Atomic scale cryogenic microscopy to understand the degradation of vitrified nuclear waste

Department of Materials, Imperial College London
Supervisors: Dr Michele Conroy (IC), Prof Mary Ryan (IC) and Prof Baptiste Gault (IC)
Sponsor: Department of Materials, Imperial College London

Are you interested in cutting-edge corrosion characterisation techniques to push understanding of real-world engineering systems? Corrosion is one of the most cross-disciplinary and complex problems that has enormous societal impact – 3% of annual GDP is lost worldwide fighting corrosion and its consequences.

What is really happening at the atomic scale leading to macroscopic degradation? Theory predicts that even single atoms in the ‘wrong’ location can be the driving force for large-scale corrosion mechanisms, yet these remain elusive. Understanding the mechanisms of materials degradation in complex environments is critical to develop appropriate protection measures, for risk models across a range of industrial sectors and is particularly critical for nuclear, and, ultimately, design new materials with enhanced service life time.

Here, we have a very exciting opportunity for you to be at the forefront of the development of atomic-scale liquid-solid corrosion mechanisms through application of new methodologies including state-of-the-art cryogenic microscopy and microanalysis to bring insights into the native hydrated state at interfaces within physical systems.

The primary framework of this project is in the vitrification process that is used to encapsulate and stabilize high-level radioactive waste in a glass form, for long term safe, storage. Understanding the corrosion mechanisms involved in the reactions between glass and atmospheric water vapor conditions is fundamental to long-term assessment of nuclear waste glasses. For this project you will focus on innovative cryogenic sample preparation to target specific regions of interest at altered corrosion layers of glass and perform atomic-scale microscopy using our world-unique infrastructure.

While some analyses of corrosion can be carried out in-situ, nuclear waste storage approval requirements are on the time scale of hundreds if not thousands of years. Synthesized ancient glasses provide an opportunity to study natural corrosion processes which are intermediate in time span between geological natural glasses and short-term laboratory tests lasting a few hours to several decades. In this project, you will also work with Dr Carolyn Pearce the director of iDREAM a
Department of Energy research center at Pacific Northwest National Laboratory, along with other collaborators at WSU, NIST and the Smithsonian to analyse and compare ancient glass samples with pristine materials to elucidate corrosion mechanisms. You will gain hands on experience with cryogenic focused ion beam sample preparation and atomic scale microscopy techniques such as 4D-scanning transmission electron microscopy (4DSTEM) and atom probe tomography in the newly established, £10M EPSRC funded cryo-EM lab at the Department of Materials, at Imperial College London. You will also be applying machine learning and statistical methods to analyse large 4DSTEM data sets and make robust decisions about the quality of the samples and data collection conditions. This project will push the boundaries of light element identification at pico-meter scale resolution to advance our understanding of corrosion processes.