ISSUE 3/2015

X'PRESS

HOW TO EDUCATE?

PANalytical
get insight

Welcome to the latest issue of **X'Press**

Pieter de Groot
Corporate marketing director

At the end of the year 2015 we look back on an exciting year, where we have not only seen a hopeful rise of the economy, but also an unprecedented progress in our exploration of the universe. Late 2014, mankind landed Philae on a comet and in July 2015 spacecraft New Horizons flew by Pluto and took astonishing pictures that led to the recent discovery of ice volcanoes on Pluto. In achieving this scientific and economic progress, education plays an important role. For this issue of X'Press we have collected a few aspects and examples of education.

Schools and universities, like the Penn State University are well-known educational institutions. Not only can students work on their research here but the lab is also open to industrial clients – a combination where academic and industrial research can mutually inspire each other. The Bulgarian Institute of Science is another fine example of an educational institution, featuring excellent equipment, which attracts an increasing number of students.

A well-equipped lab can serve as support for teachers of any educational institution. In our interview with the head of PANalytical's research facilities in Sussex (UK), Prof. Paul Fewster describes his own education, the equipment he worked with and his contributions to research and education of many students who are involved with X-ray diffraction.

Education can be done anywhere, be it in an academic or an industrial lab, a workshop, seminar or individually. On the following pages we give several examples of how we at PANalytical share our expertise with our customers, so that they can make optimal use of their equipment. Our specialists often do this on-site and in the customers' own language.
Here too we strive to maintain our long tradition of investing in education: last year's OpenLab events, the PANalytical Award (supporting young scientists) and the worldwide deployment of the renowned Duncan& Willis X-ray fluorescence course are just a few examples of our firm belief in the benefits of good education.

I hope that you can look back on a successful and fulfilling year 2015 and I wish you a good start of 2016.

Kind regards,
Pieter de Groot

LATEST NEWS

PANalytical's HSvu – world's first X-ray powder diffraction 'app'

HSvu displays all kinds of X-ray diffraction scans, handling various formats of almost all X-ray diffraction equipment suppliers. It shows existing data, but does not perform analyses nor does it change data or converts file formats.

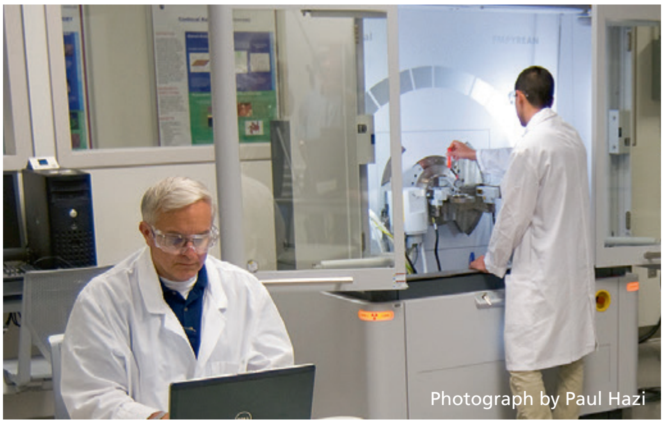
Additionally HSvu shows and reports all details from an X-ray diffraction analysis performed by the HighScore (Plus) analysis software from PANalytical.

* Open a scan or a diffraction analysis from your email account...

* Share your powder diffraction data with friends by dropbox, facebook, email...

Currently HSvu is only available for iOS devices in the appstore:
https://geo.itunes.apple.com/us/app/hsvu/id1022333171?mt=8

In this issue



Photograph by Paul Hazi

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X-ray Scattering Lab at Penn State serves multiple disciplines

The X-ray Scattering Laboratory in Penn State's Materials Research Institute (MRI) is the primary source for X-ray diffraction at Penn State. Led by staff scientist Nichole Wonderling, the lab serves a wide array of disciplines from materials science to geoscience to food science and everything in between. Additionally, the lab works with a broad range of industrial clients. It is part of MRI's 'Three Labs One Solution' initiative: clients can fabricate a material or device in the Nanofabrication Laboratory, measure its properties in the Materials Characterization Laboratory and also attain a theoretical model in the Materials Computation Center.

A well-equipped laboratory for the study of both crystalline and soft materials, both biomaterials and polymers, the Scattering Lab maintains several X-ray diffractometers, including a PANalytical X'Pert MRD (installed 1995), an X'Pert PRO MPD (installed 2008) and an Empyrean (installed in 2012).

The lab can support a variety of applications, such as qualitative and quantitative powder diffraction, high-resolution diffraction, residual stress, X-ray reflectivity, micro-diffraction, single crystal (Laue) orientation, non-ambient diffraction, and small-angle X-ray scattering (SAXS).

The Empyrean in the Scattering Lab is equipped with a PIXcel^{3D} detector and a ScatterX^{78} attachment which has proven valuable in terms of time savings, ease of use, and wide angular range. By allowing users to scan the atomic and nanoscale on a single instrument it has provided a valuable number of new capabilities. "The ScatterX^{78} enables us to do small-angle work on a multipurpose X-ray diffraction system," Wonderling says. "We can cover two different angular ranges – SAXS and WAXS – without the need to switch instruments or even optics up to 78° 2θ, hence the name. We recently worked on particle size distribution of titanium oxide nanoparticles, and because PANalytical provided reference samples and automated analysis software, the process was straightforward and extremely simple to do."

In a recently submitted paper in collaboration with graduate student Tomasz Modzelewski in the Harry Allcock group at Penn State, Wonderling used the ScatterX^{78} to characterize polyphosphazene materials with varying sidechain lengths and concentrations. "The SAXS technique allowed us to study this isotropic system and gain an understanding of sidechain interactions," Wonderling reports. These results were presented at the Denver X-ray Conference (DXC) in August 2015.


Photograph by Paul Hazi

"The PANalytical ScatterX^{78} is a highly useful addition to the materials characterization capabilities at Penn State, with growing relevance for X-ray characterization of soft biological materials."

- Nichole Wonderling, X-ray Scattering manager, Materials Characterization Laboratory at Penn State University (PA, USA)

Lab staff not only support both academic and industrial researchers on an individual basis but also through a variety of workshops. In August 2015, the lab partnered with PANalytical to offer a SAXS symposium featuring presentations by PANalytical's product manager of nanomaterials, Jörg Bolze, and XRD applications specialist Mike Hawkridge.

Attendees were provided with an overview of SAXS and introduced to a range of applications available on lab-based diffractometers. According to Wonderling, "The event was a huge success. Within just a few days, registration had to be closed because we were at maximum capacity.

All of the feedback we received was highly positive and I believe our attendees learned a great deal about the technique. It is my hope that we can continue to partner with PANalytical to offer this type of opportunity to the Penn State community on an annual basis."

PennState Materials Research Institute

Penn State (USA), Pennsylvania's only land-grant university, was chartered in 1855 as one of the nation's first colleges of agricultural science. Penn State comprises 24 campuses, 17,000 faculty and staff and 100,000 students. Their online World Campus empowers anyone to pursue an education – anytime, anywhere.

The X-ray Scattering Lab at Penn State's Materials Research Institute is not only a well-equipped research facility but also supports lab-based courses in e.g. materials science, geosciences or engineering.

Keep fit for future developments

Paul Fewster, head of the PANalytical Research Centre in the UK about 'How to educate'

'How to educate?' is the theme of this issue of X'Press. The editors of X'Press asked Paul Fewster to share yet another aspect of education: how has his research career tuned in with education – of himself and of others.

How did you enjoy your own education and how have things changed since then?
I have always been interested in how things work and this naturally led me to study physics where you study things from first principles. The timing of my own studies matches the development of computation. In the early 1970s, when I was a PhD student, calculators were electromechanical and, to write programs, data input was on punched cards or paper tape. The calculation of a Fourier map took 12 hours and elucidating the structure of an enzyme took about 10 years.

My PhD supervisor (who was at the Royal Institution when Lawrence Bragg was Director) introduced me to Dorothy Hodgkin and David Phillips to help me choose a project, and also insisted that I should calculate at least one Patterson and Fourier map by hand as part of my education. This tough introduction to research was a fascinating challenge for me, and I think it instilled in me the need to exploit computers and automation for all of these tasks, so that my time could be freed up to do the real thinking. I have always incorporated the latest computation methods into my work.

"Even after more than 40 years in this subject I am still educating myself and I hope that this will help others to educate themselves in XRD."

- Paul Fewster, head of the PANalytical Research Centre in the UK

Could you describe the highlights in your career in R & D?

Whilst I was in Philips Research Labs I put a lot of work into controlling our diffractometers using computers and analyzing results by computation methods. It was a non-trivial task for that time but the hard work paid off and I was pleased with the results because experiments could be performed overnight, and our output improved considerably.

Because one of my tasks was to work with new semiconductor structures, I had to simulate the diffraction patterns and build instruments that were fit for purpose. The result of this was the eight-crystal high-resolution diffractometer that later served as a prototype for the MRD.

In 1991 I was awarded the UK Institute of Physics' Patterson Medal and Prize for this innovation and a DSc from the University of London in 1994. In 2006 I was presented with the Industrial Crystallography Award from the BCA. Most recently I have been studying diffraction from polycrystalline materials. This has drawn on my understanding of theory and computation from all stages of my career. My book (X-ray Scattering from Semiconductors and other Materials, World Scientific), which is now in its 3rd edition, is an opportunity for me to share the insights that I have gained over my career. I hope it will be useful for those who are interested in taking their education in some aspects of diffraction theory and practice a little further.

How do you feel that pure research fits with industry?

I understood from my time in Philips Research Laboratories that the role of research was to look after the long-term future of the company. This relied on not necessarily predicting the future but to have a sound understanding of all we do.

I found this thoroughness very engaging because it brought real advances that could be built upon.

In research we're a bit like firemen, we have to keep scientifically fit so that when someone says "how" or "why" we have some answers. In this way the company is itself educated in the principles behind its products and is not surprised by changes in prevalent thinking.

How have you been involved in the wider research and education community?

Whilst at PANalytical and Philips Research I was often travelling to talk at conferences and workshops to share our results and exchange knowledge. In addition to leading the research group, I have been involved in the wider scientific community including the British Crystallographic Association; I have been co-editor of the Journal of Applied Crystallography and Acta Crystallographica A, and served on various committees of the Institute of Physics. In addition to helping in conference organization, I have been a reviewer and advisor for the grant-awarding bodies and synchrotron facilities.

All of these activities kept me in contact with many university research groups and we have often hosted visiting students and collaborators at the research labs, giving us the opportunity to learn from each other.

What comes next?

One of my present preoccupations is questioning some of the basics of X-ray diffraction, which can have impact on the measured intensities and interpretation of the microstructure for example. I have published a theory* which describes the origin of the diffraction from perfect crystals and powders and this will be followed with further articles on imperfect crystal diffraction, for example, the appropriateness of the kinematical approximation rather than dynamical theory.

* Paul F. Fewster, "A new theory for X-ray diffraction"; Acta Cryst. A70, 257-282 (2014)

Paul Fewster graduated in physics and obtained a PhD in the crystallography of biological structures from the University of London. In 1981, following a 5 year research fellowship at Southampton University he joined Philips Research Labs, UK, to run the central X-ray diffraction facility and to develop instruments, automation methods and analysis software programs for X-ray diffraction.

His innovations led to Philips Analytical's MRD series of diffractometers and the scientific algorithms incorporated in the Epitaxy software. Since 2002 he has led the team at PANalytical Research Centre, UK where he continues to develop ground-breaking methodologies for XRD.

Research and education

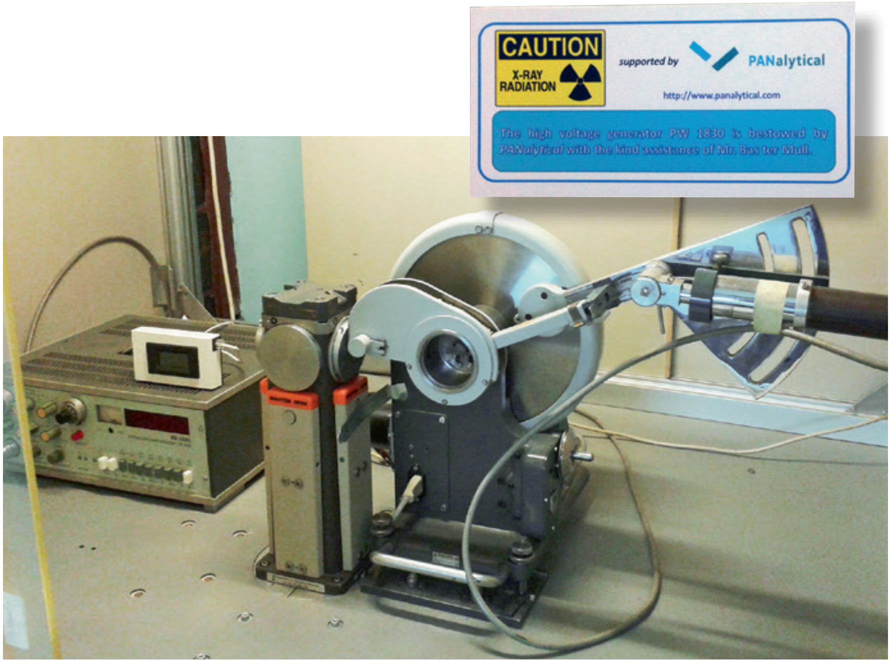
at the 'Rostislav Kaischev' Institute of Physical Chemistry, Bulgarian Academy of Sciences

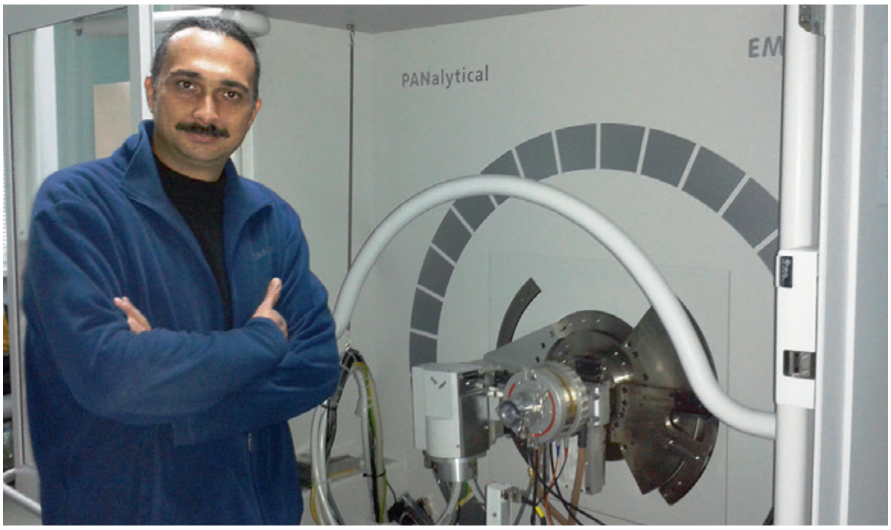
The XRD Laboratory is part of the Institute of Physical Chemistry at BAS and has a long tradition in the application of X-ray diffraction methods. In the 1960s the lab purchased new research equipment and chose the most modern and suitable X-ray diffractometer from Philips, which included a Müller Micro 11 generator, a PW1050 goniometer and a number of attachments e.g. for texture measurements or the determination of residual stress, a spinner and several cameras.

This diffractometer has been maintained and updated on a regular basis and has served as an extremely reliable and versatile workhorse for many complex research projects. About 7 years ago PANalytical's Bas ter Mull was able to arrange the donation of a second-hand generator as backup for/ addition to the old Micro Muller 111 generator. Both old systems are still in use today for standard phase analysis, education and training.

In 2013 the XRD lab received funds from the 'Development of the Competitiveness of the Bulgarian Economy' program (financed by the Structural Funds of the European Union), for the purchase of a well-equipped Empyrean multipurpose XRD platform. Following installation, PANalytical's Milen Gateshki gave extensive training to the users in their own language, introducing them to a large variety of applications.

The new system is extremely versatile and enables easy transition between different applications such as grazing incidence diffraction, XRD texture investigations and diffraction from details or parts of large objects, and it includes attachments for the investigation of fast processes at high temperatures.





"We are very proud of our new XRD instrument, which not only enables the most sophisticated analyses but also attracts many students who can be educated very well in the art of X-ray diffraction analysis".

- Dr. Georgi Avdeev, head of the XRD Laboratory at IPC-BAS

The XRD Laboratory not only conducts research activities for the Institute of Physical Chemistry and the other institutes of the Bulgarian Academy of Sciences, but also for industrial users. The well-equipped Empyrean now offers new research possibilities and opens up XRD analysis to a much larger range of materials. Grazing incidence diffraction of children's teeth, analysis of explosives, pharmaceutical products, ancient ceramics, pieces of hydraulic pumps, polymer thin films, metal alloys or thin films deposited by various methods are just a few examples.

At the beginning of October 2015 the XRD Laboratory of IPC hosted the practical module of the 'International School on Introduction to the Rietveld Structure Refinement', organized by the Bulgarian Crystallographic Association with the support of the International Union of Crystallography and the European Crystallographic Association. PANalytical was one the sponsors of this six-day event with more than 40 participants. A number of international scientists provided lectures and exercises about X-ray diffraction analysis, from the basics up to structure refinement.

This workshop was a legacy event of UNESCO's International Year of Crystallography in 2014 where numerous comparable events were organized (a summary of this successful year can be found in X'Press 1/2015).

Bulgarian Academy of Sciences (BAS)

Founded in 1869, the Bulgarian Academy of Sciences (BAS) is located in Sofia, the capital of Bulgaria. The Academy publishes and circulates scientific works, encyclopedias, dictionaries and journals. It consists of many independent scientific institutes and laboratories in natural sciences as well as social sciences and art.

One of the most prestigious research institutes of BAS is the Institute of Physical Chemistry (IPC), established in 1958 by the renowned Bulgarian physicochemist Rostislav Kaishev, one of the founders of present day crystal growth science.

ифхс

At present 90 researchers and 10 PhD students research phase formation, crystalline and amorphous materials, interface and colloid science and electrochemistry and corrosion processes.

БЪЛГАРСКА АКАДЕМИЯ на НАУКИТЕ 1869

Expertise for Tikomet

The recycling of hardmetal scrap has become increasingly popular during recent years because tungsten is a valuable metal with only limited resources. Additionally, recycling saves costs for raw material and considerably reduces the environmental impact. Following a dramatic price increase of tungsten in 2005 the Finnish company Tikomet Oy has specialized in the recycling of hardmetal scrap with the zinc process. This process does not involve any chemical modification of the raw material, meaning that clean scrap of uniform quality is needed as raw material.

Tikomet's modern analytical lab is well-equipped for all aspects of quality control during the various stages of the recycling process.

For precise and reproducible elemental analysis they have purchased a PANalytical Axios^{mAX} X-ray fluorescence (XRF) spectrometer together with an Eagon 2 fusion machine.

There are, however, only very few commercially available reference materials, which were not suitable for Tikomet's requirements.

To meet the strict quality control goals for the advanced zinc process, the application had to be customized for a wide variety of elements also in very low concentrations. That's why the company approached PANalytical Nottingham for help.

A set of synthetic standards was made from pure oxides along with the complete application and fusion method. These standards cover the analytical ranges required, with some ranges exceeded to enable more accurate weighing of components.

They contain tungsten (W) as main component (68 – 87 %), a varying amount of cobalt (between 4 and 25 %) and up to 16 other elements as impurities, such as Mg, Al, Cr, Fe. The standards were validated with a suite of Tikomet's samples previously analyzed by ICP and an outside XRF laboratory.

Subsequently PANalytical's Mark Ingham visited the customer site in Finland for five days to install, calibrate and validate the application. Additionally he provided extensive training for Tikomet's personnel, including calibration, sample preparation, optimization of the fusion method and good laboratory practice (GLP).

With a solid procedure in place Tikomet now feels even more confident about the detailed test certificate they provide for each batch of produced powder.

"PANalytical's expertise provided us with very suitable standards. Especially the training proved extremely valuable for our confidence in the analysis results obtained from the new instrument."

- Dr. Taneli Laamanen, laboratory manager at Tikomet


Raw materials for Tikomet

TIKOMET
A GTP Company

Founded in 1994, Tikomet Oy is specialized in the recycling of hardmetal scrap. Their new state-of-the-art recycling facility is located at Jyväskylä in central Finland. A dedicated team of 38 employees buys high-quality hardmetal scrap and turns it into tungsten carbide-cobalt (WC-Co) powders by employing the zinc process.

These reclaimed powders are used to replace up to 100 % of virgin material used in the production of new hardmetal products, thus conserving the limited tungsten resources and protecting the environment.

Tikomet operates in accordance with ISO 14001:2004 environmental management system which was certified in 2015.

Hardmetal recycling

Picture copyright of Plansee Group

Hardmetal consists of tungsten carbide (WC) embedded in a metallic cobalt binder. It is a fine gray powder, which can be pressed and sintered into shapes for use in e.g. industrial machinery, cutting tools and many other tools and instruments. Tungsten carbide has two times the stiffness of steel and high hardness.

During the zinc process hardmetal scrap is treated with zinc on graphite boats in a special furnace. The molten zinc reacts with the cobalt binder and during the process all of the zinc is distilled off to be reused.

The resulting porous cake is then milled and homogenized to obtain a high-quality tungsten carbide-cobalt powder, which can be used as raw material in the production of new hard metal tools.

Tikomet has optimized this process as a cost-efficient and environmentally friendly recycling method for hardmetal.

Learn more about this topic from our new application note 'High-quality *in operando* X-ray diffraction analysis of pouch bag lithium-ion batteries' in the knowledge center on our website.

www.panalytical.com/knowledgecenter

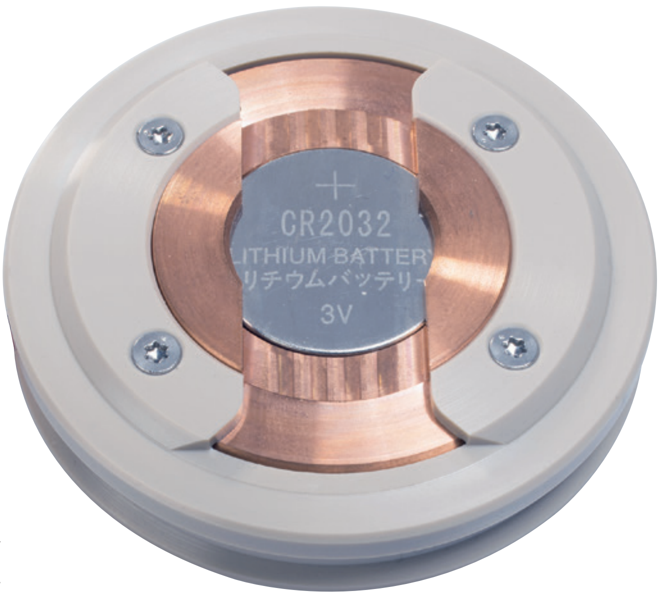
About **batteries**

An **energetic** research area

Energy is something that we all need and most of us depend upon electricity. We also need to store this electrical energy so that we can use it when and where we need it. We have become accustomed to mobile devices containing rechargeable batteries, we expect them to be rapidly re-charged and to have a lifetime almost as long as the device that they power. Batteries for electric vehicles (EVs) also need to be robust and lightweight while having a large capacity, which is also a requirement for the off-grid storage of electricity produced from intermittent renewable sources such as solar or wind energy. All these things together mean that research into materials for batteries and energy storage is a hot topic. In this active research area new X-ray diffraction (XRD) applications are continuously arising and at PANalytical we offer suitable solutions to these new challenges.

Batteries typically exploit chemical reactions involving charge transfer by ions. Ions in one part of the battery transfer to the other part of the battery during use, with the release of electrons that flow around an external circuit. They can be recharged by connecting them to a source of electrons that reverses the chemical reaction.
The schematic drawing in the box illustrates the principles of charge storage in a lithium battery, a typical example of an 'electrolytic cell'. Globally many research centers are investigating the possibilities for different types of battery, using different chemical reactions and a variety of materials to support both the chemical reactions and to provide a mechanical structure for the battery.

The latest winner of the PANalytical Award, Matteo Bianchini, is active in this research area too (see X'Press issue 2/2015).



Sample stage specifically for X-ray studies of a button cell

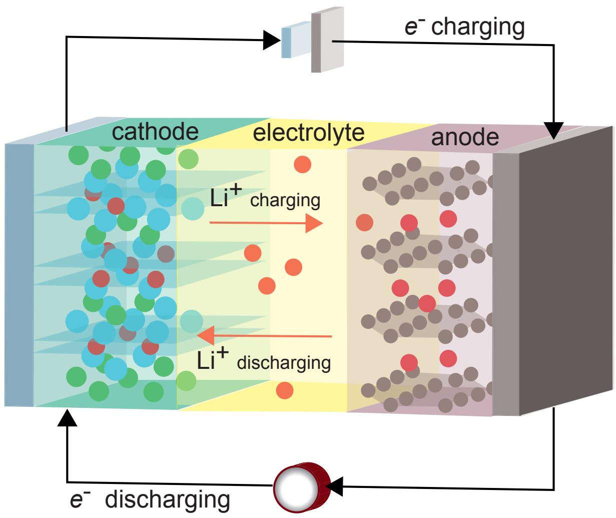
Ion exchange in a lithium-ion battery

The **cathode** accepts electrons from the external circuit and ions from the electrolyte and is 'reduced'. Cathodes are often transition metallic oxides or phosphates. During discharge Li^+ ions are 'intercalated' (incorporated) into the cathode material.

The **anode** provides electrons to the external circuit and is 'oxidized' as a result. Anodes can be made from materials containing carbon/graphite or metal alloys. During discharge intercalated Li^+ ions are released into the electrolyte and the electrons flow in the external circuit.

The **electrolyte** is an ionic conductor but an electric insulator. It connects the two electrodes and provides the medium for charge transfer inside the cell. The electrolyte is often a non-conducting inorganic solvent containing a dissolved lithium salt, e.g. $LiPF_6$ in propylene carbonate. The distance between the anode and cathode is made as small as possible.

When a battery has discharged an excess of lithium ions is held in the cathode. Upon charging the lithium ions transfer back into the anode.



A number of research themes related to materials research for battery technologies make use of X-ray methods:

Exploration of materials combinations
A variety of cathode/ion/anode/electrolyte materials are investigated in order to optimize the energy costs and gains for new battery designs. The suitability of new materials as electrodes is dependent upon their crystal structures and how well ion species can be taken up and released by the electrode material. These crystal structures and the extent to which intercalation causes phase changes or strain in the host lattice are often studied using X-ray diffraction.

Exploration of desirable structural parameters for the electrodes
For example good crystallinity tends to favor better cyclic stability, however a higher charge capacity is observed in less crystalline or even amorphous materials. X-ray powder diffraction, especially in combination with pair distribution function (PDF) studies, is a useful technique for exploring crystallinity, lattice disruption and grain size.

Exploration of the physical connectivity of the components
Large improvements in charging and discharging speed and efficiency can be made by increasing the surface areas of the anodes and cathodes. Complex interpenetrating phases, and nanostructured surfaces are investigated, such as films of nanowires, nanoparticle arrays or porous materials. At the macroscopic level the electrodes may be sheets that are multilayered and coiled around each other as is the case for AA or pencil batteries. Small-angle X-ray scattering (SAXS), grazing-incidence small-angle scattering (GISAXS) and computed tomography (CT) can explore these micro- and macrostructures.

Monitoring the crystalline quality of electrodes during battery use
The repeated transfer of charge-carrying ions in and out of the electrode structures puts strains on the unit cells and hence the fabric of the electrodes or can even induce phase changes in the crystal structures. Deterioration of performance is most commonly due to the structural defects that can build up in the electrodes hindering the free movement of ions. The non-destructive XRD methods can be used in combination with dedicated *in situ* stages to directly observe charge and discharge reactions in battery cells.

PANalytical now provides a number of new products and enhancements to deal with the challenges of battery research. Hard (Mo and Ag) radiation is necessary for some of the *in situ* studies and here the new GaliPIX^{3D} detector can facilitate powder diffraction, PDF and CT measurements all on one instrument. New *in situ* stage options e.g. for whole button cells and pouch cells enable measurements both in reflection and transmission. Together with enhancements to the Highscore Plus software suite that performs Rietveld and PDF analyses, they illustrate PANalytical's commitment to this important research area.

Get ready for high productivity with **TheOx® Advanced** fusion instrument!

You want a fusion instrument that corresponds better to the realities of today's laboratories? Think TheOx Advanced Claisse Fluxer®, a product that has been developed to suit your ever-changing needs.

Claisse launched this new generation of the world-renowned TheOx instrument last August at the Denver X-ray Conference in Colorado (USA).
Just like its previous version, TheOx Advanced Claisse Fluxer has six fusion positions. It is used to prepare glass disks for XRF analysis as well as borate and peroxide solutions for ICP analysis.
This durable instrument has a completely redesigned interface and is easier to install.

It increases safety and analytical performances, thus providing significant added value.

Do not hesitate to contact your local sales representative for more information on this fusion instrument.

Inline EDXRF analysis:
Easy production control of flat materials

For the continuous elemental analysis of flat materials PANalytical has developed a new powerful in-line solution. A compact measuring head incorporates proven Epsilon 3^X technology, using energy dispersive X-ray fluorescence (EDXRF) for the analysis. This building block can easily be integrated in any production line for flat materials where it hovers above the continuously moving product. Sensors take care of the synchronization between movements of the product and measuring head as well as of variations in product height.

Dedicated software makes the setup for a variety of measurements very easy. Commands, entered via a remote console or on via the instrument, can initiate two different scan modes: 'skating mode' or step-by-step mode. Depending on the application a complete elemental analysis can be obtained and reported every three seconds of measuring time, thus quickly revealing the distribution of elemental concentrations across the entire product.

Results overviews and tracking data can be followed on the system's easy-to-use graphical user interface while the built-in OPC connectivity can be configured for a seamless integration into an existing production line.

"With this new inline EDXRF analyzer PANalytical brings analysis closer to any flat product than ever before. "

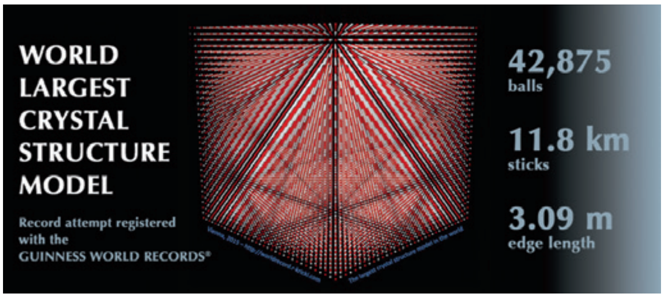
- *Mark Pals, Priority Lane Automation manager*

Events calendar 2016

The list shows a selection of events during the next few months where you will find us. Please come by and visit us when you attend any of these events.

21 - 24 February	SME Exhibit	Phoenix, AZ, USA
6 - 9 March	PDAC	Toronto, ON, Canada
6 - 10 March	Pittcon	Atlanta, GA, USA
19 - 22 March	63rd Japan Society of Applied Physics Spring Meeting	Tokyo, Japan
5 - 7 April	PECOM 2016	Villahermosa, TB Mexico

www.panalytical.com/events



Honoring the 100th anniversary of the Nobel Prize for William H. and William L. Bragg

Dr. Robert Krickl, Vienna, November 2015

Ore and Minerals Analysis (OMA) Workshop in Brazil

As announced in X'Press 2/2015 the first OMA Workshop was held on 24 August 2015 at the Physics department of the UFMG (Universidade Federal do Minas Gerais, Brazil). More than 70 representatives from mining companies and research institutions attended this workshop. They enjoyed lectures about a large variety of subjects relevant for mining customers, presented by researchers and PANalytical specialists.

The 2nd and 3rd editions of this successful workshop have already been planned for the spring of 2016. Keep an eye open for the invitation – we hope to be able to again welcome many participants who are interested to get familiar with modern analytical solutions for the mining industry.

Colophon

Please send your contributions, suggestions and comments to the following address.

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PANalytical
get insight

XRF in the hands of scientists

For research and education

Epsilon 1 - fully integrated energy dispersive XRF analyzer consists of a spectrometer, built-in computer and analysis software:

- Analysis across the periodic table
- Factory pre-calibrated for Omnian standardless analysis
- Accurate and reproducible data
- Non-destructive analysis
- For any type of sample
- Wide analytical concentration range (ppm - %)

For more information: **info@panalytical.com - www.panalytical.com/epsilon1**