The MacDiarmid Institute for Advanced Materials and Nanotechnology

Founded in 2002 and named after the 2000 NZ Nobel Laureate Alan MacDiarmid, the MacDiarmid Institute for Advanced Materials and Nanotechnology was one of NZ's first (now seven) Centres of Research Excellence. It is based in the School of Chemical & Physical Sciences of Victoria University, although its operations include Canterbury, Massey and Otago Universities, and the CRIs, IRL and IGNS in Wellington as partner institutions. Its director, Professor Paul Callaghan, PCNZM (Physics-VUW), arguably the most well recognised member of the NZ scientific community, has steered the MacDiarmid Institute from infancy to what is now a major player in the chemical and physical research arena not simply in this country but internationally. The aim of the Institute is to enhance NZ's capability in nanoscience and nanotechnology and to benefit the country both through graduate student training and technology spin-off. As Paul says '*We see ourselves as the premier NZ centre for innovation and knowledge creation in fundamental and applied materials science and technology*'. In its four-year existence four spin-off companies (Anzode, magritek, Nanocluster Devices, and BioImprint/BioChip) have been generated through use of targeted goals attained through ***five*** thematic areas each with its own *Theme Leader*. These are outlined below.

Theme I, Nanoengineered Material and Devices is led by Dr. Roger Reeves (Physics and Astronomy-Canterbury). In this area the nanofabrication in ever decreasing sizes of integrated circuits (and the development of totally new devices) is critically explored. An important thrust in the research is directed towards the discovery and development of new materials that lend themselves to device fabrication. Within this area are research objectives covering the design and characterisation of new materials systems at the nano-scale, and the fabrication of devices from these or other materials that encompass optical and optoelectronic materials and devices, with targeted outcomes such as better UV-sensitive materials (for monitoring exposure to UV radiation), improved polarising filters (for TV displays or optical imaging systems), and ultra-sensitive optical biomolecule detection devices.

Electronic and magnetic materials and devices are being examined with a view to better understanding of the way magnetic atoms interact in a non-magnetic host material. The fabrication of new types of magnetic sensors (for reading computer hard drives) using atomic clusters, and the development of new types of electronic devices that rely on electron field emission, *e.g.* for improved flat-panel TV displays, form another area. Chemically and biologically active materials that could lead to devices with carbon-based surface self-assembly techniques (for creating selective arrays of bio-sensors), and the establishment of new techniques for manipulating cells and cell membranes (for miniaturized cellular diagnostics) and improved bio-sensors are also under investigation.

In many cases these objectives will assist in gaining a better understanding of materials and devices at the nano-scale, but new technologies will emerge for incorporation into products and processes that we all use every day. The diversity of research stems from the interests of the Principal Investigators. Principal Investigators do not have to align their interests artificially to a small common set of objectives. They are given the freedom to explore, with the only requirements being those of excellence, ethical integrity, and an alignment to the overall objectives of the Institute.

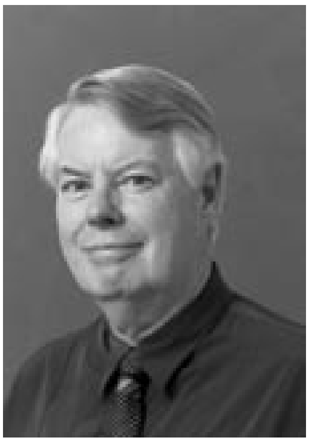
Theme II encompasses novel electronic, optic-electronic and superconducting materials and its leader is Dr. Andy Edgar (Physics-VUW). The current frontiers in this challenging field are found in novel materials, in nano-scale architecture within new materials or composites, and in novel ways of understanding old materials that remain elusive to theoretical description. The work is arranged under four objectives. The first is focused on determining the crystal structure and properties of previously unexplored metal nitrides since, with the exception of the wide band gap semiconductor GaN, others are unexplored. The second objective concerns a broad class of materials in which the interaction between electrons forces their motion and quantum states to be strongly correlated and is one of the most challenging problems in modern physics. The materials include the high temperature superconductors for which the IRL group (in particular Jeff Tallon and Grant Williams) is especially well-known. Objective three is concerned with composites that consist of glasses with nano-crystalline inclusions as such materials undergo a change in refractive index on irradiation thereby forming the basis of a range of applications including Bragg gratings for optical fibre filters and optical memory devices. Some of the materials under investigation are close to commercialization as X-ray storage phosphors. The final area is one that provides theoretical support for the other objectives not simply of this area but also for those in the first, third and fifth themes. Moreover, a new initiative has been aimed at providing high-pressure capability for a number of programmes that range across several of the Institute themes. For example, pressure dependent effects provide a fundamentally important route to establishing the nature of electronic interactions, and high temperature spectroscopy represents a relatively unmapped frontier in the science of high-Tc superconductors.

Theme III examines conducting polymers and is led by current NZIC President, Assoc. Prof Keith Gordon (Chemistry-Otago). Here existing NZ expertise is used to create new materials based on conducting polymers, carbon nanotubes, nanofibres, and quantum dots. In turn, these materials are targeted for the fabrication of devices and thin films used as light-emitting diodes, all-plastic solar cells, molecular sensors, and switchable surfaces. These materials are electro-active in the sense that they respond to or generate electrical energy. As the materials are crafted on a nanometer scale they are termed *nanostructured electromaterials*. The work is underpinned by computational modeling of the materials both at a molecular level (to understand properties such as mode of polymerisation and polaron structure) and in a bulk sense to gain insight into conduction mechanisms. Thus synthetic strategies provide monomer units with in-built electronic functionality such as donor-acceptor units, and fluorescence and phosphorescence capabilities, with the incorporation of additional functionality, *e.g.* alkoxy groups, to aid solubility and processability. These materials then form the feedstock for the generation of films, fibres, and nanoparticles that can subsequently be employed in the various devices.

Assoc. Prof. Kate McGrath (Chemistry-VUW) leads ***Theme IV*** *Soft Materials*. Soft materials and complex fluids represent one of the most challenging areas of interdisciplinary research as they possess both solid and liquid-like properties. These include polymer melts and solutions, lyotropic and thermotropic liquid crystals, micellar surfactant phases, colloidal suspensions, and emulsions. Complex fluid systems also include the class of materials known as *porous media*. The subject of flow, dispersion, and diffusion in porous media has major interdisciplinary significance and underpins chromatographic separation technology, biological perfusion, and wood treatment technologies to name but a few examples.

The molecular basis of soft material rheology, studied by use of NMR and optical methods, allows the links between nanostructure and rheology to be probed. Molecular assemblies at the basis of living organisms are the ultimate nanotechnology. Here structural organization is important at the molecular (a few nanometres), mesoscopic (many nanometres), microscopic (micrometres) and macroscopic (millimetres) scales. In comparison, motions range from very fast (tumbling water molecules) to comparatively slow (cell division). Adjustment of the macroscopic properties of complex fluids by control of the underlying nanostructure is aimed at giving, for example, better delivery systems and enhanced emulsion stability. Manipulation of the interfacial domain in emulsions is to be assessed by achieving controlled coalescence and the diffusion of a tagged macromolecule across the membrane interface.

Soft materials based upon biopolymeric networks are everywhere in nature and the technological arena. An elucidation of structure-function relationships in such biomaterials promises to reveal the design rules of nature and facilitate the use of biopolymers as engineering materials. The self-assembly of semi-flexible polymers in solution, in melts, and in blends is being examined experimentally and theoretically to gain better understanding of how important known polymers such as DNA have significant internal stiffness. Surface Enhanced Raman Scatterings (SERS) and plasmon resonance enhancement of fluorescence are new experimental tools. These are now being used to probe, at the molecular level, the physical and dynamic basis by which the mechanisms of biological processes take place – single biomolecule physics. The importance of plasmonics in current nanotechnology research is vast and researchers in this area use 3D assemblies of nanoparticles for surface enhanced Raman scattering. Here it is hoped to produce an entirely new type of materials for application in tracing molecules via Raman spectroscopy.



Theme V deals with advanced inorganic and hybrid nanostructured materials and is led by Assoc. Prof. Ken MacKenzie (Chemistry-VUW and IRL). It is concerned with the development of such innovative materials, inorganic polymers, composite and hybrid materials - including those utilizing conducting polymers with specific structures and surface properties. It draws thematically on the idea of extending function and performance of conventional inorganic materials by introducing novel surfaces and interfaces. These interfaces may be with organics in composite and hybrid materials, they may be nanostructured to provide steric selectivity and high surface area, or they may be internal interfaces in the form of topological defects associated with ultra-high strain. The associated science is complex and its elucidation is dependent upon a various spectroscopic techniques. However, the scope for structural, compositional, and functional variation within these materials is huge. The associated impact encompasses technologies for energy conversion and storage, environmental sustainability, sensors, electronics, and biotechnologies.

The research of this theme covers new materials design, synthesis, and characterization that will allow new approaches to energy conversion and storage, and to controlling surface functionality. Moreover, an understanding and control of the nano- and micro-structures of these materials, of the reaction mechanisms, phase transformations, rates and processes involved, is vital to further development.

Integral to the theme is the world-class competence of its investigators and the need for instrumental methodologies that include Solid State NMR, X-ray Powder Diffraction, Electron Microscopy, Ion Beam Analysis, and SQUID magnetometry. For success in this area access to international centres of neutron diffraction, muon spin relaxation, and synchrotron X-ray science for the researchers is essential and has been arranged.

Compiled by the Scientific Editor from material supplied by Margaret Brown (Manager, MacDiarmid Institute for Advanced Materials and Nanotechnology); further articles describing the chemical work of the MacDiarmid Institute are to be provided by the chemically-based theme leaders and should appear in April 2007.