An investigation of metallic uranium corrosion in a Geological Disposal Facility (GDF) setting.


Overview:
Uranium metal was used as a high-density fuel material in the UK’s Magnox reactor programme, the first generation of nuclear reactors used in the UK. Metallic uranium and the magnesium alloy ‘Magnox’ cladding used to enshroud it are both considered reactive metals and represent a significant part of the metallic inventory in legacy wastes at Sellafield in Cumbria.

The Nuclear Decommissioning Authority (NDA) carries the liability for its safe management and ultimately its disposal (for which Radioactive Waste Management (RWM), a subsidiary of the NDA are responsible). Uranium is considered a reactive and some its corrosion products, if developed in enough mass, are potentially pyrophoric.

Geological disposal is internationally recognised as the safest long-term solution for higher activity radioactive wastes and the UK’s legacy wastes, including those containing uranium metal, are intended to be managed in this way. The current PhD project will investigate the corrosion behaviour of unirradiated Magnox uranium metal, under conditions analogous to a Geological Disposal Facility (GDF) both (i) pre-closure and (ii) post-closure. The project will also seek to conduct analysis of micro-samples of reactor-irradiated uranium to determine if corrosion rates are closely comparable to those derived from unirradiated metal.

This study aims to better underpin the expected behaviour of metallic uranium following disposal in a GDF. It is expected that any residual uranium metal present in an Intermediate Level Waste (ILW) package will be encased in either grout or sludge but there is the potential for raw waste storage in self-shielded boxes; which would mean that ‘carry-over’ uranium in the raw waste, which is already part-corroded, could directly contact groundwaters in a GDF. Accordingly the study will examine the corrosion behaviour of uranium under water at high pH and carbonate content whilst (i) naked and part-corroded, and in comparison to (ii) U encased in grout and (iii) entrapped in Mg(OH)₂ sludge. The primary focus would be on unencapsulated uranium corrosion in water chemistries analogous to a GDF environment and would include studies of gas release rates under these conditions as well as the pH transition from pond-water chemistry to GDF water chemistry. This is an area of research yet to be studied in any detail.

Experimental Approach:
Utilising virgin metallic Uranium material provided by the National Nuclear Laboratory (NNL), Springfields laboratory, the current studentship will use cutting edge materials analysis techniques to provide a nano to micro to millimetre scale observation of uranium corrosion behaviour. Techniques will include X-ray tomography (XRT), secondary ion mass spectrometry, high-resolution electron microscopy and X-ray diffraction. The techniques are all routinely used and available at the IAC in Bristol, which is a leading international centre for uranium research, and lead institution for the Sellafield Centre of Expertise (CoE) for Uranium and Reactive Metals (URM). To compliment the materials analysis, leaching studies will utilise solution analysis techniques such as ICP-MS and ICP-OES to determine evolving U concentrations in different GDF-analogous groundwater solutions (oxic and anoxic). In addition, the project will seek to link with a planned Sellafield-NNL-Bristol project to conduct experiments on irradiated uranium to determine corrosion rates under different exposure conditions.
The project will setup a series of enclosed cells experiments, using sealed, water-filled steel housings to hold small uranium wire samples in a fixed position. These special cells will permit periodic measurement of the evolving corrosion state of the uranium metal using X-ray tomography. Such an analytical approach will enable a detailed study of corrosion without disrupting the experimental system. Residual gas analysis mass spectrometry will be used in conjunction with such experiments to determine the arising gases under GDF conditions; this will include both H₂ and CO/CO₂/CH₄ releases, with the latter derived from oxidation of entrapped carbide particles. Feasibility of such experiments has already been proven with several precursor XRT studies in Bristol and using the Diamond synchrotron facility.

The candidate:

It is expected that the prospective candidate will have a 1st or 2.1 class degree in Materials Science, Mechanical Engineering, Physics or a related discipline. Due to likely security clearance requirements there is a strong preference for applications from UK and EU nationals.

This PhD project will be funded by Radioactive Waste Management in association with the Nuclear Futures CDT and conducted in conjunction with the EPSRC-funded TRANSCEND project and linking to the Sellafield CoE. The student will benefit significantly from access to this consortium, attending and presenting at annual research meetings and workshops.

Milestones/deliverables:

- End of year 1 – State of the art literature review and annual report #1
- End of year 2 - Annual report #2
- End of year 3 – Annual report and a final thesis. #3
- 2 Journal publications
- 1 conference oral presentation

Cost and an invoicing schedule:

The PhD is to be part funded by RWM Ltd and the Nuclear Futures EPSRC Centre for Doctoral Training (CDT). This will enable the student to benefit from being connected with RWM but part of a larger CDT cohort with wider access to facilities and training.