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DALTON CUMBRIAN FACILITY NEWSLETTER

December 2020

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WELCOME

Dear friends, colleagues and collaborators,

We've been working hard over the last few months to support our user community. Our staff has continued to work as two teams with one team working in the lab for a two week period before handing over to the other team. This has provided some interesting challenges and the teams have adapted marvellously to the new way of working. We're now looking forward to the two week extended holiday afforded by the Christmas period; our last day of operation is Friday 18th. During the holiday, the gamma irradiator will sustain a single continuous irradiation and users have already booked their spaces in the sample rack to ensure that photons do not go to waste.

Read on for an update on the in-situ SIMS analysis the accelerator team has been preparing for. The staff profile puts Samir in the spotlight as he tells us about his career journey following the path of ion beams. On page 5, our case study focuses on a collaboration between chemists and the National Nuclear Laboratory to support a government project.

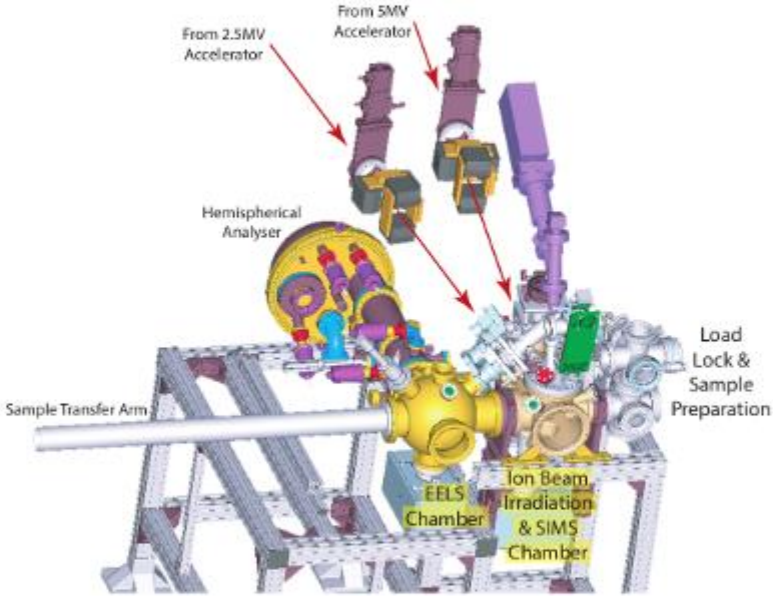
Merry Christmas; we'll look forward to seeing you in the New Year!

Fred Currell
Director of DCF

Laura Leay
Editor

ACCELERATOR SYSTEMS DEVELOPMENT

Progress has been made on the development of a new Henry Royce Institute funded end-station during the Covid-19 induced working from home period this summer. The end station will contain two specific analytical tools and a new sample holder and transfer mechanism. A SIMS (Secondary Ion Mass Spectroscopy) instrument housed in one chamber will give elemental depth profiling in the mass range 1–300 a.m.u. An adjacent chamber will house high spatial resolution HR-EELS (High energy Reflection-Electron Energy Loss Spectroscopy) to provide information on electronic band structure and dielectric properties (from the plasmon peaks in the low-loss part of the spectrum) or chemical state information (oxidation state etc. from core-hole spectroscopy in the high-loss part of the spectrum). The use of a nanofocus electron gun as the EELS source will give an imaging capability in this analysis with a spatial resolution in the region of 150-500 nm, allowing chemical state imaging of ion beam irradiated samples.



Whilst recording of SIMS or EELS data at the same time as ion beam accelerator beams are incident on the sample will not be possible, the fact that the sample is mounted on a remote controlled sample transfer mechanism will allow for the sample to be easily moved to an analysis position without vacuum breaking, so analysis can be performed at defined intervals during a longer irradiation. The transfer mechanism will take samples mounted on industry standard flags, with the sample stage incorporating both electron beam heating and liquid nitrogen cooling options enabling sample temperatures in the range -170 °C to +1,200 °C. Samples will be mounted onto the sample stage through a load-lock. As the EELS technique is particularly surface sensitive, the load lock will also include ion etch cleaning sample preparation. The irradiation end chamber will accept beams from both our ion beam accelerators, allowing its use with the full range of ion beams available at DCF.

Some of the major components have already arrived at DCF, with others still on order and a few in the final stages of design. Due to the complexity of this new development, and the challenges of working under on-going Covid-19 restrictions, completion of this project is something to look forward to in the latter part of 2021.

STAFF PROFILE

Samir de mores Shubeita
Accelerator officer

Q: Tell me about your career journey so far.
Ever since my undergraduate degree I've enjoyed working with particle accelerators. I started off using PIXE and RBS for materials analysis and I really enjoyed the combination of fundamental physics, practical applications and teamwork. My masters and PhD were both in fundamentals of ion-solid interactions, specifically looking into the interaction of clusters of protons with ultra-thin films. After my PhD, I moved to Rutgers University in New Jersey, USA, for a post-doctoral position. There I worked at the Laboratory for Surface Modification which was part of the Institute for Advanced Materials, Devices, and Nanotechnology, a multidisciplinary institute combining physics, chemistry, biology and engineering expertise. I was mostly involved in projects related to atomic structure analysis of doped silicon carbide and topological insulators, but also had a hand in ion beam analysis of nanoparticle implanted organic targets. I also had the opportunity to operate a Helium Ion Microscope, a novelty at the time in terms of materials imaging, as well as contributing to the initial stages of developing/adapting a time-of-flight detection system to it.

I started off at DCF in late 2014 as a post-doc, working on improving the existing end-station capabilities for radiation damage experiments. After 3 years, a position become available to join the team as a member of staff which was too good to turn down. At a crossroads between adventuring into a teaching or taking on a technical role at DCF, the decision was rather easy for me. The combination of technical and scientific work that DCF allows me to be part of was what I was looking for.

Q: Where did you start off?
I graduated in Physics in 2004 from the Federal University of Rio Grande do Sul, Brazil, and then went on to do a 2 year masters and a 4 year PhD, all at the same university, working at the Ion Implantation Laboratory of the Physics Institute. With limited finance, the focus is on developing existing technical know-how and you are challenged to do a lot with the existing capabilities. In Brazil, there is not much opportunity if you have a degree in physics; for the most part you either stay in academia, become a teacher or leave. Unlike the UK, opportunities in industry, for example, are very limited. So, like many colleagues, I went where the opportunities are. As lots of colleagues did the same thing, my network of colleagues is very widespread through nations that provide such opportunities.

Q: What do you enjoy most about your job?
The diversity of my role is very satisfying. I like very much the technical side of it, but also really enjoy going back to the fundamental science, on occasion. You get to do both when you work with a particle accelerator. My background work in ion-solid interactions comes in quite handy. I also really enjoy seeing progress in other people's work and am very glad to help support them.

Q: Are there any particular research interests you'd like to talk about?
At the moment I am not conducting any research of my own at DCF, but one of the good things about my job is that I get to provide advice (technical and fundamental) to others, effectively contributing to their research. I still have a passion for materials analysis with ion beams, so I'm looking forward to the ToF-SIMS we're soon installing at DCF. I also hope that in the future opportunities to co-supervise student research projects would be open to me at DCF.

Q: What are your interests outside of work?
I enjoy walking in the Lake District. Buttermere and Eskdale are my favourite parts of the Lakes (so far) as the scenery is very striking. I haven't found the time to walk up Scafell Pike yet. Even though it's England's tallest mountain, there have been too many other places that capture my imagination.

PROJECT SPOTLIGHT

Radiation tolerance of small organic molecules for the next generation fuel cycles

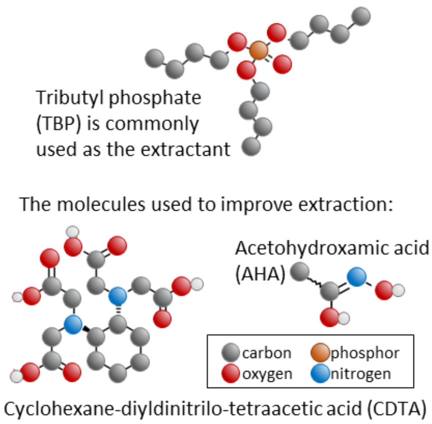
Alex Baidak, Liam Isherwood & Elen Clayton, Department of Chemistry & DCF

THE CHALLENGE

The UK's government Advanced Fuel Cycle Programme is set to define a new nuclear fuel production, recycling and waste management regime which will use the latest technological developments to arrive at an efficient fuel cycle. As part of the overall research programme, the Aqueous Recycle Programme will determine the optimum conditions for reprocessing of spent nuclear fuel, using liquid-liquid extraction. It is not clear how the molecules that are used in the extraction processes behave under the high acidity, high doses of α, β and γ radiation and extended contact times. Experimental studies in this area are highly needed.

THE SOLUTION

A collaboration with National Nuclear Laboratory has been established to tackle the above challenge for a selection of small organic molecules, namely, AHA and CDTA, (shown in the figure to the right) relevant to next generation nuclear fuel cycles. Relying on bespoke agitation cells and chromatography methods available at DCF, irradiations are conducted using both the Co-60 irradiator and ion beam accelerator. The rate of radiolytic degradation of the extractant is quantified alongside the rate that degradation product(s) are produced as well as the subsequent degradation of those products.



In addition, molecules such as AHA can undergo hydrolysis, causing them to decompose under low pH. To account for this mode of degradation, hydrolysis experiments are being undertaken at elevated temperatures to determine similar parameters to the radiolysis experiments. Furthermore, in order to achieve an in-depth understanding of the fundamental radiation-chemical reactions we are collaborating with Idaho National Laboratory; our American collaborators conduct pulse radiolysis experiments to reveal which reactions are fastest and therefore govern the degradation process.

THE BENEFITS

Essential data collected from DCF will underpin the next generation of solvent extraction processes by assisting with defining the radiation dose limit where aqueous processes are no longer viable and molten salt techniques may be required. In addition, this project contributes to the revitalisation of radiation chemistry research in extraction processes in the UK: this project has already led to a PhD iCase award which will be concerned with the design and testing of a bespoke irradiation flow loop for the direct simulation of intimate mixing that occurs in real separations processes.