History and Excellence

The University of St Andrews is Scotland’s top rated research institution and one of the leading research-intensive universities in the world. As an ancient seat of learning, the University, founded in 1413, has enjoyed a high reputation for teaching, scholarship and research for almost six centuries. St Andrews attracts outstanding scholars from around the world who continually enhance the reputation of this academic gem by conducting ground breaking research across all disciplines. Within the Faculty of Science, this includes Physics, Chemistry, Biology, Mathematics and Computer Sciences.

The University demonstrated its excellence in the most recent UK wide Research Assessment Exercise (RAE). The RAE is the UK Government procedure conducted every 5-7 years for producing ranking and benchmarking of research quality in all UK Universities by grading from 1 to 5* according to research outputs and other key research performance indicators. St Andrews achieved the best result in Scotland with every subject area in the University achieving international status in research. All science areas assessed, i.e. Physics, Chemistry, Computer Science, Mathematics and Biology were awarded the top 5/5* grade confirming that within St Andrews resides one of the most productive and stimulating science environments in the UK.

The University continues to maintain an enviable reputation for success in teaching and was runner up placed 6th with the ‘University of the Year award’ in the Sunday Times UK University Guide table 2007. St Andrews was named 4th best university in the UK and the ‘big success story’ of the Guardian University Guide 2007 reporting that ‘St Andrews has equalled its highest-ever ranking this year with a string of improvements in performance during the past year.’ In the Times Good University Guide 2007 the University was named ‘Scottish University of the Year’ and attributed the award to the ‘University’s consistently outstanding teaching and research’ combined with its success in the National Student Survey which measured student satisfaction with teaching and resources at their university. St Andrews students rated themselves as the top mainstream university in the UK.

St Andrews is a charming mediaeval town located in a spectacular coastal setting steeped in history with excellent facilities and easy access to the mountains for hill-walking and skiing. The St Andrews Old Course is famous as the world’s very first golf course. Fine hotels and gourmet restaurants are plentiful in and around the town. St Andrews is very safe with good quality housing and excellent schools. It is recognised as an ideal place not only to study and carry out research but also to live and bring up a family. The larger cities of Dundee, Edinburgh and Glasgow are within easy reach. St. Andrews is easily accessible by rail and a good road network while being close to national and international airports.

Strategy, Collaborations and External Engagement

Consistent with its history, St Andrews aim is to radically renew the research landscape in Scotland. It strategy takes advantage of a powerful well-resourced research communities to attract and mix leading researchers from around the world at very different stages of their career, and to produce world-class and interdisciplinary, fundamental and applied research crucial to build a flourishing knowledge economy.

The University of St Andrews is an enthusiastic supporter of the Scottish Funding Council (SFC) strategy of developing research pooling and excellence across Scottish HEIs and has taken a leading role in the development of this innovative concept. St Andrews has taken a leading role in the development of the Scottish Universities Physics Alliance (SUPA) including the Universities of Edinburgh, Glasgow, Heriot-Watt, Paisley, St Andrews, Strathclyde, and the joint Chemistry Research School of Edinburgh and St Andrews (EaSICHEM). SUPA has a coherent approach to staffing strategy, research training, research initiatives and funding opportunities. This pooling creates the largest group of Physics researchers in the UK and provides a single ‘front door’ for potential staff, sponsors, and industrial collaborators. EaSICHEM is the premier Chemistry research school for Chemistry in Scotland and one of the largest in the UK, with around 500 researchers working on both core and interdisciplinary chemistry. The aim of these two initiatives is to place Scotland at the forefront of international research in Physics and Chemistry through an agreed national strategy, an inter-institutional management structure, and co-ordinated promotion and pursuit of excellence.

The University is experienced in working closely with multinational industrial organisations and smaller companies. This includes not only student placement in companies, collaborative PhD studentships, collaborations with industry through part and fully sponsored research projects, but also research services and consultancy. Both the School of Chemistry and the School of Physics & Astronomy have a long history of arranging industrial projects for MSc and MChem students. Some recent examples of companies involved in the placement schemes have included: CIBA, Coherent Scotland, GlaxoSmithKline, Intel Inc., Rolls-Royce and Selex S&AS. In 2002, the international Johannesburg-based company SASOL established its European Research Laboratory at the University of St Andrews to undertake research into homogeneous catalysts, a process of making chemicals faster, cheaper and greener, leading to chemical feedstocks for plastics, detergents and other commercial products. The co-location of the SASOL Laboratory on the same campus provides a very successful model for industrial collaboration and interaction.

The University of St Andrews - Scotland’s first University
Advanced Materials and NanoSciences at St Andrews

The School of Physics & Astronomy and the School of Chemistry, both renowned for international excellence in research and teaching, host a wide range of research in Materials and NanoSciences underpinned by some leading established research groups who, collectively, have a wealth of expertise and infrastructure. Both Schools contribute to both theoretical and experimental aspects of materials’ research and promote a vibrant and dynamic research environment, especially via a commitment to recruiting leading young researchers. As a result an unusually high proportion of their staff are independent Advanced Research Fellows funded by agencies including the Royal Society, the Royal Society of Edinburgh, EPSRC, RCUK as well as SUPA and EaStCHEM.

St Andrews Schools offer one of the highest concentrations of state of the art equipment for Materials and NanoSciences research in the UK, funded through competitive awards from EPSRC or by the Scottish Funding Council (SFC) and the establishment of collaborative cross-school initiatives such as the Organic Semiconductor Centre and the Scottish Centre for Interdisciplinary Surface Spectroscopy. St Andrews benefits from the major research facilities in the UK and abroad, while both EaStCHEM and SUPA provide access to additional facilities and expertise at the University of Edinburgh and other Scottish HEIs.

The close links that have been developed between fundamental research and technological application make St Andrews an interesting and dynamic place to carry out not just research but also development and knowledge transfer activity, as illustrated by Photonic Innovation Centre and the recent spin-out companies such as Lumicure Ltd or St Andrews Fuel Cells Ltd.

The School of Chemistry

Chemistry has been taught at St Andrews since 1811 and the first Professorship in Chemistry was established in 1840. Nobel Prize Winners Sir Robert Robinson and Sir Norman Haworth spent some of their most important years at St Andrews. Today 60 % of Staff are under 45, while senior staff include, for instance, the established world leaders P.G. Bruce (FRS, FRSE, FRSC) and D.J. Cole-Hamilton (FRS, FRSC).

Research and teaching are carried out in modern, state of the art laboratories and to illustrate the constant interest in keeping the facilities up-to-date over the past 6 years alone more than 35 % of laboratory, write-up, lecture theatre and computational space have been refurbished and modernised at a cost of £10.4M. The Purdie Building and the adjoining Bio-Molecular Sciences Building offer excellent joint facilities that allow strong mutual interaction.

Research excellence in Chemistry was recognised by a recent award of £5M of additional funding to each of St Andrews and Edinburgh to develop a joint research school: EaStCHEM.

The School of Physics & Astronomy

The School of Physics & Astronomy is widely recognised for its research, both experimental and theoretical, in the areas of Condensed-Matter Physics (magnetism, superconductivity and semiconductors), Photonics (laser physics and optoelectronics, organic semiconductors, millimetre wave, quantum optics and quantum information) and Astrophysics.

With an expanding academic research base, 70% of academic staff are currently under 45 and mix early career Advanced Research Fellows with established leading groups such as that of W. Sibbett (FRS, FRSE, FEOS, FInstP, CBE). Our younger materials-related staff are making real impact, illustrated for instance by Scientific American listing U. Leonhardt among the top 50 policy, business and research leaders in 2006 for his work on metamaterials, and the awards of the 2007 Beilby Medal to I.D.W. Samuel (FRSE, FInstP) for his work on organic semiconductors and the 2004 Daiwa Adrian Prize to the group of A.P. Mackenzie (FRSE, FInstP) for their work on novel oxide materials.

The School offers a unique, interdisciplinary and stimulating research environment with a continuous interest in carrying out both research and teaching in modern, state of the art laboratories, investing c.a. £10M on its Advanced Materials and NanoSciences laboratories in the past few years.

Recent Highlights Include:
- theoretical prediction of invisibility cloaking
- development of diode-based skin cancer phototherapies
- extreme slowing of light in optical waveguides
- discovery of new forms of electronic self-organisation near quantum critical points in special oxide metals
- design of novel porous material for gas storage and biomedical applications

Looking Forward…

Substantial future investment is planned in collaborative research through not only the Schools’ participation in EaStCHEM and SUPA but also through the expansion of the science campus. As part of the former initiative a joint Physics laboratory with Edinburgh’s A.D. Huxley has already been completed and the latter investment include notably the creation of a major new Institute for Medicine and the Sciences, which will adjoin the Physics and Astronomy building, embed researchers from both Physics and Chemistry, and include a materials and instrumentation-related push into medical physics and chemistry.
A team of researchers at the University of St Andrews have demonstrated one of the smallest optical switches ever made. Switching light is a fundamental function of an optical circuit, and even though many types of optical switches have been created, most operate by imposing a phase shift between two sections of the device in order to direct light from one port to another or to switch it on and off. As typical refractive index changes are very small, this method usually requires making the devices longer, which increases the overall footprint, or using resonant enhancement, which reduces the bandwidth.

The team led by Professor Thomas Krauss has used photonic crystal technology to reduce the size of the switch to only a few wavelengths of light, i.e. the entire switch is only about 1/10th the size of a human hair. The device created by the St Andrews team is a slow-light-enhanced optical switch 36 times shorter than a conventional device with the same refractive index change and a switching length of 5.2 µm. The switch, reported in Optics Letters Jan 15 issue, is aimed at applications in telecommunications, where the researchers foresee its use in routing of optical signals. The technology may also be used in small consumer devices that connect every home or office to an optical fibre and supply high data rates, including television on demand.

The work is part of the UK Silicon Photonics project, a consortium led by Surrey University, that has just received a funding boost from EPSRC, with £1.4M awarded to St. Andrews. The group aims to address the increasing need for optical components at all levels of the communications network that carries the ever-increasing flow of data over the internet. By focussing on silicon as the material platform, the photonic devices developed by the group can be mass-produced in a similar way as computer chips for the microelectronics industry.

Basic Science Success Stories

Cloaking Devices

The idea of invisibility has fascinated people for millennia and has been an inspiration or ingredient of countless myths, novels and films. Invisibility is an optical illusion, like a mirage in the desert. Many optical illusions are caused by the bending of light in transparent substances, such as air or glass, but an invisibility device is something more subtle: it bends light around an object as if nothing were there, it causes light to flow like water around an obstacle.

Recent research, including pioneering work done at St Andrews by Professor Ulf Leonhardt and his group, has turned invisibility from fiction into science. Cloaking actually combines some highly abstract ideas that normally belong to the physics of curved space, general relativity, with one of the latest and most active trends in engineering. This practical use of general relativity in electrical and optical engineering may seem surprisingly unorthodox as relativity has been associated with the physics of gravitation and cosmology, black holes or the expanding universe. From an experimental and material science prospective, cloaking devices take advantage of the development of electromagnetic meta-materials, which have designed properties that stem from man-made small structures and which, for cloaking in the visible range of the spectrum need to be made smaller than the wavelength of light, merging the vibrant fields of metamaterials with Nanophotonics.

The first operational cloaking device worked in the microwave region of the electromagnetic spectrum, however cloaking for plasmons in the visible range has more recently been demonstrated and significant international research towards invisibility in the visible range of the spectrum is in progress. These developments have inspired a wide range of ideas for novel metamaterials and Science magazine regarded cloaking as one of the top-ten research breakthroughs in 2006 (in 5th place and top in engineering and physics). Metamaterials and cloaking have enormous potential applications, which we only start to become aware of as the field is growing, and the environment associated with the leading position St Andrews’ team is a guaranty of major UK contributions in a near future.

Light flows around an object hidden by an invisibility device.

Photonics Reduces Switch Size

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Hair (left) vs the actual switch (tiny rectangular area in the centre of the image, right handside inset: zoom-in).

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Control on the Nanoscale by Self-Assembly

A straightforward generation of structures over extended areas with feature sizes matching the molecular length scale is one of the major challenges in nanotechnology. Since current so called top-down technologies, i.e., methods where structures are generated through processing of bulk material, become increasingly cumbersome and expensive with decreasing feature size, alternative concepts based on self-assembly are explored. This bottom-up approach starts on the small scale and patterns are produced by using molecular building blocks which organise spontaneously. Beside its simplicity, the advantage of this approach lies in the flexibility afforded by the virtually unlimited possibilities to design organic molecules.

The research group of Dr Manfred Buck focuses on the generation of nanoscaled structures by applying the concepts of self-assembled monolayers (SAM) and supramolecular self-assembly. The latter employs non-covalent intermolecular interactions such as hydrogen bonding or metal-coordination networks to form two-dimensional porous networks. To take full advantage of the flexibility of the self-assembly approach, a main focus is on solution based preparation and processing which includes applications in the field of electrochemical nanotechnology. Two steps crucial for the development of this field were recently achieved by the group. One is the preparation of a robust bimolecular network from solution through which the flexibility of the self-assembly approach can now be harnessed. The other one is the combination of supramolecular self-assembly with SAMs which opens unprecedented opportunities to functionalise surfaces on the ultrasmall length scale.

Chiral Heterogeneous Catalysis

Most molecules used in the development of drugs in the pharmaceutical industry exist in two non-superimposable mirror image (enantiomeric) forms. There is a rapidly increasing demand for pure enantiomeric compounds since two enantiomers may have dramatically different physiological properties. Currently, most industrial chiral reactions utilise homogeneous or enzyme catalysts. Though these methods are often successful in producing highly enantioselective processes, they are often expensive, which sets one of the major goals of heterogeneous catalysis in the 21st century: to develop higher yielding and cheaper industrial chiral catalysts.

A number of chiral heterogeneous catalysts are known, but their commercialisation has been hampered by a lack of understanding of the surface chemical processes controlling the enantioselective reaction. Dr Chris Baddeley’s research group has focused on the Ni-based catalysts. The key step in producing enantioselective catalysts of this type is the adsorption, from solution, of chiral molecules such as $\alpha$-amino acids (e.g. glutamic acid) and $\alpha$-hydroxy acids (e.g. tartaric acid). Using, scanning tunnelling microscopy (STM) and surface vibrational spectroscopy at both vacuum-solid and liquid-solid interfaces, the role of intermolecular hydrogen-bonding on the stabilisation of catalytically important surface species has been examined; a correlation has been established between the conditions of optimum catalytic performance and the molecular conformation of the reagent.

In addition, the corrosion of metal surfaces by chiral carboxylic acids is known to create chiral arrangements of surface metal atoms which may themselves catalyse enantioselective surface reactions. Dr Baddeley’s group has shown that the corrosion of 2-D Ni nanoclusters by chiral species leads to the formation of 1-D chiral metal-organic co-ordination networks which may have applications beyond chiral catalysis in the formation of supramolecular surface architectures.
Commercialisation Success Stories

Light-Emitting ‘Sticking Plaster’ Revolutionises Skin Cancer Treatment

Skin cancer is a major and rapidly growing problem in the UK, affecting more than 10% of the population in their lifetimes and usually requiring unpleasant hospital-based treatments. Many skin cancers can be treated by light in combination with a drug (known as photodynamic therapy), but current light sources are large and cumbersome, and a lengthy hospital visit is required.

Professor Ifor Samuel has used advances in organic semiconductors to make a wearable ‘sticking plaster’ light source for the treatment of many skin cancers. Working with Professor Ferguson at Ninewells Hospital, Dundee, he has developed the idea from concept, through prototype to clinical demonstration in a pilot trial.

The new treatment is much more comfortable and convenient for the patient, avoiding the pain associated with conventional photodynamic therapy. It is expected to transform skin cancer treatment by opening up the possibility of management by family doctors or even at home, thereby relieving the heavy load it places on hospitals. The patented technology was a finalist in the International Academy of Science’s awards for Outstanding Technology of the Year 2007 and is being developed, under license, by Lumicure Ltd, a University of St Andrews spin-out company.

In other research areas, Professor Samuel has also developed extremely efficient solution-processed LEDs and advanced polymer lasers and optical amplifiers.

Renewable Energy Breakthrough from Solid Oxide Fuel Cells

Owing to the many pressures from global warming, decrease in cheap oil supply, loss of energy security and an ageing energy infrastructure, dramatic changes are required in our energy economy. Renewables offer a major component for this energy future and are driving towards a decentralised energy system, but these technologies on their own are currently not robust enough to deliver fully the required changes. Fuel cell and related technology can greatly extend this penetration, especially if fuel cell scalability and flexibility can be fully exploited.

Fuel cell technology is a particularly important enabler for biomass utilisation, offering high efficiencies of conversion in fairly small unit sizes and is essential to the new distributed energy economy. With a large team of over 30 researchers, St Andrews combines careful, focused, basic studies with development actions that have the realistic possibility to be implemented in industrial development thus providing step change advances in energy technology. St Andrews seeks to optimise fuel cell technology, improving durability and stability and reducing cost of manufacture, to enable widespread introduction.

The University has patent and patent application coverage on a novel Solid Oxide Fuel Cell design called the SOFCRoll which offers the potential of higher power densities, lower materials costs and lower manufacturing costs than other fuel cell designs through the scalable manufacturing of its proprietary high surface area, low volume and mass design. This technology has been licensed to St Andrews Fuel Cells Ltd, a spin-out company from the University, established in 2005 from its Fuel Cell group. The company created and directed by Professor John Irvine is developing a new design of fuel cell and will control manufacture of this low-cost platform fuel cell technology for a range of applications, including small-scale backup power, portable power and domestic power generation. The company continues to have close links with the University.

‘Sticking plaster’, light source made of organic semiconductor for the treatment of skin cancers.
Long Lasting Lithium Battery

To support renewable energy technologies and reduce carbon emissions, while maintaining our standard of living, developed societies need batteries combining more efficient storage with reduced weight and size. Such a technology will, for example, find applications in hybrid vehicles, electronic clothing and in complementing wind or tidal powers as well as solar based devices, which only collect energy intermittently.

Professor Peter Bruce has been at the leading edge of the development of lithium rechargeable batteries for over 15 years. With two other researchers he was the first to report the LiMn2O4 cells which are non-toxic, have the highest rate capability of any lithium battery and are now used in the latest power tools, where they store up to three times the energy of conventional batteries, such as nickel cadmium batteries.

More recently, with UK EPSRC funding, Professor Bruce’s team has focused on the key areas of electrode and electrolyte design required for large-scale energy storage, targeting potential improvements come from taking oxygen from the air to react with lithium ions rather than having to carry the reagents around in the battery, as is conventionally done.

Professor Bruce has patented his research and licensed it to companies in Europe and Japan. ITI Energy Scotland is clustering their energy storage companies in Fife i.e deliberately around the activities at St Andrews. A further application with which Professor Bruce is involved concerns wireless distributed computer networks as they require very small high energy density batteries to power each node in the network.

Zeolites

A material normally used to clean up car exhaust fumes could one day be used in dressings and surgical equipment to prevent severe skin infections and blood clots which might even help combat infections by the MRSA superbug. The technology developed by Professor Russell Morris and the members of his research group within the School of Chemistry is part of several research programmes running on microporous solids and their use in gas storage applications.

The University has filed a patent application for the novel uses of zeolite materials technology which is of interest to pharmaceutical and cosmetics applications companies, and has recently exclusively licensed this zeolite technology to a large UK chemical manufacturing company, Ineos Silicas Ltd.

The zeolite technology will be developed further in preparation for bulk manufacturing and subsequent use of the materials by healthcare and cosmetic companies in a variety of product applications, including uses in wound healing promotion, particularly in diabetic patients, and as anti-thrombosis coatings for surgical instruments.

Representation of the novel Li/O2 battery taking oxygen directly from the air.
Specific Expertise and Thematic Areas

Meta-Materials Properties and Quantum Physics
Metamaterials are artificial macroscopic composites having a periodic 3D architecture designed to produce an optimized combination of two or more responses to specific excitation. It is commonly used to label material having unusual properties. The first metamaterials were developed in the late 1940’s but along with recent progress of nanotechnology and material science they have recently been at the centre of a lot of experimental and theoretical attention.

Quantum physics of metamaterials is developed to predict novel properties. It has already been used for left-handed metamaterials showing that attraction may turn to repulsion leading to quantum levitation.

The use of modern metamaterials to design media that create perfect invisibility is another area of research where practical interests include escaping detection by other electromagnetic waves or sound.

Photonic Crystals & Waveguides
Novel optoelectronic components based on photonic crystal waveguides promise a new era of integrated photonic devices.

Semiconductor photonic crystals and novel metallic structures of nano and micrometer scale, fabricated by lithography techniques, allow spatial and spectral dispersion, ultra-fast properties and nonlinear effects to be tuned.

The use of quantum dots for ultrafast lasers provide a new and exciting novel gain material which have the potential to deliver the gain bandwidths required for the generation of very short pulses. In addition, using the absorption properties of quantum dots will provide an exciting new range of saturable absorbers with the potential for precise electrical control.

Organic Semiconductors & Quantum Dots
The combination of novel semiconducting optoelectronic properties with simple fabrication makes organic semiconductors and inorganic semiconductor quantum dots promising for applications in displays, solar cells, lasers and optical amplifiers.

We are pursuing these applications with an interdisciplinary approach combining materials synthesis, photophysical investigation to develop the next generation of materials and devices.

Solid State Quantum Dots & Lasers
Pulses shorter than 400 fs have been generated from a 2-section quantum dot GaAs laser and have provided the first demonstrations of the use of quantum dot saturable mirrors to produce sub-200 fs pulses from vibronic solid state lasers.

Focus is now oriented toward demonstrating the potential of these nanomaterials for the full temporal control of ultrashort pulses.

Superconductivity – Correlated Electrons & Recording Media – NanoMagnets
The scientific and technological promise of correlated electron materials is enormous. Quantum criticality, pairing mechanisms, improved detection methods and optimization of materials growth including ruthenates and other oxides are some of our present priorities. Aiming for the most productive approach we link experimental physics and theoretical research.

Ceramics & Ferroelectric Materials
In addition to traditional nano-magnetic recording media, the properties of ferro-electric materials are receiving a lot of attention at St Andrews. Understanding the nature of ferroelectricity in materials of various length scale is indeed a key element to develop their usage in information storage (FeRAM) technology.

Intrinsic and extrinsic effects in both bulk and nano-scale ceramic systems are carefully studied to gain a better understanding of material properties and to design optimized integrated ferroelectric devices.

Research activities focus on designing new ferroelectrics such as PbTiO$_3$, BiScO$_3$, BiPbNbO$_3$, CL and fluorinated derivatives, as well as high permittivity materials and relaxors for both capacitor applications and thin film non-volatile memory (NVRAM) devices.

References:

- Science 312, 1778 (2006)
- Nature Mat. 4, 7, 530 (2005)
- Patent PCT/GB98/03172; Patent UK0206356.8
- Optics Lett. 31, 1444 (2006)
- Science 307, 1203a (2005)
Numerical Predictions of Material Properties and Structures

Of interest from a fundamental perspective as much as for material science industry targeting material or pharmaceutical applications for instance, it is crucial to develop numerical and theoretical methods allowing the prediction of material structures and the extraction from experimental measurements of more precise information linking material properties and structures.


St Andrews is working at predicting properties of materials from first principles, and crystal structures “ex nihilo” in high pressure environments.

Illustrating the strong connection between Physics and Chemistry in material science, numerical methods are also being developed to predict Nuclear Magnetic Resonance parameters in the solid state.

CASTEP code - marketed by Accelrys Inc.

Non-Equilibrium Effects in Nanoscale Devices

In nanoscale strongly correlated systems, it is easy to reach regimes where linear response theory does not apply. We consequently develop fully non-equilibrium theoretical techniques that can cope in these circumstances. Our early research focused on Kondo systems, and other set-ups are now also under consideration.


Electro-Active Polymers

Electrical potential applied across the thickness of electro-active polymers (EAP) can induce dramatic and reversible bending making EAP ideal candidate to fabricate solution processable electro-actuators.

Investigations of this type of materials are carried out by combining electrochemical and NMR techniques as a better understanding of their properties and morphology could lead to enhanced electroactive devices.


Polymer Electrolytes & Lithium Batteries

Crystalline polymer electrolytes PEO₂ₓLiₓFₓ (X=P, As, Sb) conduct better than amorphous complexes of the same composition. Li⁺ ions move through cylindrical tunnels formed by poly(ethylene oxide) chains.

Nature 412, 520 (2001)
Nature 433, 50 (2005)

Nanomaterials with the TiO₂-B structure exhibit considerable promise as anodes for rechargeable lithium batteries with high capacities, excellent cycling stability and good rate capability.

Chem. Com., 2454 (2005)

Solid Oxide Fuel Cells

Solid oxide fuel cells are high temperature devices that convert the energy from ‘burning’ gases directly into electricity, with very high efficiency.

Under development are such materials as LSCM, a novel redox stable anode material to replace the less stable Ni/YSZ cermet in current use.

Patent WO03036746
Patent EP1532710

A new type of patented fuel cell design “SOFCRoll” is also under development, which promises improved volumetric density and lower manufacturing costs.

Fuel gases include H₂, natural gas, CH₃OH.

Gas Storage, Zeolites & Porous Materials

Zeolites and functional materials are designed and synthesized through novel organic-inorganic hybrid solids to well-ordered mesoporous solids.

Mesoporous solids possess regular arrays of pores in the 10-100 Å range, which can be functionalized to target applications including catalysis, gas (H₂, CO₂, NO) separation and storage, as well as bio-delivery.

Chem. Com., 3305 (2006); Patent WO003032

Ionothermal synthesis uses ionic liquids as the solvent and template for preparing new types of zeolitic material.

Solid state NMR and synchrotron microcrystal X-ray diffraction are used to obtain structures and assess properties.

Multinuclear Solid-State Nuclear Magnetic Resonance (NMR) Spectroscopy

NMR spectroscopy provides an element-specific probe of local structure, order and dynamics in solids, without any requirement for long range order. NMR spectra in the solid state, however, are broadened by a range of anisotropic interactions which hinder the extraction of information, and the development of novel experimental methods is required to achieve high-resolution spectra, particularly for nuclei with high spin quantum number, such as $^{23}$Na, $^{17}$O, $^{27}$Al, $^{49}$Sc and $^{93}$Nb.

In St Andrews, we combine a multinuclear NMR approach, new experimental methods and DFT calculations, to study structure and dynamics in a range of materials, including high-pressure mineral silicates, microporous frameworks, ferroelectric perovskites, and ceramic phases proposed for the encapsulation of radioactive waste.

Surface Reactivity

Chemical reactions on surfaces are vital to a wide range of technological applications, including gas sensing, catalysis, and biocompatible materials.

STM provides structural information at the atomic scale needed to better understand the processes governing chemical transformations at surfaces and to devise novel strategies towards the conception of new heterogeneous catalysts.

Surface Functionalisation & Nanopatterning

Self-assembled monolayers (SAMs) and supramolecular networks are exploited to tailor surface structures and properties down to the nanoscale.

Scanning probe microscopy and nonlinear optical spectroscopy are used as in situ techniques to achieve understanding at the molecular level.

Molecular Electronics

Controlling interactions between adsorbed molecules and those between adsorbate and substrate will underpin advances in sensors technologies, energy related materials etc.

STM and vibrational spectroscopy are exploited to study molecules relevant to molecular electronics, organic electronic devices and other thin film architectures.

Fluid Properties & Functional Coatings

The determination of the properties of tiny volumes of fluid is essential in micro-fluidics and lab-on-chip technologies. Actively driven micro-cantilevers as well as thermal noise measurements can be exploited to determine fluid properties such as viscosity, density and flow rates in micro-channels with high precision and accuracy.

Functional coatings that can tailor the interaction between proteins and surfaces in liquids are vital in the biomedical and biosensing areas.

Bio-Photonic Applications

With various emphases, interaction of light and matter is a key-strength of the department and St Andrews activities aim at providing biosciences with innovative sensitive tools for measurements and imaging.

Optical tweezers and manipulation, micro-fluidics, fluid sorting, cell transfection, fluorescence resonance energy transfer, phototherapy, optically stimulated neuronal growth are a few of the projects, which illustrate the on-going strong interactions between Physics and Biomedical sciences at St Andrews.

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Facilities and Capabilities

Materials and NanoSciences at St Andrews are supported by major facilities across the full spectrum of chemistry and physics, ranging from magnetic resonance to optical spectroscopy and scanning probe techniques, together with all the standard physical and chemical evaluation techniques. Staff and students also make extensive use of materials characterisation facilities at UK and international central laboratories including ESRF, ILL, ISIS, BESSY, SRS and MEIS Daresbury and RAL.

Unique and specialist facilities at St Andrews are highlighted “in-a-box”.

Optical and Electron Spectroscopy

- **Vibrational spectroscopy**: HREELS, polarisation modulation reflection absorption IR spectroscopy is currently being designed
- **X-ray Photoelectron Spectroscopy** (XPS)
- **Raman Spectroscopy**

**Time-Resolved Spectroscopy**: St Andrews has led the Ultrafast Photonics Collaboration headed by Professor Sibbett and focusing on the delivery of next-generation components and networks needed to provide datacomms up to rates of 100 Tbit/s. The University has developed unique facilities to investigate ultrafast electronic processes in both organic and inorganic low dimensional semiconductors, initiatives led by Professor Samuel at the Organic Semiconductor Centre and the groups of Professors Dunn, Krauss and Miller, respectively to develop novel optoelectronic devices as well as picosecond and femtosecond tunable laser sources

**ARPES / STM**: A state of the art Angle Resolved Photo-Emission Spectroscopy system for high-resolution k-space mapping at low temperature is currently designed and set up at St Andrews in a collaboration led by Dr Felix Baumberger. This facility will be complemented by a low-temperature Scanning Tunneling Microscope (STM) designed and set up by Dr Renald Schaub, providing local spectroscopic information with high energy- and atomic-scale real-space resolution.

**Terahertz (THz) Radiation**: University of St Andrews uses and develops extensively non-linear optical spectroscopy techniques (SFG, SHG) and also works on the development of compact sources of Terahertz (THz) radiation

**Microscopy**

- **Scanning probe microscopes**: including variable temperature UV-STM, electrochemical STM and liquid phase AFM/STM
- **Electron Microscopy**: High resolution TEM and SEM instruments combined with composition analysis of nanostructural materials
- **FTIR instruments**: including study of molecular vibrations at surfaces equipped with modulation capabilities and facilities for in-situ studies of molecular adsorption in liquids

**Magnetic Spectroscopy**

**NMR**: Solution spectrometers, from 200-600 MHz, several with full robotic control and networking. Two solid-state spectrometers, one an open-access service machine (400 MHz) and the second (600 MHz), within the group of Dr Sharon Ashbrook, a research-dedicated instrument for the development of new experimental methods and application to a range of problems in materials science, chemistry, colloids and geology.

**High Field ESR**: The HIPER project is headed by Dr Graham Smith and started in May 2004 with the main objective to construct a revolutionary new high field pulse ESR spectrometer working at 94 GHz with single nanosecond π/2 pulses and nanosecond dead-times with GHz detection bandwidths that will allow Fourier transform (FT) ESR to be used as a general technique and to demonstrate breakthrough applications across the scientific spectrum.

**Very Low Temperature & Very High Magnetic Field** are part of the facilities focusing on magnetic properties and superconductivity investigations and allowing St Andrews researchers to reach 25 mKelvin and 17 Tesla, respectively.

**Composition and Structure Characterisation**

- **X-ray crystallography**: extensive facilities for single crystal studies as well as powder diffraction studies - several CCD diffractometers, three of which have high brilliance rotating anodes, one with robotic sample changing. This is unique in the UK.
- **Mass spectrometry**: several mass spectrometers, with high resolution and different ionisation regimes (EI/CI, electrospray, FAB, MALDI, ES MS/MS)
- **Electrochemistry**: surface, solid state & solution
- **Other materials characterisation facilities include**: porosimetry, BET isotherm measurement for surface area, TGA, DTA, DSC, gas chromatography (GC, GCMS), temperature-programmed reduction/decomposition (TPR / TPD), elemental and spectroscopic analysis (ICP-MS, UV-VIS & GX IR spectrometers)

**Fabrication and Manipulation**

- **Clean rooms**
- **Micro-fluidics and optoelectronic devices**
- **E-beam and photolithography facilities**
- **Glove-boxes**
- **Organic and metal evaporators**
- **Organic light emitting diodes (OLEDs) and solar cells**
- **Fabrication and characterisation facilities**
- **Scanning probe microscopes**
- **Fuel cells**

**Optical Tweezers** are part of very intense activities led by Professor Kishan Dholakia, whose group focuses on the development of optical micromanipulation techniques, the investigation of novel light fields, the characterisation of particle dynamics (at the atomic, nano, and micron scale) in optical light fields, the development of optical traps and sorting within microfluidic environments, as well as the exploration of novel laser techniques for cell biology and medicine.

General Facilities

- **Excellent Research Computing Facility**
- **Analytical and Characterisation Services**
- **Mechanical & Electronic workshops**
People

St Andrews has a wealth of expertise and resources directed at advanced materials research. Some of our key researchers and their expertise is highlighted below.

Dr Pascal André
SUPA Advanced Fellow, 
School of Physics & Astronomy
Hybrid colloidal nanoparticles (metal, magnets, semiconductors QDs), Organic-inorganic dendrimers, Amphiphilic molecules, Photophysics and optoelectronics, Optical near-field microscopy, Supercritical fluids.

Dr Sharon Ashbrook
RCUK Academic Fellow and Lecturer, 
School of Chemistry
Multinuclear solid-state nuclear magnetic resonance (NMR), Method development, Structure and dynamics in solids, Minerals, Ceramics, Microporous frameworks, Ab initio calculations.

Dr Chris Baddeley
Reader, School of Chemistry
Alloys, Chirality at surfaces, Heterogeneous catalysis, Surface science, Scanning probe microscopy, Infra-Red spectroscopy, Medium energy ion scattering.

Dr Richard Baker
Lecturer, School of Chemistry

Dr Felix Baumberger
Lecturer, 
School of Physics and Astronomy
Ruthenates and rhodates, Correlated molecular solids, Angular resolved photoemission (ARPES).

Dr Tom Brown
Lecturer, 
School of Physics and Astronomy
Solid state semiconductors, Quantum dots, Compact short pulse laser systems, Pulse characterisation, Non-linear optics, Biophotonics.

Professor Peter Bruce (FRS, FRSE, FRSC)
School of Chemistry
Solid ionic conductors, Intercalation compounds, Polymer electrolytes, Synthesis’ structure determination, Solid state chemistry, Electrochemistry, Solid state ionics.

Dr Manfred Buck
Reader, School of Chemistry
Ultrathin organic films, Self-assembled monolayers (SAM), Buried interfaces, Electrochemistry, Surface science, Scanning probe microscopy, Nonlinear laser spectroscopy.
Professor David Cole-Hamilton  (FRSE, FRSC)  
Deputy Head, School of Chemistry  
MOCVD precursors and semiconductor quantum dots, Polymer synthesis, Dendrimers, Homogeneous catalysis, Carbonylation chemistry, Homogeneous catalyst recovery, Fluorous biphasic catalysis, Supercritical fluids.

Professor Malcolm Dunn  (FRSE, FInstP)  
School of Physics and Astronomy  
Gas imaging, Drug detection, Nonlinear optics, Optical parametric oscillator designs, Frequency comb generation, Terahertz parametric generation.

Professor Kishan Dholakia  (FRSE, FOSA, FInstP)  
School of Physics & Astronomy  
Optical trapping, Cooling & manipulation techniques, Optical guiding, Optical sorting, Plasmonic, Optical vortices, Beam particle dynamics, Optical binding, Brownian studies, Biophotonics, Raman spectroscopy.

Dr Santiago Grigera  
Reader, Royal Society University Research Fellow, School of Physics and Astronomy  
Metallic ruthenate, Superconductor, Correlated electron systems, Metamagnetic transitions and quantum criticality, Vortex, Magnetism, Biophysics.

Dr Georg Haehner  
Reader, School of Chemistry  
Functional organic films, Liquid/solid interactions, Protein adsorption, Fluid properties, Interface Science, Scanning probe techniques.

Dr Chris Hooley  
EPSRC Advanced Research Fellow and Lecturer, School of Physics and Astronomy  
Theories of: Nanoscale systems, Quantum dots, Far-from-equilibrium effects, Strongly fluctuating magnets, Kondo systems, Strongly correlated electron physics.

Professor John Irvine  (FRSE)  
EPSRC Senior Fellow, School of Chemistry  

Professor Thomas Krauss  (FRSE, FInstP)  
School of Physics & Astronomy  
Photonic crystals, Optoelectronics, Semiconductor nanofabrication, Plasmonics, Biophotonics.
Professor Steve Lee (FRSE, FInstP)
Head, School of Physics & Astronomy
Multilayer Composites, Silicon micromachining (MEMS), Vortex matter, Recording media, Biosensors, Neutron Scattering, Muon spin rotation (SSR), Neutron scattering, Nanomagnetism, Condensed Matter, Strongly correlated electron physics.

Professor Ulf Leonhardt
School of Physics & Astronomy
Theory of: Metamaterials, Quantum levitation, Invisibility, Quantum catastrophes, Light in moving media.

Professor Alan Miller (FRSE, FIEEE, FOSA, FInstP)
School of Physics & Astronomy
Optical properties of semiconductors, Low dimensional semiconductors, Optoelectronic devices and photonic switching, Nonlinear optics, Ultrashort pulse laser techniques, Ultrafast laser interactions in materials.

Professor Russell Morris
School of Chemistry
Synthesis, characterisation and application of porous materials, Zeolites, Metal organic frameworks, Ionic liquids, Gas storage, Medical applications.

Professor Andy Mackenzie (FRSE, FInstP)
Director of Research
School Physics & Astronomy
Physics of correlated electrons, Magnetism and superconductivity, Low temperature properties, Extremely pure oxide metals.

Professor Ulf Leonhardt
School of Physics & Astronomy
Theory of: Metamaterials, Quantum levitation, Invisibility, Quantum catastrophes, Light in moving media.

Dr Phil Lightfoot
Reader, School of Chemistry

Dr Chris Pickard (FInstP)
Reader, School of Physics & Astronomy
Intercalated graphites, Diamonds, Carbon nanotubes, Hydrogen, Crystal structures, High pressure physics, Superconductivity, Solid state NMR, Prediction of materials properties (CASTEP code), Computational condensed matter physics.

Dr Finlay Morrison
Royal Society University Research Fellow, School of Chemistry
Electroceramics, Ferroelectrics, Thin films, Functional oxides, Nano-structured oxides, Solid state chemistry, Dielectric properties.
St Andrews scientists have been very successful in winning personal fellowships that provide full salaries to allow the development of cutting edge research areas:

- Royal Society University Research Fellowships (Kishan Dholakia, Thomas Krauss, Andy Mackenzie, Russell Morris, Finlay Morrison, Ifor Samuel)
- Royal Society of Edinburgh Personal Fellowships (Russell Morris, John Irvine)
- EPSRC Advanced Fellowships (Chris Hooley, Steve Lee, Chris Pickard, Graham Turnbull)

Professors John Irvine and Ifor Samuel currently hold prestigious EPSRC Senior Fellowships in recognition of their research leadership.
Advanced Materials & NanoSciences Research

Scotland’s first university

University Facts and Figures

In the academic year 2006/2007 the University had a total of 6,799 full-time students.

Postgraduates: 1,053
• 55% of Postgraduates on Research programmes
• 45% of Postgraduates on taught Research Programmes

Undergraduates: 5,746

Staff:
• Academic and Research: 897
• Support and Academic Related: 1,151
• Staff/Student Ratio: 1 to 10

Useful Websites

- University of St Andrews: http://www.st-andrews.ac.uk/
- Chemistry: http://ch-www.st-andrews.ac.uk/physics/
- Physics & Astronomy: http://www.st-andrews.ac.uk/physics/
- EaSIChem: http://ch-www.st-andrews.ac.uk/eastchem/
- SUPA: http://www.supa.ac.uk/
- Organic Semiconductor Centre: http://www.st-andrews.ac.uk/physics/osc/
- BioPhotonics: http://www.st-andrews.ac.uk/biophot/
- Photonic Innovation Centre: http://www.st-andrews.ac.uk/pic/
- RAE: http://www.st-andrews.ac.uk/about/Factandfigures/
- Prospective Students: http://www.st-andrews.ac.uk/admissions/

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Produced by the Reprographics Unit, University of St Andrews January 2008.
Photographs: broad daylight and University photographs.
Printed on recycled paper.