
Electron Physical Science Imaging Centre Launch Event

Highlights from the launch of the new electron Physical Science Imaging Centre (ePSIC) at Diamond Light Source

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An invitation-only event was held from 5th–6th September 2016 to launch the new state-of-the-art imaging facility, opened on 5th September 2016, which will see the University of Oxford, UK, Johnson Matthey Plc, UK, and Diamond Light Source, UK, in close collaboration on the study of nanoscale materials. The ePSIC is located at the Harwell Science and Innovation Campus in Oxfordshire, UK, and was officially opened by Sir John Meurig Thomas from the University of Cambridge, UK, alongside senior representatives from both Johnson Matthey and Diamond Light Source. Sir John is a world renowned expert in materials and surface chemistry, having authored over a thousand research papers, co-authored 30 patents and, in 1991, was knighted by Queen Elizabeth II for “services to chemistry and the popularisation of science” (1, 2).

ePSIC Launch Conference

The launch event was planned to coincide with an invitation-only conference in the field of microscopy and the study of novel materials at the atomic scale.

Approximately 90 delegates attended from six different countries, with an even mix of academic and industrial backgrounds. The first session began with a welcome from Professor Andrew Harrison, the Chief Executive Officer of Diamond Light Source, who stated that the inauguration of this facility was the “most auspicious day since the opening of Diamond” before going on to exemplify the work at Diamond as a fruitful interface between industry and academia.

The scientific programme began with a plenary lecture from Sir John, who presented an entertaining and roughly chronological account of the evolution of electron microscopy from its early use, for example to verify Frank’s theory of crystal growth (3), through to more modern applications, touching for example on the study of zeolites in the petrochemical sector and the understanding of novel materials such as metal-organic frameworks (MOFs). Sir John’s plenary lecture was dedicated to the memory of his fellow scientist and long-time friend, Ahmed Zewail (4), an internationally renowned scientist and world expert in the field of femtosecond chemistry who died in August 2016.

Dogan Ozkaya, Senior Principal Scientist at Johnson Matthey, discussed how the company plans to benefit from its involvement in this collaboration. One of its main areas of interest is catalysis, and understanding how molecules come together and react on surfaces is a fundamental aspect of optimising existing products and designing the next generation of improved processes. Combining electron microscopy with computational

Facilities at ePSIC

The ePSIC facility features two electron microscopes which can image materials with atomic resolution down to 10–30 nm. The centre will operate in the same manner as Diamond's beamlines, being open to scientists from around the world. The beamtime and time on the microscopes are accessed *via* peer reviewed applications.

The two electron microscopes will enable researchers to see the detailed structure of materials such as catalysts (**Figure 1**), but also to take slow-motion images of reactions at an atomic scale. The new building also houses the I14 hard X-ray nanoprobe beamline, a dedicated facility for micro-nano small-angle X-ray scattering (SAXS) and nanoscale microscopy at the Diamond Light Source synchrotron. This nanoprobe

can penetrate further into a material than other methods, allowing two-dimensional (2D) and three-dimensional (3D) structural analysis of catalysts down to the nanoscale. The analysis lengthscales of the microscopes and beamline are highly complementary and significant interaction between the two are expected.

Accompanying the two microscopes for the physical sciences will be microscopes to support research in the life sciences. Known as the electron Bio-Imaging Centre (eBIC), this centre will provide similar tools to ePSIC for cryoelectron microscopy research into biological matter such as viruses and bacteria.

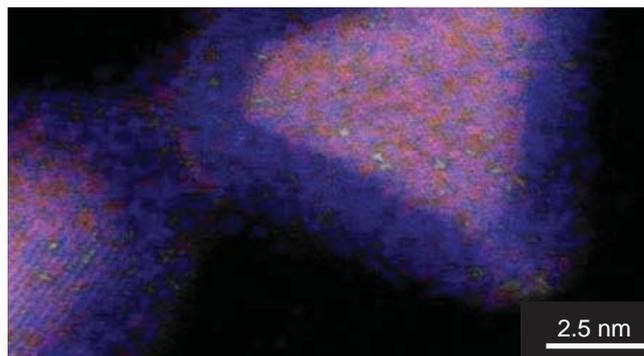


Fig. 1 The new atomic resolution microscope allows analysis down to individual atoms within materials. Image © 2016 Johnson Matthey Plc

techniques, such as density functional theory (DFT), can enable the visualisation of individual surface atoms and help generate an understanding of how they influence catalysis. The ePSIC is the first facility in the world with the dual capability to study samples on both an electron microscope and the hard X-ray nanoprobe beamline at the same location.

One physical occurrence during analysis using high energy electrons is the potential for energy transfer to affect the properties of the sample. Professor Jamie Warner from the University of Oxford is looking to exploit this phenomenon in his work on 2D materials. These materials have a range of potential applications, from optoelectronics and electronics through to various energy applications. Graphene is a commonly known 2D material and has been the focus of Warner's recent work (5) alongside other 2D materials such as molybdenum disulfide and tungsten disulfide. The Warner group introduces and studies defects in these 2D materials in order to understand how they affect the mechanical properties and influence deformation under loads. By selectively removing atoms to create defects in MoS₂ and WS₂ it is possible to either dope catalytically active atoms into these defects or potentially use these materials as highly selective filtration membranes. The

use of electron microscopy could displace conventional techniques such as chemical exfoliation.

Professor Joachim Mayer next outlined the use of aberration corrected techniques in developing materials for energy applications. Correcting aberration is vital to achieve the necessary image resolution for microscopy at the atomic scale. One example involved the fundamental understanding of platinum-nickel and platinum-nickel-cobalt nanoparticle growth, which is key to developing catalytically active species for fuel cell applications. Aberration corrected techniques are also being applied to next-generation solar cells. Currently the maximum efficiency can reach around 28% but it is hoped new developments of layered systems, which can convert a broader wavelength range from the incident light, could increase this efficiency up to 60%. Other applications include the development of novel steel materials with the combination of high strain properties and increased hardness. The desired outcome would be to develop stronger, more lightweight materials.

Just as the use of high energy in microscopy can affect surfaces (described above) it can also affect the *in situ* measurement of reactions by imparting additional energy to the system. Nigel Browning, from Pacific Northwest National Laboratory, USA,

highlighted his work to mitigate these effects and enable the capture of highly resolved images at low energy doses using techniques such as inpainting (6). The use of mathematical techniques like this as well as Fourier transforms can allow for lower incident energy dosages, and therefore less physical interaction with the sample, while maintaining the necessary resolution to observe molecular transformations. His work on *in situ* transmission electron microscopy (TEM) is applied across many disciplines including biomedicine, batteries, materials synthesis and corrosion.

The second half of the conference programme diverged from pure microscopy to touch upon related areas of advanced characterisation techniques, including electron tomography, where John (Jianwei) Miao from the University of California, Los Angeles (UCLA), USA, pointed out that advances in this field have taken place at a faster rate than Moore's Law in terms of increased resolution. Peter van Aken from the Max Planck institute in Stuttgart, Germany, introduced his work studying the imaging of plasmonic modes of gold tapers. Quentin Ramasse of SuperSTEM, Daresbury Laboratory, UK, discussed work being carried out at the SuperSTEM project on electron energy loss spectroscopy (EELS) and the final scientific presentation from Cambridge University's Paul Midgley reviewed his group's use of analytical electron tomography for the study of superalloys.

Conclusion

The conference was formally brought to a close by Professor Angus Kirkland from the University of Oxford, followed by tours of the facilities. The ePSIC

participants are looking forward to working together to exploit this unique facility. Professor Andrew Hamilton, Vice-Chancellor of Oxford University, said:

"Bringing together these powerful instruments in one place will be hugely beneficial to researchers, both in academia and industry, who are studying materials at the atomic scale. This new facility could lead to advances in many exciting research areas including graphene technology and the development of cleaner, greener fuels." (7)

References

1. 'Curriculum Vitae, Awards and Honours, Professor Sir John Meurig Thomas', VIII.11, Electron Microscopy Group, Department of Materials Science & Metallurgy, University of Cambridge, UK: <http://www-hrem.msm.cam.ac.uk/people/thomas/CV5.pdf> (Accessed on 31st October 2016)
2. *The London Gazette (Suppl.)*, No. 52563, 14th June, 1991, B2
3. K. Wada, *Nature*, 1966, **211**, (5056), 1427
4. J. Meurig Thomas, 'Ahmed Zewail Obituary', *The Guardian*, Monday 22nd August, 2016
5. J. H. Warner, E. R. Margine, M. Mukai, A. W. Robertson, F. Giustino and A. I. Kirkland, *Science*, 2012, **337**, (6091), 209
6. A. Stevens, H. Yang, L. Carin, I. Arslan and N. D. Browning, *Microscopy (Tokyo)*, 2014, **63**, (1), 41
7. Science, Integrated Facilities, ePSIC, Facility Partners: <http://www.diamond.ac.uk/Science/Integrated-facilities/ePSIC/Facility-Partners.html> (Accessed on 3rd November 2016)

The Reviewer



Dan Carter has a PhD in Inorganic Chemistry from the University of Nottingham, UK. He currently manages Johnson Matthey's in-house team of information analysts who support the company's business activities through provision of information and expert searches. This work can range from providing commercial insight to analysing technology platforms or patents and supporting research and development. The team also publishes *Johnson Matthey Technology Review*.