factsinsight

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31 Dec 2024

X-ray Powerhouse

Revolutionising Instrument Training

Looking Ahead

FROM LAB TO RESEARCH HUB

A cornerstone for materials characterisation

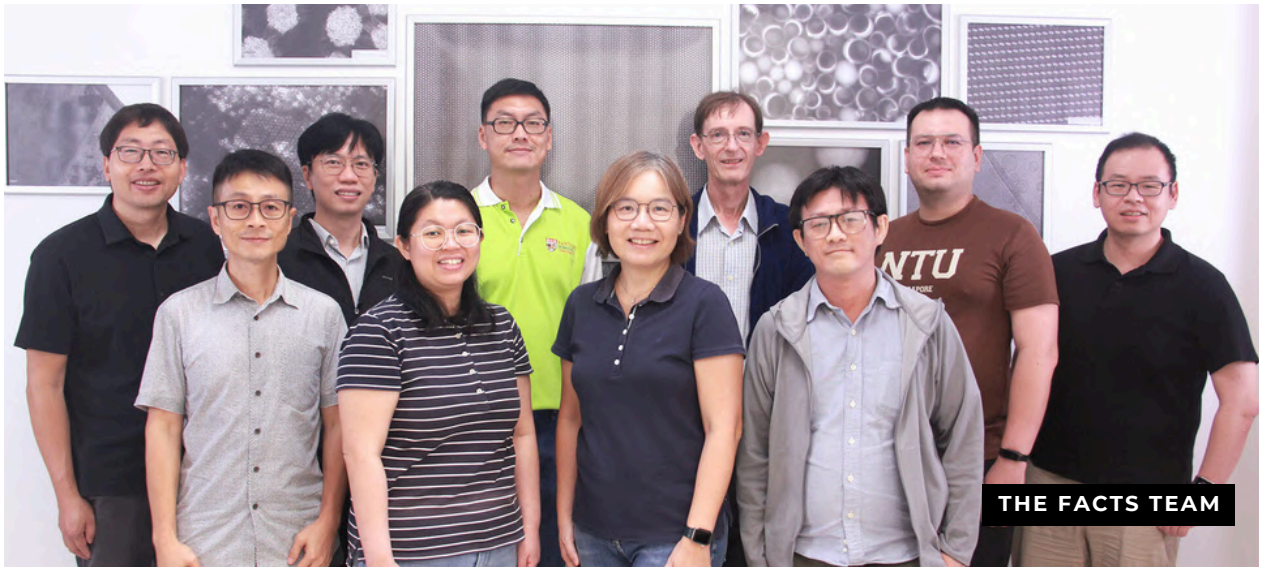
Education to Research

The Art of Science

ISSUE #01

FACTS INSIGHT

31 DEC 2024



THE FACTS TEAM

Advancing Cross-Disciplinary Research through Advanced Characterisation

Welcome to the inaugural issue of FACTS Insight, an occasional newsletter highlighting the role of the Facility for Analysis, Characterisation, Testing and Simulation (FACTS) at NTU in advancing cross-disciplinary research. Since its beginnings as a small lab in 1996 at NTU's School of Applied Science, FACTS has evolved into a cornerstone of advanced scientific research. In 2004, it became a 24-hour facility, joined the College of Engineering in 2009, and ultimately achieved university-wide status in 2017.

Today, FACTS provides NTU researchers and collaborators with access to state-of-the-art characterisation tools that support innovative solutions to complex scientific and technological challenges. Among its advanced equipment are two aberration-corrected transmission electron microscopes (ACTEMs) and a focused ion beam (FIB), acquired in 2013 and housed in specialised facilities.

FACTS' strength is a dedicated team of scientists who help researchers fully leverage these resources. We are proud that several FACTS users have been recognised as Highly Cited Researchers, underscoring the facility's impact on NTU's research excellence.

Professor Lam Yeng Ming, Director of FACTS, highlights the facility's essential role in NTU's research ecosystem: "With our advanced X-ray and electron microscopy capabilities, we enable researchers to access critical characterisation tools for innovation in science and engineering. FACTS serves as a catalyst for research breakthroughs, empowering NTU research groups to tackle challenges across fields such as energy, nanotechnology, healthcare, and environmental science."

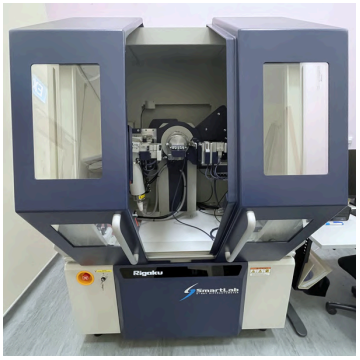
Beyond characterisation, FACTS fosters interdisciplinary collaboration, linking researchers across diverse fields to address global challenges.

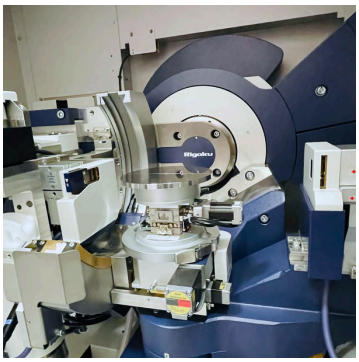
Inside:

Editor
Dr Andrew Wong
Advisors
Prof Lam Yeng Meng and Dr Chris Boothroyd

The cover page image illustrates the concept of wave-particle duality, generated by DALL·E, an OpenAI tool.

FACTS Boosts Research Capabilities with Three New X-ray Diffractometers from Rigaku





From left to right: The newly commissioned XRD systems at FACTS offer high-resolution and in-situ analysis of crystalline materials. *Photo: Andrew Wong*

FACTS is transforming materials research with the unveiling of advanced XRD capabilities.

The 2024 launch of FACTS' new X-ray Diffraction (XRD) suite marks a transformative step forward in materials characterisation. Featuring two state-of-the-art Rigaku SmartLab XRD systems, this development underscores FACTS' commitment not only to acquiring cutting-edge instrumentation but also to replacing aging equipment to ensure researchers have access to the best tools available.

Researchers undergoing training on the Rigaku XRD. *Photo: Andrew Wong*

FACTS' new XRD systems introduce a range of advanced capabilities designed to address modern challenges in materials science. One notable enhancement is the XSPA detector technology, which effectively suppresses the fluorescence background. This feature is particularly critical for studying materials containing elements like Fe, Mn, and Co, such as structural alloys, batteries, and catalysts. The modular in-situ stages further enable dynamic studies, allowing researchers to observe material behavior under varying temperature, mechanical, and environmental conditions, closely mimicking real-world scenarios.

The systems include switchable optics and tailored source profiles, optimized for the analysis of advanced manufacturing materials such as 3D-printed components. These features enable detailed failure analysis and performance evaluation. Their high-throughput design allows for large-area mapping, the use of multiple sample holders, and rapid 2D data collection, which can support machine learning and AI-driven approaches in materials research.

Upgrading the Research Ecosystem

FACTS demonstrates its commitment to cutting-edge research with investments in state-of-the-art and replacement instrumentation. The new XRD suite overcomes the limitations of aging systems, providing researchers access to advanced techniques like phase identification, RSM, XRR, and PDF analysis. This ensures FACTS remains a leader in precision and efficiency for materials research.

FACTS Enhances Instrument Training with Innovative Hybrid Learning Content

Researchers undergoing training on the Zeiss Crossbeam 540 Focused Ion Beam.
Photo: Andrew Wong

FACTS has launched a new initiative employing hybrid training methods that leverage technology to enhance the efficiency of instrumentation training.

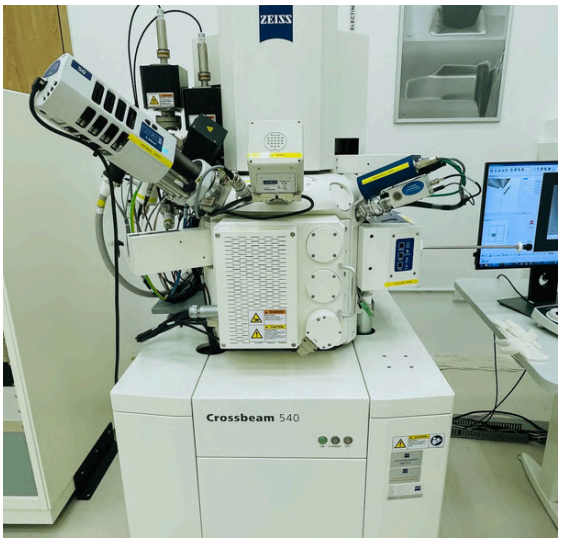
Led by Professor Lam Yeng Ming, alongside Dr. Xi Lifei and Alan Lim, this project aims to revolutionise laboratory instrument training at NTU. By integrating traditional face-to-face instruction with hybrid learning techniques, FACTS seeks to create a training programme that is more flexible, efficient, and impactful.

The hybrid learning model combines online theoretical modules, pre-recorded video demonstrations, hands-on practice, and regular competency assessments. Developed for the NTUlearn platform, the training content is tailored to support researchers mastering Scanning Electron Microscopy (SEM) and Focused Ion Beam (FIB) techniques. Ninety participants will take part in the study, divided into two groups to compare the effectiveness of traditional versus hybrid training methods. A follow-up survey conducted three months after trainees begin using the instruments will ensure continuous improvement of the content.

After enrolling in the hybrid training, participants begin with online theoretical modules enriched with animations and audio, followed by detailed video demonstrations of instrument operation. This structured approach ensures a solid foundation is built before progressing to practical, hands-on training.

About the Zeiss FIB at FACTS

- Transmission electron microscope (TEM) Sample preparation involves creating a thin cross-section for electron beam analysis. Colloidal samples can be drop-cast onto a copper grid and dried.
- Bulk samples are prepared through mechanical thinning or ion milling, such as with the Focused Ion Beam (FIB).
- FACTS has a FIB for TEM lamella preparation, used in materials science and semiconductor industries.
- The FIB is equipped with Ga ion beam, gas injection systems (Pt and C), and an in-situ manipulator for analysis, cross-sectioning, and nanofabrication.



Zeiss Crossbeam 540 *Photo: Andrew Wong*

Outlook 2025: Expanding Frontiers in Materials Characterisation

ISPAC 2025: Discover cutting-edge polymer science at NTU Singapore, 23–27 June.
Banner: Teddy Salim

2025 promises to be a transformative year for FACTS, marked by cutting-edge advancements, global collaborations, and impactful initiatives in materials characterisation. From introducing advanced instruments to hosting the prestigious ISPAC 2025 symposium, FACTS is poised to solidify its position as a leader in innovation and research excellence.

To support the ever-evolving demands of scientific research, FACTS is expanding its advanced characterisation infrastructure with next-generation tools. A new high-resolution transmission electron microscope will replace older existing TEMs, offering enhanced functionalities such as improved resolution, faster imaging capabilities, and advanced analytical options, ensuring researchers have access to the latest technology. Complementing this will be a plasma-focused ion beam (FIB) system, enabling the preparation of larger cross-sectional areas, critical for advanced applications in materials science and semiconductor research. Additionally, the introduction of X-ray computed tomography (X-ray CT) will provide non-destructive, 3D imaging of samples at micron-level resolution, making it invaluable for a range of applications.

Another key highlight of the year is the 36th International Symposium on Polymer Analysis and Characterization (ISPAC 2025), which FACTS is proud to co-organize with NTU's School of Materials Science and Engineering (MSE).

Scheduled for 23–27 June 2025, this prestigious symposium will bring together global leaders in polymer science from academia, industry, and government. The 5-day event features a 2-day intensive school followed by a 3-day conference, offering participants an opportunity to explore innovations in polymer analysis and characterisation. Discussions will focus on emerging topics such as AI-driven polymer characterisation, sustainable polymer development, healthcare and food applications, industrial composites, and novel materials for emerging technologies.

Beyond ISPAC 2025, FACTS will continue to strengthen regional ties by engaging the ASEAN scientific community through workshops and training programs. These initiatives will inspire innovation, foster knowledge sharing, and solidify FACTS' role as a leader in materials characterisation and education. With these developments on the horizon, 2025 promises to be an exciting and impactful year for FACTS.

ISPAC2023 was held at Stellenbosch, South Africa in 2023.
Banner : ISPAC website

Advancing Research through Education

The TEM short course began with lectures and concluded with practical demonstrations.
Photo: Andrew Wong

FACTS Short Courses with Demonstrations and Instrument Training

FACTS offers a variety of learning opportunities throughout the year to ensure researchers can fully leverage our advanced characterisation equipment and gain the technical expertise needed for impactful research.

Our hands-on short courses cover essential techniques like transmission electron microscopy (TEM), scanning transmission electron microscopy (STEM), energy dispersive x-ray spectroscopy (EDX), x-ray diffraction (XRD), x-ray fluorescence (XRF), and scanning electron microscopy (SEM). These courses combine foundational theory with practical demonstrations, empowering participants to develop the skills necessary for independent operation.

In addition to scheduled courses, we provide on-demand instrument training, offering personalised support for researchers aiming to master specific systems. For those seeking to go beyond the basics, we offer advanced training in techniques such as high-resolution TEM (HRTEM) and electron energy loss spectroscopy (EELS), equipping researchers for atomic-scale imaging and in-depth data analysis. This comprehensive training programme enables researchers to enhance their analytical accuracy and depth of insight, maximizing the potential of FACTS' cutting-edge technology in their research.

FACTS Collaborates with UNSW for Advanced TEM Training

This collaboration provides NTU and UNSW researchers with in-depth TEM training, combining remote instruction with live demonstrations to enhance expertise in advanced microscopy techniques.

The course is conducted in person for NTU participants and remotely for those from UNSW, featuring live demonstrations of TEM operations at NTU. It offers a comprehensive experience for researchers, covering key topics such as sample preparation, high-resolution TEM (HRTEM), electron diffraction, and scanning transmission electron microscopy (STEM). Additionally, UNSW contributes to the programme by conducting courses for NTU users on specialized topics such as two-beam theory and practical considerations of STEM. While there were no hands-on sessions for users, demonstrators effectively demonstrated the techniques remotely, ensuring participants gained a clear understanding of the methods.

The programme fosters a collaborative learning environment, enabling participants to discuss challenges and innovative applications. This initiative strengthens research ties between FACTS and UNSW, paving the way for future collaborations. By completing this course, researchers gain essential skills to improve the precision and impact of their microscopy work across various scientific and engineering fields.

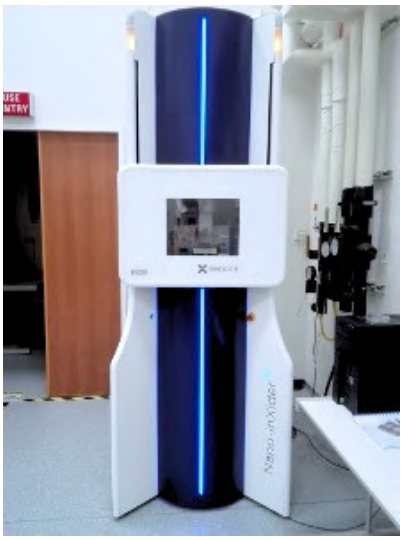
Postgraduate Student Orientation

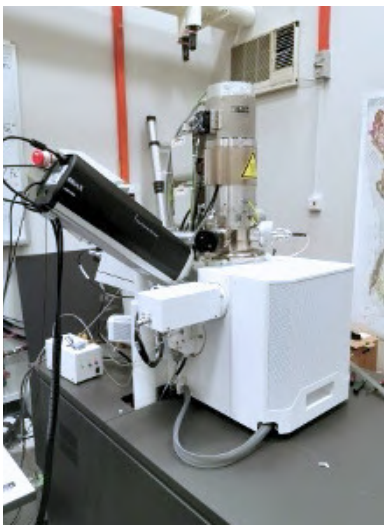
Presenting an overview of FACTS instruments and training to new postgraduate students during the August 2024 orientation. *Photo: Andrew Wong*

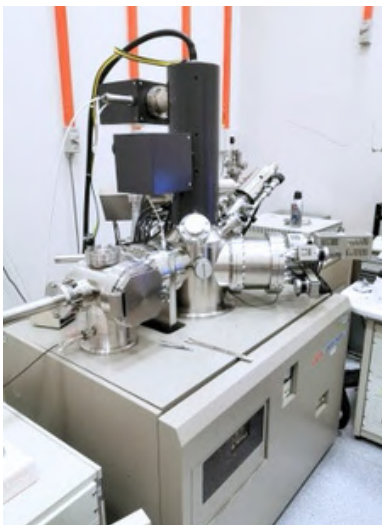
In August 2024, FACTS warmly welcomed a new cohort of postgraduate students, introducing them to the extensive resources, state-of-the-art facilities, and dedicated support available to enhance their research experience.

Our scientists are committed to assisting students throughout their research journeys, providing personalised guidance, technical expertise, and insights to help them effectively navigate and make the most of our advanced instruments.

To ensure a solid understanding of foundational concepts, all students are required to complete comprehensive online courses before engaging in hands-on training. These courses cover essential theory and safety protocols. Once this initial learning is complete, students participate in practical sessions, gaining experience with the equipment under expert supervision.







From top to bottom right: FACTS Instruments – JEOL JEM ARM300F Atomic Resolution Transmission Electron Microscope, Xenocs Nano-InXider (Small angle and Wide Angle X-ray instrument), Environmental Scanning Electron Microscope Thermo Fisher Scientific Quattro S, and JEOL JAMP-7830F Auger Electron Spectrometer. *Photo: Andrew Wong*

Welcoming Local and International Visitors

FACTS regularly hosts a wide range of visitors, including junior college students, industry professionals, polytechnic lecturers, overseas academics, and international delegates. These outreach efforts are pivotal in showcasing NTU's leadership in research and its state-of-the-art facilities, while also demonstrating FACTS' integral role in supporting the broader research ecosystem at NTU.

Through FACTS, NTU provides researchers with access to cutting-edge instrumentation and expertise, enabling them to tackle some of the world's most pressing challenges. These visits highlight how FACTS' advanced tools and capabilities empower researchers to drive innovation, foster interdisciplinary collaboration, and achieve breakthroughs in fields such as energy, nanotechnology, and materials science.

By engaging with both local and international communities, FACTS not only inspires the next generation of scientists but also reinforces NTU's commitment to advancing knowledge and building a vibrant research ecosystem. These efforts affirm FACTS' mission to be a cornerstone of NTU's research excellence.

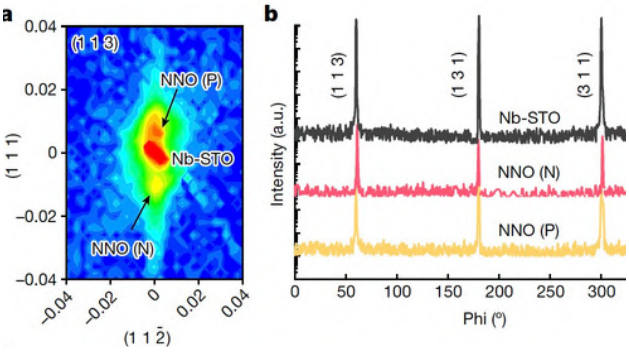
Top to bottom: International visitors from universities in Jilin and Lanzhou, China, as well as Diponegoro University in Indonesia, were introduced to various characterization instruments at the facility.
Photo: Andrew Wong

Recent Publications from FACTS Users

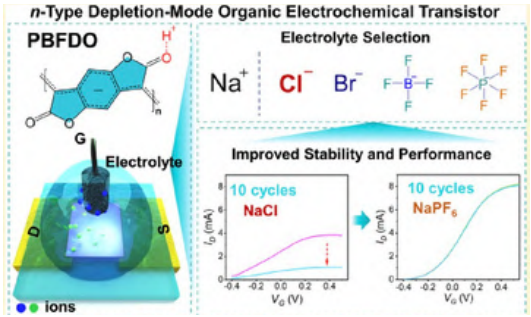
Breaking Limits: Ultrahigh Piezoelectric Performance in Sodium Niobate

Piezoelectric materials, which convert mechanical energy into electrical energy, are crucial for applications like medical imaging, wireless communication, and MEMS devices. Traditional strategies to enhance their performance, such as balancing material phases or introducing nanoscale imperfections, have been effective but face inherent limitations, restricting their potential in demanding applications.

In this study, a novel approach was developed by leveraging the coexistence of antiferroelectric and ferroelectric phases in sodium niobate ($NaNbO_3$) thin films.

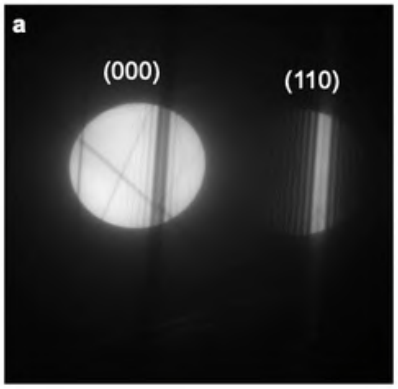


This phase competition creates structural instability, enabling the material to achieve an unprecedented piezoelectric response exceeding 5,000 pm/V. This breakthrough offers a new pathway for designing high-performance materials, advancing next-generation energy and communication technologies. **Lam Yeng Ming** is a Professor in MSE, NTU. **Liu Huajun** is a Group Leader at IMRE, A*STAR, and **Lin Baichen** is a postgraduate student at MSE, NTU. *Nature*, 2024, 633, 798-803



Efficient Transistors

This study introduces an advanced n-type Organic Electrochemical Transistor (OECT) using poly(benzodifurandione) (PBFDO). By incorporating larger ions, the researchers enhanced its stability and performance, particularly in aqueous environments. These improvements result in faster response times, better signal detection, and compatibility with advanced circuits like logic gates. The innovation narrows the gap between n-type and p-type materials, making it highly suitable for bioelectronics and next-generation sensor technologies. **Leong Wei Lin** is an Associate Professor in EEE, NTU. *Chem. Mater.* 2024, 36, 18, 8639–8648



Tabletop X-rays

This study introduces a groundbreaking method to generate water-window X-rays using compact tabletop setups instead of large synchrotron facilities. By leveraging the unique properties of van der Waals materials, the researchers achieved tunable X-ray photon energies, essential for high-contrast imaging in biological and medical research. This novel approach enables accessible, non-invasive imaging of biological cells without staining, opening new possibilities for spectroscopy and diagnostics. **Wong Liang Jie** is an Associate Professor in EEE, NTU. *Nature Photonics 2024, 18, 1203-1211.*

ART SCIENCE
in black & white

MOIRÉ

STEM ADF imaging revealed a moiré superlattice in a MoS_2/WSe_2 bilayer, formed by stacking monolayers.

Xiangbin Cai/ SPMS, NTU - under the supervision of Prof Weibo Gao

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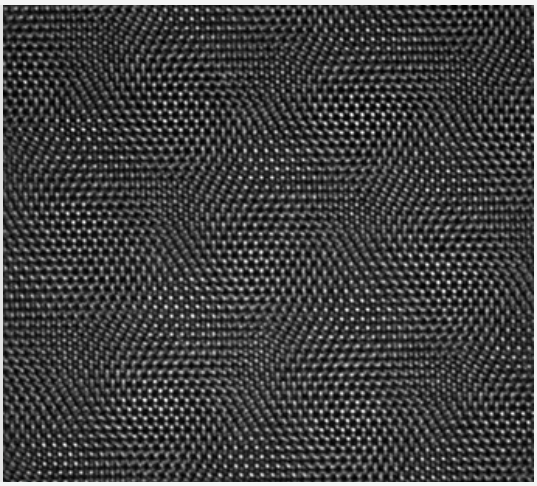
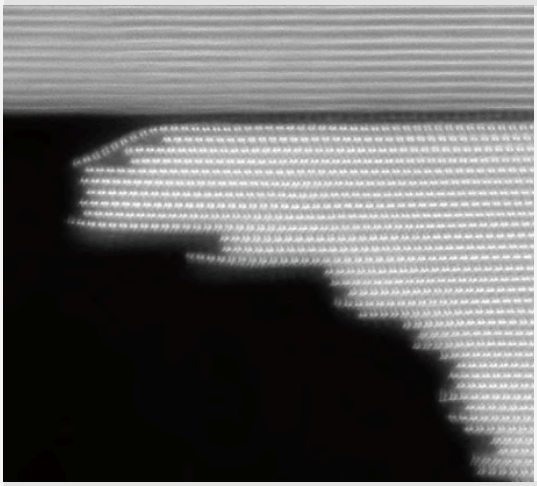




HOMOSTRUCTURE

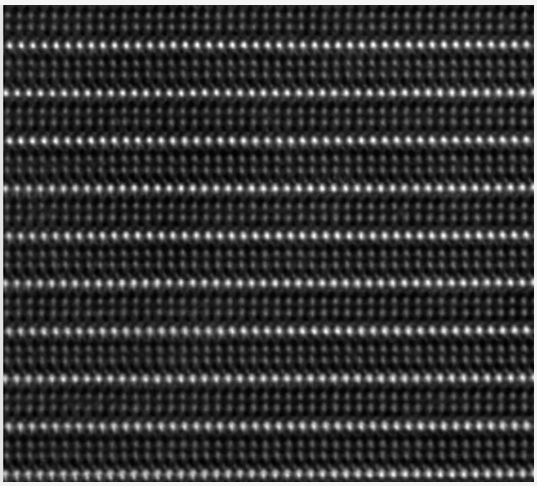
Cross-sectional STEM of WS_2 homostructure.

Zhou Xin/ MSE, NTU - under the co-supervision of Asst. Prof. Song Peng and Prof. Liu Zheng

SUPERLATTICE

Cross-sectional STEM image of a SnS/WS_2 superlattice.

Zhou Xin/ MSE, NTU - under the co-supervision of Asst. Prof. Song Peng and Prof. Liu Zheng



Where Creativity Meets Discovery

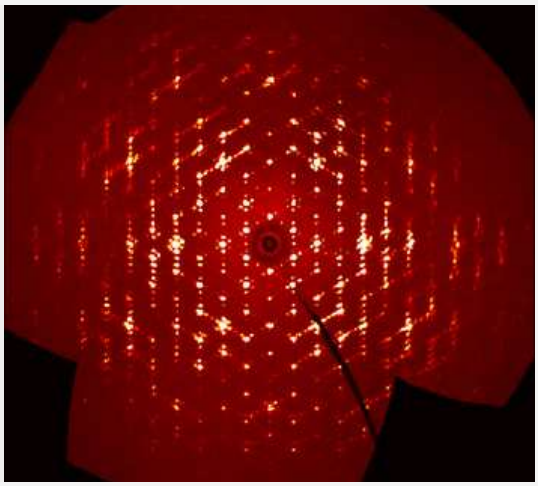
ART SCIENCE

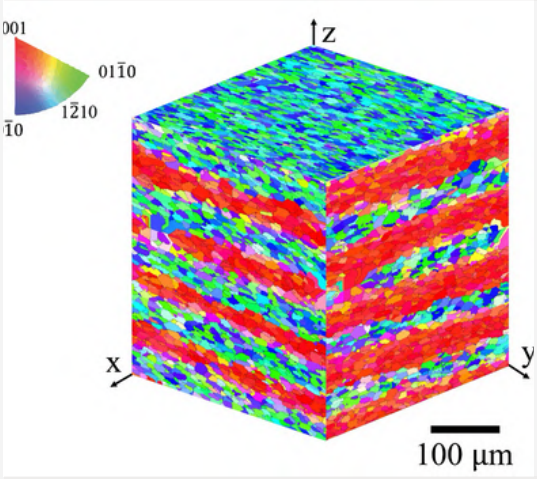
in colour

SUPERSTRUCTURE

Single crystal XRD of imidazolium lead bromide at 220 K reveals a 4-fold superstructure with satellite peaks and threefold twinning.

Walter Wong/ MSE, NTU- under supervision Assoc. Prof Andrew Grimsdale





BIOINSPIRED

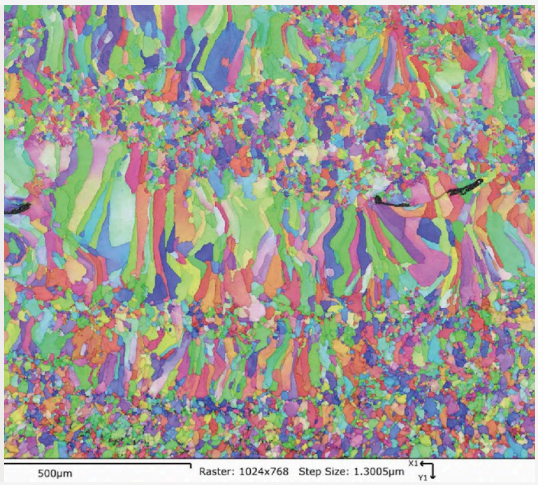
Inverse pole figure map of Al_2O_3 grains shows bioinspired periodic texture, mimicking mantis shrimp for energy dissipation and functional applications.

Rohit Pratyush Behera/ MAE, NTU - under supervision of Asst. Prof Hortense Le Ferrand

MANUFACTURING

EBSD image shows Fe-3.5wt%Si@SiO_2 additively manufactured via laser powder bed fusion to reduce eddy current loss in electric motors.

Xiaojun Shen/ EEE, NTU - supervised by Asst. Prof Christopher H.T. Lee



Where Creativity Meets Innovation