



**School of Electrical  
and Computer Engineering**

# **Research 2010**

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*Front cover: Soundwaves Interference Pattern (Nasim Radmanesh)*

## Message from the Head of School

“Welcome to RESEARCH 2010 from Electrical and Computer Engineering at RMIT. This annual publication is aimed at giving a brief summary of the diverse and exciting research that has taken place in the School over the last year. Electrical and Computer Engineering is situated right at the heart of the city of Melbourne, with the practical Electrical Engineering of trams and trains a reality on our doorstep. Inside our Swanston Street buildings, we conduct a wide range of research activities spanning vital work on power pole fire prevention through to tiny nanotechnology. We are a strong, research-centric school with some 120 Higher Degree by Research students and, as evidenced by the list at the rear of this publication we have a correspondingly high publication

output. Particularly pleasing in this last year has been a further increase in our publications in high quality journals. This booklet can only present a small flavour of our activities which are expanding with new researchers and teams joining us. I would encourage you to visit our web site or contact us directly for more information on any of our research presented here and, of course, we are happy to answer those ‘do you research in ...’ questions – often we can give a positive response!

Enjoy this brief overview of our past year’s research activities !”

**Professor Ian Burnett**

*Head, School of Electrical and Computer Engineering*

## Message from the Deputy Head (Research)

The School of Electrical and Computer Engineering is one of the most research intensive Schools at RMIT with a wide diversity of research interests. This *Research 2010* publication aims to provide the reader with an overview of the School’s research activities undertaken during 2009.

Our research strength areas are represented by six Research Groups. These groups are:

- Biomedical Electronics
- Industrial Automation & Control Systems
- Information & Signal Processing
- Micro/Nanoelectronics & Sensor Technology
- Microplatforms
- RF and Antennas

In addition to these groups we also have an increasing research effort in Engineering Education.

Several of our researchers were awarded prestigious research grants in 2009. Of special note are the three ARC Discovery Grants awarded to Professor Arnan Mitchell, Dr. Thach Nguyen and Professor Tom Koch (*Novel silicon photonic devices harnessing new leakage behaviour*), Dr. Madhu Bhaskaran (*CMOS compatible ultra-high response piezoelectric thin films for efficient energy harvesting*), and Professor Ian Burnett and Dr Christian Ritz (*Encoding and communicating navigable soundfields*).

Professor Arnan Mitchell, Dr. Thach Nguyen and Dr. Madhu Bhaskaran also received an ARC Linkage Grant for a project with QuintessenceLabs on silicon photonic platform technology for quantum encryption and communications.

Research in our School is supported by a large number of postgraduate research students. Currently, in 2010 we have 123 Higher Degree Research (HDR) students, with 90% undertaking PhD studies. In 2009, 23 HDR students submitted their theses for examination. In addition to

our postgraduate research students, we have a relatively large number of Research Fellows who make a significant contribution to the School’s research performance.

In 2009, the School participated in the *ARC Centre of Excellence for Ultrahigh bandwidth Devices for Optical Systems (CUDOS)* and in three Cooperative Research Centres (CRCs). These were the *Advanced Manufacturing CRC*, the *Automotive CRC*, and the *Smart Services CRC*. We also participated in the *Defence Materials Technology Centre*.

Our research is strongly supported by the staff and facilities of the School’s two Research Centres; the *Microelectronics and Materials Technology Centre*, and the *Australian Centre for Radiofrequency Bioeffects Research*.

Our researchers collaborate with those from other Schools at RMIT and with a large number of national and international research groups. Many of the School’s researchers have an involvement with RMIT’s Research Institutes, in particular, the *Platform Technologies Research Institute*. Three of this Institute’s research programs are of particular interest: *Nano Materials and Devices*, *Security and Safety*, and *Intelligent Industrial Information Technologies*.

In 2009, the School’s research output included 4 books, 8 book chapters, 89 journal papers and 132 conference publications. A list of these publications is to be found at the end of this booklet.

I hope this publication provides you with an exciting glimpse of the research undertaken within our School.

More details about our research can be found at [www.rmit.edu.au/eleceng/research](http://www.rmit.edu.au/eleceng/research).

**Professor Mike Austin**

*Deputy Head (Research)*

*School of Electrical and Computer Engineering*

# Biomedical Electronics

The research focus of the Biomedical Electronics research group within the School of Electrical and Computer Engineering is an investigation of the electrical and electromagnetic properties of living systems and the influence of electromagnetic radiation on living systems: organisms, tissues, cells and biomolecules.

The group's research focus areas include:

- Biomedical electronics
- Biomedical signal processing
- Electrical and electromagnetic properties of the human body
- Biomedical instrumentation for complementary medicine
- Electrophysiology – the biological effects of electromagnetic fields on living systems
- Therapeutic effects of electromagnetic radiation

## HIGHLIGHTS:

From 2004 to 2009, the group was a leading member of the **Australian Centre for Radiofrequency Bioeffects Research** (ACRBR). This National Health and Medical Research Council (NHMRC) funded *Centre of Excellence* was established in 2004 to investigate possible biological and health effects of human exposure to radiofrequency (RF) field radiation from mobile phones and other radio sources. Studies covered the broad range of 'proteins to people', including molecular, *in vitro*, animal, human, epidemiological and RF dosimetry studies. Funding for the ACRBR finished at the end of 2009 and a proposal for future funding has been submitted.

In 2009, Associate Professor Dinesh Kant Kumar was awarded a CNPQ (Brazil) Professorial Fellowship and an EU Erasmus Mundus Fellowship.

Associate Professor Dinesh Kant Kumar commenced a new industry funded project analysing retinal scans of the human eye. Analysis of retinal vessels on the eye fundus image has shown vascular changes with age, gender difference and diabetes. The system may have applications for detection of amphetamine and other illegal drug abuse. The project is being funded by Melbourne based industry partner AI Pty Ltd.

Dr. John Fang initiated a new research project on the "Design of the optimised intra-ocular and extra-ocular wireless communication link for retinal prosthesis". Important aspects of this project include bandwidth analysis, small antenna design, power estimation and SAR simulation.

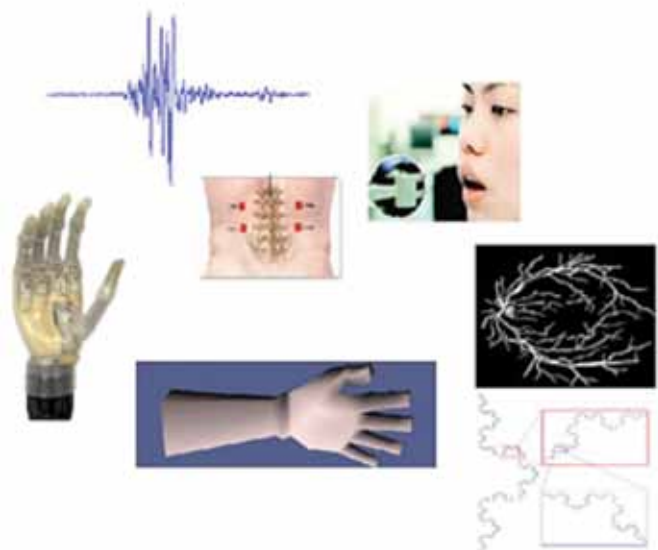
During 2009 the research group was visited by two distinguished international visitors. These were Professor Nitish Thakor from John Hopkins Medical Center and Editor in Chief of the IEEE Journal of Biomedical Engineering, and Professor Roberto Merletti, EU Professor for Biosignals and Editor of the Journal of Biosignals.

Dr. Margaret Lech continued her collaboration with psychologists from the ORYGEN Research Centre (Australia) and the Oregon Research Institute (USA) on engineering-based methods of detecting early symptoms of depression in adolescents based on speech and image analysis.

## STAFF:

Researchers in the Biomedical Electronics Group are:

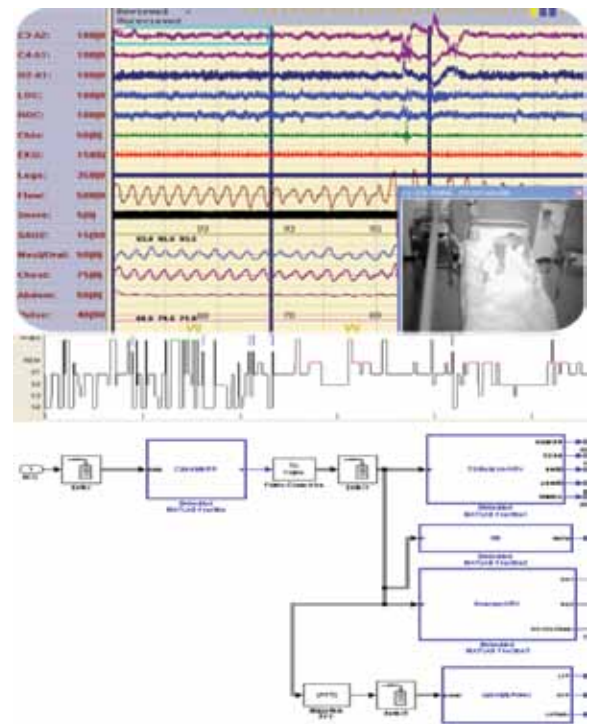
- Professor Irena Cosic – group leader
- Associate Professor Dinesh Kant Kumar (biomedical instrumentation, electrophysical signals)
- Dr. Dean Cvetkovic (bioelectromagnetics, sleep, neurofeedback)
- Dr. Qiang (John) Fang (biomedical electronics, bioinformatics, signal processing)
- Dr Margaret Lech (signal, image and speech processing)
- Dr. Elena Pirogova (biomolecular electronics)
- Dr. Vuk Vojisavljevic (biophysics)
- Dr. Sridhar Arjunan (Research Fellow)
- Dr. Ganesh Naik (Research Fellow)



## Sleep Research

Dr. Dean Cvetkovic is leading a team researching aspects of human sleep. The study of sleep is a research area of major interest worldwide. At RMIT, aspects of sleep currently being investigated include:

- Responses of human brain activity and real-time sleep onset detection for sleep induction which can measure and analyse EEG and ECG activity and depending on results, modify external stimuli such as lights, sounds and magnetic fields back to the human subject.
- The interaction between human EEGs and ECGs in order to classify healthy forms of sleep and depressive disorders.
- The development of automated sleep detection and the effects of auditory stimulation on sleep architecture.
- Effects of sleep offset (the process of waking up) on human mood states.



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## Electromagnetic radiation as a modulator of protein activity: therapeutic applications

The Biomedical Electronics group is leading the program “*Electromagnetism: biophysical modulators*” in RMIT’s Health Innovation Research Institute (HIRi).

To understand the possible health effects of electromagnetic radiation (EMR) we have to understand the underlying mechanisms of EMR bioeffects on living systems at all levels (in vitro and in vivo): molecules, cells, tissue and whole body exposure. These mechanisms can be elucidated by undertaking evidence based research in a laboratory environment to enable us to draw any scientifically valid conclusions on health outcomes.

Dr. Elena Pirogova is a project leader of two projects funded by the HIRi: “*Use of electromagnetic waves for wound healing*” and “*Protein activation via electromagnetic radiation*”. Current research activities are focused on:

- Modulation of protein activity using infra red and visible light, and low intensity microwaves
- Low intensity light therapy LED driver exposure system for cancer treatment
- Low Frequency (LF) electromagnetic field exposure system for promotion of wound healing
  - Anti-inflammatory peptides and electromagnetic radiation (EMR) for wound healing
  - *de novo* designed peptides and electromagnetic radiation (EMR) for cancer therapy



# Industrial Automation & Control Systems

Academic and research staff in the Industrial Automation & Control Systems research group are involved in a broad range of research projects which are funded by national competitive ARC Discovery and Linkage Grants, the Advanced Manufacturing CRC (AMCRC), the Automobile CRC and by our industrial partners.

Research areas include:

- Industrial automation
- Industrial decision support systems
- Integrated & intelligent control systems
- Intelligent control of manufacturing plants and processes
- Adaptive and distributed control systems

## HIGHLIGHTS:

In 2009, the group continued its participation in the Control Systems Program in the AMCRC. Led by Professor Liuping Wang, the research investigated the optimisation and advanced control of machine dynamics. There are three projects in the Control Systems Program: (1) real-time estimation of inertia parameters for optimisation of machine performance; (2) adaptive control of the start-up and stopping phases of a machine; and (3) automatic-tuning of control systems. The research was supported by key industry partners Australian Numerical Controls and Automation Pty Ltd (ANCA) and ANCAMotion.

Professor Xinghuo Yu was recently elected a Fellow of the Australian Computer Society. The citation read for “distinguished contribution to IT in Australia in the area of research into computer systems engineering and control systems technologies”.

Professor Xinghuo Yu was appointed Vice President (Planning and Development) of the IEEE Industrial Electronics Society (IEEE ES) for 2010 at the annual meeting of its governing body in November 2009.

Professor Yu was also named an IEEE Distinguished Lecturer for 2010/2011, recognising his leadership in his research field of intelligent and complex systems and in advancing new technical developments that shape the global community.

Professor Yu, with Professor Ross Broadfoot of QUT and Drs Roland Dodd and Andrew Chiou of CQU were awarded a Sugar Research and Development Corporation development grant for 2010-2012. This grant supports the implementation of a supervisory control system for sugar processing operations in sugar mills.

The system is based on an intelligent industrial decision support platform developed from a successful ARC Linkage Grant which investigated the implementation and commercialisation aspects of the technology.

In 2009, Professor Liuping Wang published a book titled “*Model Predictive Control System Design and Implementation Using MATLAB*”. The book presents improved methods for the design and implementation of Model Predictive Control (MPC) systems.

Professor Wang hosted an international workshop at RMIT in December 2009 on environmental modelling and control system design. The workshop had fifteen internationally renowned speakers from Europe, USA, New Zealand and Australia, and was well attended, with participants from RMIT, Melbourne University, ANU, UNSW, Victoria University and several other institutions in Australia. The workshop proceedings were published by Springer in a book entitled ‘*System identification, environmental modelling and control system design*’.

Professor Xinghuo Yu presented a paper at the First China-Australia ICT Summit which was held on 8 and 9 November, 2009 in Shanghai, China. The summit was aimed at advancing ICT research and promoting research collaboration between China and Australia. He was also invited to give a Distinguished Lecture at the 4th IEEE Conference on Industrial Electronics and Applications, Xi’an, 25-27 May 2009.

In September 2009, Professor Xinghuo Yu received a Chang Jiang (Chinese name for Yangtze River) Scholar award from the Ministry of Education in China. The Chang Jiang Scholar is a most prestigious award established by the Ministry of Education of China and the Li Ka-Shing Foundation (Hong Kong) to acknowledge outstanding contributions made by Chinese scientists and overseas scholars in various research fields. Following this award, Professor Yu has been appointed as a Chang Jiang Endowed Chair Professor (visiting) at South-East University, Nanjing, China, one of the major research universities in China, where he will make regular short term visits over the next three years.

## STAFF:

Researchers in the Industrial Automation & Control Systems Group are:

- Professor Liuping Wang (team leader)
- Professor Xinghuo Yu
- Professor Andrew Jennings
- Dr. Sven Dominka

- Dr. Yong Feng
- Dr. Peter Graszekiewicz
- Dr. Selva Moorthy
- Dr. Wei Peng
- Dr. Nguyen Vu Truong
- Dr. Thurai Vinay
- Dr. Bin Wang
- Dr. Alan Wong
- Dr. Hao Lan Zhang
- Mr. Christian van der Velden

## Control System I

The Control System I program in the Advanced Manufacturing CRC (AMCRC) began in October 2008 and was completed in December 2009. Led by Professor Liuping Wang, in collaboration with key industry partner Australian Numerical Controls and Automation Pty Ltd (ANCA) and its subsidiary ANCAMotion, the research program investigated three projects related to the control of machines.

### Inertia Control

Depending on the work piece, and whether a CNC machine is in a cutting or grinding mode, there will be a different wheel pack attached to a spindle motor which varies under different operating conditions. The control parameters of the CNC machine can be affected by a change of inertia of the wheel pack during the production process. The aim of this project was to investigate the automatic detection of inertia mismatch using control engineering techniques. A mathematical model based on a differential equation that captures the dynamics of a spindle motor is identified in real time as the first step to implement auto-adjust of the control parameters.

### Adaptive Start-Up and Stop

The response time of a machine during the start-up and stop phases is important in order to reduce manufacturing cycle time. The ANCA machines make frequent start and stop operations in their cutting or grinding processes. In order to increase production rate and reduce unnecessary energy consumption during the start-up and stop phases, it is desirable for the spindle motors to accelerate or decelerate to the desired operating conditions in a minimum time. In addition, in order to automate the process of wheel pack change, the spindle motor is required to align its angular position correctly, which translates to a stop position accuracy of 0.01-0.03°.

The aim of this project was to design and implement adaptive control of spindle motors during start-up and stopping. The control systems used were based on model predictive control which naturally exhibits the required functionalities of 'jerk-free' and smooth

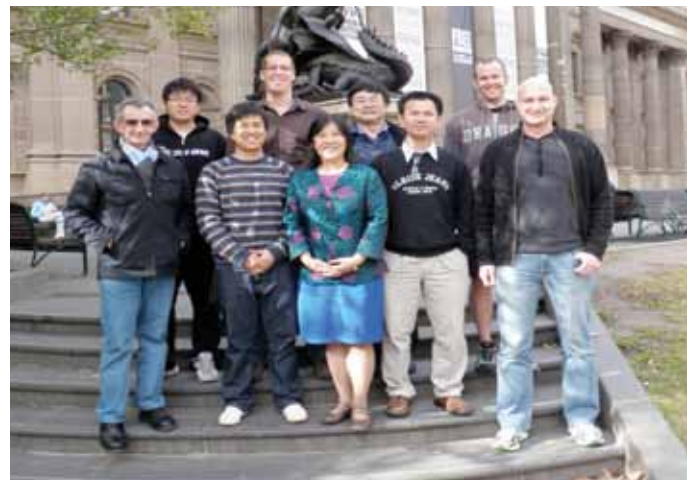
reference trajectory change. Hard constraints on the maximum and minimum torque current as well as the rate of change are imposed to ensure safe operation of the electronics and mechanics of the system. In the adaptive start-up process, the spindle motors operate in a specified constant torque at the very initial phase, followed by a high performance closed-loop control to the desired operating condition. In the adaptive stop process, the spindle motors are in closed-loop control, following a desired velocity trajectory to a low speed. In the very final moment of the stopping process, the spindle motor's angular position is sensed in a feedback operation to stop at the required position with the desired accuracy.

### Auto-Tuning of Controller

The aim of this project was to develop and implement auto-tuning algorithms for the velocity and position controllers in a spindle motor. In an auto-tuning mechanism, the system has two modes: the controller tuning mode and the controller-in-operation mode. An auto-tuning mechanism should be designed such that a smooth transition is guaranteed when switching from one mode to another, as a jerky transition can cause damage to the machine.

Aspects of the Inertial Control and Adaptive Start-up projects underpin the control auto-tuning mechanism. The controller architecture is based on the structure of a predictive control system, where smooth transition, reference signal filtering to avoid jerk and imposing operational constraints are embedded in a single framework. The control system performance is specified using either the bandwidth of the closed-loop system or the closed-loop response speed.

As well as delivering research outcomes, the Control System I program was also built around education and training, collaborations, innovation and building capabilities in control systems.



*Professor Liuping Wang (centre) and members of the Control Systems I research team.*

# Information & Signal Processing

Information and Signal Processing at RMIT is a research strength area of international standing. Research includes algorithms, architectures, design and implementation techniques relating to a range of information systems, visual communication systems, DSP and embedded systems.

Research areas include:

- Audiovisual signal and information processing
- DSP (digital signal processing) for communications
- DSP for biomedical engineering and applications
- Multimedia content description and semantics
- Speech/image/video signal recognition and understanding
- Embedded and reconfigurable DSP systems

The group's research activities are aligned with those of the Security and Safety research program in RMIT's **Platform Technologies Research Institute**.

## HIGHLIGHTS:

In 2009, Professor Ian Burnett and Dr. Christian Ritz (University of Wollongong) were awarded an ARC Discovery Grant (DP1094053, \$210,000, 2010-2012) titled "*Encoding and Communicating Navigable Soundfields*". A succinct summary of this project is as follows. "While sound recording is commonplace, it is not currently practical to completely record a sound space such that the experience can be reproduced at a chosen 'listening point'. This is a significant restriction for audio applications in the entertainment, surveillance and virtual/mixed reality areas. The project will research novel and practical solutions to this problem and offers a significant conceptual advance in the transmission of complex audio scenes. This project will build fundamental new technology and IP for Australia in the digital media and audio space, one of the fastest growing sectors of our economy".

In May 2009, Professor Henry Wu, jointly with Professor K. R. Rao of the University of Texas at Arlington, conducted a half-day tutorial on *Digital Video Image Quality and Perceptual Coding* at the 2009 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP 2009), in Taipei, Taiwan.

On a research collaboration and exchange project, Professor Henry Wu was invited to visit the research team led by Professor Weisi Lin, School of Computer Engineering, Nanyang Technological University in September 2009. He presented two research seminars on *Perceptual Digital Picture Coding* and *Robust*

*Statistical Temporal Filtering for Temporal Fluctuation Artifact Reduction*, respectively.

Professor Henry Wu visited Xidian University, China, in October 2009, and presented a talk on *Robust Statistical Temporal Filtering for Temporal Fluctuation Artifact Reduction*, as a core member and guest professor of the National 111 Programme on Fundamental Theory and Technology of Modern Wireless Information Networks funded by the Ministry of Education, China.

The Group's Visual Communications Engineering Research Laboratory acquired a TRUE3Di 3-D display monitor to support further research and development in perceptual image and video coding and compression.

PhD candidate Mr. Jie Xiang Yang visited the Tampere International Center for Signal Processing (TICSP) at the Tampere University of Technology (Finland) on an international exchange programme as part of his PhD research. Mr. Yang presented two research seminars at TICSP and the Nokia Research Center in Tampere, Finland.

## STAFF:

Researchers in the Information and Signal Processing Group are:

- Professor Hong Ren (Henry) Wu
- Professor Ian Burnett
- Professor Xinghuo Yu
- Assoc. Professor Zahir Hussain
- Dr. Paul Beckett
- Dr. Namunu Maddage
- Dr. Damian Tan
- Dr. Jidong Wang
- Dr. Zhengya (Yale) Xu



TRUE3Di 3-D Display, Courtesy of TRUE3Di

# Micro/Nanoelectronics & Sensor Technology

Research in Micro/Nanoelectronics and Sensor Technology is one of the School's major research activities and is of international standing. This research is primarily undertaken in the School's Microelectronics and Materials Technology Centre (MMTC). Much of the research undertaken by the group is aligned with that undertaken in RMIT's **Platform Technologies Research Institute**.

Research areas in Micro/Nanoelectronics & Sensor Technology include:

- Modelling and simulation of electronic materials and devices
- Modelling of electronic and optical phenomena in nano-structures
- Novel fabrication technologies
- Surface acoustic wave based liquid, gas and biosensors
- MOS based gas sensors
- Nano-structured thin films
- Nanotechnology enabled fuel cells

## HIGHLIGHTS:

In 2009, Associate Professor Kourosh Kalantar-zadeh and Dr Anthony Holland spent time overseas as part of their RMIT Research Leave Awards. During the final quarter of 2009, Kourosh spent six weeks at the University of California, Los Angeles (UCLA) before moving on to the Massachusetts Institute of Technology (MIT) in Boston, USA. At UCLA, Kourosh worked with Prof. Richard Kaner on the development of atomically thin metal oxides, using the novel idea of mechanical exfoliation.

At MIT, Kourosh enjoyed the opportunity to work with Prof. Michael Strano on a new class of thermopower systems. These are carbon nanotube based devices wrapped in a combustive material which can generate exceedingly large energy rates, which are stored in relatively small volumes.

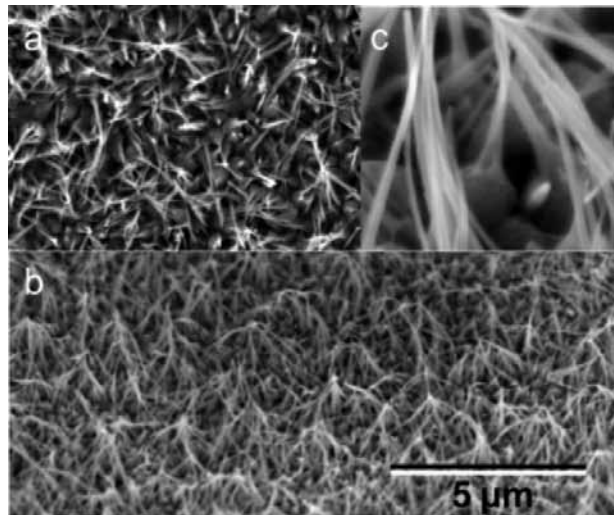
In 2009, Dr. Anthony Holland was awarded an RMIT Research Leave award. During semester 2 he visited Trinity College Dublin, where he worked with Dr. Tatiana Perova, and Queens University Belfast, where he worked with Professor Mervyn Armstrong. Anthony's collaborative research is in the area of germanium semiconductor devices.

A new area of collaborative research in the School is the use of dielectrophoretic forces to manipulate micro/nano particles. Associate Professor Kourosh Kalantar-zadeh and Professor Arnan Mitchell are investigating the development of microfluidic systems for the separation of nanoparticles.

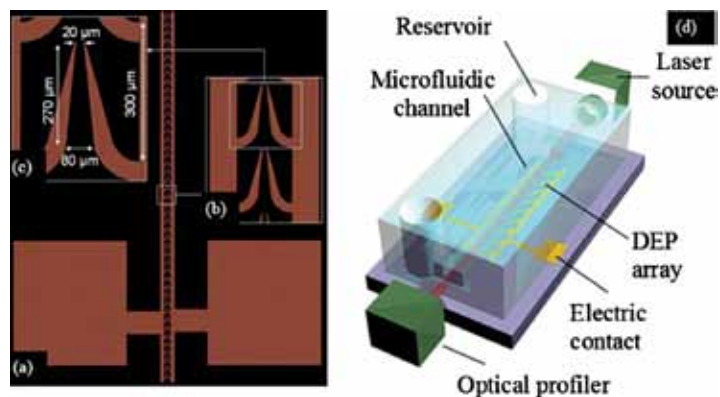
## STAFF:

Researchers in the Micro/Nanoelectronics and Sensor Technology Group are:

- Assoc. Professor Kourosh Kalantar-zadeh (Group Leader)
- Professor Alireza Baghai-Wadji
- Professor Wojtek Wlodarski
- Dr. Anthony Holland
- Dr. Glenn Matthews



ZnO thin film made of nanowires.

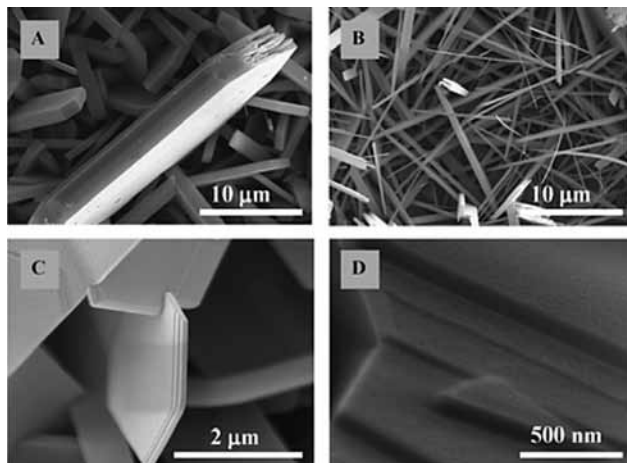


Schematic of a microfluidic system using curved dielectrophoretic electrodes.

## Synthesis of Nanostructures

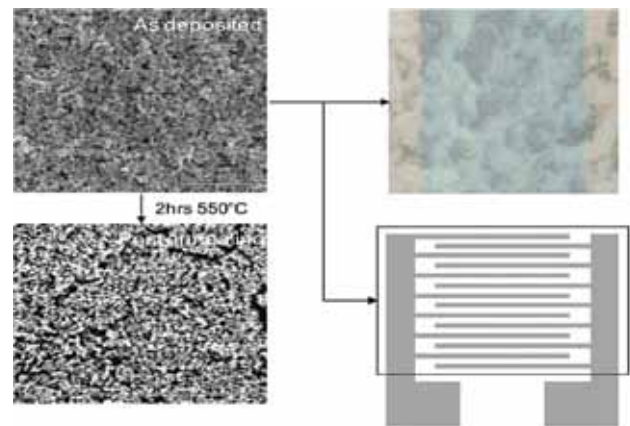
An area of on-going research by this research group is the synthesis of nanostructures for various applications including sensors and electronic devices. Led by Associate Professor Kourosh Kalantar-zadeh, the group is investigating the fabrication of different nanostructured materials, such as the metal oxides ZnO, MoO<sub>3</sub> and WO<sub>3</sub>, by various techniques including anodisation and mechanical exfoliation.

An example of this work is the fabrication of atomically thick metal oxide sheets. Sheets of MoO<sub>3</sub> of nanoscale thickness have been formed from several fundamental sheets of orthorhombic MoO<sub>3</sub>, which can be processed in large quantities via a low cost synthesis route that combines thermal evaporation and mechanical exfoliation. These fundamental sheets consist of double-layers of linked distorted MoO<sub>6</sub> octahedra. Atomic force microscopy (AFM) measurements show that the minimum resolvable thickness of these sheets is 1.4 nm.



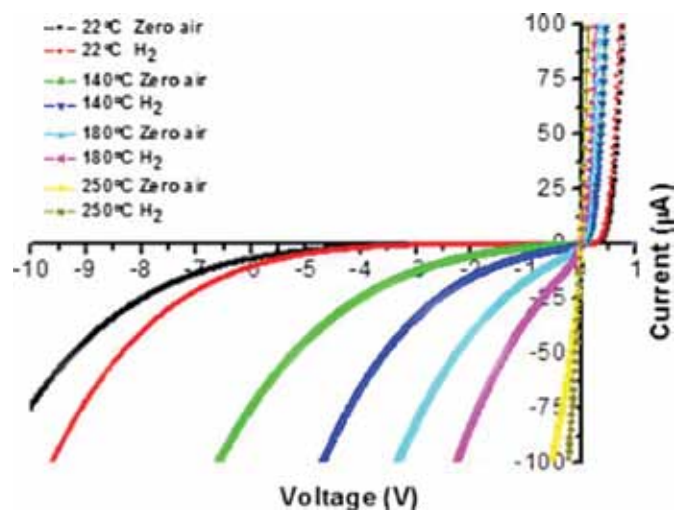
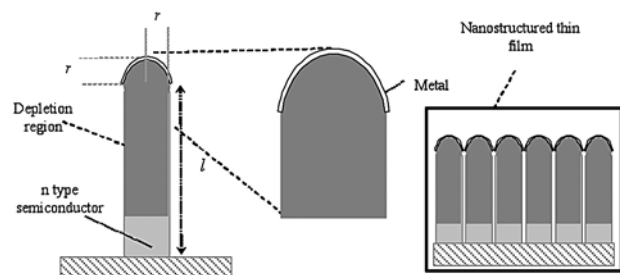
MoO<sub>3</sub> sheets of nanoscale thickness.

One application area of these nanostructured materials is thin film sensors. The School's Sensor Technology Laboratory was established over 20 years ago and is led by Professor Wojtek Wlodarski. The focus of the sensor research activities is the development of biochemical, chemical and gas sensors. An example of this work is the development of a nanostructured thin film hydrogen sensor, as shown below.



A H<sub>2</sub> sensor based on a WO<sub>3</sub> nanostructured thin film.

The study of ohmic and Schottky contacts is also an area of ongoing research by this research group. Dr. Anthony Holland, Professor Wojtek Wlodarski and Associate Professor Kourosh Kalantar-zadeh are currently involved in the study of such contacts using epitaxially grown films and nanostructured layers.



Example of a nanostructured Schottky contact and its I-V curves at different temperatures.

## Microplatforms

The Microplatforms research group aims to create new technology platforms by exploiting the current revolution in accessible microtechnology in order to enable fundamental research across all fields of science, to achieve breakthroughs in important problems, and to harness discoveries in order to create practical new technologies. The Group is a highly integrated team of engineers with expertise spanning photonics, fluidics, sensors, advanced materials, micro- and nano-technologies, electronics and control. Our microplatforms enable fundamental research in physics, chemistry and biomedicine.

Much of the Microplatforms research is undertaken using the facilities of the School's Microelectronics and Materials Technology Centre and is aligned with Nano Materials and Devices research program in RMIT's **Platform Technologies Research Institute**.

The Microplatforms Group comprises six sub-groups:

- Integrated Optics
- Lab-on-a-Chip Technology
- Nanotechnology Enabled Devices
- Fundamental Materials and Microsystems
- RF Microplatforms
- Sensors

Current research areas include:

- silicon photonic devices
- nonlinear photonic devices
- fluid infiltrated optical waveguides
- nano-imprinted sensors
- microfluidic systems
- piezoelectric materials for energy scavenging
- novel thin film synthesis

### HIGHLIGHTS:

In 2009, Professor Arnan Mitchell, Dr. Thach Nguyen and Professor Tom Koch (Lehigh University, USA) were awarded an ARC Discovery Grant (2010-2013, \$300,000) for a project on *novel silicon photonic devices harnessing new leakage behaviour*. Dr. Nguyen has been appointed an ARC Postdoctoral Fellow as part of this project on silicon photonic integrated optics. He aims to establish RMIT as a national leader in the emerging field of silicon photonics.

Dr. Madhu Bhaskaran was awarded an ARC Discovery Grant (2010-2012, \$305,000) for a project on *Complementary metal-oxide-semiconductor (CMOS) compatible ultra-high response piezoelectric thin films for efficient energy harvesting*. She has been appointed as an

ARC Postdoctoral Fellow as part of this project on micro-technologies and materials science for energy scavenging.

Dr. Bhaskaran was also awarded an RMIT Emerging Researcher Grant. She will use the funding awarded to develop high performance piezoelectric thin films which are capable of reversible transduction of mechanical and electrical energy. Significantly enhanced piezoelectric performance of the thin films will enable new scientific insight and the creation of a platform for the exploration of applications in nano-sensors, nonlinear optical devices and micro-power energy harvesting modules.

Professor Arnan Mitchell, Dr. Thach Nguyen and Dr. Madhu Bhaskaran, together with commercial Partner Investigator Mr. Neil Baker from QuintessenceLabs, were awarded an ARC Linkage Grant (2010-2012, \$279,215) to develop a silicon photonic platform for quantum encryption and communications. The aim of this work is to reduce the size and cost of a cryptosystem.

Dr Sharath Sriram was awarded the 'Gold Medal for Excellence in Research' in 2009 by the Australian Institute of Nuclear Science and Engineering (AINSE) in recognition of the exceptional contribution he made during his PhD studies at RMIT University. Dr Sriram has been re-appointed for 2010 as a research fellow in the School of Electrical and Computer Engineering.

During 2009, researchers in the group commenced a Defence funded project led by BAE Systems to investigate the development of novel photonic microwave filters based on Bragg gratings in planar silica waveguides. Gratings were successfully written in silica waveguides and the detection of an RF signal modulated on an optical carrier was demonstrated.

### STAFF:

Researchers in the Microplatforms Group are:

- Professor Arnan Mitchell (Group Leader).
- Professor Michael Austin
- Professor Wojtek Wlodarski
- A/Professor Kourosh Kalantar-zadeh
- Dr. Madhu Bhaskaran
- Dr. Lam Bui
- Dr. Gorgi Kostovski
- Dr. Thach Nguyen
- Dr. Wayne Rowe
- Dr. Vijay Sivan
- Dr. Sharath Sriram
- Dr. Dingke Zhang

## Lab on a Chip Work with the Australian Centre for Blood Diseases.

Professor Arnan Mitchell and PhD student Francisco Tovar-Lopez are working in close collaboration with biomedical researchers Professor Shaun Jackson and Dr. Warwick Nesbitt at the Australian Centre for Blood Diseases (ACBD) at Monash University to develop a “lab on a chip” device to study platelet aggregation at the micrometer cellular scale. This world-first, micro-fluidic device mimics the effects of pathological changes in blood vessel geometry of micro arteries, and provides laminar flow and specific dynamic shear rates under controlled conditions.

In the past, the mechanisms of why blood platelets aggregate have not been well understood. Adequate aggregation of platelets at the right time in the right location can efficiently stop bleeding, however an abnormal response in the arteries supplying blood to the brain or heart can lead to stroke, one of the leading causes of deaths in Australia. By better understanding the exact mechanisms of platelet aggregation, more effective antithrombotic drugs and new devices to detect platelet defects can be developed.

Using the RMIT-developed micro-fluidic device, a research team at the Australian Centre for Blood Diseases was able to prove a new link between disturbed blood flow and blood clotting, in a major breakthrough that will impact on the treatment and prevention of heart disease and stroke. The research has helped researchers understand why current anti-clotting drugs do not always work.

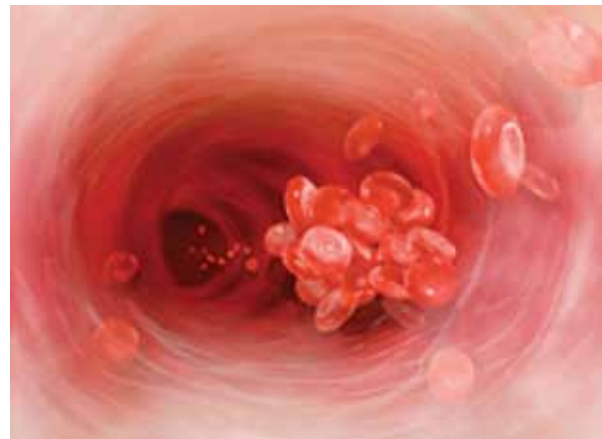
The RMIT device contains tiny microfluidic channels, each the width of a human hair, specially shaped to place blood under mechanical stress. Prof. Mitchell, who created the device with PhD student Francisco Tovar-Lopez, says the device mimicks the shape of damaged or diseased blood vessels, while allowing precise control and monitoring of blood flow.

“The aim of this research is to recreate the specific micrometer scale fluidic conditions to initiate and sustain platelet aggregation”, said Professor Mitchell. “Using this platform we can study platelet aggregation in whole blood, under the action of specific drugs, or even study specific platelets defects. Biologists are excited by this technology as it is simple and reproducible. The ability to simplify the dynamic stress environment through micro-engineering enables the study of cell response mechanisms that simply cannot be observed in isolation using macroscopic scale systems”.

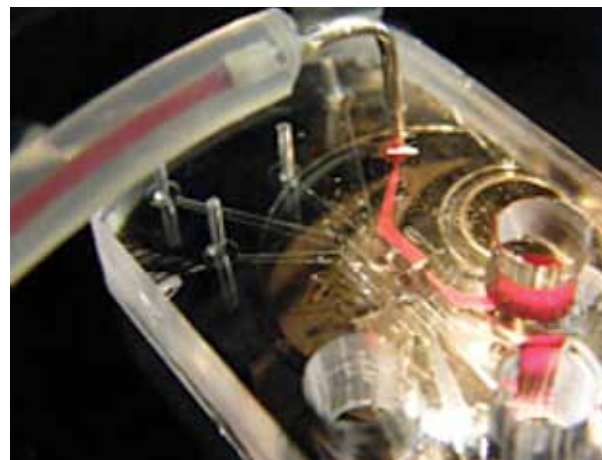
PhD student Francisco Tovar obtained a mechanical engineering degree at the National University of Mexico (UNAM). He has expertise in the theory of Computational Fluid Dynamics, the experimental observation of flows using micro-particle image velocimetry and creation of lab-on-a-chip platforms using micro-fabrication. Through this diverse range of background and skills he spans the gap between biomedical research at the ACBD, Monash and microengineering at the MMTC, RMIT.

“This research is right at the core of what we do at the Platform Technologies Research Institute,” Prof. Mitchell said. “Our aim is to engineer platforms that enable researchers to make fundamental discoveries, making what scientists dream of doing a practical reality”.

This exciting research was published in the prestigious *Nature Medicine* journal in June, 2009.



*An RMIT platform technology enabled researchers to make a fundamental discovery about how blood clots form. Image © istockphoto*



*The micro device mimics the shape of damaged or diseased blood vessels.*

# RF and Antennas

Our School has a long history of research in the area of RF Engineering. Currently there are three main research areas of interest to this group; RF devices and circuits, antennas, and microwave photonics. This research is undertaken using the facilities of the School's microwave laboratory, anechoic chamber and the Microelectronics and Materials Technology Centre and is aligned with that undertaken in RMIT's **Platform Technologies Research Institute**.

Current research areas include:

- Tunable RF devices using barium strontium titanate (BST)
- Tunable metamaterials for antenna applications
- Embedded antenna technology in smart polymeric composite structures
- Low profile broadband spiral antennas
- Slotted waveguide antennas in stiffened structures
- High dynamic range photonic links
- Photonic microwave filters
- Microwave photonic signal processing
- Detection of partial discharges in high voltage insulators

## HIGHLIGHTS:

During 2009, Dr. Wayne Rowe and Dr. Alan Wong continued work on an ARC Discovery Grant project which aims to develop a novel technique for the detection of partial discharges resulting from failing high voltage insulators on power lines. The project involves theoretical, computational and experimental methods to investigate the initiation and the dynamics of partial discharges in high voltage insulators and to explore the propagation of radiation which results from an electrical discharge along the power line. The radiating characteristics of a power line in the presence of electrical faults are being studied and advanced electromagnetic techniques have been devised for pre-fault detection.

Historically, the addition of antennas to vehicles for radar and communications has led to a loss of vehicular performance through increased wind loading and weight. In a project funded by Australia's Defence Science and Technology Organisation, Associate Professor Kamran Ghorbani is investigating the integration of high gain antennas into existing vehicle components so that there is no compromise in performance. As a starting point, conventional panel hat stiffeners are being used as waveguides to feed moderate scale planar array antennas.

Work continued on several aspects of nonlinear microwave photonic signal processing during 2009. This research was undertaken as part of CUDOS, the *ARC Centre of Excellence for Ultrahigh bandwidth*

*Devices for Optical Systems*. A major project was the further development of a novel microwave photonic instantaneous frequency measurement system.

Associate Professor Kamran Ghorbani is leading an ARC Linkage Grant project with CME which is embedding Global Positioning Satellite (GPS) reception technology in polymeric composite materials to be deployed in automobiles. The aim of the project is to develop a manufacturing technique which will enable the integration of patch antennas and wireless communication technologies in a composite material.

An ARC Linkage Grant project with BAE Systems is investigating the design of a broadband 'photonic antenna' for airborne radar warning and electronic countermeasure systems. The project involves the development of a suite of printed antennas which cover frequency bands in the 2-40 GHz range and are which are fabricated on a single substrate. Nesting of these antennas to reduce system size and integration of this module with a custom optical modulator array and RF signal combiner will be investigated. The resulting broadband antenna suite with photonic interconnect will require minimal fabrication and packaging resources, and will thus be an economically viable photonic solution for practical defence systems.

During 2009, researchers in the group commenced a Defence funded project led by BAE Systems to investigate the development of novel photonic microwave filters based on Bragg gratings written in planar silica waveguides. Bragg grating filters were successfully written in waveguides and microwave filtering demonstrated. This work was part of a larger project investigating the development of advanced microwave receiver modules using photonics technology.

In October 2009, Professor Arnan Mitchell and Dr. Lam Bui visited Professor Bahram Jalali at UCLA (USA). Professor Jalali is a world leader in the field of photonic signal processing.

## STAFF:

Researchers in the RF and Antennas Group are:

- A/Professor Kamran Ghorbani (Group Leader)
- Professor Michael Austin
- Professor Arnan Mitchell
- A/Prof. James Scott
- Dr. Wayne Rowe
- Dr. Lam Bui
- Dr. Derek Gray
- Dr. Amir Galehdar
- Dr. Alexe Bojovschi

## Engineering Education

The School of Electrical and Computer Engineering has an increasing research effort in the field of Engineering Education. Three of our staff received highly competitive Australian Learning and Teaching Council Awards in the 2009 round of the Australian Awards for University Teaching:

Associate Professor Iouri Belski received an Award for Teaching Excellence in the field of Physical Sciences and Related Studies (\$25,000). Teaching Awards celebrate a group of the nation's most outstanding university teachers in their fields. Teaching Awards give recognition to teachers renowned for the excellence of their teaching, who have outstanding presentation skills and who have made a broad and deep contribution to enhancing the quality of learning and teaching in higher education.

Dr. Peter Burton and Dr. Mark Gregory both received Citations for Outstanding Contributions to Student Learning. These awards recognise and reward the contributions that individuals and teams make to the quality of student learning. They are awarded to staff who have made significant contributions to student learning in a specific area over a sustained period. These awards are worth \$10,000.

Dr. Peter Burton's Citation read "For the development of quasi interactive videos and the sustained and innovative use of multimedia technology in teaching engineering, providing students with individualised learning opportunities".

Dr. Mark Gregory's Citation read "For sustained commitment to the innovative application of educational technology and the introduction of an engineering stream providing graduates to support the global digital network".



*Associate Professor Iouri Belski receiving his award from Deputy Prime Minister Julia Gillard.*

# 2009 School Seed Projects

## INTRODUCTION

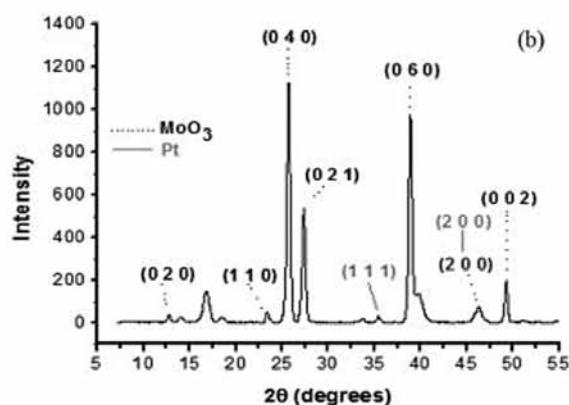
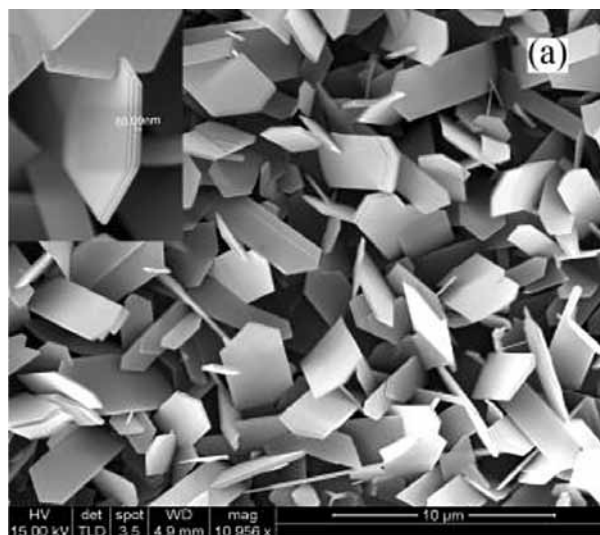
In the latter part of 2009, the School awarded six Seed research grants to School researchers for new and imaginative research projects. The six successful projects, each worth \$25,000, were selected on a competitive basis. A brief summary of each of these projects is given here.

### Highly efficient dye sensitized solar cells based on nanostructured $\text{WO}_3$ films

*Project Investigators:* Professor Wojtek Wlodarski, Dr Abu Zafar Sadek, A/Professor Kourosh Kalantar-zadeh, Dr. Vipul Bansal (School of Applied Sciences) and Dr. Kay Latham (School of Applied Sciences).

In this project, the synthesis of  $\text{ZnO}$ ,  $\text{MoO}_3$  and  $\text{WO}_3$  nanostructures was investigated and their use in hetero-junctions and in liquid media was studied. The project had several successful outcomes, including several journal papers and a strengthening of the collaboration between the SECE research group and RMIT's School of Applied Sciences (Chemistry). This collaboration has resulted in two joint ARC Discovery Grant applications, one ARC Linkage Grant application and one ARC LIEF Grant application.

Part of the project funding was used to support five summer scholarships for potential PhD students. Significantly, four of the five summer scholarship students decided to continue their studies as PhD students in SECE. The use of summer scholarship funding was thus seen as a good investment for future research.



$\text{MoO}_3$  sheets of nanoscale thickness.

## Sub-half-micron Schottky Source/Drain contacts for MOSFETs using Germanium-on-Sapphire substrates

*Project Investigators:* Dr. Anthony Holland, Assoc. Professor James Scott, Dr Paul Beckett, Assoc. Professor Geoff Reeves, Dr. Jim Partridge (School of Applied Sciences), Dr. Sasikaran Kandasamy (Melbourne Centre for Nanofabrication), Prof. H. Gamble (Queens University Belfast) and Dr. Tatiana Perova (Trinity College Dublin).

In this project, the semiconductor material germanium was investigated as a new research area for RMIT's School of Electrical and Computer Engineering. Germanium wafers were purchased and investigations were undertaken into the formation of germanides by reacting nickel with germanium and platinum with germanium. Dr. Vijay Sivan, a Post-Doctoral Fellow, was employed to establish the procedure for forming sub-micron features using electron-beam lithography. Figure 1 shows examples of features formed using electron-beam lithography. This procedure will continue to be used for forming sub-micron contacts to germanium for electrical testing and for application to other semiconductor devices.

Other activities at RMIT have been the deposition of different metals on germanium and annealing to form contacts. Some germanium samples have been sent to the Australian National University for amorphisation by germanium ion implantation into germanium crystals. This leads to better contact formation. The regrowth of germanium by solid phase epitaxy for forming good contacts after amorphisation has also been studied. This work has resulted in an Invited paper to be presented at the Electrochemical Society's High Purity Silicon XI Symposium to be held in Las Vegas, Nevada, USA, in October 2010. This paper is titled "**Recent insights into solid phase epitaxy of silicon and germanium**" by Brett Johnson, Jeff McCallum, Anthony Holland, Sasikaran Kandasamy and Nikolas Stavrias.

Colleagues from Queens University Belfast have sent germanium samples for analysis at RMIT. These samples are being tested for defects that cause poor contacts. The results from these and other tests will be presented as journal papers.

Another outcome of this Seed Grant project is a joint ARC Discovery Grant submission titled "*Fundamental materials and processing studies to support development of advanced germanium devices*". The investigators on this grant application are from RMIT, The University of Melbourne, Queens University Belfast and Trinity College Dublin.

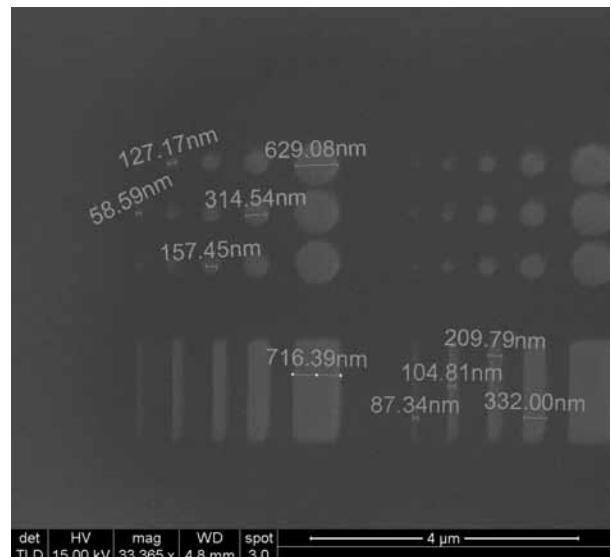
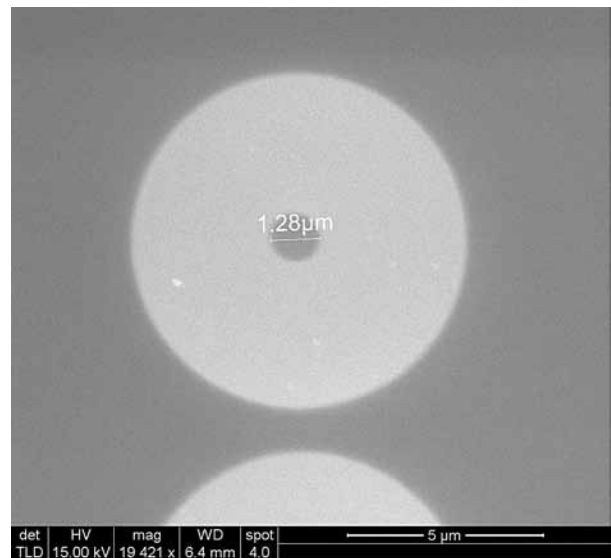


Figure 1 (a) large contact features and (b) sub-micron contact features formed using electron-beam lithography for this project.

## Pneumatic Metamaterials: Microfluidics meets Microwaves

*Project Investigators:* Professor Arnan Mitchell, Dr. Wayne Rowe, Dr. Sharath Sriram, and Dr. Madhu Bhaskaran

Reconfigurable circuits offer great opportunities for adaptable radio frequency systems. This is particularly important for electronic warfare where it is desirable to shift the resonances of the antennas on radar systems to hide them when not in use. The ultimate vision for tuneable RF structures is metamaterials for 'cloaking' where the electromagnetic response of a surface can be adapted to the environment much like a chameleon changes colour to camouflage itself. The most common methods for tuning RF structures are electronic. This is problematic as the electrical connections to the RF structure have their own RF signature which limits the application to metamaterials. In this project we have explored the use of pneumatic tuning; where air pressure can change the electronic structure without electronic control.

The project has focussed on the creation of metal structures on flexible substrates. We have developed a high yield method of creating electrodes on the material 'PDMS', a rubbery material similar to silicone sealant which is commonly used for microfluidic devices. This is an ideal platform for pneumatic control at the microscale. We have also realised a 'fishnet' metamaterial on traditional flexible printed circuit board and used this to successfully demonstrate the world's first pneumatically tuned metamaterial structure.

## Energy Harvesting Solar and Piezoelectric Micro-Devices

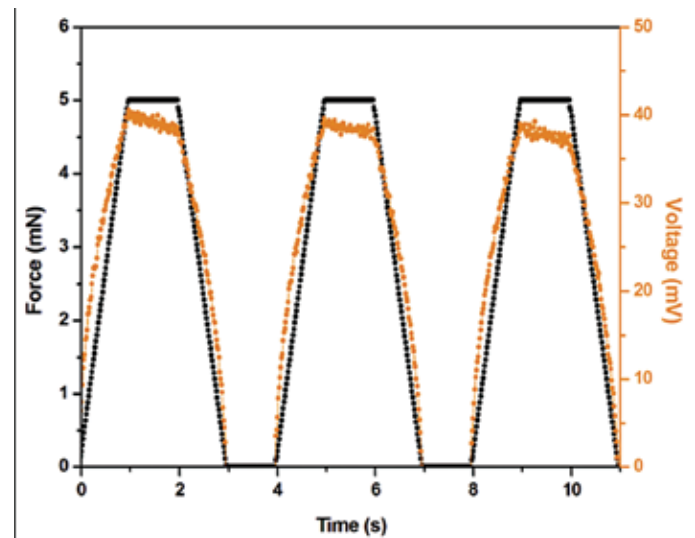
*Project Investigators:* Professor Arnan Mitchell, Associate Professor Kouros Kalandar-zadeh, Dr. Madhu Bhaskaran and Dr. Sharath Sriram

This project aimed to deliver energy harvesting platforms with a focus on solar and piezoelectric micro-devices. The long term vision of the project was to create a micro-turbine using the same techniques used to create microelectronics circuits, and couple this mechanically to the environment for example by extracting energy from convection water currents in solar hot water heaters.

With the announcement of the success of ARC Discovery Project (DP1092717) on piezoelectric energy harvesting micro-devices, this seed project focussed on the creation of a research platform in this area. Research outcomes obtained included the successful engineering of piezoelectric thin films with enhanced response and the first quantitative experimental demonstration of piezoelectric energy harvesting. This project has produced two ERA A ranked publications [1,2] however the major outcomes are still being finalised for a very high profile publication. As envisaged, this seed grant has created the platform for a concerted research effort over the next 5-10 years into alternative and 'smart' energy micro-technologies within the School.

1. S. Sriram, M. Bhaskaran, D. R. G. Mitchell, and A. Mitchell, "Lattice guiding for low temperature crystallization of rhombohedral perovskite-structured oxide thin films", *Crystal Growth & Design*, vol. 10, no. 2, pp. 761-764 (2010).

2. S. Sriram, M. Bhaskaran, and A. Mitchell, "Low-temperature deposition of high-response piezoelectric thin films", *Scripta Materialia*, vol. 63, no. 2, pp. 189-191 (2010).



Repeatable voltage generation from a piezoelectric thin film on application of a force.

## Lab-on-a-Chip Initiatives

*Project Investigators:* Prof. Arnan Mitchell and A/Prof. Kourosh Kalantar-zadeh

This project aimed to extend the lab-on-a-chip capabilities of the Microplatforms research group by pursuing three major research collaborations with external researchers in biomedical fields. The aims and outcomes of three projects are as follows:

**Lab-on-a-chip platform for monitoring and manipulating live muscle fibres:** Research on muscle fibres is important to understand the physiology of diseases such as muscular dystrophy and also certain aspects of chronic diabetes. Traditional research is conducted on freshly killed rats, separating the fibres from muscles and then attaching them to silk threads so that they can be transported to a microscope, manipulated (stretched), exposed to various chemicals (such as glucose) and measuring their contraction and relaxation both optically and mechanically. The issue with this traditional approach is that the muscles fibres degrade rapidly, particularly when exposed to air, and the attachment of the silk thread and subsequent manipulation requires a highly skilled technician to work quickly. This means that only a few fibres can be successfully harvested from any subject.

We have developed a microfluidic chip that can be used to capture the fibres directly from the muscles without exposing them to fluid and introduce them into a micro-scale fluidic cavity on a microscope slide. This has improved both the speed and the success rate of muscle fibre capture. We are currently exploring the introduction of pneumatic valves to these chips in order to immobilise, mechanically strain and monitor the expansion and contraction of muscle fibres. This project will form the basis of a PhD project in 2011 and will also be the subject of an NHMRC development grant application in 2010.

**Observation of Malaria Parasite Infection:** The Malaria parasite invades red blood cells and destroys them in the process of reproduction. The parasite cannot move itself, but instead relies on the fluid dynamic environment of blood flow to carry it through the blood stream and allow it to impact a host blood cell. The fundamental nature of fluid mechanics of mixing micron scale particles is thus critical to understanding how malaria infection propagates. This project aims to create a microfluidic platform for studying the mixing and controlling the flow of micron scale particles and can produce predictable and repeatable impacts between small parasite sized particles

and large red blood cell sized particles in a region where high resolution optical observation is possible. We have succeeded in producing such a mixing platform and are currently testing these platforms at the Walter and Eliza Hall Institute (WEHI). It is anticipated that results will be published by the end of 2010 and that this will follow on to become a PhD project in 2011.

**Microfluidic model to the blood brain barrier:**

Blood flow carries nutrients to the brain however it is important that only nutrients pass into the brain as blood itself can cause brain damage. It is important thus to be able to study the nature of the blood brain barrier. This is hard to study in-vivo, and so many in-vitro models have been developed. Most of these are conducted under static conditions in petri-dishes. It is hypothesised that blood flow plays an important role in the formation and maintenance of the blood-brain barrier and the transport of nutrients across this barrier. We have developed a model of the blood brain barrier which consists of two fluidic channels separated by a perforated membrane. This platform allows blood to flow through one channel while endothelial (brain) cells are seeded from the other channel. The two flows can communicate through the membrane without allowing the blood to pass through. This platform has been successfully realised and is currently undergoing biological testing at the Australian Centre for Blood Diseases (ACBD). We have been successful in receiving seed funding from Monash University to support this work in 2010 and it is anticipated that biological results will be published by the end of 2010. This work will form the basis of an NHMRC project grant for submission in early 2011.

## High-Speed High-Capacity Networks for Inter- and Intra-Chip Communications

*Project Investigators:* A/Prof. James Scott, Prof. Mike Austin, Prof. Arnan Mitchell, A/Prof. Kamran Ghorbani, Dr. Wayne Rowe and Dr. Paul Beckett

Silicon semiconductor fabrication technology is now capable of producing devices with nanometre-scale feature sizes. This has led to a substantial increase in processor speed and complexity. Further improvements in performance have, however, come up against a barrier: the delay caused by the electrical connections inside the chip. Electrical connection delays are now exceeding gate delays and are a major limiting factor to the development of more complex processors [1]. A related restriction is the space taken up by these electrical connections. The space and power requirements of these electrical connections also impose limitations on further integration.

The aim of this project was to conduct a thorough literature review and analysis of the state-of-the-art in both inter- and intra-chip communication techniques. Particular attention was paid to optical and RF (wireless) techniques, with a view to a very high performance solution which can be scaled to high levels of chip and system complexity.

The project funded a Research Fellow, Dr. Conrad Jacob, to assist with the literature survey.

Guided RF connection systems were investigated and compared with free-space interconnects, comprising integrated antennas. Free-space interconnects open the possibility of board area networks, where individual cores within a chip, multiple chips and printed circuit boards can connect and communicate with each other without “hard” interfacing using edge connectors or cables. The design of such interconnects is very similar to the design of communication channels, where propagation characteristics, noise and interference must be taken into account. The free-space interconnects allow a degree of freedom not possible with guided connection systems.

The other approach which was investigated uses integrated optical devices within a chip to communicate over intra- and inter-chip distances. This approach offers immense advantages for future large-scale integration. Effectively using the wide bandwidths of optical channels would provide enough communication capacity for tomorrow’s devices to continue scaling to smaller dimensions and higher complexity.

However, there are several disadvantages to optical interconnects. For example, there is a high conversion overhead for electro-optical and opto-electronic conversions, and components are also susceptible to thermal drift. The fabrication cost of implementing many, shorter interconnects is prohibitive when compared to the much simpler and cheaper metal interconnects.

The major outcome of the project was a report which details the current state-of-the-art in RF and optical interconnects, and which makes a large number of recommendations that could form the basis of a series of future PhD thesis topics.

1. *The International Technology Roadmap for Semiconductors, 2008 Update Overview*, Semiconductor Industry Association, 2008.

## 2009 Research Thesis Submissions

Name	PhD / MEng	Senior Supervisor	Thesis Title
Khaizuran Abdullah	PhD	A/Prof. Zahir Hussain	Interference Mitigation Techniques for Wireless OFDM
Himanshu Agrawal	PhD	Prof. Andrew Jennings	Robust Routing under Dynamic Traffic Demands
Noura Al-Hinai	PhD	A/Prof. Zahir Hussain	Transmission of Compressed Images over Power Line Channel
Rashidah Arsat	PhD	Prof. Wojtek Wlodarski	Investigation of Nanostructured Thin Films on Surface Acoustic Wave and Conductometric Transducers for Gas Sensing Applications
Jianguo Cao	MEng	Dr. Mark Gregory	An E-Model Implementation for VoIP QoS across a Hybrid UMTS Network
Howard D'Costa	PhD	Prof. Irena Cosic	Influence of Mobile Phone Electromagnetic Field Exposures on Nervous Function in the Human Brain and Heart
Surendran Devadoss	MEng	Dr. Thurai Vinay	Optimization and Characterization of a Thin MEMS Micro Generator
Deepak Dhawan	PhD	A/Prof. Kouresh Kalanter-zadeh	Development of acoustic wave sensors for continuous monitoring of mercury vapour in an alumina refinery
Roland Dodd	PhD	Prof. Xinghuo Yu	A Knowledge Based Supervisory Support System for Pan Stage Operations in a Sugar Mill
Alexandru Fechetete	PhD	Prof. Wojtek Wlodarski	Layered Surface Acoustic Wave Based Gas Sensors Utilising Nanostructured Indium Oxide Thin Layer
Shengbin Gao	MEng	Dr. Mark Gregory	VoIP Weathermap - A VoIP QOS Collection Analysis and Dissemination System
Elias Roberto Lopez-Lara	PhD	Prof. Arnan Mitchell	Reconfigurable Photonic Antennas
Manish Malhotra	PhD	Prof. Andrew Jennings	Dynamic Communication Across Supply Chain Services
Naomi Mathers	PhD	Prof. Andrew Jennings	Inflatable Antennas for Portable Direct Satellite Communication
Amirabbas Rezaee	MEng	Prof. Ali Baghai-Wadji Prof. Michael Austin	Phase-Periodic Quantum Structures and Perturbed Potential Wells
Andrew Ronchi	PhD	Dr. Margaret Lech	A Reliability Study of a New Back Strain Monitor Based on Clinical Trials
Niusha Sarkhosh	PhD	Prof. Arnan Mitchell	Photonic Implementation of an Instantaneous Frequency Measurement
Vijay Prasad Sivan	PhD	Prof. Arnan Mitchell	Surface machining lithium niobate using Ti diffusion technique
Chen Xu	MEng	Dr. Peterjohn Radcliffe	Building Mobile L2TP/IPsec tunnels
Chin Soon Tan	PhD	Prof. Henry Wu	A Human Visual System Based Image Coder
Yan (Rebecca) Wan	PhD	Prof. Richard Harris	Delay Analysis for Wireless Applications using a Multiservice Multiqueue Processor Sharing Model
Shern Cheng Yau	PhD	A/Prof. Dinesh Kumar	Validation of Dynamic Signature for Identity Verification
Sicong Zheng	MEng	Dr. John Fang	An Investigation of Electrical Properties of Major Constituents of Grape Must Under Fermentation Using Electrical Impedance Spectroscopy

# 2009 Research Publications

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- [1] Peng, W. and Gero, G., *A Design Interaction Tool That Adapts*: VDM Verlag, 2009.
- [2] Truong, N.V., *Nonlinear System Identification: A Wavelet based State Dependent Parameter Modeling Approach*: VDM Verlag, 2009.
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- [4] Wang, L., *Model Predictive Control System Design and Implementation using MATLAB*. London and New York: Springer-Verlag, 2009.

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- [1] Cvetkovic, D., Abdullah, H., Übeyli, E.D., Holland, G., and Cosic, I., "Alterations in Sleep Electroencephalography and Heart Rate Variability During the Obstructive Sleep Apnoea and Hypopnoea", in *Recent Advances in Biomedical Engineering*, G.R. Naik, Ed.: In-Tech, Croatia, ISBN 978-953-307-004-9, Oct. 2009, pp. 148-164.
- [2] Feng, Y. and Yu, X., "Sliding Mode Control of Chaotic Systems", in *Control of Chaos in Nonlinear Circuits and Systems*, B. W.-K. I. Ling, Herbert Ho-Ching Lam, Hak-Keung, Ed.: New Jersey: World Scientific, 2009, pp. 55-57.
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