# Professor Andrew Whittaker

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The lead researchers in the Polymer Chemistry Group are Prof Andrew Whittaker, Assoc Prof Idriss Blakey, Dr Hui Peng, Dr Changkui Fu, Dr Alison White, Dr Chang Zhang and Dr Jiacheng Zhao. These seven researchers have independent research themes but because of their complementary skills work in close collaboration.

The Group Leader, Professor Whittaker is the Deputy Director Research and Group Leader at the Australian Institute for Bioengineering and Nanotechnology, and holds an adjunct appointment in SCMB and international universities. His research interests include the fields of nanotechnology, biopolymers and polymer hydrogels, polymer degradation, polymer devices, and the application of spectroscopic methods to polymer research.

The Polymer Chemistry Group consists of ~ 30 researchers, with two academic staff (Andrew Whittaker and Dave Hill), Research Fellows and PhD and Honours students and support and administrative staff. The group is very active, holding weekly group meetings, and encourages students to travel to national and international conferences to present their work. We have outstanding links with national and international polymer groups. Our aim is to provide a supportive and stimulating environment for the training of young scientists. The projects listed below are all highly collaborative and we aim in all of the projects to impart detailed knowledge of important chemical systems, and train the student in modern analytical techniques.

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## Novel Biologically-Responsive MRI Agents

The development of MRI imaging agents has been central to the rise of MRI as a leading medical diagnostic tool. An MRI imaging agent is a molecular adjunct which enables enhanced image definition and reduced imaging times, as well as mapping of specific cell types. In this project new imaging agents will be developed which respond to specific biological triggers relevant to diseases, for e.g. changes in pH, ionic strength, oxygen tension, redox environment and temperature. The project will involve synthesis of novel functional polymers using controlled radical polymerisation methods and testing of these molecules as imaging agents in animal models. The project is supported by the Australian Research Council and the National Health and Medical Research Council and involves extensive national and international collaboration. The student will receive training in polymer chemistry, NMR and MRI and biomedical sciences. This project is suitable for PhD and Honours students. *Responsible scientist: Andrew Whittaker*

## MRI Imaging Agents for Disease Detection

The aim of this project is to develop new magnetic resonance (MR) molecular imaging strategies that will enable the in vivo monitoring of biological processes. Specifically we shall develop novel polymers for imaging of early markers of diseases such as melanoma, prostate cancer, malignant glioma and Alzheimer's disease. Specifically the project involves the synthesis of new partly-fluorinated polymers having controlled architecture for the rapidly developing field of $^{19}F$ MRI. The project aims to relate the structure of the macromolecules, determined carefully using advanced techniques such as NMR, light scattering, GPC, AFM and electron microscopy, to the performance as imaging agents. The agents will be tested in small animal (mouse) models of disease already developed by this group and our collaborators. *Responsible scientist: Andrew Whittaker and Cheng Zhang*

## Light, pH and Ion Responsive Hydrogels

The ability to actively change shape is essential to all kinds of living organisms. For example, the Venus flytrap closes its leaves in less than seconds to efficiently catch flies, and pine cones open their scales when the environment is dry to release their seeds. Inspired by such phenomena, numerous studies have aimed to develop artificial smart materials which can undergo shape transformations under the action of an external stimulus. Among the various classes of shape-changing materials, hydrogels are particularly attractive because of the potential for significant changes in volume under diverse external stimuli, and the potential for programmable complex shape changes. The interesting properties of hydrogels make them candidates for diverse applications in many fields, such as in soft robotics, artificial muscles, three-dimensional (3D) cell culture and drug or cell delivery devices. In this project we explore an innovative approach to spatially varying properties of hydrogels so that they undergo rapid and reversible shape changes on exposure to external stimuli. *Responsible scientist: Andrew Whittaker*

## Nanofunctional Surfaces for Control of the Biological Interface

Biomaterials support, repair or protect the human body. The surface of the biomaterial interacts with the body's immune system, or for external devices with pathogens. Control of the surface and how it interacts with the biological system is essential for effectiveness in its intended application. This project aims to develop innovative strategies for surface functionalisation using polymers that can either augment or attenuate the body's response to the material. Two focus applications, namely anti-microbial surfaces and functional titanium alloys have been identified for the development of the novel surface treatments. The projects will build effective pathways from materials science to pre-clinical evaluation, and will provide training in synthetic chemistry, biomaterials science and pre-clinical testing. *Responsible scientist: Hui Peng*

## Understanding Effect of Architecture of Fluoropolymers on Their $^{19}F$ MRI Properties

Despite the wide use of metal-based MRI contrast agents such as gadolinium chelates in the clinic, safety concerns have been raised regarding their potential toxic effects resulting from long-term in vivo retention. This has driven the development of organic metal-free contrast agents in various forms for use in MRI. Fluoropolymers, polymers containing fluorine, are very promising candidates as organic metal-free MRI contrast agents. However, the clinical application of fluoropolymers as $^{19}F$ MRI contrast agents has been greatly limited due to insufficient imaging sensitivity of current fluoropolymers. This project aims to boost the imaging sensitivity of $^{19}F$ MRI by controlling the architecture of synthesised fluoropolymers. The project will highlight the important relationship between the architecture and properties of fluoropolymers, contributing to the development of advanced fluoropolymers as $^{19}F$ MRI contrast agent with clinical potential.

*Responsible scientists: Andrew Whittaker and Changkui Fu*

## Preparation and Application of Precise-Defined Polymers

Although synthetic macromolecules and polymers are often termed ‘monodisperse’, their primary structures are not as perfectly controlled as natural macromolecules, such as proteins and nucleic acids. The properties of the synthetic molecular transporters result from the combination of individual molecules, each with unique properties. As such, it is critical to be able to prepare polymers with precisely-defined structures, compositions, and function, which give rise to their special and unique properties. This project will combine controlled radical polymerization with a newly-developed automated chromatography fractionation technique to prepare near-discrete materials. Applications of these well-defined polymers will cover a number of fields from energy materials e.g. solid electrolytes to biomaterial templates e.g. imaging and therapeutic agents. *Responsible scientist: Cheng Zhang*

## Design of Photo-patternable Thermal/Electrical Active Hydrogel as Smart Windows for Reducing Energy Consumption

Efficient energy management systems play a crucial role in sustainable development of society. Smart windows which can prevent the interior of a building from being overheated by reflecting a large fraction of the incident sunlight in summer and keep a room warm by absorbing solar heat in winter, have the potential to facilitate energy conservation through dynamic control of the amount of free heat captured from solar heat. This project proposes a design concept for a photo-patternable doubly responsive hydrogel to control the passive-type moving thermoresponsive smart window actively.

*Responsible scientist: Jiacheng Zhao and Andrew Whittaker*

## Protection and controlled release of small molecules

Encapsulation is a powerful technique, used in a wide range of industrial applications, to protect and allow for controlled release of active ingredients. Often, polymers are used to form a shell around the active ingredient, however, due to the porous nature of a polymer network, such shells do not effectively protect sensitive active ingredients from moisture and oxygen degradation, and can not prevent diffusion of the active ingredient into favourable bulk conditions. With the micro-plastics ban and drive for more environmentally friendly materials, this project explores the ability of inorganic materials to protect small molecule/sensitive active ingredients efficiently, whilst allowing for controlled release at the desired place and time.

*Responsible scientist: Alison White*

## Photo-directing Self-assembly of Block Copolymers as a Novel Lithography Technology for Next-generation Chips Manufacturing

Directed self-assembly (DSA) is a type of directed assembly which utilizes block copolymer morphology to create lines, space and hole patterns, facilitating for a more accurate control of the feature shapes. Block copolymers (BCPs) comprise two or more chemically dissimilar homopolymer subunits that can form distinct phases when appropriately treated. The extent of phase separation at equilibrium for BCPs is determined by the Flory-Huggins interaction parameter ($\chi$) and the overall number-average degree of polymerisation (N). Symmetrical BCPs ($f = 0.5$) can form regular repeating lamellar morphologies and are typically desired for line/spacing patterning due to their advantages in pattern transfer. To achieve the perpendicular lamellar structures, a so-called “neutral” surface, in which the interface energy between the substrate and the two blocks of the BCPs are equal, is necessary. Due to the great potential of DSA, it is widely regarded as one of the most promising candidate technologies for next-generation lithography. This project will develop new BCPs for this important application.

Responsible scientist: Jiacheng Zhao and Andrew Whittaker