

## Template for MAX IV Expressions of Interest (Draft v5)

### Administrative section

Which type of EoI are you submitting (tick one):

- ☒ Complete beamline
- ☐ Experimental stations, instrumentation, or upgrade
- ☐ Other infrastructure and capabilities: [If Other, please enter a brief explanation here]

### Title of EoI:

*GTiMAX: General Tomographic Imaging beamline at MAXIV*

### Acronym or short name:

*GTiMAX*

### Additional information (required)

Is there already a Conceptual Design Report or similar?

- ☐ NO ☒ YES – If yes, please provide a link to document here:

An original CDR for iMAX was developed in 2013, which included aspects related to 3DXRD imaging that are not included in the GTiMAX concept: <https://www.dropbox.com/s/hsotnrux7ij35fd/iMAX-CDR.pdf?dl=0>. Furthermore, the GTiMAX concept is also related to the MedMAX one, for which a CDR was developed in 2017 and updated in 2019:

[https://www.dropbox.com/s/t2ohzazjnnctmj2/MedMAX\\_CDR\\_2phase.pdf?dl=0](https://www.dropbox.com/s/t2ohzazjnnctmj2/MedMAX_CDR_2phase.pdf?dl=0)

Does the EoI relate to any areas mentioned in the MAX IV Strategy? (multiple choice)

#### Transformative Science areas

- ☒ Health and Medicine
- ☒ Tackling Environmental Challenges
- ☒ Energy Materials & Technologies
- ☒ Quantum and Advanced Materials
- ☐ Ultrafast Science
- ☐ Accelerator Science

#### Cross-Cutting topics

- ☒ Imaging
- ☐ Dynamics
- ☒ Data analysis, Machine Learning and AI
- ☐ Other
- If "Other" please specify here

Is the intended item already funded?

(most should tick no here, unless funding is already approved)

- ☒ NO ☐ YES – If yes, by which entity? Enter organisation

Is there any cross-dependence between this EoI and others?

- ☐ NO ☒ YES – If yes, which one or ones? MedMAX

## Abstract

**GTiMAX** will be a world-leading nano-to-micro-scale full-field imaging beamline focussed on multi-scale analysis of the internal 3D structures of bulk materials and objects that will lead to significant advances in many areas of science. **GTiMAX** will be explicitly designed to enable these powerful 3D imaging capabilities to be extended to 4D (time-resolved 3D) imaging of structural evolution during *in-situ/operando* experiments. This will allow direct observation and quantification of material responses to external and internal loads, e.g., during mechanical, thermal, hygrological or chemical loading. A key focus will be on the users who will be from a broad range of research areas and often with little/no synchrotron experience.

The areas of application of **GTiMAX** are wide; including energy research, climate science, material science, additive manufacturing, bioengineering, clay science, civil engineering, chemistry, biology, earth/planetary science, food science, palaeontology, archaeology and cultural heritage.

The key features of **GTiMAX** can be summarised as:

- absorption and phase contrast imaging over 10-35+ keV on medium sized (0.1 mm - 5 cm) samples;
- multi-scale imaging (on the same sample) with 3D spatial resolution in the range 100 nm – 5 mm
- focus on user-defined in-situ/operando experiments;
- robust, user friendly operation with emphasis on high throughput and the full service (including sample environments and 3D & 4D data processing/analysis tools) required for the many users who will have little experience with synchrotron measurements and lack resources for data analysis;

**GTiMAX** will exploit the unique source characteristics of MAXIV through: (i) the high coherent fraction leading to better phase contrast images; (ii) the superior brilliance enabling fast tomography with better spatial resolution (and higher contrast) than at existing imaging beamlines for bulk materials.

## Background

The GTiMAX beamline developed from the iMAX beamline concept. The iMAX concept started with a workshop in 2013 to discuss the science case/strategy for non-medical imaging at MAXIV. This workshop was attended by 55 researchers from a wide spectrum of research disciplines. The outcome was a clear recommendation to develop two complementary beamlines: (i) **NANO-MAX** for imaging at the ultimate spatial resolution for small samples using nanobeam scanning and CXI/ptychography; (ii) **iMAX** for studies of bulk materials with resolutions of 50 nm and up, with full-field, multi-modal and multi-scale imaging approaches. iMAX was presented at the 2013 MAX IV user meeting and the working group was invited by the MAX IV management to develop a CDR, which was submitted in November 2013 and accepted by the SAC in December 2013. iMAX was officially listed in the future beamlines in the MAXIV director's UM14 presentation.

Following the above developments, Swedish funding was not secured for the beamline and the iMAX concept was, in part, developed as the imaging branch of DanMAX. However, DanMAX has 50% beamtime for the imaging branch, of which 50% is for the Danish community. Furthermore, the imaging branch of DanMAX will have a strong focus on diffraction-based imaging methods. Consequently, the time available for tomography to general users will be very limited. ForMAX will also provide tomographic imaging, but with a focus towards the forestry industry and in conjunction with SAXS/WAXS capabilities, meaning that tomographic time for general users will also be limited.

On October 20th, 2021, a MAXIV strategy workshop was held to discuss the lack of tomography at MAXIV and to develop a strategy towards addressing this. This workshop involved 63 participants from many areas of science in Sweden and abroad. We also know that many interested parties were not able to join. The outcome of this workshop was a suggestion to submit again proposals for MedMAX and iMAX→GTiMAX to accommodate the strong need for 3D x-ray tomography imaging in the biomedical community (MedMAX) and an even larger community from a broad range of research areas (including materials, engineering, geology, archaeology, food science, energy research and more). The need for tomographic imaging was also strongly stated in a similar MAXIV strategy workshop on energy materials. Whilst two EoIs are being submitted for MedMAX and GTiMAX, it is considered by the proposers that the two beamlines concepts have very strong overlap and should lead towards a single combined beamline to provide world-leading tomographic imaging exploiting the brilliance of MAXIV for the complete user community of MedMAX and GTiMAX.

X-ray tomography, as a non-destructive 3D imaging technique, allows analysis of internal structures of materials without destructive sample treatment. This is invaluable, for example, when studying palaeontological, archaeological and cultural artefacts that are generally very precious and rare (often unique) such that destructive analysis is not an option. A more general, and rapidly expanding, area of application is 3D characterisation of material microstructures over representative volumes. This is essential in many areas of research to fully understand the material processes of interest. Such applications include characterisation of pore-structure and connectivity for fluid flow modelling in porous media or understanding the morphology and juxtaposition of material microstructures that control macroscopic deformation behaviour. Furthermore, the ability to observe materials under the correct environmental conditions, i.e., without damaging sample preparation, is often essential, e.g., for the observation of the structure of clay aggregates in a water environment as opposed to after destructive water removal for (2D) cryo-SEM techniques. X-ray tomography thus provides access to otherwise inaccessible information on materials in their relevant functional state/environment. Furthermore, non-destructive analysis allows repeated imaging of objects, which enables researchers to perform experiments “*in-situ*” or “*operando*” (i.e., in the imaging set-up) to follow material evolution and to characterise processes as well as structures. Such *in-situ* experiments (e.g., mechanical loading tests) enable researchers to go beyond 3D structural imaging to 4D analysis of properties and processes at the heart of materials. Thus, it is possible to identify and characterise the fundamental building blocks and behaviour-controlling processes of materials.

**GTiMAX** will provide absorption and phase contrast imaging with high spatial resolutions, permitting fine scale studies of bulk material microstructures. Combinations of these techniques with local tomography will enable multiscale analyses of structures and processes. Furthermore, an important guiding philosophy behind **GTiMAX** is the need to extract quantified information from 3D and 4D imaging that is pertinent to the research question posed. This will be provided through advanced volume analysis tools as standard for the users and through the strong links to multi-dimensional image analysis research communities.

#### *Science drivers*

Consultation with a wide user reference group provides the science drivers for **GTiMAX**, examples of which are described in the following.

#### **Material and engineering science:**

- How can topology-optimized microstructures in additively manufactured (AM) meta-materials be tuned to provide novel or smart behaviours, e.g., zero thermal expansion or magneto-activation
- What are the internal failure processes in carbon fibre reinforced polymer (CFRP) laminates that influence safety in wind turbines or aerospace wing and fuselage components?
- Which multi-scale 3D processes affect cement-based material (e.g., concrete) performance and how can curing or reinforcement be optimised to increase durability?
- What are the micro-scale processes of metal or ceramic powder sintering, e.g., for AM and what factors can lead to defects and weaknesses in 3D printed products?
- Why can granular materials (e.g., sand or AM powders) support large loads yet also flow like fluids?
- What are the structures of new materials, e.g., silica foams, and can these be engineered for optimal material performance?

#### **Energy materials**

- What structural changes occur due to lithium transport in Li-ion batteries and how can they mitigated to enhance battery life and prevent catastrophic explosion?
- How do dendrites form in Li-ion batteries and how can they be prevented to avoid short-circuits?
- Can heat/aging induced structural evolution and degradation of insulating PUR foams be prevented or retarded to increase the efficiency and life of district heating pipes?
- How can micro-structured AM materials or e-textiles be developed for practical and effective harvesting of ambient energy to replace batteries to power small wireless devices, e.g., in body sensor networks or inaccessible/remote installations.

#### **Earth and planetary sciences:**

- What are the palaeomorphological characteristics of ancient fossils that differentiate them from similar fossils or modern-day organisms and thus how did the organisms evolve?

- How do the internal structures of rocks influence fluid flow and how does this evolve during, for example, CO<sub>2</sub> sequestration or nuclear waste storage?
- What can rock textures from the 2.5 km deep COSC (Collisional Orogeny in the Scandinavian Caledonides) drill holes in western Jämtland reveal about orogenic processes in past and recent active mountain belts?
- How can particles of extra-terrestrial, relict minerals embedded in sedimentary rocks be analysed to provide information about the history of the solar system and the Earth, including possible relations between evolution of life and astronomical processes?
- Can studies of recent fossils or shells help us to understand past climate evolution and, thus, the current climate change challenges?

#### **Soil, snow and environmental sciences:**

- What are the processes of snow metamorphism that might control avalanches?
- How does bentonite structure, and thus its nuclear waste sealing potential, develop with compaction and swelling?
- How are pollutants transported through soils?
- How can salt ions be injected into very low permeability quick clays to produce microstructural changes that result in improved mechanical properties, e.g., for slope stabilisation?

#### **Food and plant sciences:**

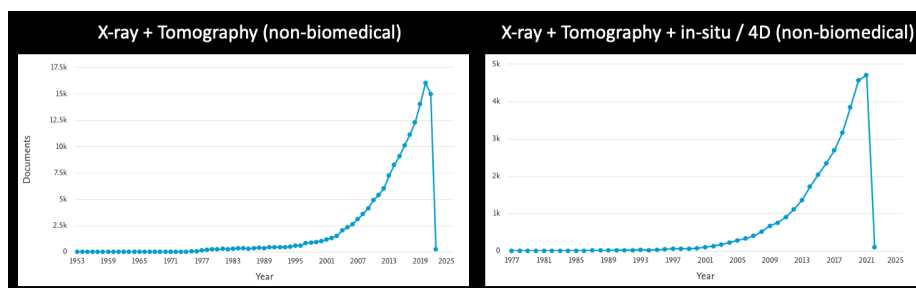
- How can bread be modified to mitigate staling, increase shelf-life and to develop energy-efficient baking processes?
- How do particle sizes and shapes in Pickering emulsions influence emulsion stability through contact angles and absorption at droplet interfaces?
- How do the microstructures and tissue integrity of fruits/vegetables evolve on drying or freezing and how does that influence product quality?
- What biological, chemical and soil-structure factors influence plant root structures and thus plant growth and crop yields?
- How can we best optimize food product processing, e.g., extrusion to better mimic meat textures to provide viable, sustainable meat alternatives.

#### **Cultural Heritage:**

- What can the internal microstructures and textures inside ceramic, stone or metal tools, weapons and other archaeological objects tell us about manufacturing processes and thus technological development of our ancestors?
- How do archaeological/cultural specimens, e.g., the wood of the Vasa, degrade in museum environments and how can we mitigate this?
- How can the mechanical behaviour of soils be improved below infrastructure developments to preserve archaeological sites?

## User community and engagement

The use of x-ray tomography imaging in a very wide range of research areas is evident in the over-subscription of imaging beamlines at synchrotrons around the world, as well as the increase in the number of such beamlines in upgrade programs. The figure below indicates the increase in publications exploiting x-ray tomography for non-biomedical purposes (Scopus search “X-ray + Tomography” and limited to non-biomedical subject areas) and also the increase in in-situ/4D studies (Scopus search “X-ray + Tomography + in-situ / 4D”, limited to non-biomedical subject areas). This has been limited to non-biomedical subject areas to highlight the wider interest beyond the MedMAX community.

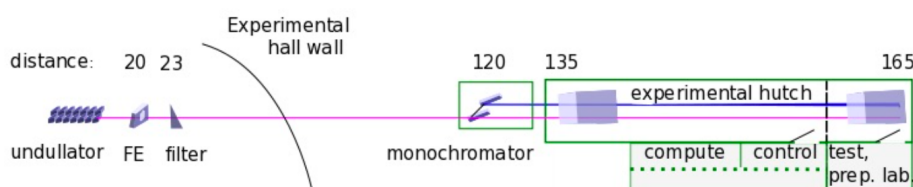


The support of the Swedish community from a wide range of subject areas has been represented in the various meetings about the beamline, described above, including the latest strategy workshop with its 63 participants. In addition, the attached list contains names of researchers who have, thus far, stated their support for the development of a dedicated tomography beamline at MAXIV. This list is by no means exhaustive and there are many more researchers who have not yet been able to express their support, but whose interest is known to the EoI group.

## Technical specifications

The GTiMAX beamline will likely follow the same specifications as MedMAX, but with modifications to optimise use for studies of materials other than biomedical and soft materials. The beamline would be placed at the MAX IV 3GeV storage ring and be optimised for micrometre-scale, time-resolved, 3D attenuation and phase imaging. Most, if not all, of the unique properties of the diffraction limited storage ring will be fully exploited. The following is largely replicated from the MedMAX EoI and based on the MedMAX CDR developed by Rajmund Mokso.

The 165 m long beamline (see figure below) will cover spatial resolutions from 100 nm to 30 $\mu$ m. The last section would be focussed towards MedMAX and optimised for in-vivo imaging.



The rationale behind the long beamline is:

- A natural beam size without any optical manipulation will be 1.5 mm at the sample position, matching perfectly the main purpose of the beamline (1 $\mu$ m spatial resolution).
- To foster development of coherent imaging methods. The highly coherent beam with a clean wavefront from the longest MAX IV beamline will likely attract pioneering methodological studies.

Specifications	nanotomo	microtomo	in-vivo tomo
Distance from source [m]	135	150	165
X-ray energy	12,24,36 keV	12-40 keV	20-40 keV
Beam size at sample	0.05-0.2 mm	1-2 mm	20-50 mm
Beam modes	Focused	Parallel	Expanded
X-ray bandwidth	$10^{-4} - 10^{-2}$	$10^{-2}$	$10^{-4} - 10^{-2}$
Flux at sample @25keV [ph/s]	$10^{12} - 10^{13}$	$5 \times 10^{15}$	$10^{15} - 10^{14}$
3D spatial resolution	100-300 nm	1-2 $\mu$ m	5-30 $\mu$ m
Trademarks	nano-scale phase tomography and spectroscopy of cells, bacteria and biologic material	fast ex-vivo and in-vivo micrometer scale imaging of tissues and selected organ regions.	in-vivo imaging of whole organs in small animals, low-dose longitudinal studies

The principal technical parameters of the beamline are summarized in the Table above. An add-on value of the highly coherent beam at the sample at approximately 150 m is the good match with the optional nano-scale resolution imaging using focusing mirrors. The 165 m long beamline will be kept as simple as possible in terms of optical elements. One, single, 30 m long experimental hut will host three instruments separated from each other by one order of magnitude in the spatial resolution domain (see MedMAX CDR for details).

### Adjacent infrastructures

The most important adjacent infrastructure connected to GTiMAX are:

- sample handling and test lab for equipment and simple sample mounting where, also, new mechanical assemblies can be developed and fine-tuned by the beamline staff and the users;
- image Quantification Centre for off-line analysis of complex multi-dimensional data;
- in-situ environments for sample loading (e.g., mechanical, electrochemical);
- office space for the imaging group staff at the second floor of the proposed satellite building.

Rough estimate of total investment cost: 120 MSEK.

Rough timeline:

- Year one: Development of new updated CDR and DDR.
- Year two: procurement and construction.
- Year three: construction and commissioning.
- Year four: commissioning and operation.

## State of the Art / Benchmarking

### International context

Inline phase contrast full-field imaging has been a great success story of 3<sup>rd</sup> generation synchrotrons and all of the world's leading synchrotrons has one or more beamlines dedicated to tomographic imaging, both at undulators, such as ID19 (ESRF), PO5 (PETRA) and I13 (DIAMOND), and at bending magnet, such as TOMCAT at SLS. The preparation of the MedMAX/GTiMAX CDR took inspiration from state-of-the-art on synchrotron tomography beamlines at SLS, ESRF, PETRA III, ANSTO, and SPring-8. GTiMAX will implement several of the most powerful and user-friendly phase-contrast approaches and should outperform existing beamlines in terms of contrast due to the specifics of the MAXIV source.

It is noted that the use of micro-tomography with lab sources has massively expanded in Sweden in recent years. This has led to a much larger community demanding access to synchrotron tomography to enable rapid in-situ/operando studies or to exploit the enhanced resolution and contrast available with synchrotron phase contrast imaging. The GTiMAX beamline would be integrated within the national (plus wider Nordic) network of laboratory tomography to be able to exploit the greater accessibility of lab tomography as a support for synchrotron-based experiments. This would be a significant strength of the GTiMAX concept. Furthermore, the aim to provide image analysis support after the experiments for all users is quite unprecedented, yet already proven as a concept in the already established QIM (Quantitative Imaging for MAXIV) collaboration between Lund University, the Danish Technical University, University of Copenhagen and MAXIV (<https://qim.dk>).

## Impact statement

GTiMAX will impact on a broad spectrum of research and development areas across the Swedish and international academic, industrial and public-sector communities, as described above. In doing so it will, for example, address many of the UN sustainability goals. In particular, GTiMAX will provide greater accessibility for these communities to world class x-ray tomography with a support structure (from the experiment development to the data analysis) to enable rapid turnaround and exploitation of results. Currently, Swedish researchers must travel abroad to conduct synchrotron-based tomography of the type described in this EoI. Whilst many excellent imaging beamlines are available internationally, the proposed GTiMAX beamline will provide greater possibilities for the Swedish community through improved involvement and collaboration in the beamline to tune the development to fit each communities' needs. Furthermore, although many other synchrotron facilities are in the process of upgrading to the multi bend achromat storage ring layout, MAX IV still provides world-leading beam parameters for imaging and the possibilities for multi-scale, phase-contrast tomography and in-situ experiments with this high-quality beam will attract many international users.



## Proposers

## Example:

- SPOKESPERSON & PRINCIPAL INVESTIGATOR – Stephen Hall, Director Lund Institute of Advanced Neutron and X-ray Science & Senior Lecturer, Division of Solid Mechanics, Lund University.
- CO-PRINCIPAL INVESTIGATORS: Mikael Sjö Dahl, Professor, Division of Fluid and Experimental Mechanics, Luleå University of Technology & Niklas Lorén, RISE. Plus the many PI's in the list of the supporting community.
- TECHNICAL LEAD – Rajmund Mokso, DTU, Lyngby, Denmark. Co-technical lead: Dina Carbone, MAX IV.
- SUPPORTING COMMUNITY – the following list of supporters is collected in an online form common to the MedMAX and GTiMAX Eols. There is also significant industry interest.

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The above list of supporters filled in an online form with the following text and also explicitly stated their support for both GTiMAX and MedMAX or just GTiMAX:

*“As part of the ongoing strategy process at MAX IV, expressions of interest (Eoi) for dedicated tomography endstations for soft materials (MedMAX) and hard materials (GTiMAX) is being submitted. The Eois propose an optimised tomography beamline with capability to do fast tomography on length scales bridging the gap from nano to meso scale.*

*The aims of the proposals are to:*



1. Increase the imaging capability at MAX IV by enabling high throughput fast tomography for studies involving a large number of samples. A phase retrieval pipeline will ensure optimal image contrast in low contrast samples.
2. Increase the imaging capability at MAX IV by providing a versatile tomography endstation with a zoom option, where a local region of interest can be selected from a larger overview scan. In this way allowing for imaging of sparse features in large samples.
3. Increase the imaging capability at MAX IV by enabling bio-medical research (including ex-vivo and in-vivo imaging experiments) with dose balanced fast imaging.
4. Increasing the imaging capacity at MAX IV by adding a dedicated tomography beamline to complement DanMAX and ForMAX, both of which will only provide limited access and limited flexibility for tomography experiments.

A brief presentation of the MedMAX project can be found here:

<https://www.maxiv.lu.se/accelerators-beamlines/beamlines/projects/medmax-beamline-project-currently-not-funded/>

More detailed information and the most recent conceptual design report can be obtained from the project coordinators:

MedMAX: Martin Bech, [martin.bech@med.lu.se](mailto:martin.bech@med.lu.se)

GTiMAX: Stephen Hall, [stephen.hall@solid.lth.se](mailto:stephen.hall@solid.lth.se)

There is a natural overlap between the MedMAX and the GTiMAX Eols, as the two are defined by the scientific interest of the user communities, but the actual endstations will be serving both communities.

In the checklist below, specific Eol support can be selected.

By signing the form below I confirm that I officially support the tomography Eol as described above with specific support detailed below."

## References

The 10 papers below, involving the PI and a national network of collaborators, have been selected to illustrate some of the domains of relevance and potential user community of GTiMAX. (Note that some of these examples have employed laboratory x-ray tomography and other complementary techniques, but they represent initial imaging studies for which GTiMAX would enable significantly increased understanding through the enhanced resolution and contrast and/or faster scanning permitting in-situ testing or imaging of larger numbers of samples to enable statistical analysis).

1. Nypelö, T., Fredriksson, J., Arumughan, V., Larsson, E., Hall, S.A. and Larsson, A., 2021, N<sub>2</sub>O assisted siphon-foaming of modified galactoglucomannans with cellulose nanofibrils, *Frontiers in Chemical Engineering*, 3, 756026.
2. Rostami J., Gordeyeva, K., Benselfelt, T., Lahchaichi, E., Hall, S., Riazanova, A.V., Larsson, P.A., Ciftci, G.C. and Wågberg, 2021 Hierarchical Build-up of Bio-Based Nanofibrous Materials with Tunable Metal-Organic Framework Biofunctionality, *Materials Today*.
3. Townsend, P., Larsson, E., Karlson, T., Hall, S.A., Lundman, M., Bergström, P., Hanson, C., Lorén, N., Gebäck, T., Särkkä, A. and Röding, R., 2021, Stochastic modelling of 3D fiber structures imaged with X-ray microtomography, *Computational Materials Science*, 194, 110433
4. Berger Ceresino, E., Johansson, E., Harumi Sato, H., Plivelic, T.S., Hall, S.A., Bez, J. and Kuktaite, R., 2021, Lupin protein isolate structure diversity in frozen-cast foams: Effects of transglutaminases and edible fats, *Molecules*, 26, 1717
5. Taylor G.J., Hall S.A., Gren J.A. and Baird E., 2020, Exploring the visual world of fossilized and modern fungus gnat eyes (Diptera: Keroplatidae) with X-ray microtomography. *J. R. Soc. Interface* 17: 20190750.
6. Sjögren, T., Hall, S., Elmquist, L., Dartfeldt, E., Larsson, E., Majkut, M., Elfsberg, J., Skoglund, P. and Engqvist, J., 2020, In situ analysis of cast irons mechanical behaviour using synchrotron x-ray

- tomography and 3DXRD, IOP Conf. Ser.: Mater. Sci. Eng., 861, 012039,
7. Ferreira, B.M.P., Andersson, N., Atterling, E., Engqvist, J., Hall, S., Dicko C., 2020, 3D structure and mechanics of silk sponge scaffolds is governed by larger pore sizes, *Frontiers in Materials – Mechanics of Materials*, 7.
  8. Lindgren, J., Nilsson, D.E., Sjövall, P., Jarenmark, M., Ito, S., Wakamatsu, K., Kear, B.P., Schultz, B.P., Lyng Sylvestersen, R., Madsen, H., LaFountain Jr, J.R., Alwmark, C., Eriksson, M., Hall, S.A., Lindgren, P., Rodríguez-Meizoso, I., and Ahlberg, P., 2019, Fossil insect eyes shed light on trilobite optics and the arthropod pigment screen, *Nature*, 573, 122–125
  9. Johansson, S., Rossi, M., Hall, S. A., Sparrenbom, C., Hagerberg, D., Tudisco, E., Rosqvist, H. and Dahlin, T., 2019, Combining Spectral Induced Polarization with x-ray tomography to investigate the importance of DNAPL geometry in sand samples, *Geophysics*, 84, E173-E188
  10. Taiwo, O.O., Paz-García, J-M. Hall, S.A. Heenan, T.M.M., Finegan, D.P. Mokso, R., Villanueva-Pérez, P., Patera, A., Brett, D.J.L. and Shearing P.R., 2017, Microstructural degradation of silicon electrodes during lithiation observed via *operando* X-ray tomographic imaging, *Journal of Power Sources*, 342 904–912.