

DALTON CUMBRIAN FACILITY NEWSLETTER

AUTUMN 2019

UPDATES FROM
DCF COMMUNITIES

UPCOMING
EVENTS

EQUIPMENT
DEVELOPMENT NEWS

STAFF
PROFILE

PROJECT
SPOTLIGHT

WELCOME

Dear Friends and Colleagues,

Although this is a shorter edition of the DCF stakeholder newsletter than the last one, this is not due to any lack of activity. The write-up area feels packed close to capacity – seven summer students have joined us to work on a range of projects. At the same time our technical team are busily at work in one of the ion-beam target rooms, upgrading our capabilities. On that note, it is a pleasure to welcome Carl Andrews to the ion accelerator team – he has joined us from Kinetic Energy Operations Ltd where he was Lead Research and Development Scientist, as well as being one of our users. Carl has quickly become integrated into the team, allowing us to once again establish round-the-clock ion irradiations.

The stakeholders' conversation has been continuing with us hosting our first Annual Stakeholders' Meeting – see the report below for more details. We have also been continuing dialog internationally as we prepare to host the 2019 Miller radiation chemistry conference, taking place in Workington on 9-13 September. With 18 invited talks, 2 poster sessions and 5 educational sessions it promises to be a science-filled week. The Miller Trustees, acting in their capacity as the international organising committee, clearly think highly of the work taking place at DCF – scanning the preliminary programme, I count at least five invited talks which are based on work done here.

I close by thanking Andy, Ruth and Alistair for their contributions to the newsletter and by wishing you all the best for the summer.



Fred Currell
Director of DCF



UPDATES FROM DCF COMMUNITIES

On 11 June, DCF held its first Annual Stakeholders meeting, attended by 50 partners from across academia and industry.

Participants heard four plenary talks relating to the stakeholder interest groups:

- **Health, Fred Currell, DCF**
- **Chemistry, Helen Steele, Sellafield Ltd**
- **Environment, Simon Norris, Radioactive Waste Management**
- **Materials, Aidan Cole, Wood PLC**

Two open, round table sessions, focussing on Chemistry/Health and Environment/Materials, provided the opportunity for more detailed discussion. The Chemistry/Health group's discussions covered the requirements of new biolab facilities within DCF and the possibility of interesting experiments at the interface between the two research areas. The Environment/Materials group explored areas of overlap between the two communities and discovered some potential avenues for collaboration.

We have received positive feedback from participants, both formally and informally, about the meeting and its structure. It can be summarised very simply as *yes, the annual stakeholder meetings are a good idea and yes the format is about right*. We have also received feedback that there may be considerable value in creating a forum for industry to set challenges that would cascade down into the various stakeholder communities to look for solutions. We are currently working up ideas to support this so watch this space.

UPCOMING EVENTS

The Miller Conference on radiation chemistry

The Miller Conference on radiation chemistry, this year hosted by DCF, takes place in September 2019 at the Enerigus Centre, Workington.

Academics, scientists and technologists from across the world will gather to exchange ideas and discuss emerging research in radiation chemistry and its applications, with speakers from a range of institutions and organisations including Sellafield Ltd, National Nuclear Laboratory and the Japan Atomic Energy Agency.



We are delighted to welcome back former DCF Director Simon Pimblott for a session on heterogeneous systems on Wednesday 11 September. Helen Steele, Sellafield Ltd, and Steve Walters, NNL, will deliver an 'Industrial Hot Topics' session on radiation chemistry issues associated with plutonium storage and spent nuclear fuels, followed by a panel discussion.

The full programme for the conference is now available to [download from the website](#). A single-day rate is available for delegates to attend specific parts of the programme that are of interest to them. Sponsorship and exhibition opportunities are available, visit the conference website for details on packages.



EQUIPMENT DEVELOPMENT NEWS

A Bruker EMX Nano EPR spectrometer has been recently commissioned at DCF. The EMX nano is an X-band Electron Paramagnetic Resonance (EPR) spectrometer. EPR spectroscopy is one of the best techniques for detecting and characterising paramagnetic materials, i.e. those that contain unpaired electrons, such as radicals, triplet states and transition metal complexes and X-band is an ideal frequency to study the EPR spectra of



a wide range of paramagnets, which could be radiation-induced. Samples can be measured in a variety of states (fluid and frozen solutions (down to 77K), powders, single crystals, films, gases and even within electronic devices or biological membranes). Hence, it has applications in a wide variety of fields, such as material science, biochemistry and chemistry, providing both structural and kinetic information, and as such is an essential technique for radiation research.

Whilst there is a state-of-the-art multi-frequency EPR facility based in Manchester, the advantages of a desktop X-band EPR spectrometer being immediately available at the Dalton Cumbrian Facility (where sample irradiations will take place) are numerous. For example:-

1. In solution, where radicals are likely to be short-lived, measuring them immediately after irradiation is essential. Even if spin trapping is used, the spin adducts produced are still only stable for an hour or two at most at room temperature.
2. Any radicals (or other paramagnetic species) trapped in irradiated solids, such as nuclear glasses, epoxy resins (used as encapsulants), paints or polymers such as PVC (used extensively in the nuclear industry) are likely to change over time, e.g. electrons and 'holes' migrating through a solid, meaning measurements immediately post irradiation are essential for reaction mechanism studies.
3. There are several dosimetry measurement systems for measuring the total radiation dose a sample has received which rely on EPR spectroscopy, such as the alanine dosimeter, which is particularly useful for radiation biology experiments, as alanine is considered as tissue equivalent, and the Bruker EPR benchtop spectrometers are designed to be used for alanine dosimetry measurements.



STAFF PROFILE

Dr Andy Smith

Experimental Officer (Accelerator Beam Lines)

Although not at DCF from the very beginning, I have been at DCF since its early days. I arrived as we were commissioning the 5MV tandem accelerator – DAFNE – but before the arrival of BABY, the 2.5MV single ended accelerator.

Before coming to DCF I was based at STFC's Daresbury Laboratory where for much of my career I worked on the Synchrotron Radiation Source (SRS) facility, mostly in scientific support of the soft X-ray EXAFS beamline, but also in development of new instrumentation and beamline developments.

As well as working on the provision of synchrotron radiation facilities, I also became a synchrotron user enjoying beamtimes at a number of other facilities within Europe and the US. My research interests mostly concerned environmental studies, largely through the development of X-ray Photoemission Electron Spectroscopy (X-PEEM) for high spatial resolution chemical imaging of mineral formation processes; and cultural heritage studies investigating the techniques developed by medieval artisans to manufacture lusterware, a metallic decoration applied to ceramics by the formation of metallic nanoparticles within the outer glaze during an additional firing process. My other major research collaboration in this period was with the Mary Rose Trust as their quest to develop new preservation techniques for Henry VIII's famous flagship.

On the closure of the SRS in 2008 I remained based at Daresbury, but moved onto optical design work for several beamlines for the Diamond Light Source. I was also involved in a variety of case study designs for potential future UK fourth generation light sources based around free electron lasers (FELs). This led to providing optical and instrumentation expertise in the team responsible for developing the IR-FEL on the ALICE accelerator at Daresbury. We achieved first lasing in October 2010, making it the first demonstration of an FEL based on an Energy Recovery Linac (ERL) accelerator in Europe. I then worked closely with the University of Liverpool to exploit the intense IR flux from the IR-FEL in their development of IR-Scanning Near-field Optical Microscopy (IR-SNOM) as a new tool for the diagnosis of oesophageal cancer.

At DCF I am enjoying the opportunity to bring my experience in the provision of large scale scientific facilities to help DCF grow, particularly the ion beam irradiation capabilities, to better meet the growing scientific and technical challenges our increasing number of users keep coming up with.

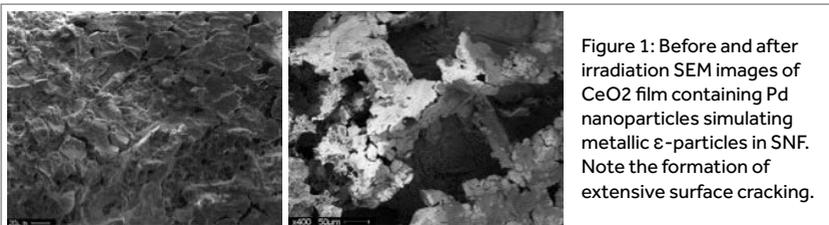
PROJECT SPOTLIGHTS

Thin-Film Spent Nuclear Fuel Models by Alistair Holdsworth

The ability to model hazardous physiochemical systems, such as highly radioactive spent nuclear fuel (SNF) is essential in developing an understanding of such materials and their behaviour under a range of possible circumstances. When dealing with radioactive materials, concepts such as the “as-low-as-reasonably-possible” or ALARP principle are necessary. This can be applied to model SNF systems by investigating them as thin films on an inert substrate, though achieving films of sufficient thickness to mimic bulk behaviour requires films of micron thickness rather than nanometer scale, increasing the difficulty of preparation and reducing the number of viable preparative routes. Similarly, achieving damage akin to that experienced by nuclear fuel in a reactor within reasonable experimental time frames is challenging, while minimising the hazardous associated with radiolytic activation.

The University of Manchester has a long-standing and significant track record in both applied and pure nuclear research across several schools including Chemistry, Materials, Chemical Engineering and Analytical Sciences (CEAS), and Mechanical, Aerospace, and Civil Engineering (MACE). Under the former interim director of DCF, Prof Melissa Denecke, the participation of the Centre for Radiological Research (CRR) in the School of Chemistry at the University of Manchester in the EU GENIORS (Gen IV Integrated Oxide Reprocessing Strategy) project was established and has been ongoing since early 2018. Our participation in GENIORS has centred around the investigation of the effects of irradiation on the structure and storage-condition leaching of thin-film SNF models based on CeO₂ and UO₂, prepared using a tuneable, scalable polymer-templated deposition technique with low-temperature calcination. Ce is used in place of U as an inactive surrogate

Our initial work, based on 5 µm CeO₂ films homogeneously doped with various ionic and metallic additives, simulating fission products (FPs) and minor actinides (MAs), utilised the gamma and particle accelerator facilities at DCF to irradiate our samples which were then characterised with XRD, SEM, and their leaching under wet SNF storage conditions investigated. Compared to similar high-temperature ceramics, our films suffered significant damage, and altered properties under both α and γ irradiation due to the lower relative crystallinity of the material, including cracking (see Figure 1), changes in oxidation stage, and an increase in the leaching of ionic species, though no segregation of model FPs occurred as is observed in actual SNF.



The next stage of this project is to investigate more complex, U- and Ce-based SNF models containing larger quantities of FPs and MAs, in addition to Th and/or Ce as Pu surrogates, simulating SNF from the Na-cooled fast reactor design under development in France presently. This will involve the ongoing support of the irradiation facilities at DCF, forming the core of the experimental program for the next stages of this project. We will use the information garnered from these additional experiments to further compare the behaviour our SNF models to published results of actual fuels, and to refine the understanding of how such models can be used to safely predict the behaviour of hazardous systems.

