**Vitrimers: a new class of re-processable polymers with applications in batteries and gas separation technologies**

*Supervisors*: Johan Mattsson1 and Nicholas Warren2

1School of Physics and Astronomy and 2School of Chemical and Process Engineering (University of Leeds)

This experimental project will derive fundamental structure-property relationships for an exciting new class of supramolecular polymers, so-called ***vitrimers***1, and use this knowledge to design vitrimer-based membranes for controlled ion (batteries) and gas transport (separation membranes). It will involve vitrimer synthesis, and detailed physical and performance characterization of concept materials.

Vitrimers are a recently invented class of supramolecular disordered solids with cross-links based on associative dynamic exchange reactions1. This results in a combination of the excellent mechanical and thermal stability of thermoset polymers, with the flexibility, malleability and processing capability of thermoplastic polymers. This is down to replacement of permanent covalent cross-links in thermosets (which result in poor processability) with reversible cross-links with tunable association kinetics; this makes vitrimers ***recyclable and sustainable***.

The unique properties of vitrimers makes them excellent candidates for a wide range of applications including self-healing materials, responsive coatings or membranes through which the diffusion of ions, small molecules (e.g. water) or gaseous species (e.g. CO2) can be controlled with relevance to the design of safe and efficient batteries2, fuel cells, water purification, or gas separation membranes3. However, there is still very limited fundamental knowledge available on how to describe or model these materials. Thus, any development of new applications needs to go hand in hand with the development of the fundamental understanding of how the dynamic cross-links affect properties such as rheology, relaxation dynamics and transport properties. In this project, we are particularly interested in investigating the use of vitrimers in the design of safer and more efficient battery materials, and in membranes with well-controlled transport of gases, as used e.g. in Li-air batteries or in CO2 capture.

Vitrimers will be synthesized in-house using techniques such as RAFT polymerisation and polymer functionalisation. The resulting properties of the produced vitrimers will be characterised in detail using techniques including: broadband dielectric spectroscopy (BDS), modulated and standard DSC, dynamic mechanical analysis (DMA), steady-state and oscillatory rheology, as well as small and wide angle x-ray scattering (SAXS/WAXS). This will enable determination of the detailed structure and relaxation dynamics. Furthermore, for applications focused on ion transport (batteries), the transport of ions will be characterized using BDS and electrochemical analysis, and the transport of gases using a custom-designed gas-diffusion rig. Thus, the student will get a thorough and broad training in experimental soft matter science. In addition, we foresee significant interactions with soft matter theorists both in Leeds and beyond, and with leading international centres for vitrimer research.

***References***: 1Montarnal, D.; Capelot, M.; Tournilhac, F.; Leibler, L. *Science* **2011**, *334*, 965. 2Gu, W., Li, F., Liu, T., Gong,, S., Gao, Q., Li, J., Fang, Z. Advanced Science 9, 2103623 (2022). 3Zhang, M., Yu, H., Zou, Q., Li, Z-A., Lai, Y., Cai,, L., Yin, P., CCS Chem. 4, 3563 (2022).