten MSc theses with substantial TEM components were completed during the year. TEM also played a role in three NTNU courses, reaching approximately 150 students, and the annual introduction course in September had 15 participants. The Centre's weekly group meetings continue to serve as an active arena for scientific exchange, often gathering more than 25 participants.

This annual report summarises the people, resources, and activities of the Centre, highlights selected scientific results, and lists all publications from 2025. For further information, please visit our homepage: TEM Gemini Centre - NTNU.

TEM Gemini Centre management, February 2026.

BOARD AND MANAGEMENT OF TEM GEMINI CENTRE

TEM Gemini Centre board:

- Kathrine Røe Redalen, Department Head, Department of Physics (DP), NTNU
- Ruben Bjørge, Research Manager, Materials Physics Trondheim, SINTEF Industry
- Ida Westermann, Department Head, Department of Materials Science and Engineering (DMSE), NTNU

Centre management:

- Randi Holmestad, Physics, NTNU, Leader
- Ruben Bjørge, Materials Physics, SINTEF Industry
- Ton van Helvoort, Physics, NTNU
- Magnus Nord, Physics, NTNU
- Bjørn Gunnar Soleim, Physics, NTNU
- Emil Frang Christiansen, Physics, NTNU
- Ursula Ludacka, Physics, NTNU
- Per Erik Vullum, Materials Physics, SINTEF Industry

Kathrine Røe Redalen

Ruben Bjørge

Ida Westermann

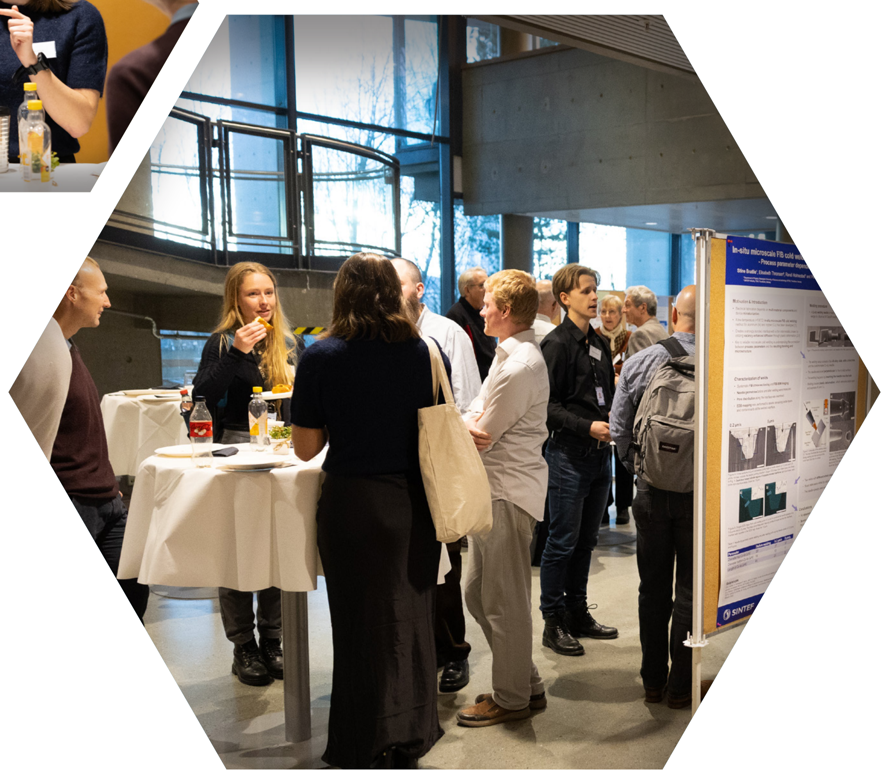
Upper: Minister of Research and Higher Education Sigrun Aasland touring the GrandARM 2 microscope during a visit to Trondheim and NTNU in October 2025. Lower: What is the coolest part of the aluminium alloy?

PEOPLE IN THE TEM GEMINI CENTRE IN 2025

- Eila Aurora Huru Bergene (Master student, DP, NTNU)
- Tina Bergh (Researcher, Department of Chemical Engineering, NTNU)
- Ruben Bjørge (Research manager)
- Stine Bratlie (Master student, PhD student, DP, NTNU)
- Liesbeth Kristine Marit Hoogen Campbell (Master student, DP, NTNU)
- Magnus Slåtten Fallmyr (Master student, DP, NTNU)
- Emil Frang Christiansen (Senior Engineer, DP, NTNU)
- Sivert Johan Vartdal Dagenborg (PhD student, DP, NTNU)
- Ali Elashery (Postdoc, DMSE, NTNU)
- Jesper Friis (Senior research scientist, SINTEF)
- Erik Gaupseth (Master student, DP, NTNU)
- Ingrid Marie Zhenni Gustavsen (Master student, DP, NTNU)
- Fredrik Johnatan Treichel Hanevold (Master student, DP, NTNU)
- Christoph M. Hell (PhD student, DP, NTNU)
- Ton van Helvoort (Prof., DP, NTNU)
- Andreas Holand (Master student, DP, NTNU)
- Kay Holm (Master student, DP, NTNU)
- Randi Holmestad (Prof., DP, NTNU / Leader TEM Gemini Centre)
- Hannah Hareide (Master student, DP, NTNU)
- Trond Hauklien (Master student, DP, NTNU)
- Andreas Holand (Master student, DP, NTNU)
- Kay Holm (Master student, DP, NTNU)
- Sindre Vie Jørgensen (Master student, PhD student, DP, NTNU)
- Inga Dahlen Konow (Master student, PhD student, DP, NTNU)
- Denis Lobe ((Master student, DP, NTNU)
- Håkon Longva Korsvold (PhD student DMSE, NTNU)
- Ursula Ludacka (Senior Engineer, DP, NTNU)
- Paul Salvatore Sjøvaag Marino (Master student, DP, NTNU)
- Calin D. Marioara (Senior research scientist, SINTEF)
- Knut Marthinsen (Professor, DMSE, NTNU)
- Sander Endré Nilsen (Master student, DP, NTNU)
- Karola Neeleman (PhD student, DMSE, NTNU)
- Magnus Nord (Assoc. Prof. DP, NTNU)
- Thyra Rolfseng (Master student, PhD student, DP, NTNU)
- Oskar Ryggetangen (PhD student, DP, NTNU)
- Jonas Fagerli Simonsen (Master student, DP, NTNU)
- Stian Skinnarland (Master student, DP, NTNU)
- Iver Karlsbakk Småge (Master student, DP, NTNU)
- Bjørn Gunnar Soleim (Senior Engineer, DP, NTNU)
- Kristian Bjørnes Thevik (Master student, DP, NTNU)
- Patrick Robert Borsheim Thomassen (Master student, DP, NTNU)
- Elisabeth Thronsen (Research Scientist, SINTEF, NTNU)
- Kristian Tveitstøl (PhD student, DP, NTNU)
- Per Erik Vullum (Senior research scientist, SINTEF and Assoc. Prof. II, DP, NTNU)
- Sophia Anastastia Wellman (Master student, DP, NTNU)
- Sigurd Wenner (Research scientist, SINTEF)
- Kristine Wiklund (Master student, DP, NTNU)

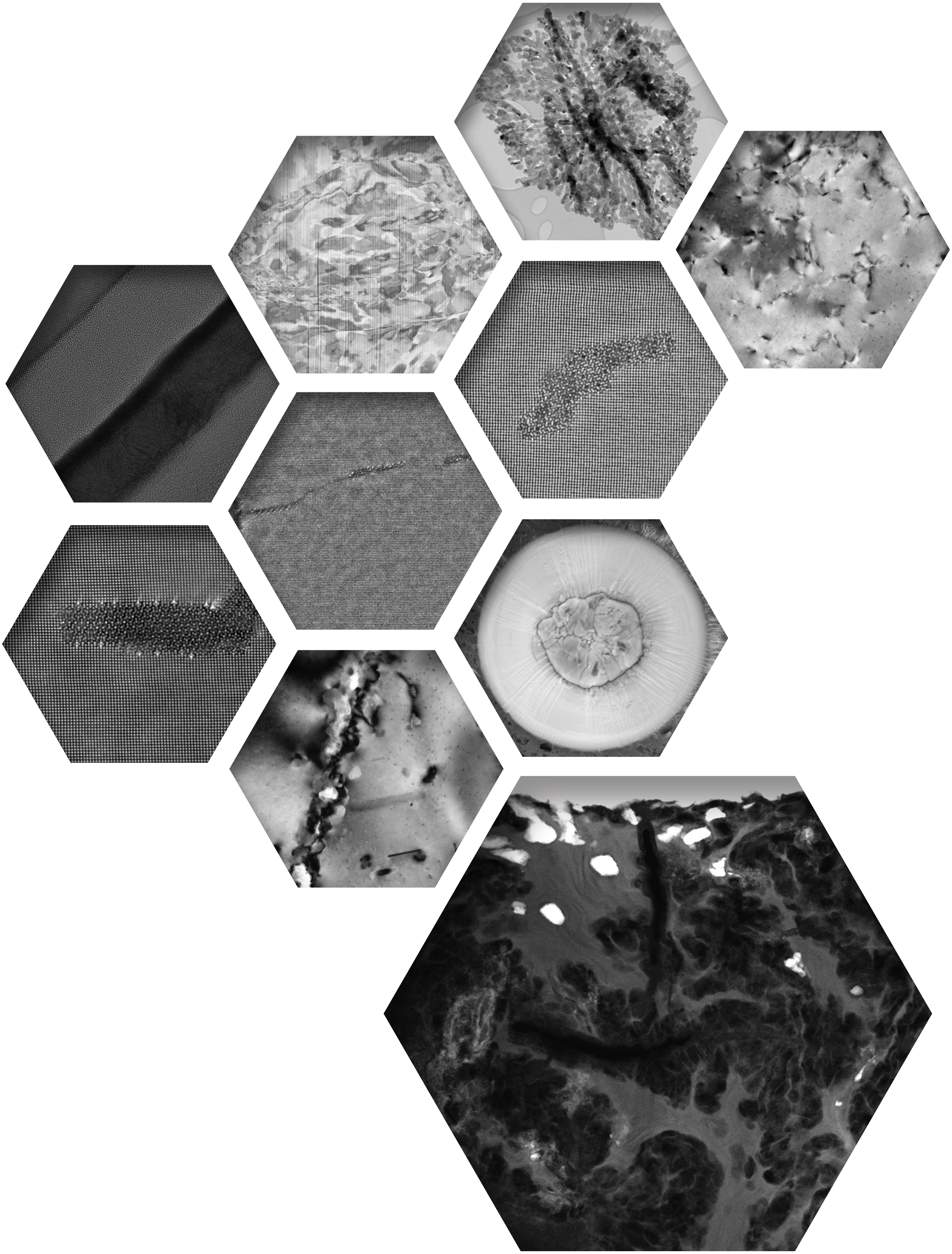
TEM Gemini Centre 2025 group photo. Photo by: Per Henning.

POSTER SESSION AT GRANDARM 2 OPENING, DECEMBER 2025



Photos by: Per Henning.

CONTENT:



THE NORTEM PROJECT

NORTEM I (Norwegian Centre for Transmission Electron Microscopy) was a nationally coordinated largescale infrastructure project (2011-2020) with three partners: SINTEF, NTNU and UiO. It was funded by the Research Council of Norway (RCN) together with the partner institutions. The total budget for new equipment and rebuilding in the project was approximately 75 MNOK, distributed across the two geographical nodes in Trondheim and Oslo.

In December 2021, the second nationally coordinated project, **NORTEM II**, was granted, securing access to new worldclass TEM instruments in Norway for another decade. This proposal included one new instrument in each node. A joint tender process for Oslo and Trondheim concluded with the signing of a contract with JEOL in December 2023.

For the Trondheim node, we ordered the *JEOL GrandARM 2*, a state-of-the-art probe corrected instrument equipped with modern cutting edge direct detectors, a CEFID energy filter, advanced probe forming systems with improved illumination flexibility, 300 kV accelerating voltage, enhanced mechanical and thermal stability, and increased automation. The instrument is optimised for structure determination, diffraction studies, and electric and magnetic field imaging. It arrived in March 2025, and we are now in the process of learning to operate it effectively.

The vision of NORTEM (II) is to be "a worldclass TEM facility providing access to expertise and state-of-the-art infrastructure for fundamental and applied research within the physical sciences in Norway." In addition to being a leading research TEM laboratory, the infrastructure provides access to a broad user community working within physics, chemistry, materials science, geology, and related fields. Operating both as a research laboratory and a national user facility requires a clear and sustainable management model, and the TEM Gemini Centre has established a sound model for running the infrastructure. The NORTEM II funding secures the future of the facility, and our task now is to make the best possible use of this large and complex investment. For more information, see the NORTEM webpages.

The Trondheim node of the NORTEM facility has three senior engineers, Bjørn Gunnar Soleim, Emil Frang Christiansen and Ursula Ludacka, who ensure maintenance, training, development of competence, and technical support. As a result, the microscopes maintain a high uptime. Per Erik Vullum has served as an adjunct (affiliated) professor (20 %) at NTNU in 2025, strengthening the interaction between NTNU and SINTEF.

THE TEM GEMINI CENTRE

The TEM Gemini Centre was established in 2006 and initially included professors, postdocs, students and engineers from the Department of Physics (DP) at NTNU, together with researchers from the Materials Physics Trondheim group at SINTEF Industry. The Department of Materials Science and Engineering (DMSE) joined in 2009, and the Centre was renominated in both 2018 and 2022. Since DMSE no longer operates TEM instruments and now has a role similar to other NTNU departments, it was agreed that DMSE should formally leave the Centre. However, because DMSE represents a significant share of the external user base, the Centre's board continues to include representatives from DP, DMSE and SINTEF.

The Centre's research groups work broadly within materials physics and materials science, studying materials down to the nanometre and atomic scale using TEM as the primary tool. The overarching objective is to *maintain a robust TEM research environment with high international visibility, supporting growth not only within the Centre but also across NTNU, SINTEF and collaborating academic and industrial partners*.

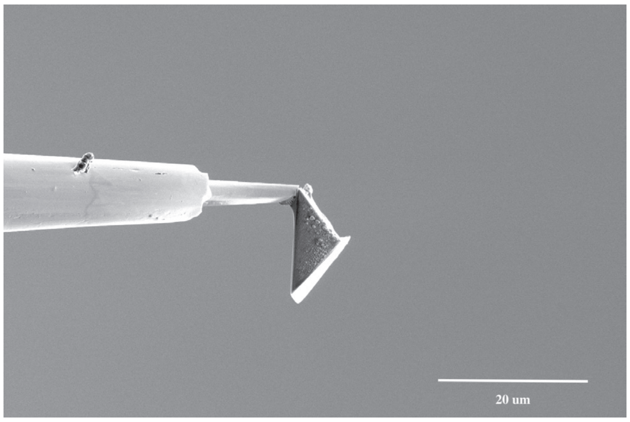
The Gemini collaboration enables the partners to pursue new opportunities, create value and strengthen competitiveness. The shared vision, "Global excellence together," emphasises coordinated strategic planning, shared arenas for concept development and information exchange, and joint approaches to investment and laboratory operations. The strategic framework encompasses all aspects of collaboration—from teaching and research to innovation projects, recruitment and internationalisation.

TEM Gemini Centre

NORTEM

SPECIMEN PREPARATION

Given the high resolution of the TEM instruments, specimen quality is often the limiting factor. Also, special holders require a dedicated specimen shape for optimal performance. The Gemini Centre has well equipped specimen preparation facilities, reflecting the broad range of materials studied. Many TEM projects utilize the focused ion beam (FIB) instruments at NTNU NanoLab and the Smart-H infrastructure with lift-out options for site-specific TEM specimen preparation. Other important TEM specimen preparation tools include an ultramicrotome, various mechanical cutting and polishing tools, tripod wedge polishing, and Ar+ ion sputtering. A recent development is utilizing chemical methods at NTNU NanoLab to remove thin film substrates, allowing for the creation of large field-of-view plan view samples with possibility of electrical bias. (see the section on “Advanced clean room fabrication of in-situ TEM chips” for more information on this).



SE Image of plane-view TEM lamella attached to a micro-manipulator needle while preparing TEM samples by FIB.

USER STATISTICS FOR 2025

The total registered used time for the three instruments in 2025 was 2691 hours, including 115 non-paid hours used for testing, competence development, demonstrations, and guided tours. Of the 2678 paid hours, the use by NTNU corresponds to 80 %, externals (with NTNU operator) 2 %, and SINTEF 18 %. NTNU’s use is divided over six departments, where the main use is from Department of Physics (93 % of NTNUs paid hours). 74 different projects used TEM in 2025. The infrastructure had in total 51 users, of which 36 were hands-on operators. 5 of the users were based at SINTEF, 17 were PhD candidates and 17 were master students. The table below shows an overview of the use.

Microscope use in hours	ARM200F	2100F	2100	SUM
SINTEF	287	65	95	447
NTNU - Physics	265	849	661	1775
NTNU - Other departments	95	22	11	128
NTNU - Visitors from abroad	27	0	12	39
NTNU - Teaching lab	0	59	68	127
External	15	45	0	60
NTNU - Set-up/testing/training/demonstrations	79	35	1	115
Total use	768	1075	848	2691

The facility was used for regular courses, project and master projects. In 2025 more than 150 students had a TEM lab exercise, for example students in the courses

- TFY4220 - Solid State Physics
- TFY4330 - Nanotools
- TMT4166 - Experimental Materials Chemistry and Electrochemistry

THE TEM INSTRUMENTS IN TRONDHEIM

The TEM Gemini Centre has three TEMs installed as part of the NORTEM project in 2013 - a JEM-2100 LaB_6, a JEM-2100F and a double corrected JEM-ARM200F. In addition, the GrandARM 2 was installed in 2025 (see pages 12-15).

JEOL double corrected JEM-ARM200F (cold FEG)

This is Norway's only double corrected TEM. The stable cold FEG with both probe and image spherical aberration correction and the most advanced EDX and EELS systems allow unique studies at the atomic scale. The microscope is placed in a custom designed room with water cooled walls and field cancellation.

The ARM features:

- Cold field emission gun with energy spread of < 0.3 eV
- Fully aligned at 80 and 200 kV
- Cs-probe corrector (Resolution in HAADF < 1Å)
- Cs-image corrector (Resolution in HRTEM < 1 Å)
- Centurio SDD EDX (solid angle 0.98 sr)
- Quantum GIF with DualEELS and 2k CCD
- 4k RIO CMOS (side mounted)
- Quantum Detectors quad-chip (512x512) MerlinEM direct electron detector
- Stable 5-axis gonio with piezo control in x, y and z-directions
- Detectors for BF(2x), ABF, ADF, and HAADF(2x) STEM
- Gatan GMS 3,4, 64 bit
- Aberration corrected low mag. STEM-DPC magnetic imaging (3 nm)

JEOL JEM-2100F

This FEG TEM is optimized for all- round advanced materials studies with focus on scanning precession electron diffraction (SPED) and tomography.

The 2100F features:

- 200 kV Schottky field emission gun (energy spread 0.7 eV)
- Gatan 2k UltraScan CCD (bottom mounted)
- Scanning option with BF and HAADF detector
- Oxford X-Max 80 SDD EDX (solid angle 0.23 sr)
- ASTAR Nanomegas precession diffraction system for phase and orientation mapping
- Gatan TEM/STEM tomography
- Medipix/QD TEM/STEM direct detector

JEOL JEM-2100

The 2100 LaB_6 is the workhorse for routine TEM studies, configured for easy access and a broad user group. This is the instrument new users are trained on. The set-up is optimized for conventional TEM techniques as BF/DF-TEM and SAED.

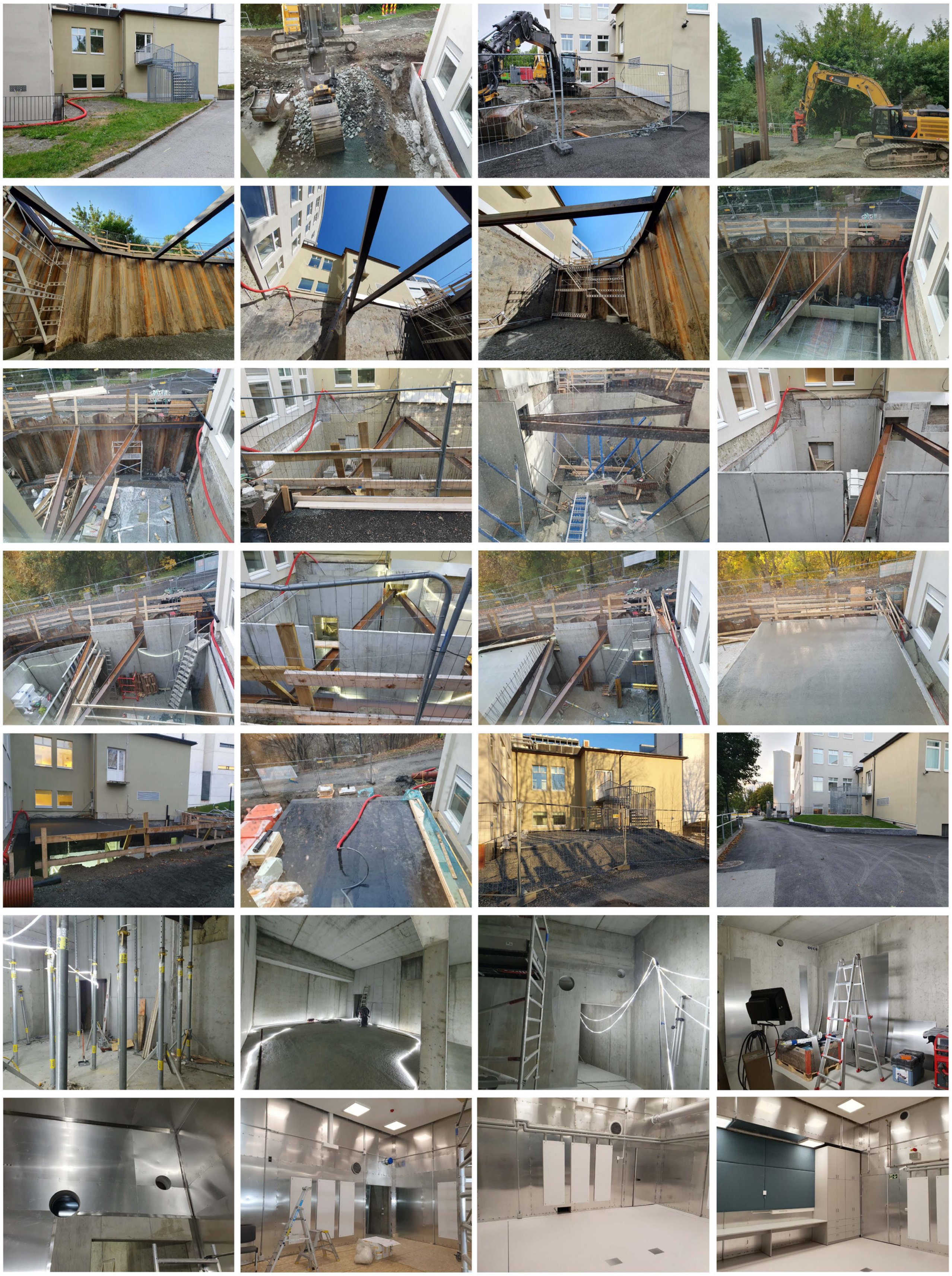
The 2100 features:

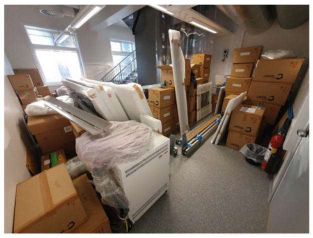
- Gatan 2k Orius CCD (side mounted)
- Scanning option with BF and HAADF detector (DigiScan)
- GIF system with 2k CCD
- Oxford X-Max 80 SDD EDS (solid angle 0.23 sr)

Instrument photos by O. M. Melgård

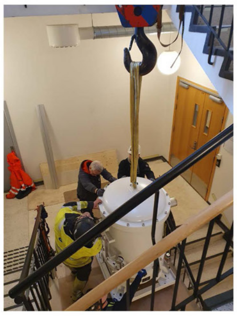
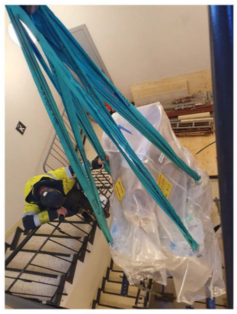
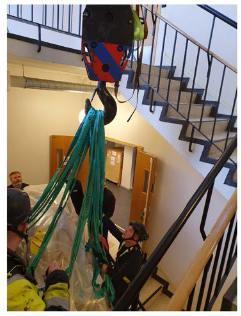
THE NORTEM II FACILITY AND THE GRANDARM 2

The picture series show the construction of the dedicated laboratory for NORTEM II from July 2024 to March 2025, and the delivery and installation of the JEOL JEM-ARM300F2 (GrandARM2) from March to November 2025 (see page 14 for more details).

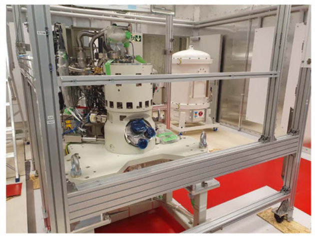


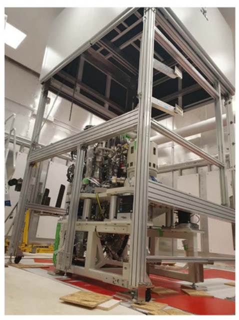
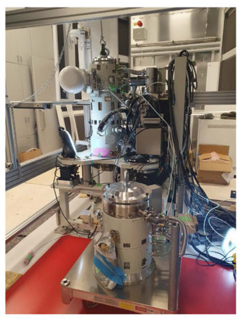



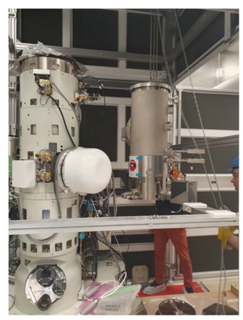
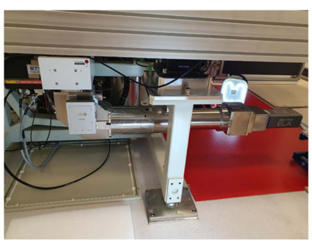
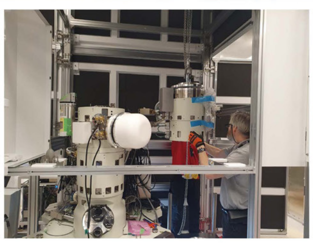
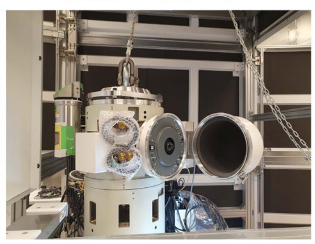
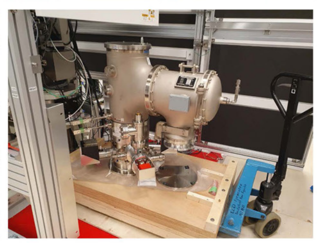






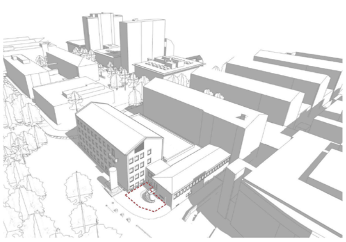






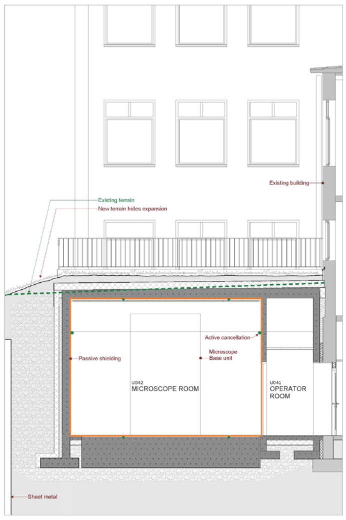



The NORTEM II Facility

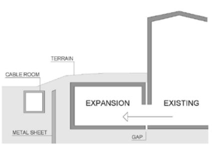
NORTEM
The Norwegian Centre for Transmission Electron Microscopy

Transmission electron microscopes (TEMs) enable imaging at the atomic scale, but mechanical vibrations, external electromagnetic fields, and temperature fluctuations can compromise the performance. To meet the exceptionally strict requirements for the NORTEM II instrument, extensive planning, collaboration across multiple disciplines, and precise execution were demanded when the new laboratory was built. This poster highlights the dedicated work in the building process led by NTNU Property Division, to create a laboratory facility that enables NORTEM to fulfill the vision of being a world-class TEM centre providing access to expertise and state-of-the-art infrastructure for fundamental and applied research within the physical sciences.





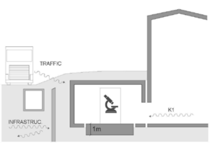
CONCEPT



LAB BUILDING

- A building extension to existing building, K1 at NTNU
- Built as a separate construction not attached to K1
- Entrance from K1, floor U2
- Expansion is hidden under surrounding terrain
- Existing cable room in conflict with construction pit
- Sheet piling installed between cable room and pit

GROUND VIBRATIONS



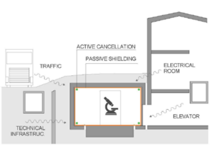
Ground vibrations criterias:

- Horizontal < 3.1 μm/s 1 Hz band to 80 Hz band
- Vertical < 3.1 μm/s 1 Hz band to 80 Hz band

Measures to achieve criteria:

- Distance to existing building
- Separate foundation for microscope with 1 m depth
- Microscope foundation is not attached to surrounding construction
- Sheet metal left in ground to shield some vibration
- Road built as even as possible

MAGNETIC FIELDS



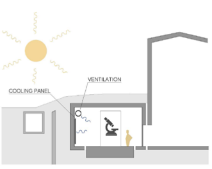
Magnetic fields criteria:

- AC/DC < 50 nT_{pp}

Measures to achieve criteria:

- Passive shielding, 2.35 mm thick metal plates surround the lab (2 mm Al + 0.35 mm NiFe)
- Active cancellation system
- Technical equipment without magnetic disturbance in lab

STABLE CLIMATE



Climate criteria:

- Room temperature 15-25 °C
- Drift 0.2 °C/hour or less
- Temperature variation 0.05 °C/min or less
- Airflow 100 mm/s or less
- Humidity < 60 %

Measures to achieve criteria:

- 9 cooling panels
- Sensitive ventilation system
- No windows to expansion building

NORTEM II

THE NORTEM II PROJECT

- Is funded by The Research Council of Norway's program for infrastructure of national importance
- Has three project partners: NTNU, UiO, and SINTEF
- Includes two new state-of-the-art TEM instruments: one in Trondheim (2025) and one in Oslo (2026)
- Building in Trondheim is funded by NTNU (own share from the Property Division, the Faculty of Natural Sciences and the Department of Physics)

FEASIBILITY STUDY - LOCATION OF LAB

- Should be located in close contact with existing NORTEM area
- Should be an expansion and not located in an existing building
- Should not be in conflict with future building projects

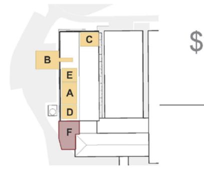
FINAL MICROSCOPE FACILITY

- Expansion housing: microscope room, operator room and technical room
- On the same level as the other three TEMs and supporting labs in K1
- Area: 70 m2
- 7 consulting entrepreneurs: HRP AS, Lusparken Arkitekter AS, Müller-BBM Industry Solutions GmbH, Multiconsult Norge AS, OPAK Trondheim AS, PPM Prosjekt AS, Rambøll Norge AS
- 14 executing entrepreneurs: Aktivgruppen AS, AS Byggservice, B.Bersvendsen AS, BN Entreprenør AS, Bravida Norge AS, CERTEGO AS, Crane Norway AS, Field Geospatial AS, Lindbak Interiør AS, Midtnorsk Brannsikring AS, Nippon Gases Norge AS, Schneider Electric Norway AS, Systron EMV GmbH, Trym Bygg AS

MICROSCOPE: JEOL JEM-ARM300F2

- Aligned for 4 acceleration voltages: 60, 80, 200 and 300 kV
- Cold field-emission gun (CFEG) electron source
- Probe corrected (JEOL STEM Cs corrector)
- Wide gap pole piece (WGP)
- CEOS CEFID energy filter (for EFTEM, ESI and EELS)
- STEM detectors (BF, ADF)
- EDS detector
- DECTRIS ELA post-filter direct electron detector (DED)
- NanoMEGAS acquisition system (precession)
- Electron dose modulator synchrony (EDM)
- FEMTUS software
- Remote controlled from a separate operator room

START UP



- **2020 NOV** – APPLICATION TO THE RESEARCH COUNCIL OF NORWAY
- **2021 DEC** – GRANT FROM THE RESEARCH COUNCIL OF NORWAY FOR MICROSCOPE
- **2022 JAN-JUN** – FEASIBILITY STUDY - LOCATION
- **2022 JUL** – TENDER PROCESS FOR MICROSCOPE STARTED
- **2023 AUG - DEC** – BUILDABILITY
- **2023 DEC** – CONTRACT SIGNED WITH JEOL FOR PURCHASE OF MICROSCOPE

- **2023 DEC - 2024 JUN** – DETAIL PROJECT
- **2024 MAY** – BUILDING APPLICATION
- **2024 MAY** – TENDER - CONCRETE WORK
- **2024 JUL** – NITROGEN TANK TO TEMP. LOCATION

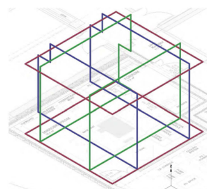


Illustration: Active cancellation coils

- **2024 MAY - JUN** – CONSULTING ENTREPRENEUR FOR PASSIVE SHIELDING AND ACTIVE CANCELLATION

- **2024 JUL** – EXCAVATION WORK

- **2024 AUG - OCT** – CONCRETE WORK
- **2024 SEP** – TENDER - ALL REMAINING WORK
- **2024 SEP - 2025 FEB** – INSTALLATION WATER / COOLING / VENTILATION / ELECTRICAL / BUILDING CONSTRUCTION

- **2025 JAN** – INSTALLATION PASSIVE SHIELDING AND PREP. ACTIVE CANCELLATION

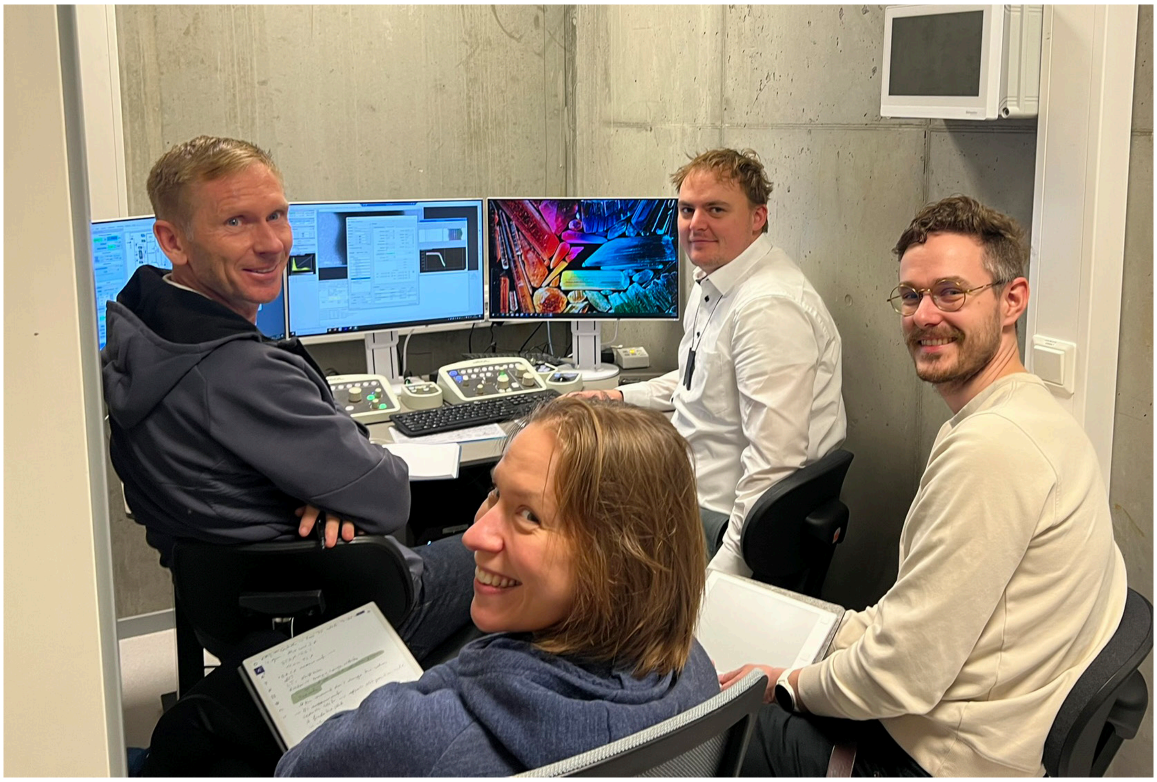
- **2025 JAN** – NITROGEN TANK REESTABLISHED
- **2025 MAR** – DELIVERY OF MICROSCOPE TRANSPORT TO LAB

- **2025 MAR - NOV** – INSTALLATION, CALIBRATION AND PERFORMANCE TESTING OF MICROSCOPE
- **2025 DEC** – LAB AND MICROSCOPE IN USE

OFFICIAL OPENING

Poster made by: Bjørn G. Soleim, Bjørn S. von der Leyen, Anders Stenberg and Kristine Øvsteba

NTNU Norwegian University of Science and Technology
TEM Gemini Centre
SINTEF



Various photos from the GrandARM 2 process.

FOCUS AREAS

Transmission electron microscopy (TEM) is a key technique for fundamental and applied research across the physical sciences, including geology, metallurgy, semiconductor technology, chemistry and physics. NORTEM has defined five core focus areas for the TEM Gemini Centre- light metals, energy materials, nanotechnology, magnetic materials, quantum materials and catalysis -highlighted in both the NORTEM I and II proposals and in recent strategy documents.

These fields continue to offer strong potential for growth and for addressing outstanding scientific challenges using TEM, and all five were active areas of work in 2025. Across these research domains, advanced data processing and analysis are playing an increasingly important role.

ALUMINIUM - LIGHT METALS

The study of aluminium alloys using TEM has long been a cornerstone of the Trondheim TEM environment, and numerous successful projects have been carried out over the years. Most activities are joint efforts between NTNU and SINTEF and are supported by the Research Council of Norway (RCN) and the Norwegian light metal industry, particularly Hydro Aluminium.

PhD candidate Christoph Hell completed his PhD in 2025. He was employed in the competence project *SumAl - Solute cluster manipulation for optimized properties in AlMgSi based Al alloys*, with industry partners from Norway (Hydro, Benteler and Raufoss Technology), Austria (Neuman), Sweden (Hydro) and Germany (Speira). The project generated an in depth understanding of early stage solute ordering and atomic clustering through advanced experiments and modelling. Randi Holmestad was project leader, and the work combined TEM studies and modelling within the TEM Gemini Centre. SINTEF contributed significantly with TEM analyses, atom probe tomography (APT) measurements and modelling. In particular, Calin Marioara has several publications on clustering from this project.

The Nano2021 project *InSane – In-situ studies of highly conductive bonded interfaces between aluminium and copper at the nanoscale* was a collaboration between Department of Physics, SINTEF and the Department of Mechanical and Industrial Engineering (MTP), led by Randi Holmestad. The aim was to perform nanoscale joining in the FIB and to understand and further develop the HYB (Hybrid Metal Extrusion & Bonding) method. Jørgen Sørhaug completed his PhD on advanced TEM in this project in December 2024. In 2025, Ambra Celotto (MTP) defended her thesis, focusing primarily on producing the joints in the FIB. The InSane activities now continue in the KSP project *MAD – Tailoring metallurgically bonded nanoscale interfaces between Al, Cu and Ni involving deformationenhanced diffusion*, which started in 2025 with industry partners Hydro, Corvus Energy and Professor Grong. The project is led by Randi Holmestad, with SINTEF contributions from Per Erik Vullum and Elisabeth Thronsen. In 2025, Stine Bratlie joined the MAD project as a PhD student and will use TEM and FIB to further develop and understand cold joining between Al and Cu at the nanoscale.

The TEM Gemini Centre is involved in SFI PhysMet - *Centre for Sustainable and Competitive Metallurgical and Manufacturing Industry*, based at DMSE and led by Professor Knut Marthinsen. TEM plays a central role in Research Area 1 (RA1), Multiscale materials analysis, headed by Randi Holmestad, with SINTEF participation led by Sigurd Wenner. Within RA1, three PhD candidates are currently working on aluminium related topics. Håkon L. Korsvold (DMSE) combines APT and TEM to study grain boundaries and precipitates in order to understand corrosion mechanisms in aluminium alloys. Inga D. Konow (DP) investigates the interaction between precipitates and deformation (T8/T9 tempers) in 6xxx alloys in close collaboration with Hydro. In 2025, Thyra Rolfseng joined the research area to study precipitates in 7xxx alloys using in-situ heat treatment experiments in the TEM.

The FRIPRO project *QUATRIX - Quasicrystal nucleation in a metallic matrix* ended in 2025. Led by Ruben Bjørge at SINTEF, the project examined the structure and precipitation mechanisms of quasicrystals in aluminium alloys to establish generic knowledge about quasicrystal formation. Oskar Ryggetangen is finalising his PhD within this project, focusing on electron diffraction analysis supported by advanced high resolution TEM.

SINTEF played a major role in the Green Platform project *AluGreen*, involving numerous industrial partners and focusing on recycled aluminium across multiple scales. The project ended in 2025. Increasing the use of recycled aluminium is essential for the green transition and remains a major challenge for industry. Parts of the AluGreen work will continue in the newly funded SFI FAST- *Future Aluminium Structures*, granted in December 2025. The SFI includes 16 industry partners across the aluminium value chain and research partners NTNU and SINTEF. Randi Holmestad is Centre Director. Four NTNU departments (MTP, the host department, Structural Engineering, DMSE and DP) and four SINTEF departments participate. A total of 18 PhD positions are planned over the eight year programme, including two

Celebrations at the SFI Award ceremony. From the left; Kathrine Røe Redalen (Dept head IFY, NTNU) Toril Hernes (pro-rector research,NTNU) Ida Westermann (Dept head IMA, NTNU) Trude Sundset (CTO Hydro) Erik Wahlström(pro-dean research NV, NTNU) Randi Holmestad (IFY, NTNU) Tomas Manik (IMA, NTNU) DirkNolte (SINTEF Industry) David Morin (KT, NTNU) Geir Ringen (MTP, NTNU) Torgeir Welo (Depthead MTP, NTNU) Odd Sture Hopperstad (KT, NTNU) Photo: Aleksander Stokke Båtnes.

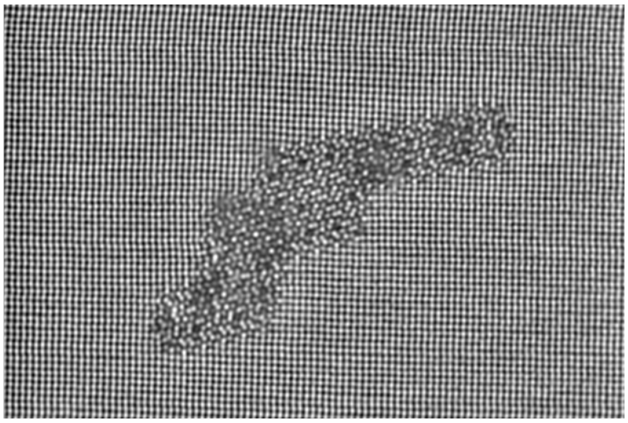
two associated with the TEM Gemini Centre, in addition to SINTEF involvement.

In recent years, the TEM Gemini Centre has participated in several international aluminium alloy collaborations. The UTFORSK project *SuReAl – Norwegian–Japanese collaboration on Sustainability and Recycling in Aluminium alloy development* was granted in 2024. In 2025, two NTNU master's students, Hannah Hareide and Kristian Thevik, completed internships in Japan, and we hosted a longer visit from Science Tokyo (Hinata Tanaka). The UTFORSK project coorganised the The Trondheim International Summer School on Aluminium Alloy Technology (ISSAAT), in June, which gathered 60 participants from academia and industry. Ten participants from Japan attended with UTFORSK support.

A new project in the aluminium portfolio, the IPN project *RACE - Recycled Aluminium Corrosion Engineering*, received funding in 2025. The project involves Hydro and Benteler, includes SINTEF participation, and will support one PhD student in the TEM Gemini Centre starting next year.

As seen from the publication list, the TEM Gemini Centre has contributed to several invited and contributed talks on aluminium research at international conferences over the last year. These include the Gordon Conference on Metallurgy (Stonehill College, USA), Microscopy & Microanalysis (M&M) in Salt Lake City, USA, the XXV Conference on Applied Crystallography (Poland), and EUROMAT (Granada, Spain), demonstrating the strong international recognition of our aluminium related work.

The project *Sustainable graphite Inoculants for Ductile cast Iron* (SIDI) is an innovation project for the industrial sector (IPN) with Elkem in Kristiansand. Here, Elkem aims at a fundamental understanding at atomic level of the graphite nucleation that determines the final properties of the cast iron, systematize that knowledge, and offer scientifically based recommendations for internal product development and client foundries. To achieve that goal, Elkem researchers work closely with research scientists from NTNU and SINTEF providing access to advanced characterization and numerical modelling.



HAADF-STEM image of precipitate in AA6060 alloy.

ENERGY MATERIALS

TEM has proven to be a crucial characterization tool to understand and improve the efficiency of both conventional and novel types of solar cells. The TEM Gemini Centre activities within solar cells include both types and a large range of materials. The Gemini Centre is participating in the FME SUSOLTECH (The Norwegian Research Centre for Sustainable Solar Cell Technology) on solar cells and project students, PhD students and SINTEF researchers within TEM are actively taking part in subprojects related to both conventional as well as third generation solar cells.

SINTEF has worked together with ELKEM and IFE in three consecutive IPN projects within production of tailored Si powders for use in Li-ion batteries. The aim is to develop Si/graphite-based composites as anodes in commercial Li-ion batteries. TEM is the primary tool to characterize and understand the behaviour of the anode composites as a function of structure, morphology and cycling conditions. From the beginning of 2022 this R&D is continued through the Green Platform project SUMBAT. Another IPN project, "ASAP", is led by the company CENATE, a spin-off company to Dynatec. This project also aims to develop Si-based materials optimized for anodes in commercial Li-ion batteries. TEM is here a central characterization tool to study and understand the behaviour of the initial and cycled Si-based electrodes. ASAP ended in Dec. 2025 but will be followed up with a new IPN project "CENSEI" from 2026. "REWAMP" is a new IPN projected that started in 2025. Vianode is the project owner, and the aim is to utilize more of the low-grade coke and graphite fines as active materials in both Li- and Na-ion batteries. In REWAMP TEM is used to study the structure and chemistry of the anode materials. In-situ TEM is utilized to study the structure and crystallization of coke as a function of temperature. TEM is also used in several other projects related to development of Li-ion battery technologies. Such projects include the competence project "LongLife", the SINTEF project "SANE", the Horizon EU project "IntelliGent", and the M-ERA.NET project "SUSTBATT". In LongLife TEM is used to study Li-ion anodes based on sub-stoichiometric SiNx. TEM is an important tool to understand how variations in electrochemical cycling conditions, electrode formulations and structure, chemistry and morphology of active powders couple to the functional properties of the battery cells. In "SANE" solid state batteries are made with pure silicon anodes. TEM is here used to describe how the anode materials develop as a function of cycling conditions. SUSTBATT is a project where the inherently nanostructured SiO_2 frustules, collected from diatoms, are reduced to SiOx during a magnesiothermic reduction reaction. The resulting sub-stoichiometric silicon oxide powders are mixed with graphite to make composite Li-ion battery electrodes. TEM is an essential tool to describe the chemistry, morphology and crystalline structure of the powders after the magnesiothermic reduction, and to describe how the powders develop in the electrode during electrochemical cycling.

NANOTECHNOLOGY

For nanotechnology and nano-sciences as well as quantum technology TEM plays an essential role. TEM is important because it can analyse structure and composition on the same small volume and thereby contribute to understand and tailor the properties of nanomaterials. The TEM Gemini Centre activities at all levels cover nanoparticles, 1D-nanostructures (i.e. nanowires, carbon nanotubes, cellulose fibrils), thin films and 2D-materials such as graphene. NTNU NanoLab is our direct neighbour and many of the TEM operators also use complementary equipment in the cleanroom and NorFab is an important partner for the TEM Gemini Centre in many projects. With collaborators, primarily in Trondheim, we develop methods for correlated studies where TEM is directly combined with SEM, EBSD, Cathodoluminescence, Photoluminescence and Scanning Probe Microscopy techniques. Hereby, more all-round characterization of nanomaterials is realized. Many of our MSc students follow the Nanotechnology study program, a further demonstration that TEM is integrated part of practical nanotechnology. These MSc projects include both practical as well as theoretical/computational focus. In the TEM Gemini Centre, both NTNU and SINTEF have worked with start-up companies within nanotechnology. TEM is here the only tool able to both describe the crystal structure in nanostructures, including various types of defects, and the chemical composition for example in heterostructured nanowires and thin films. With increased activities related to quantum technology, which falls today under the nanotechnology focus area, the header might be adapted to Nano-and Quantum technology.

MAGNETIC MATERIALS - IMAGING ELECTROMAGNETIC FIELDS

The TEM is an excellent tool for studying magnetic materials. It can characterize both the structure, composition and the ferromagnetic domains themselves. This allows for highly correlated studies where one can see how the domains behave, for example where one gets domain pinning, followed by detailed study of crystal structure and chemical composition to understand why it got pinned. Furthermore, by utilizing the objective lens in the TEM combined with tilting the sample, one can easily apply an external magnetic field across the material to study how the domains change as a function of external field.

In the TEM Gemini Centre we focus on improving the methodology for doing such in-situ magnetic experiments: both through the data processing methods, how to best acquire the data and by automating the experiments themselves. Most of this work is done using Scanning Transmission Electron Microscopy – Differential Phase Contrast (STEM-DPC), which utilizes the MerlinEM 4D-STEM detectors on our JEM-2100F and ARM200F. This was part of the Young Research Talents project granted to Associate Professor Magnus Nord by the RCN: “In-situ correlated nanoscale imaging of magnetic fields in functional materials” (InCoMa), and performed by PhD students Gregory Nordahl, Sivert Dagenborg and Kristian Tveitstøl. This project ended in august 2025.

The follow-up researcher project “Nanoscale imaging of magnetic skyrmion dynamics in thin film devices” (NIMSKY) started in 2025 and is a collaboration between NTNU and SINTEF Industry (Sigurd Wenner), lead by Magnus Nord. This project focuses on studying the nanoscale movement of magnetic skyrmions by using custom made in-situ TEM chips (see next section), combined with advanced in-situ experiments.

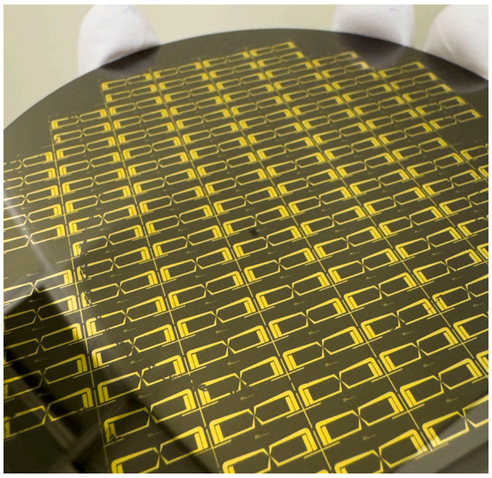
An obstacle for doing the aforementioned in-situ experiments by using the objective lens and tilting the sample, is the large amount of manual input needed to do them. These experiments can easily require more than 100 datasets, which includes tilting, moving and acquiring the data. Doing all this manually is not feasible, so as part of the Horizon Europe IMPRESS project work is being done on automating these experiments. This is being done by PhD student Kristian Tveitstøl, where the plan is to extend this to other types of TEM characterization.

ADVANCED CLEAN ROOM FABRICATION OF IN-SITU TEM CHIPS

Preparing solid state samples for TEM is typically done using tools like the Focused Ion Beam liftout or mechanical polishing. While these techniques work very well for cross section geometry, they are less than ideal for large plan view samples. Especially if one wants to apply an electrical bias across some structure in the sample. For example, if one wants to study how magnetic domain walls move when subject to an electric current.

Improving this has been a focus of associate professor Magnus Nord, by utilizing chemical “back-etching”. Here, nanostructures of magnetic material and electrical contacts are deposited on 100 mm Si-wafer with a chemical etch stop (Si_3N_4. Next, electron transparent windows are created by etching away the Si-wafer using KOH, while the thin film side is protected. By making these chips the same size as the ones used for our DENS Solutions heating holder, we can apply electrical biases directly to the thin film during TEM imaging. All this fabrication work is done at NTNU NanoLab.

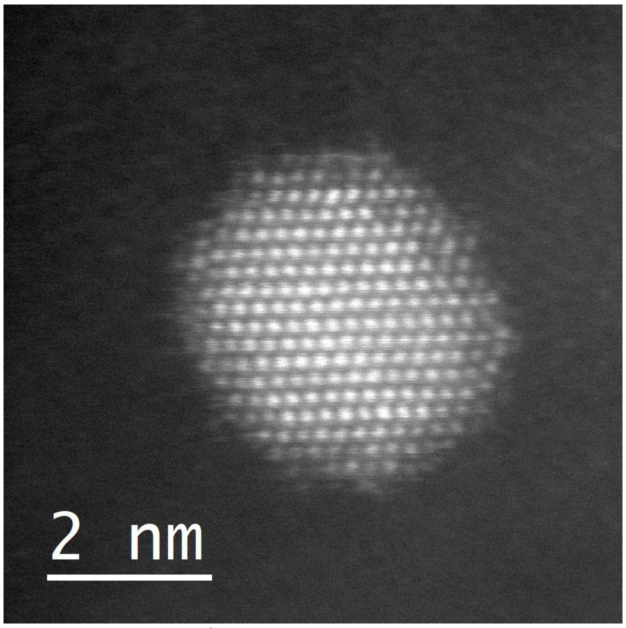
This work was started by Marthe Linnerud and continued by Sindre Vie Jørgensen, Patrick Thomassen, Trond Hauklien and is currently a main focus in the NIMSKY project. Currently it is used for studying magnetic materials, but it can be used for a large variety of materials which can be deposited onto Si_3N_4.



A100 mm diameter wafer with in-situ TEM membranes before they have been cut into 10 x 4 mm chips. The gold is the electrical contacts, with the windows and samples (magnetic permalloy) not visible due to their small size (50 um).

CHEMICAL ENGINEERING - CATALYSIS AND MEMBRANE MATERIALS

The Centre has continued a strong interaction with the national catalysis environment, including the NTNU Chemical Engineering department and SINTEF Industry. The SFI *Industrial catalysis science and innovation* (iCSI), which ended in 2024, headed by Prof. Hilde Johnsen Venvik, hired Tina Bergh as a postdoc (2021-2025) to provide a platform for further applications of TEM in both academic and industrial catalysis research. She got a continuation for 2025 - 2027 as a researcher. The main goal is to develop and use improved (S) TEM methodologies for specimen preparation, in-situ heating and gas reactions, and data collection and analysis. When it comes to the materials studied, the main focus in 2025 was placed on silver catalysts for the methanol to formaldehyde reaction. The silver catalysts were studied after exposure to various reaction atmospheres at elevated temperatures by FIB-SEM tomography and STEM methods, in particular SPED. Also, the newly installed fast TEM camera on the ARM in combination with in-situ holders, will allow



HAADF-STEM image of Pt on TiO2

ADVANCED DATA PROCESSING

Data processing is a cornerstone in the TEM Gemini Centre and its role is becoming steadily more important. This includes machine learning and smart algorithms for analysis of images, spectral data and electron diffraction. The NORTEM infrastructure has three direct electron detectors, on the 2100F, ARM and the GrandARM. The TEM Gemini Centre uses the NTNU cluster IDUN, and is utilizing it particularly for initial data processing and 4DSTEM data analysis. In addition, users have access to local workstations. The group has started to use an electronic labjournal for systematic traceable documentation (RSpace). This proofs useful for development work and projects with several users. We benefit from the fact that our MSc and PhD students have a solid education regarding numerical and computational techniques. Many student projects have a (strong) data handling component. They actively contribute to open-source initiatives such as the Python library HyperSpy (hyperspy.org) and especially for electron diffraction pyXem (github.com/pyxem).

The Impress project - a Horizon Europe EU project headed by Regina Ciancio from Trieste – has the goal to design and deliver TEM instrumentation and data analysis conceived at the highest level of open standards and interoperability. Kristian Tveitstøl is a PhD student in this project, working on scripting control and automation of the TEMs in the TEM Gemini Centre. This to enable more advanced experiments, but also to increase the efficiency through automation of the TEMs.

NORDIC ELECTRON MICROSCOPY INFRASTRUCTURE (NEMI)

NEMI is the follow-up of the NordTEMhub and was granted by NordForsk in 2025 and runs from 2026 until 2031. NEMI aims to foster collaboration, enhance access to advanced instrumentation, optimize usage, enhance access to advanced instrumentation via workshops, exchange of people and competence, from PhDs to lab engineers and consolidate Nordic expertise in advanced transmission electron microscopy.Workshops are open to groups outside the consortium. Beside NTNU, there are eight member universities in this collaborative network: Technical University of Denmark (DTU, Project leader), Linköping University (LiU), Chalmers University of Technology (CTH), and Stockholm University (SU), the University of Oslo (UiO), Aarhus University, Aalto University and Tampere University (TAU). NTNU will host the first NEMI workshop, “Digital TEM: the road from smart automized data collection to advanced open source data processing”, June 2026. Another NordForsk network project was funded in 2025, and will start next year - Unconventional Computing using Ionic Gated Spintronic Nano-oscillators - which is a collaboration with University of Gothenburg, Aalto University and Aarhus University - Ursula Ludacka and Tina Bergh are involved in this.

RESEARCHERS’ NIGHT, SCHOOL VISITS AND OUTREACH

As every year, a large delegation from the TEM group were present at Researchers Night in September 2025. Beside a stand with remote operation of the ARM, there were guided tour’s for visiting pupils. In addition, NTNU guest and evnt organizers regularly request a tour of the TEM facility. For popular science and publications, see pages 30-33.

The TEM Gemini Centre at Researchers night, September 2025.

INTERNATIONAL COLLABORATION

The TEM Gemini Centre maintains productive collaborations with research institutions and scientists worldwide, as reflected in the publication list. Some of these partnerships are longstanding, while others represent new international initiatives. Through the ESTEEM3 project, our facility was used by several leading researchers across Europe, and resulting publications continue to appear. Following ESTEEM3, the RIANA project now provides a new framework for offering access to our facilities. In addition, the INTPART/UTFORSK projects ensure continued international collaboration, in particular with Japan.

Visitors from abroad in 2025 included Hinata Tanaka from Science Tokyo, Mami Mihara Narita from Nagoya Institute of Technology, and Magdalena Cichocka from TU Darmstadt. In December, the inauguration of the GrandARM 2 brought several international TEM experts to Trondheim, as described elsewhere in this report. Through the unique cutting-edge equipment in operation we expect additional international attention and visitors.

Beside the NEMI Nordic network project and EU Impress project, see elsewhere, NTNU is also involved in the work on creating a sustainable electron microscopy infrastructure collaboration in Europe and is one of the founders of the e-DREAM initiative which in 2025 applied to come on the ESFRI roadmap.

UTFORSK PROJECT WITH JAPAN

The four year UTFORSK project *SuReAl*, was granted by HKdir in 2024. This project follows two earlier INTPART collaborations and brings together 12 partners: six universities and six aluminium companies. The Norwegian partners are NTNU, SINTEF, Speira and Hydro, while the Japanese partners include Science Tokyo, Toyama University, Nagoya Institute of Technology, Kyushu University, UACJ, Kobelco, YKK and Toyo Aluminium.

The objectives of the project are to continue the strong partnership established through previous collaborations and to formalise educational components such as guest lectures, workshops, joint courses and internships. Exchange of MSc and PhD students between Japanese and Norwegian universities and aluminium companies is an integral part of the programme.

In June 2025, the project coorganised the ISSAAT summer school, which included a larger Japanese delegation.

The participants at the ISSAAT summer school, June 2025.

Photos from UTFORSK activities in 2025.

INAUGURATION OF THE GRANDARM 2

On 2–3 December 2025, the TEM Gemini Centre, in collaboration with JEOL, celebrated the inauguration of a new worldclass TEM instrument in Trondheim. More than 100 participants attended the official opening of the JEOL JEM ARM300F2 “GrandARM 2” TEM/STEM. The instrument is equipped with a cold field emission gun and operates at 300, 200, 80 and 60 kV. It is probe corrected and fitted with a CEOS CEFID energy filter featuring a 1024 × 512 direct electron diffraction detector, dose control capabilities and a NanoMegas precession electron diffraction system.

The new microscope is part of the national largescale infrastructure NORTEM, funded by the Research Council of Norway. A monochromated instrument will be installed in the Oslo node in the first half of 2026. The GrandARM 2 in Trondheim is housed in a purpose designed laboratory with extremely low electromagnetic fields, minimal mechanical vibrations and strict temperature control to ensure the highest possible stability and resolution. The first results already demonstrate excellent performance and longterm stability.

The inauguration was followed by a scientific seminar featuring internationally recognised experts presenting cutting-edge research and developments in TEM instrumentation and methodology. The programme highlighted TEM’s role in alloy design, battery technology and biological systems, as well as advances in lenses, monochromators and correlative methods combining TEM with atom probe tomography.

Invited speakers included Max Haider (CEOS GmbH, Germany; Kavli Prize laureate), Lewys Jones (Trinity College Dublin, Ireland), Williams Lefebvre (University of Rouen, France), Trevor Almeida (University of Glasgow, UK), Kerstin Volz (PhilippsUniversität Marburg, Germany), and Andreas Brech and Fredrik Hage (both University of Oslo). Local contributors were Elisabeth Thronsen (SINTEF), and Magnus Nord, Ton van Helvoort and Randi Holmestad (NTNU).

Tour of GrandARM 2 microscope. Photos by: Per Henning. Group photo by: Randi Holmestad.

Speakers at the GrandARM 2 inauguration. Photos by: Per Henning.

PHD DEFENSES IN THE TEM GEMINI CENTRE 2025

Christoph Martin Hell, 13.06. 2025

Christoph Martin Hell defended his PhD thesis Friday the 13th of June 2025. The title of his thesis was '*Age Hardening in 6xxx Aluminium Alloys - A Story of Clusters, GP-Zones and Precipitates*'. Christophs supervisor was Randi Holmestad, with Ruben Bjørge, Calin D. Marioara and Knut Marthinsen as co-supervisor. His opponents were Professor Alexis DeSchamps at the Materials and Processes Science and Engineering lab of Grenoble Institute of Technology in France and Assistant Professor Mami Mihara-Narita at the Department of Physical Science and Engineering of Nagoya Institute of Technology in Japan, with administrator Associate Professor David Morin, Department of Structural Engineering, Faculty of Engineering, NTNU, Norway.

This PhD examines how the very earliest stages of precipitation—clusters and GP zones—govern strengthening in 6xxx aluminium alloys and how heat treatment conditions modify this evolution. Using advanced LAADFSTEM imaging, the work shows that these early atomic structures can be directly visualised and that small differences in clustering strongly influence the final distribution of β′′ and postβ′′ precipitates. Rapid heating to artificial agingaging temperature produces fewer but longer and thicker precipitates and can broaden the hardness plateau, while slower industrial ramps lead to different precipitate types depending on alloy composition. The thesis also clarifies why natural aging reduces strength in Mg+Si rich alloys but improves it in leaner alloys, attributing this to shifts between homogeneous and heterogeneous nucleation. Overall, the work demonstrates the exceptional sensitivity of AlMgSi alloys to their thermal history and provides Si alloys to their thermal history and provides mechanistic insight essential for optimising industrial strengthening treatments. Christoph is now working in Hydro at Karmøy.

Chunan Li, 26.09.2025

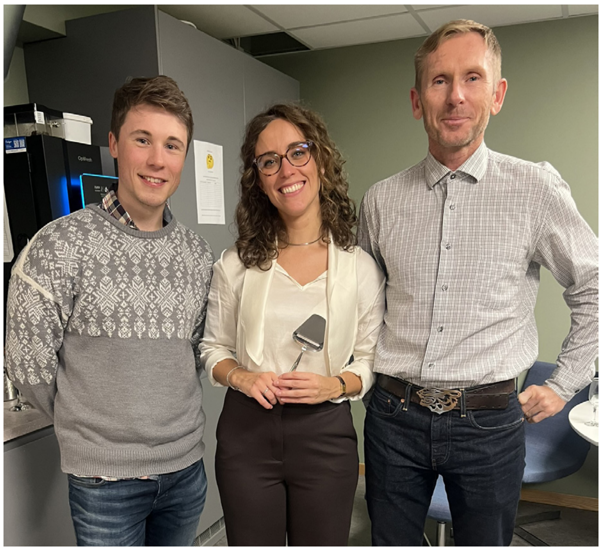
Chunan Li had defended his PhD '*Solute clustering and early-stage precipitation in Al -Mg- Si alloys*', Friday 26. September 2025. Chunan was supported by the SumAl project, and took his PhD at the DMSE department with professor Yanjun Li as main supervisor, with co-supervisors Calin Marioara and Randi Holmestad from the TEM Gemini Centre. His opponents were Professor Alexis DeSchamps at the Materials and Processes Science and Engineering lab of Grenoble Institute of Technology in France and Dr. Jostein Røyset, from Hydro Aluminium, Sunndal, Norway with administrator Xu Lu from MTP, NTNU.

The PhD focused on early stage precipitation in AlMgSi (6xxx) alloys, with emphasis on how natural aging (NA), preaging (PA) and alloy composition influence solute clustering and β″ precipitation. His work showed that short pre-aging at artificial aging temperatures can fully reverse the negative effects of natural aging in concentrated alloys, enabling higher strength and ductility. He demonstrated that NA can be beneficial in dilute alloys and documented longterm natural aging leading to unexpected strengthening through gradual GP zone growth into β″. Finally, he proposed a twostep low temperature aging strategy that produces exceptionally fine precipitates and superior strength–ductility combinations. Chunan now works as a postdoc at KTH, Royal Institute of Technology, in Stockholm, Sweden.

Ambra Celotto, 16.10.2025

On Thursday, October 16, Ambra Celotto successfully defended her PhD '*In-situ studies of conventional and microscale FIB-assisted methods for cold welding of dissimilar conductive materials*', She was a PhD candidate at the MTP department, supervised by Nima Razavi (current) and Filippo Berto (former), with Per Erik Vullum and Randi Holmestad as co-supervisors. Her opponents were Dulce Rodrigues, University of Coimbra, Portugal and Christof Sommitsch, TU Graz, Austria with administrators Sigmund Tronvoll and Knut Sørby from the MTP department at NTNU. Ambra was the second PhD student in the In-Sane project, alongside Jørgen Sørhaug.

Ambra's thesis examined how dissimilar conductive materials, such as aluminium and copper, can be joined at room temperature through cold welding. It shows that severe plastic deformation enables bonding even when the metals differ greatly in mechanical strength or chemical compatibility, producing refined interface microstructures and strong joints. The work demonstrates that deformation can also drive atomic interdiffusion, allowing intermetallic phases to form without heat, which explains how Al-Cu cold welding becomes feasible. Based on these insights, a microscale welding method using FIB-SEM was developed and optimised, achieving reproducible Al-Al and Al-Cu microjoints with clean interfaces and strong mechanical and electrical performance. The results clarify the mechanisms that make cold welding of dissimilar materials possible and provide a foundation for applying these principles in advanced microfabrication. Ambra now works as a researcher at The Italian Institute of Technology (IIT).



Sivert Johan Vartdal Dagenborg, 01.12.2025

Sivert Johan Vartdal Dagenborg defended his PhD thesis '*Realising the potential of differential phase contrast in Lorentz electron microscopy through advancements in calibration, acquisition and processing*', the 1st of December 2025. His main-supervisor was Magnus Nord, and Antonius van Helvoort was co-supervisor. The opponents were Dr. Trevor Almeida from University of Glasgow, Professor Anette Eleonora Gunnæs from University of Oslo and Professor Ragnvald Mathiesen from NTNU as administrator.

The PhD worked focused on improving the methodology for studying magnetic materials in the TEM, specifically how to use STEM-DPC to study heavily diffracting single crystalline materials. For these materials, one must carefully optimize the angle of the material to avoid the magnetic signal being lost in the noise. Furthermore, he developed the methodology to measure the external magnetic field inside a TEM by using off-the-shelf components and a commonly used in-situ TEM holder. The thesis also presented a software solution for advanced rapid live data processing of 4D-STEM data, to enable live visualization during TEM experiments. Sivert now works as a Scientific Software Engineer in the company Dipai in Ålesund, Norway.

PUBLICATIONS

TEM Gemini Centre group members put in bold. The list includes papers that used the TEM facility, in addition to papers where group members were coauthors.

Ali, A.; Bisht, P.; Schrade, M.; Xing, W.; **Vullum, P**.; Taniguchi, T.; Watanabe, K.; Mehta, B.; Belle, B. Optically Programmable Smart WSe2/hBN Heterostructure Gas Sensors. Acs Applied Materials & Interfaces 2025, 17 (36), 50977–50985. DOI: 10.1021/acsami.5c09390.

Alonso-Sánchez, P.; Hua, W.; Thangaian, K.; **Vullum, P**.; Karlsen, J.; Svensson, A.; Vullum-Bruer, F.; Campo, J.; Cova, F.; Blanco, M. Mitigating Silicon Amorphization in Si-Gr Anodes: A Pathway to Stable, High-Energy Density Anodes for Li-Ion Batteries. Small 2025, 21 (35), 10. DOI: 10.1002/smll.202504704.

Anwar, M.; Zelenina, I.; Sobieszczyk, P.; Hlawacek, G.; Tveitstøl, K.; Potzger, K.; Fassbender, J.; Hellwig, O.; Lindner, J.; Krupinski, M.; **Nord, M.**; Bali, R., Confinement Driven Spin-Texture Evolution in Directly Written Nanomagnets. Adv. Funct. Mater. 2025, 35 (49), 11. DOI: 10.1002/adfm.202513904.

Asheim, K.; Wagner, N. P.; **Vullum, P. E.**; Foss, C. E. L.; Mæhlen, J. P.; Svensson, A. M. Effect of Concentration of Lithium Bis(fluorosulfonyl)imide on the Performance of Silicon Anodes for Li-Ion Batteries. Electrochemical Science Advances 2025, Article. DOI: 10.1002/elsa.70009 Scopus.

Bartawi, E.; Shaban, G.; **Marioara, C**.; Rahimi, E.; **Bjørge, R.**; Sunde, J.; Gonzalez-Garcia, Y.; **Holmestad, R**.; Ambat, R. Effect of minor addition of Zn on precipitate crystal structures and intergranular corrosion in 6082 Al-Mg-Si alloys. Corrosion Sci. 2025, 249, 11. DOI: 10.1016/j.corsci.2025.112844.

Bergh T., Scanning precession electron diffraction - beyond orientation and phase mapping, Microsc. Microanal. 2025, 31, ozaf048.288. DOI: 10.1093/mam/ozaf048.288.

Brzozowski, D.; Liu, Y.; Neeleman, K.; **Nord, M.**; Hallsteinsen, I. Growth Control of Highly Textured Bi2Te3 Thin Films by Pulsed Laser Deposition. Cryst. Growth Des. 2025, 11, ; Early Access. DOI: 10.1021/acs.cgd.5c01013.

Bugten, A.; Michels, L.; **Bjørge, R.**; Chernyshov, D.; Mcmonagle, C.; van Beek, W.; Pires, A.; Simoes, S.; Ribeiro, C.; Li, Y.; et al. Influence of B and Cu on microstructure and eutectoid transformation kinetics in spheroidal graphite cast iron. Materialia 2025, 43, 13. DOI: 10.1016/j.mtla.2025.102511.

Chatterjee, P.; **Nord, M.**; He, J.; Meier, D.; Brüne, C. Challenges and insights in growing epitaxial FeSn thin films on GaAs(111) substrate using molecular beam epitaxy. J. Vac. Sci. Technol. A 2025, 43 (2), 7. DOI: 10.1116/6.0004238.

Dagenborg, S.; D'Alessio, A.; Brand, E.; Vitaliti, N.; Palliotto, A.; Hallsteinsen, I.; Trier, F.; Park, D.; Pryds, N.; **Nord, M.** Quantifying the orientation dependence of diffraction contrast on magnetic STEM-DPC imaging of freestanding oxide thin films. Phys. Rev. Mater. 2025, 9 (4), 11. DOI: 10.1103/PhysRevMaterials.9.044405.

Dagenborg, S.; **Tveitstøl, K.**; Zelenina, I.; Nordahl, G.; **Nord, M.** Accessible and thorough magnetic field mapping of TEMs using a commercial Hall-sensor and TEM automation for in situ magnetic experiments. Micron 2025, 198, Article. DOI: 10.1016/j.micron.2025.103877 Scopus.

Foss, C.; Talkhoncheh, M.; Ulvestad, A.; Andersen, H.; **Vullum, P.**; Wagner, N.; Friestad, K.; Koposov, A.; van Duin, A.; Maehlen, J. Revisiting Mechanism of Silicon Degradation in Li-Ion Batteries: Effect of Delithiation Examined by Microscopy Combined with ReaxFF. J. Phys. Chem. Lett. 2025, 16 (9), 2238–2244. DOI: 10.1021/acs.jpclett.4c03620.

Fröck, H.; Milkereit, B.; Broer, J.; Springer, A.; **Wenner, S.**; Oldenburg, K.; Kruse, T.; Kloetzer-Freese, C.; Kessler, O. Micro- and nanostructural evolution of copper bronze CuAl10Ni5Fe5 during cooling from solution treatments. Mater. Charact. 2025, 221, 13. DOI: 10.1016/j.matchar.2025.114795.

Giarmas, E.; Tzimtzimis, E.; Tzetzis, D. The influence of ageing conditions and liquid nitrogen cooling of extrusion dies on nanoindentation creep in 6060 aluminium alloy. The International Journal of Advanced Manufacturing Technology 2025, 137 (11), 6187–6205. DOI: 10.1007/s00170-025-15529-4.

Gazizov, M.; **Holmestad, R.**; Gazizova, M.; Kaibyshev, R. X-ray diffraction pattern analysis of an aged Al-Cu-Mg-Ag alloy. Mater. Charact. 2025, 223, 9. DOI: 10.1016/j.matchar.2025.114927.

Hai, V.; Lee, S.; Tsuchiya, T.; Katsumi, T.; Kita, K.; Khanh, P.; **Holmestad, R.**; **Marioara, C.**; Matsuda, K. Effect of Deformation on Mechanical Properties and Microstructure of Al-1%Cu-0.96%Mg-0.36%Si (mass%) Alloy. Mater. Trans. 2025, 66 (2), 220–229. DOI: 10.2320/matertrans.MT-M2024149..07

Hai, V. N.; Ahmed, A.; Lee, S.; Tsuchiya, T.; Zou, Y.; Katsumi, T.; Kita, K.; Khanh, P. M.; **Holmestad, R**.; **Marioara, C**. D.; Matsuda, K. A comparative investigation of microstructure and mechanical properties in a deformed and aged Al-Mg-Si alloy with high Cu content. Materials and Design 2025, 260, DOI: 10.1016/j.matdes.2025.115172.

Hamonnet, J.; **Nylund, I. E.**; Kontis, P.; Hua, W.; Alonso-Sánchez, P.; Rubio Zuazo, J.; Blanco, M. V.; Svensson, A. M. Degradation of LiNi0.5Mn1.5O4Cathodes in the P111i4FSI Ionic Liquid Electrolyte and Carbonate Electrolytes. ACS Applied Materials and Interfaces 2025, 17 (37), 52112–52124, Article. DOI: 10.1021/acsami.5c11439 Scopus.

He, J.; **Ludacka, U**.; Hunnestad, K.; Småbråten, D.; Shapovalov, K.; Vullum, P.; Hatzoglou, C.; Evans, D.; Roede, E.; Yan, Z.; Bourret E., Selbach S.M., Gao D., Akola J., Meier Local p- and n-Type Doping of an Oxide Semiconductor via Electric-Field-Driven Defect Migration. Advanced Science 2025, 12 (43), 9. DOI: 10.1002/advs.202506629.

He, L.; **Ludacka, U.**; Chatterjee, P.; Hartl, M.; Meier, D.; Brüne, C. Tailoring MBE growth of c-Mn3Sn directly on MgO (111) from islands to film. npj Quantum Materials 2025, 10 (1), 42. DOI: 10.1038/s41535-025-00760-9.

Hell, C.; **Lervik, P**.; **Bjørge, R**.; **Holmestad, R**. One-stage and two-stage aging of dense and lean 6000 alloys. J. Mater. Sci. 2025, 60 (46), 23792–23806. DOI: 10.1007/s10853-025-11563-5.

Hell, C. M.; Fröck, H.; **Bjørge, R.**; Milkereit, B.; **Holmestad, R.** Correlative Differential Scanning Calorimetry and (Scanning) Transmission Electron Microscopy Study of the Influence of Interrupted Quenching and Natural Aging of a 6082 Alloy. Metallurgical and Materials Transactions A: Physical Metallurgy and Materials Science 2025, 56 (12), 5726–5739, Article. DOI: 10.1007/s11661-025-07998-9.

Hua, W.; **Vullum, P.**; Hjelseng, K.; Hamonnet, J.; Alonso-Sánchez, P.; Zhu, J.; Hegedüs, Z.; Zuazo, J.; Cova, F.; Svensson, A.; Maria Valeria Blanco Unlocking the Electrochemical Activation of Diatomaceous Earth SiO2 Anodes for Next-Generation Li-Ion Batteries. Energy Environ. Mater. 2025, 8 (6), 13. DOI: 10.1002/eem2.70074.

Jensen, M. M.; Verne, M. I. N.; Kierulf-Vieira, W.; Skau, K. I.; Dhak, P.; Sjåstad, A. O. Pt–Rh Model Nanoparticle Catalysts for Selective Oxidation of Ammonia to Nitrogen A Systematic Screening Study. ACS Applied Nano Materials 2025, 8 (28), 14029–14040. DOI: 10.1021/acsanm.5c01442.

Kawahara, Y.; Thrane, E.; Mørtsell, E.; Royset, J.; **Holmestad, R.**; Kaneko, K. Cu distribution in intermetallic phases in extruded Al-Mg-Si-Cu alloys. J. Alloy. Compd. 2025, 1012, 11. DOI: 10.1016/j.jallcom.2025.178472.

Kawahara, Y, **Marioara, C.D**., **Hell, C.M.**, Thrane, E.S., Mørtsell, E.A., Røyset, J., **Holmestad, R.**, Kaneko, K. Effect of Cu addition on atomic clusters and its influence on the dispersion of precipitates in Si-rich Al-Mg-Si alloys. Materials Science and Engineering: A, 946, 2025, 149121, https://doi.org/10.1016/j.msea.2025.149121.

Kelly, M.; Erbe, A.; Hallsteinsen, I.; Lein, H. The Antifouling Mechanism and Efficacy of Graphene Nanomaterials in Composite Coatings against Marine Diatoms. ACS Omega 2025, 10 (48), 59478–59488. DOI: 10.1021/acsomega.5c09053.

Kröckel, C.; **Ludacka, U**.; Singh, R.; Kotakoski, J.; Hauke, F.; Hirsch, A.; Reich, S.; Chacón-Torres, J. Structural stability in potassium doped single-walled carbon nanotubes, and surface functionalization. Carbon 2025, 234, 11. DOI: 10.1016/j.carbon.2025.119992.

Li, C.; **Marioara, C**.; Hatzoglou, C.; **Andersen, S.**; **Holmestad, R.**; Li, Y. Chemical composition dependent atom clustering during natural aging in Al-Mg-Si alloys. Scr. Mater. 2025, 257, 7. DOI: 10.1016/j.scriptamat.2024.116474.

Mihara-Narita, M. What I Gained Through Studying Abroad. Journal of the Japanese Welding Society, 94 (2), 74–77. DOI: 10.2207/jjws.94.74.

Mysliu, E.; Lein, J.; **Vullum, P**.; Gundersen, J.; Halseid, M.; Lunder, O.; Erbe, A. Primary-equivalent corrosion protection of post-consumer scrap based aluminium. RSC Sustain. 2025, 9, ; Early Access. DOI: 10.1039/d5su00350d.

Nordahl, G.; **Dagenborg, S.**; D'Alessio, A.; Brand, E.; Vitaliti, N.; Trier, F.; Park, D.; Pryds, N.; **Sørhaug, J.**; **Nord, M**. On the effect of precession for magnetic differential phase contrast imaging. Micron 2025, 190, Article. DOI: 10.1016/j.micron.2024.103761 Scopus.

Nori, S.; Esfandiarpour, A.; Kalita, D.; Zielinski, M.; Mulewska, K.; **Bjørge, R.**; **Vullum, P.**; Ferreirós, P.; Chrominski, W.; Li, M.; Chang, Y., Zhang, Y., Diduszko, R., Macha, N., Malladi, S.K., **Holmestad, R.**, Alava, M., Kurpaska, L. High-temperature radiation resistance of NiCoFe medium-entropy alloy enabled by stable nanostructures and defect evolution mechanisms. J. Mater. Res. Technol-JMRT 2025, 37, 5448–5464. DOI: 10.1016/j.jmrt.2025.07.079.

Nori, S.; Ferreirós, P.; Kalita, D.; **Bjørge, R.**; **Vullum, P.**; Mulewska, K.; Chrominski, W.; Li, M.; Chang, Y.; Zhang, Y.; **Holmestad, R.**; Kurpaska, L.; Nanostructured NiCoFeCr alloy with superior high-temperature irradiation resistance. NPJ Mater. Degrad. 2025, 9 (1), 11. DOI: 10.1038/s41529-025-00642-2.

Nylund, I.; Eilertsen, E.; Hatzoglou, C.; Aune, K.; **Bjørge, R.**; **van Helvoort, A.**; Svensson, A.; Kontis, P. Atomic-scale insights on grain boundary segregation in a cathode battery material. Scr. Mater. 2025, 269, 8. DOI: 10.1016/j.scriptamat.2025.116905.

Richarz, L.; Skogvoll, I.; Tokle, E.; Hunnestad, K.; **Ludacka, U.**; He, J.; Bourret, E.; Yan, Z.; **van Helvoort, A.**; Schultheiss, J.; Meier D. Ferroelectric Domain Walls for Environmental Sensors. Acs Applied Materials & Interfaces 2025, 17 (33), 47576–47584. DOI: 10.1021/acsami.5c04875.

Rovira, A.; Skjæveland, J.; Rajendran, K.; **Bergh, T**.; Tingelstad, P.; Myrstad, R.; Chen, D. Influence of Metal-Support Interaction on Anisole Hydrodeoxygenation Activity on Noble Metal TiO2-Based Catalysts. Top. Catal. 2025, 68 (20), 2549–2564. DOI: 10.1007/s11244-025-02207-8.

Rubio Ruiz, R. A.; Saksala, T.; Isakov, M.; Bhusare, S.; Mohanty, G.; Pournoori, N.; Coudert, T.; Dumoulin, S.; **Bjørge, R.**; Kane, A.; Hokka M. Weakening of granite by alternating voltage excitation of dispersed quartz: A 2D numerical analysis based on cohesive interface elements with a fatigue damage model. International Journal of Impact Engineering 2025, 206, 105439. DOI: 10.1016/j.ijimpeng.2025.105439.

Ryggetangen O, **Christiansen E.F**, **van Helvoort A.T.J.**, **Holmestad R.**, **Wenner S.**, **Bergh T.**, Structure Solution of a Quasicrystal Approximant Embedded Within an Aluminum Matrix by SPED and 3DED, Microsc. Microanal. 2025, 31, ozaf048. 290. DOI: 10.1093/mam/ozaf048.290.

Ryggetangen, O.; Rhee, Y.; **Thronsen, E.**; **Marioara, C.**; Kobayashi, E.; **Holmestad, R**. The effect of Zn/Mg ratio on the precipitation of T' in Al-Zn-Mg-Cu alloys. Mater. Charact. 2025, 230, 9. DOI: 10.1016/j.matchar.2025.115685.

Saksala, T.; Ruiz, A.; Bhusare, S.; Mohanty, G.; Coudert, T.; Dumoulin, S.; **Bjørge, R.**; Kane, P.; Hokka, M. Numerical Modelling of Frictional Sliding Induced Damage and Heating Effects on Rock With an Application to Sievers' J-Miniature Drilling on Granite. Int. J. Numer. Anal. Methods Geomech. 2025, 21, ; Early Access. DOI: 10.1002/nag.4005.

Schweigart, P.; Hua, W.; Sánchez, P. A.; Lian, C.; **Nylund, I.-E.**; Wragg, D.; Lai, S. Y.; Cova, F.; Svensson, A. M.; Blanco, M. V. Deciphering the Impact of Current, Composition, and Potential on the Lithiation Behavior of Si-Rich Silicon-Graphite Anodes. Small 2025, 21 (4), 2406615. DOI: https://doi.org/10.1002/smll.202406615.

Steuer, R.; Milkereit, B.; **Wenner, S.**; Broer, J.; Huber, F.; Schaper, M.; Kessler, O. Direct Natural and Artificial Aging of Aluminum Alloy AlSi10Mg After Laser Powder-Bed Fusion. Adv. Eng. Mater. 2025, 13, ; Early Access. DOI: 10.1002/adem.202501181.

Sørhaug J.A., **Vullum P.E.**, **Bergh T.**, **Korsvold H.L.**, **Thronsen E.**, **Grong Ø**. **Holmestad, R**. TEM Studies of Nanostructure in Aluminium-Copper Welds Made by Solid State Joining, Microsc. Microanal. 2025, 31, ozaf048.108. DOI: 10.1093/mam/ozaf048.108

Thangaian, K.; Ericson, T.; **Vullum, P**.; Alonso-Sánchez, P.; Svarverud, A.; Svensson, A.; Vullum-Bruer, F.; Hahlin, M.; Blanco, M. Performance-optimized diatom-SiOx anodes for Li-ion batteries by preserving the nanostructured SiO2 shells of diatom microalgae and tailoring oxygen content. J. Power Sources 2025, 641, 9. DOI: 10.1016/j.jpowsour.2025.236837.

Tran, Q.; Agrawal, M.; Haeusler, M.; Hörmann, J.; Moqadam, M.; Redhammer, G.; Ellingsen, I.; Din, M.; **Vullum, P.**; Zettl, R.; Danner I.; Latz A.; Hennige V.; Brunner R., Rettenwander D. Uni-Axial Densification of Slurry-Casted Li6PS5Cl Tapes: The Role of Particle Size Distribution and Densification Pressure. Adv. Mater. 2025, 13, DOI: 10.1002/adma.202501592.

van Valen, Y.; **Bergh, T.**; Skrzydlo, T.; Emanuelli, M.; Gramazio, P.; Bjørkedal, O.; Lagmannsveen, A.; Lødeng, R.; Yang, J.; Venvik, H. Sub-reactions of the Silver Catalysed Conversion of Methanol to Formaldehyde. Top. Catal. 2025, 68 (20), 2462–2477. DOI: 10.1007/s11244-025-02158-0.

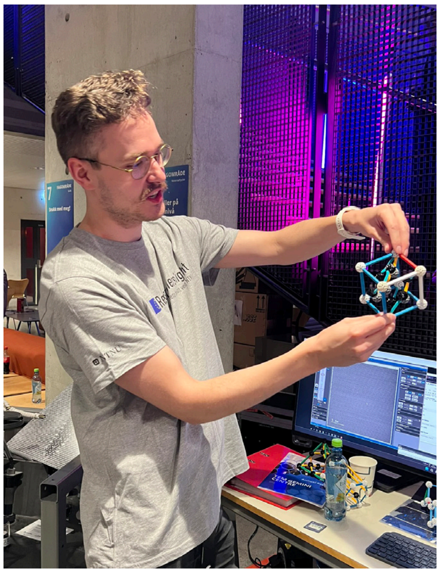
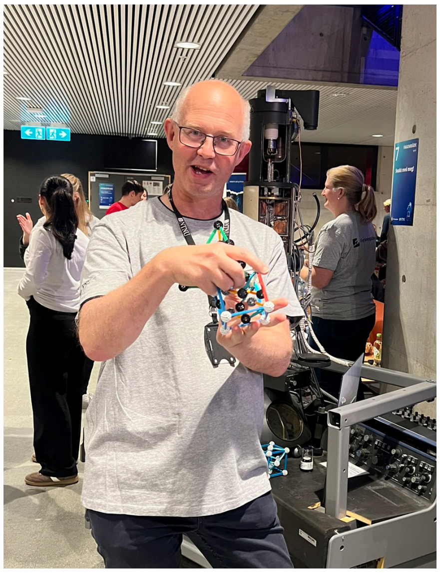
Vullum, P.; Celotto, A.; Grong, O.; **Holmestad, R**. Cold bonding of aluminium to copper by deformation-enhanced diffusion. Sci Rep 2025, 15 (1), 9. DOI: 10.1038/s41598-025-25620-1.

Zürbes, K.; Bruns, T.; Mani, E.; Bandyopadhyay, S. Seed-mediated synthesis of gold nanorods with tannic acid as the reducing agent-A kinetic study. Colloid Surf. A-Physicochem. Eng. Asp. 2025, 725, 10. DOI: 10.1016/j.colsurfa.2025.137483.

ACCEPTED / PUBLISHED ONLINE / IN PRESS

Ushakov I.N., Topstad M., Khalid M.Z., Sharma N., Grams C., **Ludacka U.**, He J., Hunnestad K.A., Sadeqi-Moqadam M., Glaum J., Selbach S.M., Hemberger J., Becker P., Bohatý L., a Kumar A., Íñiguez-González J., v**an Helvoort A.T.J.**, and Meier D., Hybrid antiferroelectric-ferroelectric domain walls in noncollinear antipolar oxides, https://arxiv.org/abs/2507.01622. Accepted for Nature Nanotechnology

Agrawal M, Tran Q-A, Häusler M, Hörmann J, Sadeqi-Moqadam M, Sellæg Ellingsen I, et al., Uni-axial densification of slurry-casted Li_6PS_5Cl tapes for solid-state pouch cells: The role of particle size distribution and densification pressure. ChemRxiv. 2025; doi:10.26434/chemrxiv-2025-2bvpq

Explaining crystal structures at Researchers night 2025.

POPULAR SCIENCE

Dette kan forbedre rekkevidden til elkjøretøy , Jørgen Andre Sørhaug og Randi Holmestad, Intervju, Gemini.no, Dato: 14.Januar 2025

Teknisk Ukeblad, Dette kan forbedre rekkevidden til elkjøretøy | Tu.no Jørgen Andre Sørhaug and Randi Holmestad, , January 2025

Adresseavisen: Supermikroskop: – Det byr på fantastiske muligheter - adressa.no Ursula. Ludacka, Magnus Nord, Bjørn Soleim and Ton van Helvoort. 30. November 2025

NTNU: NTNUs nye mikroskop kan se detaljer 1 million ganger mindre enn et hårstrå - NTNU Nyheter, Randi Holmestad, 1. December 2025

Universitetsavisa: NTNU og Sintef avduket mikroskop til 60 millioner, Randi Holmestad, Rudie Spooren, 5. December 2025

Social dinners in the TEM Gemini Centre.

CONFERENCE CONTRIBUTIONS (A SELECTION)

Tina Bergh, Scanning precession electron diffraction for structural characterisation at the nanoscale, Invited talk, RMS EBSD, Glasgow, UK, 01.05.2025

Tina Bergh, Scanning precession electron diffraction – beyond orientation and phase mapping, Invited talk, Microscopy & Microanalysis (M&M), Salt Lake City, USA, 29.07.2025

Tina Bergh, (Scanning precession) electron diffraction for catalyst characterization CATHEX / Hougen seminar, Madison, USA, 16.06.2025

Carter Francis, Kate MacArthur, Magnus Nord, Francisco de la Peña, Colin Ophus, Eric Prestat, Stephanie Ribet, Thomas Slater, Toma Susi, Steven Zeltmann, ePSIC Hyperspy Workshop 2025,digital, UK, 03.06.2025

Antonius Van Helvoort , Find your way with 4D-STEM, Invited talk, Microscience Microscopy Congress 2025 incorporating EMAG 2025, Manchester, UK, 01.07.2025

Antonius Van Helvoort, Analysis of scanning (precession) electron diffraction (S(P)ED) data, Invited talk, NordTEMHUb/ ARTEMI workshop, Linköping, Sweden, 29.10.2025

Randi Holmestad, Studies of Precipitates in age-hardenable Aluminium alloys by advanced TEM, Invited talk, XXV conference of Applied Crystallography, Wisla, Poland, 09.09.2025

Randi Holmestad, Advanced TEM for Al-alloy characterization, International Summer School on Aluminium Alloy Technology (ISSAAT), Trondheim, Norway,18.06.2025

Randi Holmestad, Nucleation and Precipitation in Age-hardenable Aluminium Alloys studied by Transmission Electron Microscopy, Invited talk, Gordon Research Conference in Metallurgy, Stonehill College, USA, 10.07.2025

Magnus Nord, Kristian Tveitstøl, Patrick Thomassen, Sindre Vie Jørgensen, Marthe Linnerud, Sivert Johan Vartdal Dagenborg, Towards in-operando TEM of device-concepts: back-etching sample preparation and automation, Invited talk, SCANDEM 2025, Bergen, 13.06.2025

Chunan Li, Calin Daniel Marioara, Constantinos Hatzoglou, Sigmund Jarle Andersen, Randi Holmestad, Yanjun Li Solute clustering and early-stage precipitation in Al-Mg-Si alloys, THERMEC'2025, Tours, France, 01.07.2025

Calin Daniel Marioara, The Effect of Si Additions to an Industrial 7xxx Aluminium Alloy in the Context of Recycling, Invited talk, FEMS/EUROMAT 2025, Granada, Spain, 15.09.2025

Oskar Ryggetangen, Emil Christiansen, Antonius Van Helvoort, Randi Holmestad, Sigurd Wenner, Tina Bergh, Structure Solution of a Quasicrystal Approximant Embedded within an Aluminum Matrix by SPED and 3D ED, Microscopy & Microanalysis (M&M), Salt Lake City, USA, 29.07.2025

Jørgen Andre Sørhaug, Per Erik Vullum, Tina Bergh, Håkon Longva Korsvold, Elisabeth Thronsen, Øystein Grong, Randi Holmestad, TEM studies of Nanostructure in Aluminium-Copper Welds made by Solid State Joining, , Microscopy & Microanalysis (M&M), Salt Lake City, USA, 29.07.2025

MASTER'S THESES

Stine Bratlie, "Chemical and Structural Characterization of ThermaSiC by Electron Microscopy", submitted June 2025. (Supervisor Randi Holmestad)

Fredrik Johnatan Treichel Hanevold, "Vector Matching for Orientation Mapping based on Scanning Precession Electron Diffraction", submitted June 2025. (Supervisor Ton van Helvoort)

Hannah Hareide, "Influence of Natural Ageing and Copper Addition on Precipitation in Al-Mg-Si Alloys - A Transmission Electron Microscopy Study", submitted June 2025. (Supervisor Randi Holmestad).

Andreas Holand, "Orientation Analysis of Polycrystalline TEM specimens facilitated by Open-Source Data Treatment", submitted March 2025. (Supervisor Ton van Helvoort)

Kay Holm, "Sample preparation and transmission electron microscopy of polycrystalline ferroelectric Ca4(Al6O12)(WO4) and DyInO3", submitted June 2025. (Supervisor Ton van Helvoort)

Thyra Rolfseng, "Strain and magnetic domain analysis of gallium ion-induced nanomagnets using LM STEM-DPC and SPED", submitted June 2025. (Supervisor Magnus Nord)

Iver Karlsbakk Småge, "Structure determination via 3D electron diffraction: tomography in reciprocal space", submitted June 2025. (Supervisor Ton van Helvoort)

Kristian Bjørnes Thevik, "Automating Extraction of Precipitate Statistics in Al alloys using Convolutional Neural Networks", submitted July 2025. (Supervisor Randi Holmestad).

Patrick Robert Borsheim Thomassen, "Fabricating in situ TEM chips for imaging magnetic domain wall movement", submitted June 2025. (Supervisor Magnus Nord)

Kristine Wiklund, "Development of a Magnetic in situ STEM-DPC Experiment of a Freestanding Perovskite Oxide Thin Film", submitted June 2025. (Supervisor Magnus Nord)

PROJECT THESES

Eila Aurora Huru Bergene, Effect of Mn on Mechanical Properties in Air Cooled 6063 Alloys- A Transmission Electron Microscopy Study, submitted December 2025. (Supervisor Randi Holmestad)

Magnus Slåtten Fallmyr, Segmentation of Electron Microscopy Data in Aluminium Alloys, submitted December 2025. (Supervisor Randi Holmestad)

Ingrid Marie Zhenni Gustavsen, Comparison Between Scanning Electron Diffraction and Conventional Transmission Electron Microscopy Techniques using Twinned GaAs Nanowires as a Test Case submitted December 2025. (Supervisor Ton van Helvoort)

Trond Hauklien, Improving the Fabrication of In-Situ TEM Chips for Characterizing Domains in Magnetic Permalloy Thin Films, submitted December 2025. (Supervisor Magnus Nord)

Denis Lobe, Orientation analysis of polycrystalline materials based on scanning precession electron diffraction and open-source data treatment, submitted December 2025.. (Supervisor Ton van Helvoort)

Paul Salvatore Sjøvaag Marino, Inoculation in Cast Iron , submitted January 2026. (Supervisor Randi Holmestad).

Sander Endré Nilsen, Gallium Ion Induced Writeable Ferromagnetism in Fe60V40, submitted December 2025. (Supervisor Magnus Nord)

Jonas Fagerli Simonsen, Transmission Electron Microscopy Characterization of 2D α-RuCl3, submitted December 2025. (Supervisor Ton van Helvoort)

Stian Skinnarland, SEM investigation and FIB extraction of a TEM lamella of chunky graphite in ductile cast iron, submitted December 2025. (Supervisor Randi Holmestad)

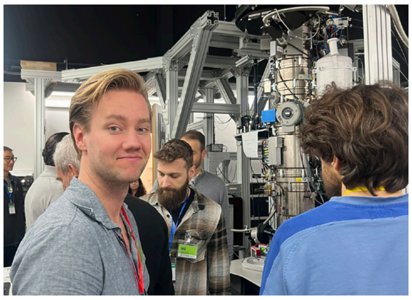
Sophia Anastasia Wellman Investigating the chemical environment of silicon in SiOx layers, submitted December 2025. (Supervisor Erik Wahlström)

Social dinners in the TEM Gemini Centre

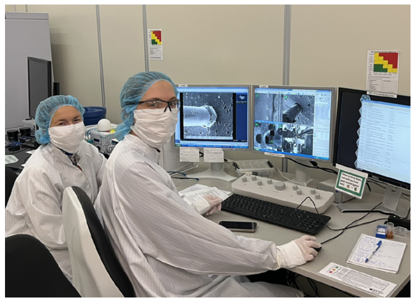
ACTIVE PROJECTS IN TEM GEMINI CENTRE IN 2025

The table below shows the larger projects connected to TEM within the Gemini Centre. They are listed by project type, title, research partners and duration. Smaller projects, both academic and with direct industrial support, are not listed and run in parallel. In total the Centre had 74 different projects using the facilities in 2025.

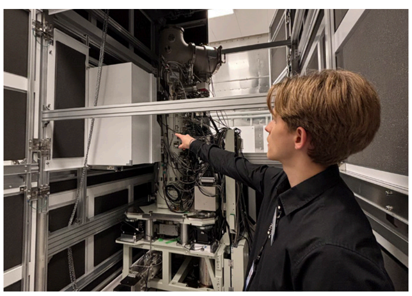
Type	Project title and partners	Involved with TEM	Duration
SFI	SFI PhysMet (Centre for Sustainable and Competitive Metallurgical and Manufacturing Industry) Partners: NTNU, SINTEF, Statens vegvesen, Forsvarsbygg, Hydro, Elkem, Neuman Aluminium, Equinor, Benteler, ThermoCalc Software	~3 PhDs NTNU, SINTEF	2020-28
SFI	SFI iCSI - Industrial Catalysis Science and Innovation for a Competitive and Sustainable process Industry. Partners: Yara Norge, K.A. Rasmussen, Dynea INOVYN Norge, Haldor Topsøe AS	1 Postdoc NTNU, SINTEF	2015-24
FME	SuSolTech – The Research Center for Sustainable Solar Cell Technology. Partners: IFE, NTNU, SINTEF, University of Oslo (UiO), CleanSi, Dynatec, Elkem Solar, Mosaic, Norsun, Norwegian Crystals, Quartz Corp, REC Silicon, REC Solar, Semilab	1 PhD, NTNU, SINTEF, UiO	2017-25
FRIPRO	QUATRIX - Quasicrystal nucleation in a metallic matrix	SINTEF, 1 PhD NTNU	2021-25
FRIPRO	In-situ correlated nanoscale imaging of magnetic fields in functional materials (InCoMa)	2 PhD NTNU	2021-25
NTNU Nano	Fabricating multilayer magnetic skyrmion TEM membranes for nanoscale in-operando studies	1 PhD, NTNU	2024-28
IPN	SIDI - Sustainable graphite Inoculants for Ductile cast Iron, Partners: Elkem, SINTEF, NTNU	Engineer time NTNU, SINTEF	2022-26
UTFORSK	SuReAl - (Norwegian Japanese collaboration on) Sustainability and Recycling in Aluminium alloy development	Travel and student exchange	2025-29
KSP	MAD- Tailoring Metallurgically bonded nanoscale interfaces between Al, Cu and Ni involving Deformation-enhanced diffusion	SINTEF, 1 PhD NTNU	2025-28
KSP	LongLife (in situ conversion alloying anode materials for long lifetime, high-energy density batteries) Partners: IFE, UiO, Forschungszentrum Jülich GmbH, Norsk Hydro ASA, Equinor ASA, Morrow Batteries AS, Elkem ASA, Cenate AS, SINTEF AS	SINTEF	2021-26
IPN	IPN ASAP.	SINTEF	2024-25
PN	REWAMP (Repurposing coke waste for scalable battery electrode material production). Partners: Vianode AS, SINTEF AS, SINTEF Energy	SINTEF	2025-27
EU/HEU	MatCHMaker, Partners: CEA, RINA-C, CSM, SINTEF, AIMEN, SIMAVI, Heidelberg Cement, GENVIA, Toyota, TU Wien, ASRO.	SINTEF	2022-26
EU/HEU	Impress - Interoperable electron Microscopy Platform for advanced RESearch and Services.	1 PhD, NTNU	2023-27
EU/HEU	RIANA- Research Infrastructure Access in Nanoscience & Nanotechnology	NTNU, Access, network	2023-28
Green platform	AluGreen, Partners: Hydro, SINTEF, NTNU, Oshaug, Metall, Christie & Opsahl, Overhalla, Betongbygg, Norcable, Corvus Energy, Ocean Sun, Kodyna, Leirvik, Nexans,Benteler, Metallco Aluminium, Prodtex, Statnett SF Nordic Office Of Architecture, Dr Techn Olav Olsen	SINTEF	2021-24
Green platform	SUMBAT, Partners: SINTEF, NTNU, UiO, UiA, IFE, Freyr, Vianode, Elkem, Morrow, Norsk Hydro, Corvus	SINTEF	2022-25












2025 was an eventful year for the TEM Gemini Centre.

PHYSICAL REVIEW MATERIALS 9, 044405 (2025)

Quantifying the orientation dependence of diffraction contrast on magnetic STEM-DPC imaging of freestanding oxide thin films

Sivert Dagenborg,[1] Andrea D'Alessio,[2] Eric Brand,[2] Nikolas Vitaliti,[2] Alessandro Palliotto,[2] Ingrid Hallsteinsen,[3] Felix Trier,[2] Dae-Sung Park,[2] Nini Pryds,[2] and Magnus Nord[1]

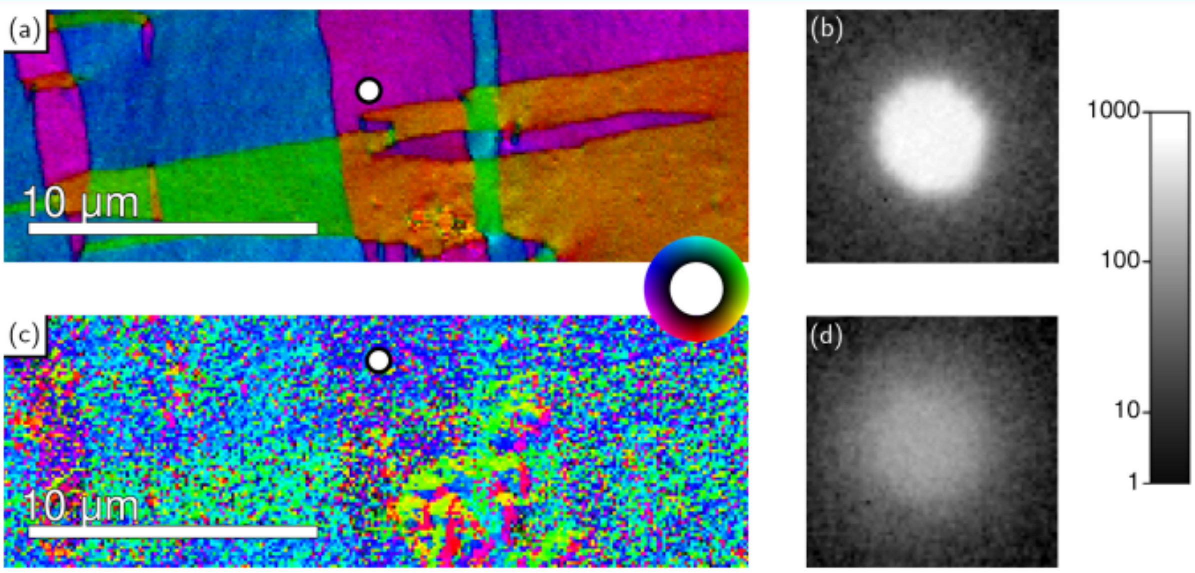
[1]Department of Physics, Norwegian University of Science and Technology, 7491 Trondheim, Norway

[2]Department of Energy Conversion and Storage, Technical University of Denmark, 2800 Kongens Lyngby, Denmark

[3]Department of Materials Science and Engineering, Norwegian University of Science and Technology, 7034 Trondheim, Norway

(Received 20 December 2024; accepted 18 March 2025; published 7 April 2025)

Scanning Transmission Electron Microscopy–Differential Phase Contrast (STEM-DPC) is a well-established nanoscale resolution technique for imaging internal magnetic and electric fields in materials. However, imaging crystalline materials is made difficult due to diffraction effects, which distort the bright-field disk and can obscure the medium-range magnetic and electric field contrasts. In this study, we employ monocrystalline regions of freestanding La0.67Sr0.33MnO3 (LSMO) thin films to systematically investigate the influence of diffraction contrast on magnetic imaging using four-dimensional STEM-DPC. This was done by tilting the sample across orientations with different amounts of diffractive scattering and processing the data using two data processing algorithms: center of mass and phase correlation. The proximity of the orientation to a systematic row is the most im portant cause of diffraction contrast whereas proximity to a zone axis had a low effect. Our experiments demonstrate only small tilt adjustments are necessary to mitigate the diffraction contrast, with x and y tilts of about 0.5◦ sufficient to reduce calculated noise in the STEM-DPC image up to 95%. Phase correlation often gives lower noise but is less robust at higher diffractive scattering compared to center of mass. To avoid the obstructive effects of diffraction contrast, systematic rows must be avoided and processing algorithms must be carefully chosen.



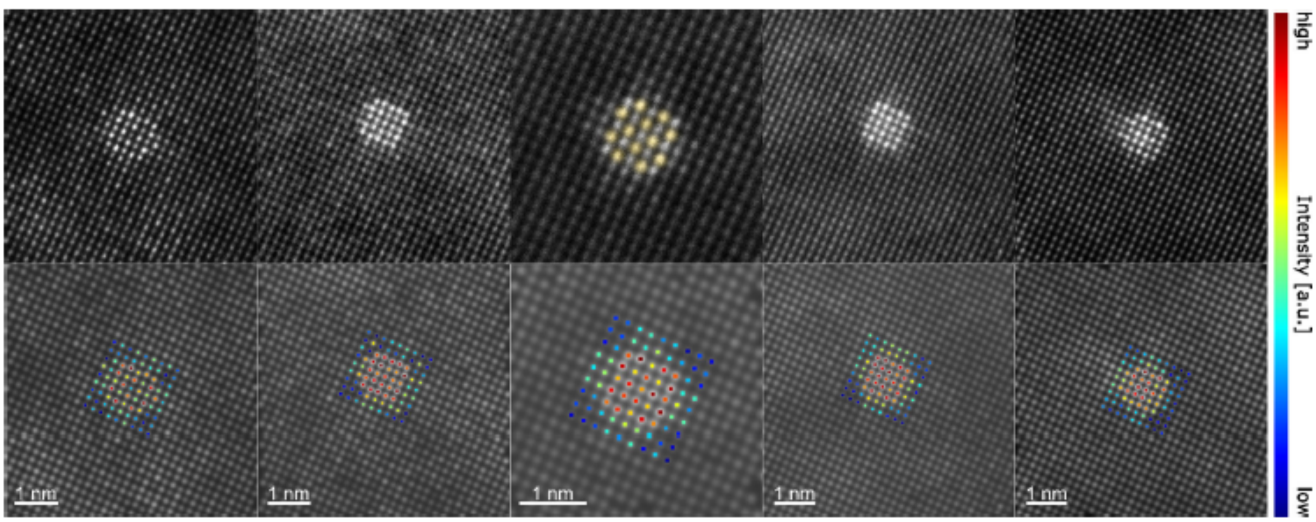
Two STEM-DPC images of the same magnetic domains at different sample orientations with (a) lower and (c) higher diffractive scattering. The sample is an approximately 20-nm-thick freestanding LSMO thin film. The datasets were processed with the phase crosscorrelation algorithm. The intensity and color of a pixel give, respectively, the estimated strength and direction of the magnetic induction, according to the color wheel. (b) An example bright-field disk taken from the white circle in (a). (d) An example bright-field disk taken from the white circle in (c). The intensity scale for the disks is logarithmic and shown on the right.

ORIGINAL RESEARCH ARTICLE

Correlative Differential Scanning Calorimetry and (Scanning) Transmission Electron Microscopy Study of the Influence of Interrupted Quenching and Natural Aging of a 6082 Alloy

CHRISTOPH M. HELL, HANNES FRÖCK, RUBEN BJØRGE, BENJAMIN MILKEREIT, and RANDI HOLMESTAD

In this work the effect of interrupted quenching and natural aging prior to artificial aging was analyzed on the early GP-zones and resulting precipitates in a 6082 alloy by differential scanning calorimetry (DSC) and (scanning) transmission electron microscopy ((S)TEM). DSC was used to ''scan'' along the precipitation path and find interesting temperatures which were subsequently analyzed by (S)TEM. It was found that natural aging prior to artificial aging results in ''square GP-zones'', whereas directly aging without natural aging results in mainly ''β-eye'' GP-zones. Furthermore, it was shown that the square GP-zones facilitate the precipitate growth, since significantly wider and longer precipitates arise from microstructures with square GP-zones. On the contrary, ''β-eye'' GP-zones result in many but significantly smaller precipitates. A suggested atomistic model of the square GP-zones which builds around a vacancy is suggested. Simulations of this model result in the same contrast variations in low-angle annular dark-field STEM as observed experimentally. Lastly, it was found that reducing the vacancy concentration by interrupted quenching from the solution heat treatment temperature limits the coarsening effect of the square GP-zones on the final precipitates.



Scan distortion corrected LAADF-STEM micrographs of square GP-zones acquired from different conditions heated to 150 C. The bottom row shows the same micrograph as the top row but highlighting the relative atom column intensity differences within the GP-zone. This was done by the atom counting module of StatSTEM.[43] The center image is displayed with a higher magnification for better visualization. The yellow marked atom columns of the center image from the top row are typically seen with a higher atom column intensity.

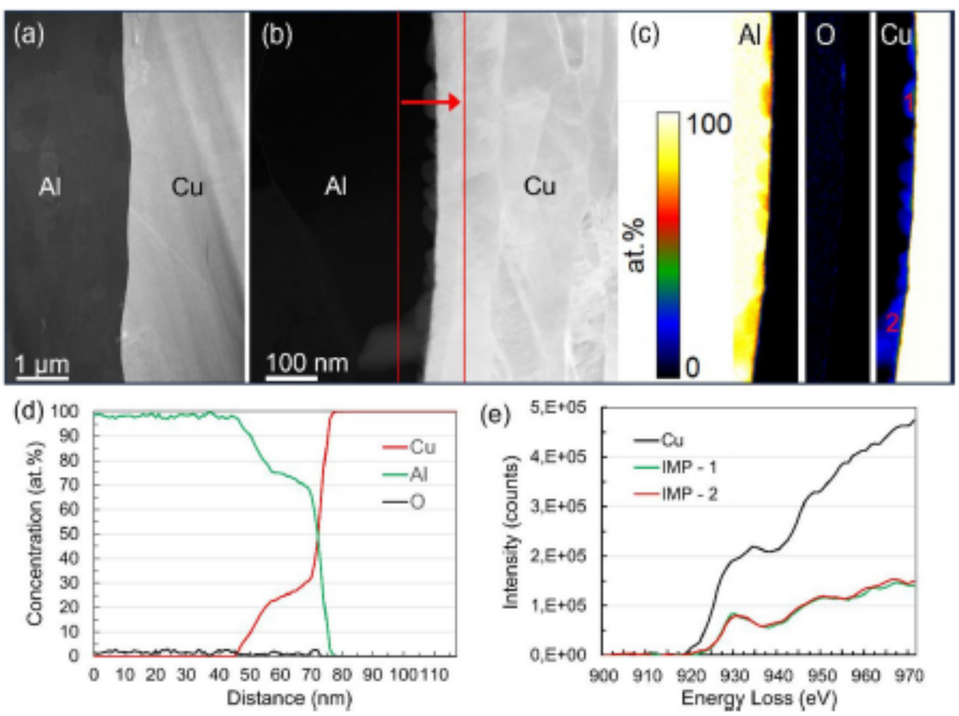
scientific reports

OPEN

Cold bonding of aluminium to copper by deformation-enhanced diffusion

Per Erik Vullum[1,2], Ambra Celotto[3], Øystein Grong[3] & Randi Holmestad[2]

Cold bonding between dissimilar metals and alloys offers several benefits, such as the absence of soft heat-affected zones and thick intermetallic layers with properties that differ from those of the base metals. At room temperature, thermally driven diffusion processes are negligible, but we demonstrate here that mechanically strong bonds are still feasible through high plastic deformation and high strain rates. If the strain rate is high and the temperature is kept low to avoid significant annihilation of vacancies, mechanically strong bonds involving intermetallic compound formation can still form through vacancy-driven diffusion across the contact interface. In the present investigation, two different experimental setups were employed to demonstrate strong bonding between copper and aluminium at room temperature, using phenomenological equations for excess vacancy formation and diffusion to highlight the underlying bonding mechanisms involved. Transmission electron microscopy is used to verify the bonding mechanisms.



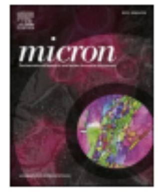
High angle annular dark field scanning transmission electron microscopy (HAADF STEM) images of the Al-Cu interface is shown in (a) and (b). Quantified Al, O and Cu maps, from the red framed area in (b), based on electron energy loss spectroscopy (EELS) mapping, are shown in (c). (d) Line profiles showing the chemical composition along the direction of the red arrow in (b). Background subtracted EEL Cu L2,3 edges from locations 1 and 2 in the Cu map and from the Cu bulk.

Micron 190 (2025) 103761

Contents lists available at ScienceDirect

Micron

journal homepage: www.elsevier.com/locate/micron

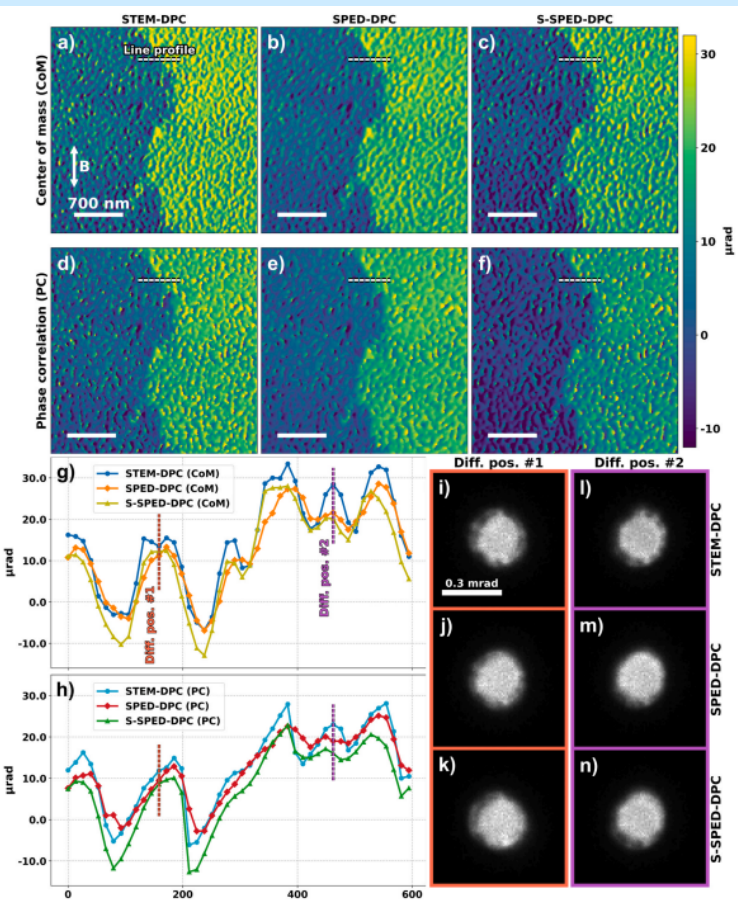


On the effect of precession for magnetic differential phase contrast imaging

Gregory Nordahl [a], Sivert Dagenborg [a], Andrea D'Alessio [b], Eric Brand [b], Nikolas Vitaliti [b], Felix Trier [b], Daesung Park [b], Nini Pryds [b], Jørgen Sørhaug [a], Magnus Nord [a,*]

[a] Department of Physics, Norwegian University of Science and Technology (NTNU), Trondheim 7491, Norway
[b] Department of Energy Conversion and Storage, Technical University of Denmark (DTU), Fysikvej 310, 2800 Kgs. Lyngby, Denmark

The separation of diffraction effects from phase contrast is a major challenge for differential phase contrast (DPC) imaging in scanning transmission electron microscopy (STEM). The application of electron beam precession has previously been proven successful in homogenizing the direct beam and improving the imaging of both long range electric and magnetic fields. However, magnetic STEM-DPC imaging performed in a low magnification (LM) STEM mode suffers from significant aberrations of the probe forming lens and the consequent impediment of small precession angles. By investigating the application of precession path segmentation to LM-STEM pre cessed scans for the imaging of LSMO and FeAl thin film samples, the initially reported benefits of precession were discovered to be less substantial than originally assumed. The segmentation methodology reveals that precession induced beam phase shifts account for a large part of the DPC induction profile smoothing, and the precession path is non-circular, leading to streaking artifacts in the reconstructed induction maps.



DPC induction maps from the 20 nm LSMO thin film sample, acquired with the three different STEM techniques, a) and d) STEM-DPC, b) and e) SPED-DPC, and c) and f) probe-shift corrected S-SPED-DPC. The induction maps were processed by a)-c) the center of mass-, and d)-f) phase correlation algorithms. Doubleheaded arrow in a) shows the integrated magnetic induction component direction. g)-h) Plots of extracted induction line profiles across a domain wall as marked in the induction maps, from the center of mass- and phase correlation algorithms, respectively. i)-k) and l)-n) diffraction patterns from the three aforementioned scan types, extracted from scan positions #1 and #2, respectively. The respective scan positions are marked in the line profiles g) and h).

Scripta Materialia 269 (2025) 116905

Contents lists available at ScienceDirect

Scripta Materialia

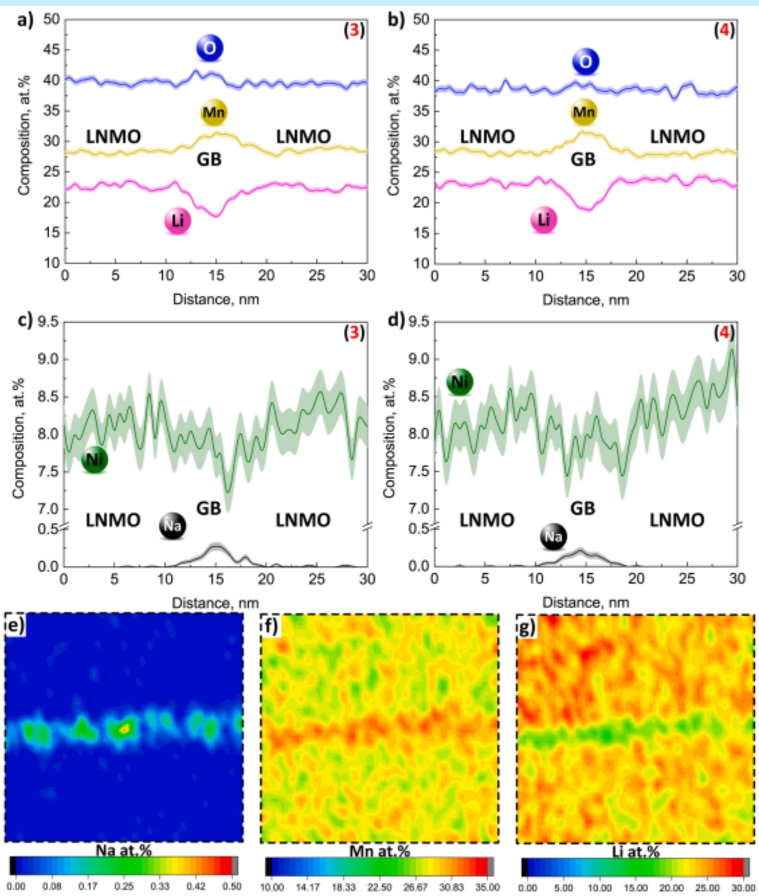
journal homepage: www.journals.elsevier.com/scripta-materialia

Atomic-scale insights on grain boundary segregation in a cathode battery material

Inger-Emma Nylund [a], Elise R. Eilertsen [a], Constantinos A. Hatzoglou [a], Kaja Eggen Aune [b], Ruben Bjørge [b,c], Antonius T.J. van Helvoort [b], Ann Mari Svensson [a], Paraskevas Kontis [a,*]

[a] Department of Materials Science and Engineering, NTNU Norwegian University of Science and Technology, 7491 Trondheim, Norway
[b] Department of Physics, NTNU Norwegian University of Science and Technology, 7491 Trondheim, Norway
[c] SINTEF Industry, 7465 Trondheim, Norway

The grain boundary segregation of the Co-free pristine spinel LiNi0.5Mn1.5O4 cathode material has been studied by transmission electron microscopy and atom probe tomography. The segregation of Mn and the depletion of Ni at grain boundaries was observed by electron energy loss spectroscopy. These observations were also confirmed by atom probe tomography at other grain boundaries, which also revealed segregation of O and depletion of Li at grain boundaries. In addition, both methods revealed the occurrence of grain boundary segregation of Na, which is an impurity. Finally, segregation of O and Mn and a depletion of Li are also observed at dislocations. This observation has the potential to provide further support for the segregation behavior at the grain boundaries of this cathode material. These near-atomic-scale observations provide new insights that can be used to improve the synthesis and efficiency of Li-ion battery materials.



a-d) 1D composition profiles perpendicular to the dislocations as denoted by the arrows #1 and #2 in Fig. 2b Error bars are shown as lines filled with colour and correspond to the 2σ counting error. e-g) 2D concentration maps corresponding to the semi-transparent yellow rectangular box in Fig. 2b.

Materials Science & Engineering A 946 (2025) 149121

Contents lists available at ScienceDirect

Materials Science & Engineering A

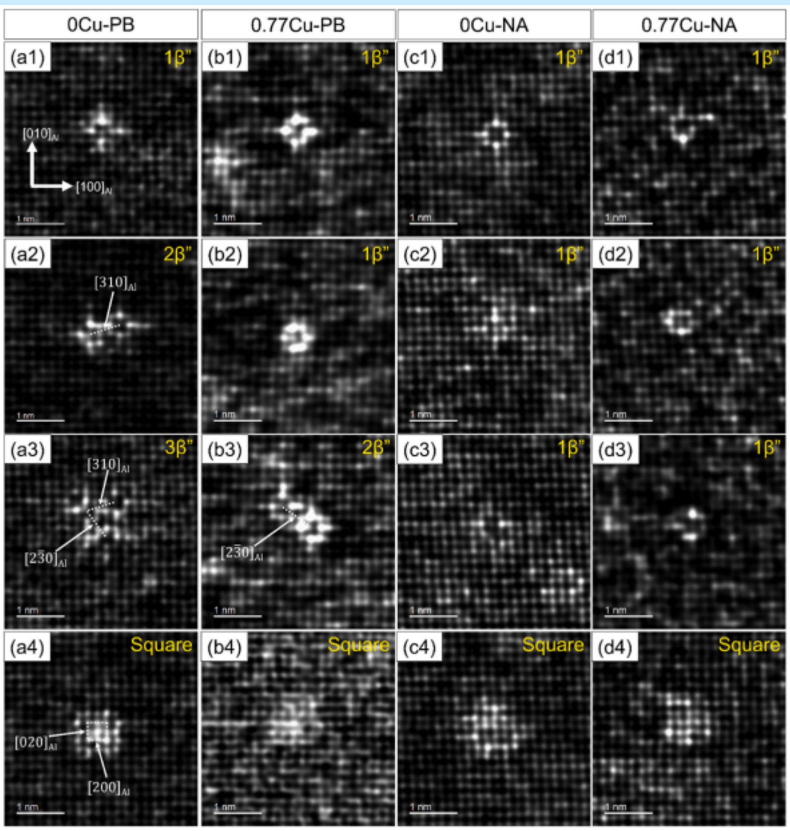
journal homepage: www.elsevier.com/locate/msea

Effect of Cu addition on atomic clusters and its influence on the dispersion of precipitates in Si-rich Al-Mg-Si alloys

Yasuhito Kawahara [a,*], Calin Daniel Marioara [b], Christoph Martin Hell [c], Elisabeth Savitri Thrane [d], Eva Anne Mørtsell [d], Jostein Røyset [d], Randi Holmestad [c], Kenji Kaneko [a]

[a] Department of Materials, Kyushu University, 744 Motooka, Nishi, Fukuoka, 819-0395, Japan
[b] SINTEF Industry, N-7465, Trondheim, Norway
[c] Department of Physics, Norwegian University of Science and Technology (NTNU), Høgskoleringen 5, N-7491, Trondheim, Norway
[d] Research and Technology Development, Hydro Aluminium, Romsdalsvegen 1, N-6601, Sunndalsøra, Norway

In this study, the effect of Cu addition on the structures of atomic clusters and Guinier-Preston zones in Al-Mg-Si alloys and their connection to age-hardenability were studied by atomic-resolution scanning transmission electron microscopy. Cu addition promoted the formation of 1β” zones consisting of single structural units (eyes) of the β”-phase, as well as extended ‘Disordered Frank-Kasper’ (DFK) atomic clusters, in both naturally- and 90 ◦C pre-aged conditions. During a subsequent artificial aging at 175 ◦C, the DFK clusters dissolved, while β”-based precipitates were formed having Cu enrichment at several atomic sites. A refined precipitate distribution was achieved by Cu addition, suggesting that enhanced formation and thermal stabilization of β” structural units by Cu incorporation contributed to the enhanced age-hardenability in Cu-added alloys.

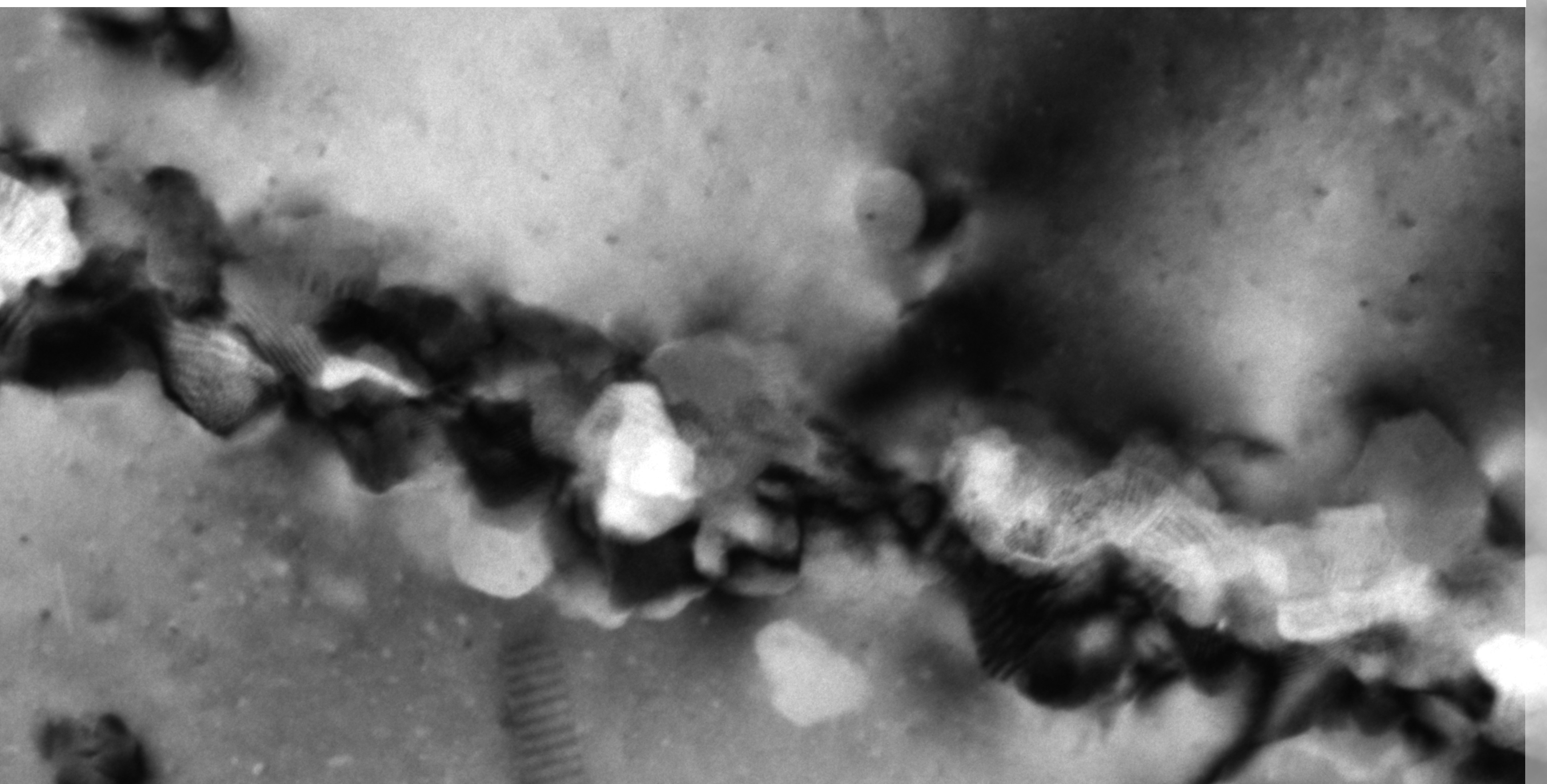


Detailed characterization of the bright-contrasts indicated by yellow solid arrows in Fig. 1(a1)-(d1). (a1)-(a4) 0Cu-PB, (b1)-(b4) 0.77Cu-PB, (c1)-(c4) 0Cu-NA and (d1)-(d4) 0.77Cu-NA. Multiple β”-eyes were rarely recognizable in the Cu-containing variants. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

SINTEF

NTNU
Norwegian University of Science and Technology

TEM Gemini Centre



CONTACTS:

Department of Physics NTNU:

Prof. Randi Holmestad, randi.holmestad@ntnu.no

Prof. Ton van Helvoort, a.helvoort@ntnu.no

Assoc. prof. Magnus Nord, magnus.nord@ntnu.no

Senior eng. Bjørn Gunnar Soleim, bjorn.soleim@ntnu.no

Senior eng. Emil Frang Christiansen, emil.christiansen@ntnu.no

Senior eng. Ursula Ludacka, ursula.ludacka@ntnu.no

Materials Physics Trondheim, SINTEF Industry:

Res. manager Ruben Bjørge, ruben.bjorge@sintef.no

Senior res. scientist Per Erik Vullum, pererik.vullum@sintef.no

Res. scientist Sigurd Wenner, sigurd.wenner@sintef.no

Senior res. scientist Câlin D. Marioara, calin.d.marioara@sintef.no

Res. scientist Elisabeth Thronsen, elisabeth.thronsen@sintef.no

You can find us in the Natural Science Building (Realfagbygget) in the 4th floor – B4 and D4 corridor. The microscopes are in the basement of Chemistry Block 1 - K1. For general enquiries: temlab@phys.ntnu.no