

SCHOOL

24-25 September 2007

Lectures Abstracts

Lecturers profiles

Nanoscience: proteins as nanostructures
F. Beltram
SNS- Pisa (Italy)

Nanoscience: from micro to nanoelectronics
F. Beltram
SNS- Pisa (Italy)

Name:	Professor Fabio BELTRAM	Institution:	SNS-Pisa
Status:	Lecturer	Country:	Italy
<p>About Professor Fabio Beltram: Fabio Beltram obtained the Doctor Degree in Physics and in Electronic Engineering. He carried out research activity from 1986 to 1991 in the USA at Bell Laboratories, since 1992 he is at the Classe di Scienze of the Scuola Normale Superiore where he is now Full Professor of Physics of Matter. Since 1995 he has been Director of the Physics Laboratory at Scuola Normale Superiore. Since 2001 he has been Director of CNR-INFM NEST the "National Enterprise for nanoScience and nanoTechnology". At present he is Vice Director of Scuola Normale Superiore and Vice President of Fondazione Toscana Life Sciences, and a member of COST, Physics, Materials and Nanosciences Committee</p> <p>Fabio Beltram and his group carry our research work in the field of nanoscience and nanotechnology with a rather broad spectrum of topics. He has always worked on the physics and applications of semiconductor and hybrid superconductor-semiconductor nanostructures. This activity appeared in over one hundred and eighty publications on electron states and transport and on the optoelectronics of low-dimensional systems. Increasingly in the last years Fabio Beltram has carried out research activity in the field of molecular biophysics in order to apply his expertise in nanotechnology and in the engineering of nanostructures to significant issues in nanobiotechnology and biomedicine. Topics presently investigated include: coherent transport in semiconductor nanostructures with an emphasis on many-body effects, logic gates for quantum computation, single-photon sources for quantum cryptography, THz laser sources, ballistic transport in nano- and hybrid superconductor-semiconductor structures. In the context of molecular biophysics main lines include the design and exploitation of molecular-medicine vectors, biosensors, and novel mutants of green fluorescent proteins for single-molecule proteomics in live cells.</p>			

Micro-photonics: Towards all-optical logic circuits and signal processing

Benjamin EGGLETON

CUDOS, ARC Centre of Excellence for Ultrahigh-bandwidth Devices for Optical Systems School of Physics, University of Sydney

This tutorial will review recent progress in developing breakthrough photonic materials and structures that allow for the control of light at the sub-micron scale. These photonic structures underpin all-optical logic circuits and optical signal processing that promises to revolutionize next generation communication systems and computer systems. I will review the basic principle of micro-photonics, including photonic bandgap structures, optical nanowires and nanofabrication strategies. Examples of applications will be discussed.

<u>Name:</u> Professor Benjamin EGGLETON	<u>Institution:</u> CUDOS, ARC Centre of Excellence for Ultrahigh-bandwidth Devices for Optical Systems School of Physics, University of Sydney
<u>Status:</u> Lecturer	<u>Country:</u> Australia
<p>Professor Benjamin Eggleton is currently a Federation Fellow and Professor of Physics at the University of Sydney. He is Director of the Centre for Ultrahigh-bandwidth Devices for Optical Systems (CUDOS), an ARC Centre of Excellence. He studied at the University of Sydney, obtaining his BSc (Hons 1) in 1992 and his PhD in Physics in 1996. After graduation, he went to the United States to join Bell Laboratories, as a Postdoctoral Fellow in the Optical Physics Department. He then transferred to the Optical Fiber Research Department as a Member of Technical Staff and was subsequently promoted to Technical Manager of the Optical Fibre Grating group. Soon after this, he became the Research Director of the Specialty Fiber Business Division of Bell Lab's parent company, Lucent Technologies; here, he drove Lucent's research program in optical fibre devices. He has co-authored more than 160 journal papers, has presented more than 40 invited and plenary presentations at international conferences, and has filed 35 patents. He has received several significant awards. Most notably, in 2007 he received the Pawsey Medal from the Australian Academy of Sciences, in 2004 he received the Prime Minister's Malcolm McIntosh Science Prize for Physical Scientist of the Year, in 2003 the ICO Prize (International Commission for Optics), and in 1998 was awarded the Adolph Lomb Medal from the Optical Society of America. Other achievements include the award of the distinguished lecturer award from the IEEE/LEOS, a R&D100 award, and being made an OSA fellow in 2003. He is an Associate Editor for IEEE Photonic Technology Letters, the Editor for Optics Communications and serves as Vice-President of the Australian Optical Society.</p>	

Mobility Spectrum Techniques for Determining Transport Parameters in Semiconductor Nanostructures

Professor Lorenzo (Laurie) Faraone
Microelectronics Research Group
The University of Western Australia

For modern semiconductor device nanostructures containing multiple populations of distinct carrier species, conventional Hall and resistivity data acquired at a single magnetic field provide far less information than measurements as a function of magnetic field. However, the extraction of reliable and accurate individual carrier densities and corresponding mobilities from the field-dependent data can present a number of difficult challenges, which were never fully overcome by methods such as multi-carrier fitting, the mobility spectrum analysis of Beck and Anderson, or hybrid mixed-conduction analysis. More recently, in order to overcome the limitations of these methods, several research groups have contributed to development of the quantitative mobility spectrum analysis (QMSA) procedure, which is now available as a commercial product. The algorithm is analogous to a fast Fourier transform, in that it transforms data from the magnetic field domain to the mobility domain. QMSA converts the field-dependent Hall and resistivity data into visually-meaningful transformed outputs comprising the conductivity density of electrons and holes in the mobility domain. In this lecture, the background to the development of QMSA will be presented, in addition to practical examples of the application of QMSA to synthetic data sets and real experimental data that are representative of modern semiconductor device nanostructures.

<u>Name:</u>	Professor Lorenzo Faraone	<u>Institution:</u>	University of Western Australia
<u>Status:</u>	Lecturer	<u>Country:</u>	Australia
About Professor Lorenzo Faraone:			
<p>Professor Faraone is Head of the Microelectronics Research Group (MRG) at The University of Western Australia (UWA), and Director of the WA Centre for Semiconductor Optoelectronics and Microsystems (WACSOM). Prior to joining UWA in 1987, he worked primarily in the area of silicon-based microelectronics technology with RCA Labs in Princeton, NJ, USA: in particular, silicon dioxide growth technology, degradation and failure, as related to non-volatile memory devices and radiation-hard silicon-on-sapphire CMOS. Since joining UWA he has worked on compound semiconductor devices, including AlGaIn/GaN HEMTs and 2D electron gas transport studies, HgCdTe-based infrared sensor technology, as well as MEMS technologies for infrared applications. The MRG has a vertically integrated capability in HgCdTe semiconductor MBE growth, infrared sensor array fabrication, and packaging/testing facilities. Recent research has focussed on MEMS and the infrared microspectrometer concept, which provides enhanced tuneable hyperspectral and/or multi-spectral capabilities to IR focal plane arrays. The activities at UWA also include research into laser beam induced current (LBIC) imaging, as well as mobility spectrum techniques for magneto-transport studies. This has resulted in the development of the Quantitative Mobility Spectrum Analysis (QMSA) technique that allows the transport properties of individual carriers in a multi-layer/multi-carrier semiconductor system to be determined accurately and unambiguously..</p>			

Ion Beam Physics in Nanotechnology**Prof. D. Jamieson****University of Melbourne**

A single atom is the ultimate machine tool for nanotechnology. The passage of a single swift ion through matter leaves a track that can be as small as 20 nanometres in diameter and 100 microns in length. The impact of single atoms with semiconductors can be detected with sensitive electronics and so the atoms themselves can be counted into microelectronic devices for atomically precise nanofabrication. This lecture presents an introduction to the ion beam physics that is the basis of these useful properties. The lecture will cover the in-solid interaction, the induction of charge in semiconductor depletion layers, cosmic-ray induced upsets in electronic devices and the tools for high precision ion beam lithography.

Ion Beam Analysis in Nanotechnology and the Environment

The interaction of energetic ions with matter triggers a cascade of secondary radiation that can be detected to reveal hidden features in the structure and composition of materials. This lecture presents applications of focused ion beams in nanotechnology and the environment. These include the imaging of trace elements in minerals and diamonds to a sensitivity of less than 10 parts per million, the profiling of corrosion nucleation sites in aluminium alloys, the mapping of implanted ions in semiconductor materials and the investigation of art materials for authentication. For electrical characterisation applications include the imaging of the charge collection efficiency of poly-silicon photovoltaic cells, collection of ion induced charge for diamond detectors at high temperature and the investigation of internal electric fields of semiconductor devices. Examples are also given of the use of a nuclear microprobe to implant and modify materials at the micro and nano scale for the fabrication of novel gadgets that exploit emerging quantum technologies.

<u>Name:</u>	Professor David JAMIESON	<u>Institution:</u>	University of Melbourne
<u>Status:</u>	Lecturer	<u>Country:</u>	Australia
About Professor David Jamieson: d.jamieson@unimelb.edu.au			

Measuring Atom-Specific Surface Chemical Reactivity

R. Rosei

Physics Department and Center of Excellence for Nanostructured Materials, Trieste University,
Trieste, Italy

It has been firmly established that the atom-projected d-band center of mass of Transition Metal systems, is a good descriptor of surface local chemical reactivity [1].

Any modification, like atomic coordination changes, alloying and adsorption processes, brings about shifts of the atom-projected d-band center of mass. Surface Core Levels (SCLs), as measured by High Resolution X-Ray Photoelectron Spectroscopy, shift almost rigidly with the center of the d-band, and provide therefore a measure of local surface reactivity changes [2].

I will present a number of examples which illustrate this paradigm. In particular, I will present SCL shifts measurements originating from Rh atoms, with coordination number varying between 3 and 12, and SCL shifts originating from Rh, Pt and PtRh surfaces, upon adsorption of O, H, N and CO species. I will show that the energy shifts and intensity changes of time-lapsed SCL spectral components, contain information from which the kinetics and dynamics of surface processes can be directly determined. For each of the presented systems, DFT calculations show that SCL shifts provide a good spectroscopic descriptor of atom-specific, surface chemical reactivity changes.

[1] B. Hammer and J. K. Norskov, Adv. Catal. **45**, 71 (2000)

[2] A., Baraldi S.Lizzit, G. Comelli, M. Kiskinova, R. Rosei, K. Honkala, J.K. Norskov, Phys. Rev. Lett. **93**, 046101 (2004)

Name:	Professor Renzo ROSEI	Institution:	University of Trieste
Status:	Lecturer	Country:	Italy
<p>About Professor Renzo Rosei:</p> <p>Prof. Renzo Rosei professional vita.</p> <ul style="list-style-type: none"> - Director of the Center of Excellence for Nanotechnology (University of Trieste), 2003–present; - Chair of the Program Advisory Committee of Elettra, 1995 – 2001; - Scientific Director of Elettra (Synchrotron Radiation Facility) 1991–1995; - Deputy Scientific Director of Elettra (Synchrotron Radiation Facility), 1987–1991; - Founder and Director of TASC–INFM Laboratory, 1983 – 1987; - Full Professor at University of Trieste since Nov. 1982 – - Visiting Scientist at Fritz Haber Institut (Berlin), July–Sept. 1982; - Full Professor at University of Calabria, 1980 – 1982; - Visiting Scientist at Physical Sciences Laboratory, University of Madison, 1979 –1980; - Visiting Professor at Iowa State University, Ames, Iowa 1977; - Assistant Professor of Physics at University of Rome I, 1972 – 1980; - Post–Doctoral Fellow, Iowa State University, Ames, Iowa 1969 –1971; - Research Assistant, University of Rome I, 1963 – 1969; - Laurea Degree, University of Rome I, 1963. 			

NANOSTRUCTURED MATERIALS FOR INTERMEDIATE TEMPERATURE**SOLID OXIDE FUEL CELLS (IT-SOFCs)**

Enrico Traversa,

Department of Chemical Science and Technology, University of Rome Tor Vergata, Rome 00133, Italy

Environmental problems lead to the need for new technologies for sustainable energy production and storage, to reduce pollutant emissions from fossil fuel combustion and to increase energy safety. Solid oxide fuel cells (SOFCs) are promising as electrochemical power sources: the technology is proven, but costs are too high for general use. The major trend in the present research activities on SOFCs is the reduction of operation temperature to reduce costs and improve lifetime. This can be achieved either by reducing the thickness of the YSZ electrolyte to reduce ohmic drop, or by using alternative electrolytes such as ceria, lanthanum gallate, or bismuth oxide. The main drawback of reducing operation temperature is the increase in polarization drops at the electrode/electrolyte interfaces. An increase in the triple phase boundary (TPB) at these interfaces can improve the electrode performance. Operating SOFCs at temperatures below 700°C allows the use of stable nanocrystalline oxides as electrode (both anode and cathode) materials to extend the TPB length. This talk will summarize examples of recent works on the study of electrolyte (ceria), cathode (pyrochlore and perovskite oxides), and anode materials (Ni-YSZ cermets), performed in the lab of the author, in which the electrochemical properties are affected by the reduction of grain size at the nanometer level.

Name:	Professor Enrico TRAVERSA	Institution:	Università di Roma TorVergata
Status:	Lecturer	Country:	Italy
About Professor Enrico Traversa: Enrico Traversa received his “Laurea” (Italian Doctoral degree) in Chemical Engineering from the University of Rome La Sapienza in 1986. In 1988, he joined the University of Rome Tor Vergata where he is currently professor of Materials Science and Technology and Director of the Doctorate Course in “Materials for Environment and Energy”. He is an European editor of Sensor Letters. He is Junior Vice Chair of the High Temperature Materials Division of The Electrochemical Society and member of the International Relations Committee of the Materials Research Society. Elected in the World Academy of Ceramics in 2007. He is author or co-author of seven patents, more than 400 scientific papers (about 200 of them published in refereed international journals), and edited ten books or special issues of journals.			

Name:	Dr Eric WACLAWIK	Institution:	Queensland University of Technology
Status:	Lecturer	Country:	Australia
1992 - 1997	PhD in Chemical Physics Flinders University of South Australia, Australia		
1991	BSc Hons (Class I) Physical and Inorganic Chemistry Flinders University of South Australia, Australia		
PROFESSIONAL MEMBERSHIPS & AWARDS			
Member, Royal Australian Chemical Institute (MRACI) Vice Chancellor's Award for Excellence in Teaching, 2003			
PUBLICATIONS			
Eric's group has publication track record on molecular self-assembly and interfaces using Scanning Probe Microscopy and spectroscopy as principal research tools. He has co-authored over 40 publications in international journals on nanotechnology, chemical physics and physical chemistry, including 18 published papers on inter- and intra-molecular charge transfer.			
SHORT BIOGRAPHY			
Eric Waclawik is a Ph.D. Graduate of Flinders University (1997) in Chemical Physics and Spectroscopy (supervisor: Prof. Warren Lawrance). As Postdoc at University of Toronto he studied liquid crystal dynamics with Prof. James Donaldson and at Exeter University with Prof. Anthony Legon, FRS. , Microwave Spectroscopy of pre-reactive complexes. As Lecturer of Nanotechnology at Flinders University , he developed their undergraduate Bachelor's degree in Nanotechnology. Eric is a Senior Lecturer in the School of Physical & Chemical Sciences at the Queensland University of Technology , where he leads a research program concentrating on nanomaterial-platforms for photovoltaic energy production.			

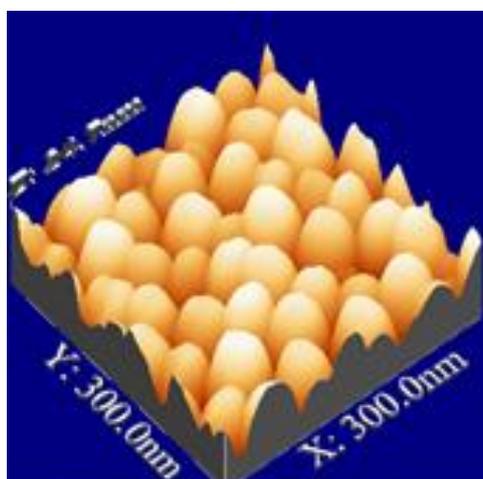


Strained heteroepitaxy of GaAs/InAs and Ge/Si interfaces

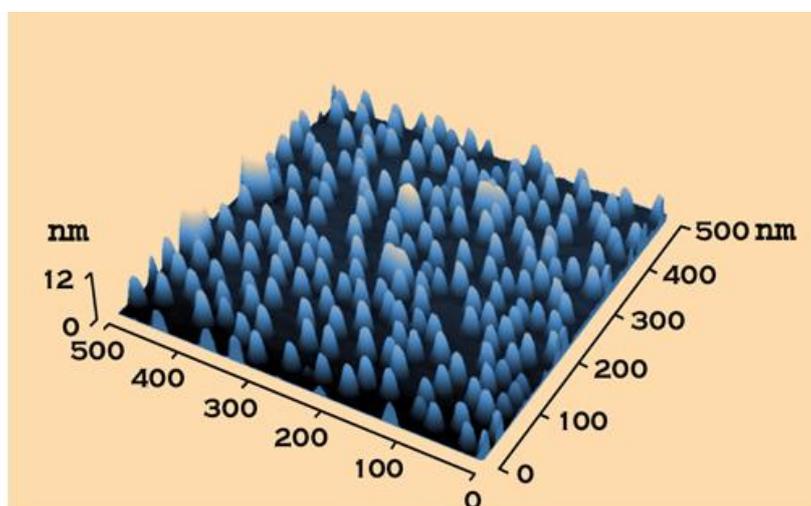
A. BALZAROTTI and A. SGARLATA

Department of Physics, University of Roma "Tor Vergata", Via della Ricerca Scientifica, 1 Roma, Italy.

It is well known that strained semiconductor interfaces with large lattice mismatch (higher than 2-3%) can be epitaxially grown from the gas phase following the Stranski-Krastanow growth mode. The first layers grow pseudomorphically as a flat compressively strained wetting layer (WL) up to a critical thickness θ_c ; subsequent overlayers accommodate into three-dimensional islands, called quantum dots (QDs). In this presentation we illustrate the effect of the thermodynamic and kinetics processes of the growth of two prototype III-V and IV-IV systems, - i.e. InAs on GaAs and Ge on Si- by studying the morphology of the WL and of the self-assembled QDs (island density and size, volume distribution etc.) by RHEED and high-resolution STM and AFM microscopies. The influence of different growth modes (CG and GI), of the surface orientation and steps will be described by specific experiments. Finally, the perspectives open by surface nanopatterning with ion beam lithography for long-range lateral positioning of self-assembled QDs will be briefly demonstrated on the Si/Ge



Self-assembled Ge
Quantum Dots on Si(001)



Self-Assembled InAs Quantum Dots on GaAs(001)
system.

Name:	Dr. Anna SGALATA	Institution:	Università di Roma TorVergata
Status:	Invited Speaker	Country:	Italy

SCHOOL: POSTER SESSION

25 September 2007

16:00 – 19:00

Magnetic characterization of exchange bias in Co/CoO nanoparticles

Lester BARNSELY

Nanoscale Science & Technology Centre, Griffith University

Exchange bias materials and nanostructures have attracted significant interest from researchers as a possible approach for beating the superparamagnetic limit, due to their ferromagnetic stability, even at higher temperatures, approaching room temperature. A high sensitivity vibrating sample magnetometer, contained within a He cryostat with an 8T magnet, has been built for taking measurements of magnetization of exchange bias samples, such as Co/CoO nanostructures.

Name:	Mr Lester BARNSELY	Institution:	Nanoscale Science & Technology Centre, Griffith University
Status:	Student	Country:	Australia
About Mr Lester Barnsley: Nanoscale Science and Technology Centre, Griffith University Second year post-grad student, currently researching magnetic Co-based exchange bias materials and nanostructures. Recently built and commissioned a state-of-the-art vibrating sample magnetometer with a He cryostat at Griffith University's Nathan campus, which will be used to undertake this research, as well as other work on magnetic materials and magnetic nanostructures in the future.			

Name:	Mr Daniel BELCHER	Institution:	University of Newcastle
Status:	Student	Country:	Australia
About Mr Daniel BELCHER:			
Presentation Topic:			

Name:	Mr Stuart BELL	Institution:	Queensland University of Technology
Status:	Student	Country:	Australia
About Mr Stuart Bell:			
Presentation Topic:			

Electrical, optical and structural properties polymer-carbon nanotubes mixtures for organic solar cells applications

Nunzio Motta, John Bell, Eric Waclawick, Michele Giulianini, Marco Bernardi , Roland Goh

School of Engineering Systems - Queensland University of Technology - Brisbane (QLD)

A number of conductive polymer composite materials have been investigated in the last years for use in organic photovoltaics applications. Composite materials made up of a conductive polymer and carbonaceous nanostructured materials (carbon nanotubes, here called CNTs, and fullerenes, especially C₆₀) have proven to be efficient donor-acceptor systems for **bulk heterojunction organic photovoltaic cells** due to the high interfacial specific area and the ultrafast charge transfer that allows the separation of strongly bound excitons.

We have undertaken a study of the **structural and electronic properties of materials made up of a polymer and CNTs** in order to study the feasibility of **new organic solar cells architectures**.

In our study the morphology of composites obtained mixing poly-3hexyl-thiophene (P3HT) and single or multi-walled carbon nanotubes have been investigated using electron microscopy and Raman spectroscopy; the details of the nanoscale structure of the molecular junction between acceptor and donor have been successfully investigated by **Scanning Probe Microscopy**. Composites were prepared from a sonicated dispersion of CNTs in a rrP3HT solution in chloroform and chlorobenzene.

The encouraging results obtained so far make this system a suitable one for organic photovoltaics and optoelectronic devices, as was already reported recently by other authors, due to the non-covalent bonding of the polymers to CNTs that allows efficient excitons separation while, unexpectedly, **CNTs also act as templates** in the polymer solidification favouring local ordering at the P3HT-CNTs interface.

Conductivity measurements of the composite were performed to establish the amount of nanotubes needed to reach the **percolation threshold** is only about 2 %w/w, compared to the 20-30% needed in polymer-fullerenes compounds. This proves advantageous for the construction of lightweight solar cells. Test solar cells have been built by evaporating suitable Al contacts on the film.

Although the manufacturing of these organic photovoltaics solar cells is still at a very early stage in our research, I-V curves (under illumination) have been measured by using a home-built **sun simulator** (respecting the AM 1.5 standard) to assess the efficiency of the photovoltaic cells.

These measurements provide useful data regarding the **overall process** of charge generation, separation and transport through the mixture.

<u>Name:</u> Mr Marco BERNARDI	<u>Institution:</u> Queensland University of Technology
<u>Status:</u> Student	<u>Country:</u> Australia
<p>About Mr Marco Bernardi: Queensland University of Technology, School of Engineering Systems O Block, Gardens Point Campus, 2 George St. Brisbane QLD 4001 Level 7 Room 718 Phone: +61 7 3138 2423, Mobile: +61 0422 096 497, E-mail: marco.bernardi@qut.edu.au Date and place of birth: Roma, Italy, 06/12/1982</p> <p><u>Education</u></p> <ul style="list-style-type: none"> • Laurea Specialistica" (Masters Degree) in Materials Science and Technology, Department of Physics of the University of Rome "Tor Vergata", 2007 • Laurea Triennale" (B.Sc. Hons.) in Industrial Chemistry, Specialisation in \Materials and Resources", University of Rome "La Sapienza", 2004, Summa Cum Laude, discussing the thesis \Synthesis and Characterization of Nanostructured Materials" <p><u>Research Funding</u></p> <ul style="list-style-type: none"> • 2007 Endeavour Research Fellowship (grant of \$25000 AUD), Australian Government DEST, Research Project:"Fabrication of reproducible nanometric holes arrays by FIB on Si(100) for the controlled growth and STM characterisation Ge Quantum Dot array" at Queensland University of Technology, Brisbane • 2007 Travel Scholarship "Australian Research Network for Advanced Materials 2007 Annual Workshop" , ANU Kioloa Coastal Campus, Kioloa NSW, Australia • 2004 Travel Scholarship at the "2004 Lectures in Chemistry and Physics", • The Nanotechnology Revolution", funded by the "Onassis Foundation Science Lecture Series", held at the Foundation for Research and Technology Hellas, Heraklion, Crete, Greece 	

<u>Name:</u> Mr Michele GIULIANINI	<u>Institution:</u> Queensland University of Technology
<u>Status:</u> Student	<u>Country:</u> Australia
<p><u>Education</u></p> <p>I received the electronic engineering degree in December 2000 from "Università degli studi di Roma Tre" in Rome defending the thesis "Study and modelling of deep defects in semiconductors".</p> <p>In September 2006, I started a PhD at QUT with the following title "Polymer and carbon nanostructures mixtures for photovoltaic applications"</p>	
<p><u>Presentation Topic:</u> Electrical, optical and structural properties polymer-carbon nanotubes mixtures for organic solar cells applications.</p>	

<u>Name:</u> Ms Tara BUSBRIDGE	<u>Institution:</u> Nanoscale Science & Technology Centre, Griffith University
<u>Status:</u> Student	<u>Country:</u> Australia
About Ms Tara Busbridge:	
<u>Presentation Topic:</u>	

<u>Name:</u> Mr Ching Yuan (Tom) CHENG	<u>Institution:</u> ARC Centre of Excellence for Functional Nanomaterials, University of Queensland
<u>Status:</u> Student	<u>Country:</u> Australia
About Mr Ching Yuan (Tom) Cheng	
<u>Presentation Topic:</u>	

<u>Name:</u> Mr Ben CUNNING	<u>Institution:</u> Nanoscale Science & Technology Centre, Griffith University
<u>Status:</u> Student	<u>Country:</u> Australia
About Mr Ben Cunning	
<u>Presentation Topic:</u>	

<u>Name:</u> Ms Kerry DUNN	<u>Institution:</u> INRS-EMT
<u>Status:</u> Student	<u>Country:</u> Canada
About Ms Kerry Dunn	
<u>Presentation Topic:</u>	

Patterned Attachment of Carbon Nanotubes to Silicon

B. S. Flavel, J. G. Shapter, J. S. Quinton

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Current device and process scaling in the semiconductor industry has led to a continuous demand for the increased density of silicon-based electronics and a decrease in the cost per bit. However, scaling techniques currently employed will soon reach physical and technical limitations and alternative methods are now being investigated. One such method is molecular electronics which has been proposed to circumvent the limitations associated with current semiconductor devices allowing for scaling down to the molecular level whilst dramatically decreasing the associated cost. Two promising approaches within the field of molecular electronics are the use of single-walled carbon nanotubes as interconnects and redox active molecules as a storage medium. However, for any molecular electronic approach to be successfully integrated into existing technologies the ability to precisely control the orientation and position of molecular interconnects and storage media is of crucial importance. This work presents an approach to fabricate an electro-active and site selective array of carbon nanotubes, which is ideal for use in electronic devices.

A monolayer of methyl terminated hexadecyltrichlorosilane was self assembled onto a p-type silicon (100) substrate which provided a resist for electrochemical anodization with an atomic force microscope cantilever. Through precise control of the cantilever's position on the surface and the voltage applied, a variety of different surface architectures have been etched into the substrate. Carbon nanotubes, with high carboxylic acid functionality, have been immobilised to these etched regions using a condensation reaction. Highly selective condensation has been shown to be possible, both directly onto etched silicon regions as well as with the use of amine terminated 3-aminopropyltriethoxysilane as a molecular anchor. Redox-active ferrocenemethanol is then attached to the immobilised carbon nanotube structures. Using the technique of cyclic voltammetry the oxidation and reduction of ferrocene is observed. This has demonstrated that such controlled nano-structured electrodes are ideal candidates for use as molecular electronic devices, in particularly molecular memory as it may be possible for information to be stored in the discrete redox states of ferrocene.

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Gold Nanoparticle Core-Shell Latexes Synthesised by Miniemulsion Polymerisation

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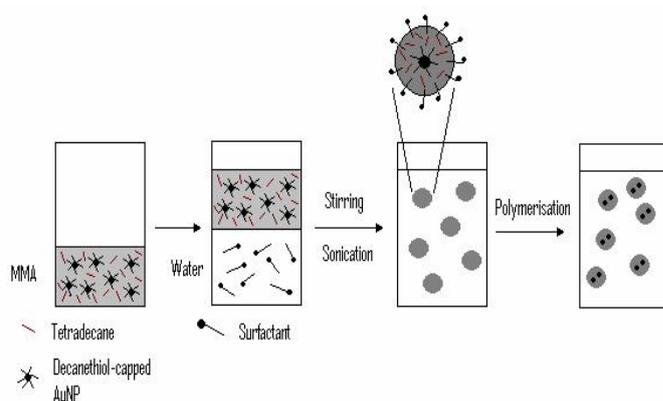
Telephone: (07) 3864 5243

I. ABSTRACT

The incorporation of inorganic nanoparticulate materials into polymeric materials has recently received some attention within the literature.^{1, 2} Incorporating nanoparticles in a core-shell arrangement can be achieved by a miniemulsion technique. This affords a novel route to designing materials with specific, yet multi-functional applications.

In the past, these systems have been prepared through kinetically controlled growth outwards from the nanoparticle core.^{3, 4} These techniques have several disadvantages in that there are limitations in degree of homogeneity and compositions accessible. The current investigation overcomes these shortcomings as the initial emulsification creates 'nanoreactors' that contain all required components of the reaction and is highly flexible in system design.

The preparation of gold nanoparticle/PMMA core-shell latexes has been successfully achieved using miniemulsion polymerisation. The use of either anionic or non-ionic surfactants with the use of a suitable hydrophobe to achieve a stable miniemulsion is presented. Latexes were synthesised via conventional miniemulsion polymerisation routes, shown in Scheme 1.



Scheme 1. The synthetic route by which core-shell latexes are produced.

Initially, the gold nanoparticles are synthesised via the Brust method⁵ so that they are soluble in the monomer, methyl(methacrylate) (MMA). To this mixture is added a hydrophobe (tetradecane) which prevents destabilisation of the nanodroplets by

Ostwald ripening. When this is added to a surfactant/water solution and sonicated and stirred vigorously, a stable emulsion forms. Upon heating and initiator addition, the nanodroplets act like 'nanoreactors' and polymerise to form the Au nanoparticle/PMMA latexes. The latexes show good homogeneity and size distribution as shown in Figure 1.

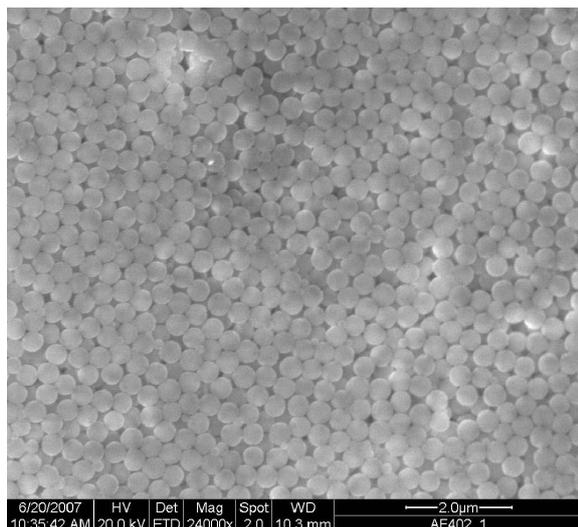


Figure 1. SEM image of AuNPs encapsulated in PMMA latexes.

REFERENCES

- (1) Landfester, K., *Annu. Rev. Mater. Res.* **2006**, 36, 231-279.
- (2) Landfester, K., *Adv. Mater. (Weinheim, Ger.)* **2001**, 13, (10), 765-768.
- (3) Ohno, K.; Koh, K.-m.; Tsujii, Y.; Fukuda, T., *Macromolecules* **2002**, 35, (24), 8989-8993.
- (4) Kotal, A.; Mandal, T. K.; Walt, D. R., *J. Polym. Sci., Part A: Polym. Chem.* **2005**, 43, (16), 3631-3642.
- (5) Brust, M.; Walker, M.; Bethell, D.; Schiffrin, D. J.; Whyman, R., *J. Chem. Soc.; Chem. Com.* **1994**, (7), 801-802.

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Status:	Student	Country:	Australia
About Mr Adrian Fuchs: School of Physical and Chemical Sciences Queensland University of Technology, Brisbane, Australia			

<u>Name:</u> Mr Yanan GUO	<u>Institution:</u> The University of Queensland
<u>Status:</u> Student	<u>Country:</u> Australia
About Mr Yanan Guo:	
<u>Presentation Topic:</u>	

Hydrolytically Stable Phosphorylated Hybrid Silicas for Proton Conduction

Yonggang Jin, Shizhang Qiao, João C. Diniz da Costa, Bradley P. Ladewig and Max Lu*

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The state-of-the-art technology of proton exchange membrane fuel cells (PEMFCs) is based on perfluorosulfonic acid polymer membranes, which is incapable of operating at intermediate temperatures above 100 °C, a technological preferred working temperature for PEMFCs. In this regard, sol-gel derived silicon phosphate gels consisting of thermal stable silica network and functionalised phosphates have been reported as a promising candidate. However, acid leaching resulted from the hydrolysis of P-O-Si bonds constitutes a big hurdle for their practical application in FCs. In this study, we have developed a new sol-gel route to synthesize proton conductive hybrid silicas with hydrolytically stable phosphonic acid functionalization. The hybrid silicas with different amounts of phosphonic acid have been prepared and characterized using FTIR, XPS, TGA and electrochemical techniques. The fully immobilized phosphorous functionalization was confirmed on the hydrothermally treated sample. The proton conductivity of the materials depended strongly on hydration, increasing by four orders of magnitude over the relative humidity (RH) range 20-100%, up to a maximum of 0.027 S/cm at 100 °C and 100% RH. The proton conduction is believed to occur within a dynamic hydrogen bond network formed by functionalized P-OH groups and water molecules via the Grotthuss mechanism. However, the proton conductive sites (P-OH) are likely to be partially immobilized by amino groups, which reduces the free P-OH groups and restricts proton transfer. Such a restriction could be relaxed by hydration leading to an improvement of proton conductivity.

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The growth of *ta*-C films using low energy, reactive ion beam sputter deposition with *Ar* or *Xe* ions

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Abstract:

An innovative approach was taken to improve a conventional target sputtering technique where *ta*-C films were synthesised using energetic bombardment of a graphite target from a single low energy ion source and both a target and a substrate were co-joined and positioned at grazing angles to the central axis of the ion beam. In this configuration the projectile ions (*Ar* and *Xe*) simultaneously bombarded the target and the growing film. This investigation was performed on the premise that additional energy from the infringing ion flux provided to the nucleating film will be beneficial to formation of sp^3 bonding in growing films. The *Ar* and *Xe* ion energies were varied from 0.2 keV to a maximum of 1.2 keV.

Experimental results revealed that it was not possible to fabricate quality *ta*-C but only sp^2 rich polymeric *a*-C films and formation of these films was attributed to a secondary resputtering process. However, *ta*-C films were synthesised when the substrate was positioned parallel to the axis of the ion beam flux. In this arrangement the increase of incident ion energy promotes sp^3 bonding formation. The optimal angle of the target to the axis of the ion beam flux was found to be 30 deg. The increase of ion beam energy to the experimental maximum of 1.2 keV resulted in higher sp^3 fraction of above 40 %. The developed deposition method is simple, low cost and scalable for industrial applications.

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Electron field emission of nitrogen doped TiO₂ nanotube array

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Abstract

Nitrogen doped titania nanotube array vertically-aligned on a titanium substrate exhibits efficient electron field emission. Such a titania nanotube array shows very good stability at high field emission current (fluctuation < 3% at field emission current of 160 μA within 4 h) and low turn-on and threshold fields (11.2 $\text{V}\mu\text{m}^{-1}$ and 24.4 $\text{V}\mu\text{m}^{-1}$, respectively) because of the coexistence of doped nitrogen and concomitant oxygen vacancies in titania nanotubes. This work demonstrates the possibility of converting pure titania nanotubes without field emission into a favorable and efficient one through the introduction of midband and localized states both above the valence band maximum and below the conduction band minimum in the band gap of titania by the doped nitrogen and concomitant oxygen vacancies, respectively. Application of this doping concept to other transition metal oxides can be expected to broaden the scope of field emission materials.

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About Mr Gang Liu: Personal Name: Gang Liu Gender: male Position: PhD candidate Present Research Interests 1. Developing and understanding highly efficient visible light photocatalysts for photodegradation and water splitting. 2. Exploring applications of 1D nanostructured titania. Publications and Patents Publications 1. Liu G, Li F, Chen ZG, Lu G Q and Cheng H-M. The role of NH₃ atmosphere in preparing nitrogen-doped TiO₂ by mechanochemical reaction , Journal of Solid State Chemistry 2006 , 179, 331-335 2. Liu G, Chen ZG, Dong C, Zhao Y, Li F, Lu G Q and Cheng H-M., Visible light photocatalyst: iodine doped mesoporous titania with a bicrystalline framework , Journal of Physics Chemistry B 2006, 110, 20823-20828. 3. Chen ZG, Li F, Liu G, Tang Y, Cong HT, Lu G Q, and Cheng H-M, Preparation of high purity ZnO nanobelts by thermal evaporation of ZnS , Journal of Nanoscience and Nanotechnology 2006 , 6, 704-707 4. Chen Z G, Zou J, Lu G Q, Liu G, Li F, Cheng H-M., ZnS nanowires and their coaxial nanowire heterostructures with BN , Applied Physics Letters 2007 , 90, 103117. 5. Chen Z G, Zou J, Li F, Liu G, Tang D M, Li D, Liu C, Ma X, Cheng H-M, Lu G Q. Growth and magnetic property of novel yard-glass shaped boron nitride nanotubes filled periodically with Fe nanoparticles , Advanced Functional Materials Accepted . Patents 3 China patents and 1 Australia patent.			

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SLIDING OF AU DROPLET IN VAPOR-LIQUID-SOLID GROWTH OF SEMICONDUCTOR NANOWIRE HETEROSTRUCTURES

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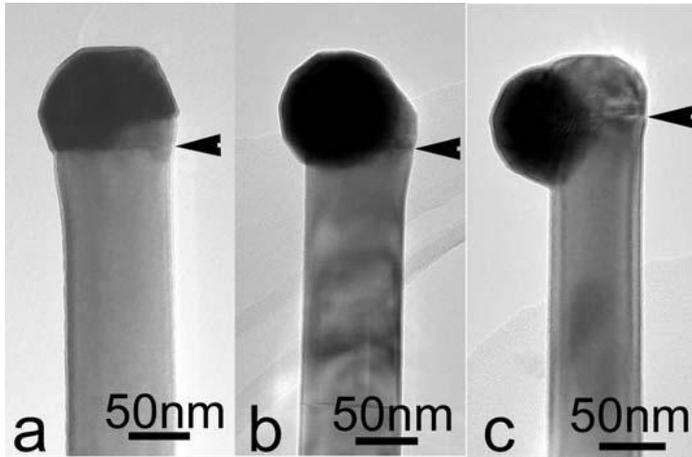


Figure 1 (a), (b) and (c) are the TEM images of InAs/GaAs nanowires tips, and they show initial stages of InAs growth on GaAs nanowires; InAs/GaAs interfaces are marked by arrows. In (a), InAs has clustered between the GaAs and Au at an edge of the growth front. In (b) and (c), Au moves sideways due to growth of the InAs cluster.

Semiconductor nanowires (NWs) and their associated heterostructures have many potential applications in nanoelectronic and nano-optoelectronic devices owing to their unique physical properties, which have drawn extensive research attention in the past decade.^[1] The vapor-liquid-solid (VLS) mechanism, using metal nanoparticles (NPs) as nucleation sites, is a commonly used process for semiconductor NWs and their associated axial heterostructures growth, and Au NPs have been generally used in this process.^[1, 2] In typical VLS growth, metal alloy nano-sized liquid droplets form and then

catalyze the nanowires growth.

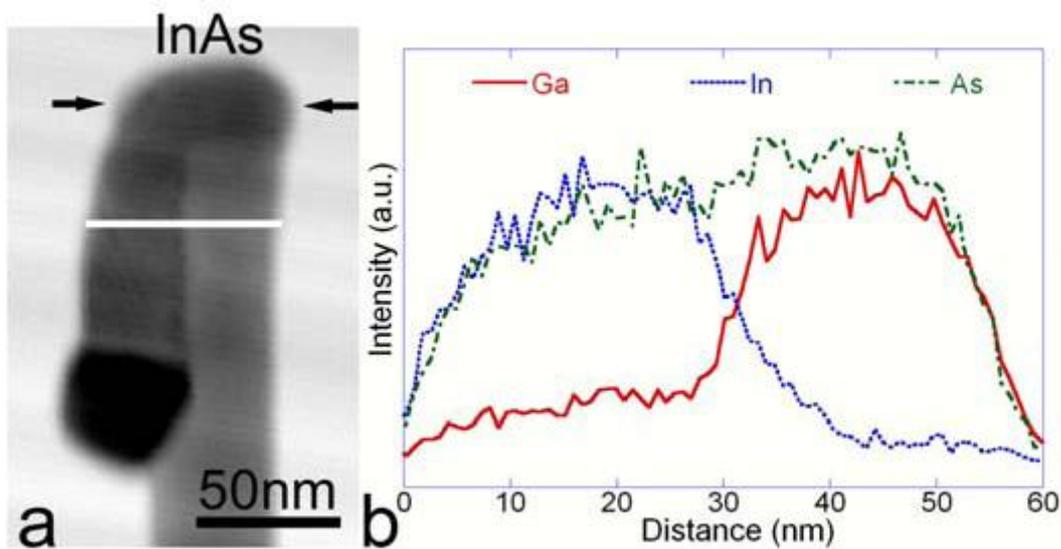


Figure 2 (a) A STEM image showing different sections of nanowires. (b) EDS analyses crossing different nanowire sections.

In this work we have grown InAs for a short duration, i.e. for 1 min, on GaAs nanowires. We observed the Au NP to slide down the original GaAs NW by preserving a Au-GaAs interface during InAs growth. Such sliding movement is understood through transmission electron microscopy observations with a sequence of : (i) the initial InAs clustering at an edge of the Au/GaAs and (ii) the Au droplets move sideways and then downwards with further growth of InAs by preserving an interface with the GaAs sidewalls. The lower interfacial energy of Au/GaAs than that of Au/InAs is attributed to be the reason behind this novel growth phenomenon. These observations give an insight of VLS growth of nanowire heterostructures.

References

Acknowledgement: This research is supported by the Australian Research Council. M. Paladugu acknowledges the support of an International Postgraduate Research Scholarship.

¹ Y. Huang, X. F. Duan and C. M. Lieber, *Small* **1**, 142 (2005).

² H. J. Fan, P. Werner and M. Zacharias, *Small* **2**, 700 (2006)

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Magnesium loaded carbon for hydrogen adsorption

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Abstract:

The development of effective hydrogen storage technologies remains a key technical challenge to the widespread use of hydrogen fuel cell vehicles and devices. Both metal hydrides and carbon materials have been studied as promising hydrogen storage materials. However, higher capacity metal hydrides, such as magnesium hydride, are limited by their slow kinetics and require operating temperatures above 300°C. While carbon materials show fast adsorption and desorption kinetics, at room temperature or higher carbon materials alone cannot achieve significant hydrogen capacity. Recently, the addition of carbon nanostructures to magnesium, via ball milling, has been reported to improve kinetics and dehydrogenation temperatures.

In this study we investigated the preparation and hydrogen adsorption properties of magnesium loaded on an activated carbon fibre (ACF). The decomposition magnesium chloride, MgCl₂, impregnated on ACF was observed by thermogravimetric analysis (TGA) under nitrogen and hydrogen atmospheres to identify process conditions for synthesis of Mg loaded ACF. The rate of hydrogen adsorption on ACF loaded with 11.2 %wt Mg was measured using a volumetric method at a temperature of 300°C and hydrogen pressure of 2.2 MPa. The adsorption was compared to that on a bulk Mg powder at the same conditions. While hydrogen uptake on both samples was slow, the Mg loaded ACF sample did adsorb hydrogen suggesting the successful synthesis of Mg particles, and not MgO, on the ACF surface. Hydrogen uptake on a magnesium weight basis was 4.0 %wt H₂/Mg for the Mg loaded ACF compared to 1.9 %wt for the bulk Mg powder.

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Thomas Rufford is a PhD student at the University of Queensland, working in the ARC Centre of Excellence for Functional Nanomaterials.			
His PhD project investigates the hydrogen storage properties of nanostructured carbon and metal hydride materials. Thomas completed a Bachelor of Engineering (Chemical) at the University of Queensland in 2000 and before starting his PhD he gained four years industrial experience as a process engineer with Shell Refining Australia.			
Thomas is currently serving as the student representative on the management committee of the ARC Nanotechnology Network. He recently returned from a four month stay as an Endeavour Research Fellow at the Institute of Metals Research of the Chinese Academy of Sciences, Shenyang, China. In 2006 he was awarded an Overseas Travel Fellowship from the ARC Nanotechnology Network to conduct research with the Energy Storage Materials Group of the National Institute of Advanced Science and Technology (AIST), Tsukuba, Japan.			

Conducting polymer/inorganic nanocrystal quantum solar cells

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Supervisor: Associate Professor Paul Meredith

Associate Supervisor: Professor Halina Rubinsztein-Dunlop

The aim of this research project is to investigate novel electron donor and acceptor systems in order to improve the efficiency of organic solar cell (OSC) devices. Motivation comes from the need to produce a low cost carbon free and renewable source of energy. OSCs offer one way of achieving this through solution based fabrication (bucket chemistry), as opposed to the high vacuum and high temperatures needed for conventional inorganic solar cells (ISC).

Unlike the efficiency of ISC, OSC devices must overcome two major hurdles, a) photon absorption generates a coulomb bound electron-hole pair (an exciton) as opposed to the generation of free carriers in bulk inorganic materials b) charge carrier mobility is limited. One possible solution, and the subject of this project, is the creation of blended electron acceptor-donor materials in a so called bulk heterojunction structure (BH). The donor-acceptor interface acts to separate the photo-generated excitons and if this acceptor material is "percolated" through the conducting polymer host matrix, often by simply mixing in solution, then a continuous, high conductivity pathway may be created for the charge carriers. Hence, the two key deficiencies of CPSCs are addressed.

The project has so far successfully fabricated thin film BH solar cells with acceptor materials ranging from nanocrystal (NC) quantum dots to fullerene derivatives. Using a novel in situ process developed here at UQ (Watt et al (2005), Materials Letters **59**, 3033), BH solar cells of lead sulphide (PbS) and lead selenide (PbSe) NCs have been grown in situ with the conducting polymers poly[2-methoxy-5-(2'-ethyl-hexyloxy)-1,4-phenylene vinylene] (MEH-PPV) and poly (3-hexylthiophene) (P3HT), and the photoelectric properties characterised. Polymer BH SCs made with the acceptor [6,6]-phenyl C₆₁-butyric acid methyl ester (PCBM) have also been fabricated and demonstrated to have a power conversion efficiency of over 2 %.

In the remainder of the project, it is planned to extend the synthesis of NCs in solution with novel dendritic materials developed at the new Centre for Photonics and Electronics at the University of Queensland Chemistry building. In doing so, we hope to push the boundaries of efficiency of these novel devices.

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About Mr Paul Schwenn: Paul Schwenn is currently researching quantum materials for use in third generation solar cells as part of his PhD in physics at The University of Queensland. His research is focussed on the synthesis and characterisation of nanocomposite donor-acceptor systems. In particular, inorganic nanocrystal quantum dots and fullerene derivatives blended with conducting organic materials.			
PRESENTATION TOPIC: Conducting polymer/inorganic nanocrystal quantum solar cells			

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NANOSCALE SUPERCONDUCTING ELECTRONICS

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Miniaturization is a continuous trend in electronics. This is not only because of the need to have a much higher density of devices in each chip, or a much smaller energy consumption, but also because miniaturization is a driving force for the appearance of new quantum phenomena and device functionality. In the case of superconductivity, the development and the miniaturization of single Josephson junctions (JJ) and of wires has led to important advancement in fields like metrology and quantum computation¹, while pairs of junctions incorporated into a Superconducting Quantum Interference Device (SQUID) architecture could eventually lead to magnetic detection with quantum-limited sensitivity². The size of the loop incorporated in a dc SQUID is a critical characteristic of the device. It has been anticipated² that the spin-noise sensitivity of the SQUID is directly proportional to the diameter of this loop, and we are interested in exploring the regime of loop size, some tens of nm, for which a single-spin flip within the SQUID loop may be detectable. In its original conception the SQUID was based on Josephson tunnel junctions, but devices with sub-100 nm necessitate the development of so-called "weak link" junctions, which exhibit Josephson behaviour³. This approach is based on the realization of very short and small superconducting wires (length and diameter \sim some ten of nm) that connects two regions of bulk superconducting film.

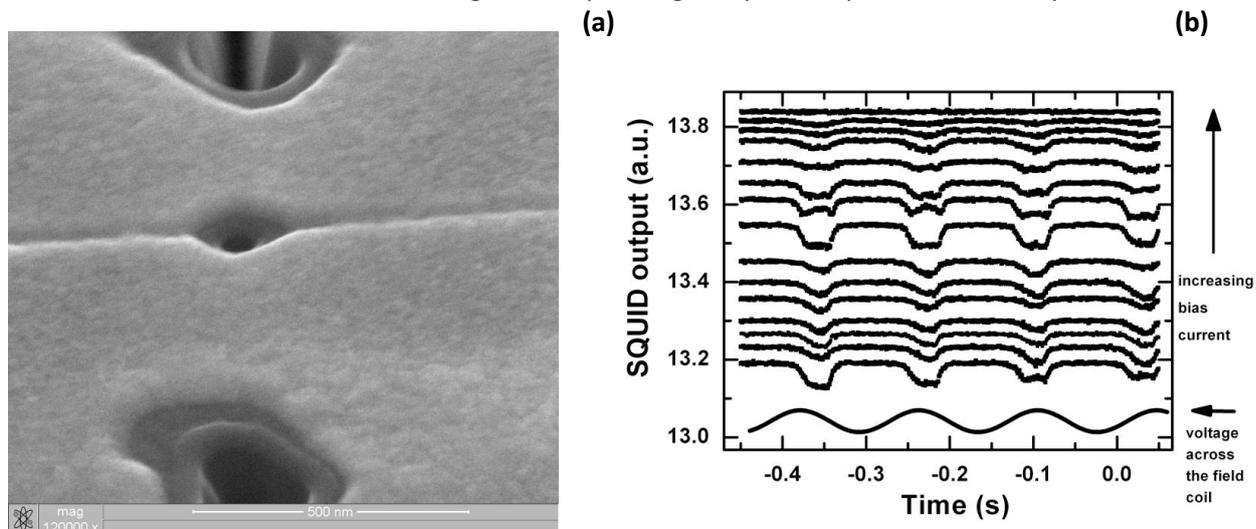
Weak links have very good noise properties, due to a low intrinsic capacitance³, and recently there have been new interesting approaches for realizing small weak links, using electron beam⁴, and atomic force⁵, lithography. Limits to, respectively, minimum feature size and reproducibility have eased the initial promise of utilising these technologies. We have taken an alternative fabrication approach, employing focused ion beam (FIB) technology to create weak link junctions and SQUIDs on Nb thin films in a rather straightforward fabrication protocol where a 35 keV Ga ion beam is utilised to mill Nb material. We have carried out accurate studies of the scaling of electronic properties for a number of devices (wires, single JJ and SQUIDs) as a function of device dimensions. For single weak-link devices we have examined the evolution of device characteristics with variation in the physical length and width of the junction, focusing on achieving reproducible control of device properties and on demonstration of phase behaviour. Short, wide junctions exhibit typical Josephson properties, with a critical current that depends of the device dimensions as expected. In narrow junctions, typically with sub-200 nm width, measurements reveal voltage steps, characteristic of dynamic phase-slip centres. For our narrowest microbridge, of sub-100nm width, transport measurements reveal a suppression of superconductivity below T_c and the data is well described by theoretical predictions for thermally activated phase-slip behaviour, with a evolution to quantum phase-slip below about 6K⁶. Quantum phase slip behaviour is anticipated in Nb filaments with dimensions below the superconducting coherence length, $\xi \sim 10$ nm. For FIB-fabricated junctions we are able to enter this regime by exploiting Ga poisoning in the periphery of the weak-link, the effective size of the superconducting junction, of order of a nanometre, being significantly smaller than the physical dimensions of the device. We have explored the scaling of SQUID spin sensitivity with loop size, and compared the scaling characteristics for weak-link based SQUIDs with those of tunnel-junction devices⁷, for a range of loop dimensions from 10 μ m to 50 nm. Furthermore, we have fabricated and characterized a dc SQUID with a loop diameter of about 50 nm (Fig. 1). For this SQUID, a flux noise of

approximately $10^{-6} \Phi_0/\text{Hz}^{1/2}$ at 6K has been achieved, from which a calculated spin sensitivity of ~ 30 spin/Hz $^{1/2}$ is predicted. Methods to improve this noise figure by utilising a SQUID-based amplification stage, will be discussed.

References:

- [1] J. Mooij and Yu. Nazarov, *Nature Phys.*, **2** (2006), 169
- [2] M.B. Ketchen, et al, *IEEE Trans. Magn.*, **25** (1989) 1212
- [3] K.K. Likharev, *Rev. of Mod. Physics* **51** (1979) , 101
- [4] S. Lam and D. Tilbrook, *Appl. Phys. Lett.*, **82** (2003), 1078
- [5] V. Bouchiat et al, *Appl. Phys. Lett.*, **79** (2001), 123
- [6] G.C. Tettamanzi, A. Potenza, C.H. Marrows, S. Prawer, D.N. Jamieson, and C.I. Pakes, in preparation for *Appl. Phys. Lett.*
- [7] C.I. Pakes, et al, *IEEE Inst. Meas.*, 50 (2001), 310.

Figure 1: (a) Scanning electron micrograph of an Au-shunted Nb dc SQUID (scale bar: 500 nm) with an estimated loop diameter of about 50 nm. (b) Output of this device at different bias currents in response to an ac-modulated magnetic field applied perpendicular to the plane of the SQUID. The lowest trace is the ac modulation voltage, corresponding to a peak-to-peak field of 100 μT .



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