**Soft thin film materials for artificial photosynthesis**

**Simon D. Connell, Peter G. Adams, School of Physics and Astronomy, University of Leeds**

Solar generation of electricity has rapidly increased in recent years from 13 TWh in 2008 to 329 TWh in 2016, suggesting that it will be a critical part of our future energy supply. As we are reaching the efficiency limits of traditional photovoltaics, there has been renewed interest in bio-inspired nanotechnologies, including the possibility of “artificial photosynthesis”. Nature has evolved a suite of photo-active nano-machines, the so-called “light-harvesting” (LH) proteins found in chloroplasts which contain high concentrations of chlorophyll pigments. This project will apply a “bio-inspired” approach where we incorporate synthetic dye molecules with LH proteins extracted from spinach and place them within carefully designed soft thin films.

Lipids are an ideal soft material for thin-films: they readily self-assemble into stable nanoscale bilayers and have tunable physical and chemical properties. By mixing different types of lipid, we will design a film which has a pre-determined viscosity, charge and specific reactive groups. Short polymer chains can be mixed with lipids to increase robustness and extend membrane lifetime. A short diblock copolymer comprised of poly(ethylene oxide) and poly(butadiene) has been shown to stabilize membrane proteins so that the proteins keep their activity for many months rather than a few days. Preliminary data suggests that Light Harvesting proteins are also stable in these polymers, therefore, this could become a more stable platform for artificial photosynthesis.

The objectives of this project are to develop lipid/polymer membranes that increase the stability of photosynthetic proteins under various physical stresses. The film properties will be varied by systematically testing the effect of the lipid saturation and chain length, the ratio of polymer-to-lipid and protein-to-lipid. Stability will be assessed across a range of temperatures and pH and to guide the optimization process. We will also exploit our knowledge of more exotic lipid behaviour to design a lipid system that will spontaneously self-assemble into a stacked multi-layer arrangement, thereby increasing protein density and light harvesting efficiency. The lipid-polymer-protein nanocomposites will be characterized using a world-class suite of techniques, including advanced spectroscopy and microscopy. Atomic Force Microscopy (AFM) will be used to map the 3-D topography and mechanical properties of the thin films at the micro- to nanoscale and fluorescence microscopy to visualize the dynamic rearrangements of membranes at scales from millimetres to nanometres.. Differential Scanning Calorimetry and/or Fluorescence Correlation Spectroscopy will quantify the phase transitions against temperature. Single-molecule fluorescence spectroscopy such as FLIM-FRET will be used to measure the rates of diffusion and specific interactions between lipids/polymers and proteins to assess their mixing behaviours. The success of this project will provide new nanomaterials which could be applied in future artificial photosynthesis devices, e.g., as coating in bio-photo-electrochemical cells.