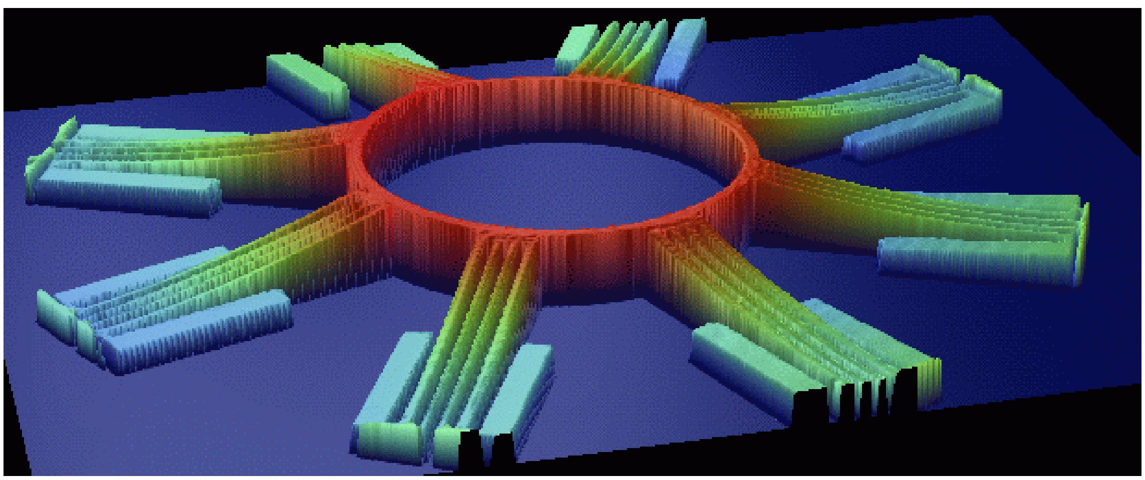
Scotland–Taiwan Hi-Tech Forum

台灣-蘇格蘭高科技論壇

Micronanotechnology Workshop

微奈米科技研討會



REPORT

Of The Royal Society of Edinburgh,
22-26 George Street, Edinburgh EH2 2PQ

October 2005

Contents

Foreword

By Professor Tariq Durrani

In October 2005, an important delegation of Taiwanese scientists and engineers visited Scotland to present their results at a keynote Workshop organised by The Royal Society of Edinburgh, held under the aegis of the Scotland–Taiwan Hi-Tech Forum in partnership with the Taiwan National Science Council, on the strategically important area of Micronanotechnology.

As background to this event, The Royal Society of Edinburgh signed a Memorandum of Understanding with the National Science Council of Taiwan in 2001 to enable joint activities between the two organisations. The bilateral agreement covers exchange visits to institutes and universities throughout Taiwan. This workshop was aimed at raising awareness and the profile of work in both Scotland and Taiwan, and to encourage and foster collaboration, through the Hi-Tech Forum.

The topic of the Workshop is particularly important, as nanotechnology is predicted to become the basis for remarkably powerful and inexpensive computers, fundamentally new medical technologies that could save millions of lives, sensors important for data collection, and for environmental protection, and new zero pollution manufacturing methods that could create greater material abundance for all. According to policy-makers, the development of nanotechnology, as the latest mega trend in science and engineering will bring a wave of radical innovation and perhaps, because of its potentially broad impact, spark the genesis of a new industrial revolution.

The Programme for the Workshop was arranged to reflect the mutuality of work on the subject in both regions, where researchers from Scotland alternated with Taiwanese guests to present their work on complementary areas.

The Workshop was organised into four specific sessions covering:

(i) BioNanotechnology incorporating MEMS (Micro-electromechanical devices)
(ii) Integration and Applications of Silicon Micro and Nanostructures
(iii) Foundry based MNT for discrete and integrated MEMs
(iv) Challenges in Micro-nano-manufacturing.

Excellent presentations were made, and there was a healthy interchange of ideas, and plans were discussed for future collaboration.

It was good to note the presence of several dignitaries at the Workshop, including Dr Ching-Jyh Shieh, the Deputy Minister of the National Science Council of Taiwan and Professor Kwang-Lung Lin, the Director General of the International Department of the National Science Council.

Dr Chang-Tze Hu and Ms Isabelle Chen from the Science Division of the Taipei Representative's office in the UK were extremely helpful in the planning of the event and in arranging the speakers from Taiwan.

Special thanks are due to Professor Deepak Uttamchandani who played a key role in organising the technical programme, and to Frances Fowler and Jean Finlayson of The Royal Society of Edinburgh, who worked long and hard to ensure excellent arrangements for the Workshop.

Programme
Wednesday 12 October 2005

9.30	*Registration, RSE entrance hall*	
9.45	Welcome	Professor Tariq Durrani OBE, FREng, FRSE
9.50	Welcome	Dr Ching-Jyh Shieh, Deputy Minister of the National Science Council of Taiwan
9.55	Introduction	Dr Kwang-Lung Lin, Director General of the International Department of the National Science Council of Taiwan
Chair:	Professor Wilson Sibbett CBE, FRS, FRSE, Chairman of the Scottish Science Advisory Committee	
SESSION 1: BioNanotechnology incorporating MEMS		
10.00	Studying Micro-Electro Mechanical Interactions in Single Heart Cells using Bionanotechnology	Professor Jon Cooper FREng, FRSE, University of Glasgow
10.30	Manipulation, Replication, Separation and Detection of Nano-Scale DNA Molecules Using Enabling MEMS Technology	Professor Gwo-Bin Lee, National Cheng Kung University
11.00	*Coffee*	
SESSION 2: Integration and Applications of Silicon Micro and Nanostructures		
11.30	Technology for Multifunctional Silicon Integration	Professor Anthony Walton FRSE, University of Edinburgh
12.00	Process and Application of Silicon MOS Structures with Ultra-Thin Gate Dielectrics	Professor Jenn-Gwo Hwu, National Taiwan University
12.30	*Lunch & Poster Session*	
Chair:	Professor Jenn-Gwo Hwu, National Taiwan University	
SESSION 3: Foundry based MNT for Discrete and Integrated MEMS		
14.15	Using Commercial Foundries for "Fabless" MEMS	Professor Deepak Uttamchandani, University of Strathclyde
14.45	Foundry Based MNT in Taiwan with Focus on CMOS MEMS	Professor Jung-Tang Huang, National Taipei University of Technology
15.15	*Tea*	
SESSION 4: Challenges in Micronanomanufacturing		
15.45	Assessing and Packaging of MEMS	Dr Marc Desmulliez, Heriot-Watt University
16.15	Development of Nanometer Resolution Working Stages	Professor Wen-Yuh Jwye, National Formosa University
16.45	**Open Forum and Panel Discussion**	
Chair:	Professor John Mavor FREng, FRSE, Vice-President of The Royal Society of Edinburgh	
17.45	*Closing remarks*	*Professor Wilson Sibbett, CBE, FRS, FRSE*

Aims and Objectives of the Workshop

The Micronanotechnology Workshop represented an opportunity for leading experts, researchers and commentators from Scotland and Taiwan to come together to:

i) discuss and learn about recent advances in this rapidly changing area;
ii) establish international ties; and
iii) explore avenues for future exchange and collaboration.

Both The Royal Society of Edinburgh and The National Science Council of Taiwan saw the event as a welcome occasion for the development of long-term ties and an important vehicle for generating collaborative initiatives.

The Royal Society of Edinburgh will be selecting participants to follow up on the outcomes, to monitor the longer impact of the meeting.

Welcome Address & Introduction

Delegates were warmly welcomed by Professors Durrani and Lin, Drs Shieh and Edgar Lin, who all expressed delight that this meeting was taking place. They each recognised that the workshop is a practical way of building on the Memorandum of Understanding that was signed between The Royal Society of Edinburgh (RSE), Scotland's National Academy of Science and Letters and The National Science Council (NSC) of Taiwan in 2001. As Professor Durrani pointed out, the timing of this workshop is very appropriate as the UK government is committed to increasing research funding over the coming years in a few key areas including micro- and nano-technology. Dr. Edgar Lin, the Taipei Representative in the UK, commented on the similarities of Scotland and Taiwan; both being small regions whose financial well-being depends on fostering Intellectual Property. Professor Lin expressed the expectation that the workshop would be the basis of further cooperation between the two regions. Initial follow-up collaboration might be supported through the joint funding scheme – the RSE–NSC Bilateral Exchange Programme.

Session 1

BioNanotechnology incorporating MEMS

Chair: **Professor Wilson Sibbett CBE, FRS, FRSE, Chairman of the Scottish Science Advisory Committee**

Studying Micro-Electro Mechanical Interactions in Single Heart Cells using Bionanotechnology

Professor Jon Cooper FREng, FRSE, University of Glasgow

The need for rapid and sensitive methods for the analysis of DNA, proteins and cells has generated considerable interest in the development of new microfluidic analytical platforms, fabricated using methods adapted from the semi-conductor industry. These Lab-on-a-chip methods often involve having a miniaturised biochip (as an analytical device), with rather larger instrumentation associated with the control of the associated sensors and of fluidics.

This talk explored first the development of new Lab-on-a-chip platforms for DNA and protein analysis, showing some of the general advantages that can be realised through the miniaturisation of analytical devices. In one example, it was shown how microtechnologies associated with Lab-on-a-chip can provide the functional framework and packaging surrounding assays based upon optical nanosensors in DNA analysis.

The second half of the talk described how Lab-on-a-chip systems have been developed for a series of single cell assays. One particular interest involves exploring the development of nanocalorimetry, where the metabolic activity of the cell can be directly measured thermally, with a resolution of 0.1 mK.

These non-specific nanocalorimetric assays have been further developed, within the same microfluidic systems and have resulted in a variety of new analytical platforms. In the final example, the development was described of new tools to help explore the relationship between the electrical activity of the heart cell and its function, determined in the context of its (mechanical) contraction.

Manipulation, Replication, Separation and Detection of Nano-scale DNA Molecules Using Enabling MEMS Technology

Professor Gwo-Bin Lee, Department of Engineering Science, National Cheng Kung University

In the past decade, microfabrication of miniature fluidic devices has attracted considerable interest and made substantial impacts. One of the most promising applications is chemical and biochemical analysis. Recently, MEMS (Micro-electro-mechanical-system) technology for nano-biotechnology has also been under intensive exploration. DNA is a nano-scale molecule which carries important genetic information. In this talk, four topics related to DNA molecules using MEMS-enabled technology were introduced, including (1) novel magnetic tweezers capable of stretching and rotation of a single DNA molecule to investigate physical properties of DNA; (2) a micro-device for fast DNA amplification process using a miniaturized system; (3) an integrated system for DNA separation; and (4) an integrated microfluidic system for detection of DNA. Manipulation, replication, separation and detection of nano-scale DNA was demonstrated. The technology developed will be a powerful tool for bio-nanotechnology.

REPORT ON SESSION 1

Professor Jon Cooper's presentation demonstrated the advantages of moving to micro-scale systems for biological applications. For example, most biological processes operate through diffusion: reducing sensor dimensions by a factor of ten means that diffusion takes place 100 times faster. Reactions are also dependent on surface area, and small components have a larger surface-to-volume ratio and so also enhance reaction rates. Micro-scale systems allow individual cells, the natural unit of biological interactions, to be studied. At an even smaller scale, functionalised gold nano-particles labelled with a dye component were used as the basis of a micro-fluidic system to enable the detection of bacteria such as E-Coli.

The heart cell is of great interest to medical researchers since heart disease is a major cause of death and at present there are no therapeutic drugs. One of the devices for studying heart cells that Professor Cooper described was a nanocalorimeter capable of detecting a thermal output of 1.6 nW per cell. A miniature patch clamp system was also developed for studying heart cells. By adding a Ca^{2+} sensitive dye to the cell the calcium wave propagation along the cell could be observed optically in response to the contractions induced by caffeine stimulation at one end of the cell.

Professor Gwo-Bin Lee's work on manipulating DNA again highlighted the advantages of operating at the micro-scale when studying biological applications. Physical properties of single DNA strands, such as spring constant, were investigated. The strand was anchored to a substrate and a magnetic particle was attached to the free end. The strand was placed over a set of micromachined electro-magnetic coils and by controlling the magnetic field the strand could be moved around and stretched. This technique avoids the photo-induced damage that can occur with optical tweezers.

Larger quantities of DNA were dealt with in the DNA separator that Professor Lee described that used micro-fluidic channels for separation of DNA types by electrophoresis. Detection of DNA was carried out by measuring laser-induced fluorescence.

Another example of a micro-fluidic system was the miniaturised DNA amplification system that had significant advantages over the standard PCR system. It could execute 32 cycles in 15 min, with a power consumption of 1 W, compared with standard current systems that take 3 hours and consume 100 W for the same numbers of cycles.

Session 2
Integration and Applications of Silicon Micro and Nanostructures

Chair: **Professor Wilson Sibbett CBE, FRS, FRSE, Chairman of the Scottish Science Advisory Committee**

Technology for Multifunctional Silicon Integration

Professor Anthony Walton FRSE, University of Edinburgh

The direction of developments in the integrated circuit industry are very well defined by the ITRS roadmap and huge resources are being invested by the major players to help ensure they will meet these goals. In parallel with this, CMOS technology is not only shrinking in dimensions, but also making available increased performance at an ever reducing cost. This provides many opportunities for using the technology for new and novel applications that would not previously have been possible. In particular there are opportunities integrating new materials and micro/nanosystems (MEMS/NEMS) with CMOS/other semiconductor technologies. This presentation reviewed some of the technologies and processes that lend themselves to integration with CMOS and other available semiconductor microelectronics.

Process and Application of Silicon MOS Structures with Ultra-Thin Gate Dielectrics

Professor Jenn-Gwo Hwu, National Taiwan University

High-*k* gate dielectrics with an equivalent oxide thickness (EOT) of smaller than 2nm are prepared by using anodization in deionized water or oxidation in HNO_3 of ultra-thin metal films. Both Al_2O_3 and HfO_2 metal oxides with good I-V and C-V characteristics were shown. The demonstrated process is cost-effective and uses a low process temperature. The substrate injection currents in MOS structures with an SiO_2 layer thinner than 2.5nm and a substrate of 1~10 Ωcm exhibit saturation behavior and are very sensitive to temperature. The MOS structures biased under constant voltage or constant current were demonstrated to be applicable as on-chip temperature sensors. Scanning frequency anodization in deionized water was proposed as a method to compensate the leakage paths existed in ultra-thin gate oxides.

REPORT ON SESSION 2

There are obvious benefits to integrating CMOS and MEMS/NEMS, with MEMS sensors and actuators linked closely with controlling/interrogating electronics, but there are technological challenges to be overcome. Professor Walton described a variety of ways in which this integration can be achieved. The two technologies can have conflicting processing requirements, e.g. CMOS should not be exposed to temperatures above 435^0C in order to avoid diffusion of Al, thus precluding the laying down of poly-Si after CMOS processing. Such conflicts can be avoided by completely separate processing, with MEMS on one substrate and CMOS on another. The two parts can then be assembled either at the chip scale (wire- or bump-bonding) or at the wafer scale (low temperature wafer bonding).

Single substrate solutions are sometimes possible, with either (a) CMOS processing carried out first, then MEMS/NEMS; (b) MEMS/NEMS processing carried out first, then CMOS; or (c) both carried out in an integrated process. Option (b) may prove problematic for CMOS foundries: they are likely to be reluctant to accept a wafer processed outside their plant since they will be wary of introducing contamination from materials used in MEMS processing that could contaminate their processes. Professor Walton described some recent integration projects from his institution, including the sub-millimetre radiation detectors (SCUBA2) for the new James Clerk Maxwell telescope, and a "lab-on-a –pin" project that involved the assembly of three chips.

Professor Hwu's presentation concentrated on a single key component of CMOS processing, namely dielectrics and a method for increasing their performance. As CMOS technology moves to smaller and smaller devices, gate leakage through thin SiO_2 dielectrics (<2 nm) by electron tunnelling compromises the performance of devices. By choosing metal oxides as an alternative gate material, fabricated by anodization of thin metal films, leakage currents have been reduced by three orders of magnitude. The temperature sensors that can be fabricated by this technology were shown to have a fast response time and do not exhibit hysteresis. They could be used for environmental monitoring, at either the macro-scale or the micro-scale to monitor temperatures in different areas of an IC.

Session 3
Foundry-based MNT for Discrete and Integrated MEMS

Chair: Professor Jenn-Gwo Hwu, National Taiwan University

Using Commercial Foundries for "Fabless" MEMS

Professor Deepak Uttamchandani, University of Strathclyde

Commercial foundries are increasingly offering MEMS prototyping and manufacturing services, mainly for the benefit of organisations not equipped with costly and high-maintenance fabrication facilities. Both cost-effective prototyping, via multi-user fabrication processes, and custom-prototyping services are available from these foundries. During this talk the speaker outlined his experience of using international commercial foundries for MEMS research, and examples were given of successful MEMS projects with applications in the RF and photonics fields. The talk assessed the advantages and disadvantages of using foundries from the perspective of a university based user and explored whether the "fabless" MEMS model can successfully follow approaches used in the microelectronics industry.

Foundry-Based MNT in Taiwan with Focus on CMOS MEMS

Professor Jung-Tang Huang, National Taipei University of Technology

In world-wide league tables, Taiwan is in first place for CMOS foundry and in second place for fabless IC design in-house. Therefore Taiwan is expected to play an important role in foundry-based MNT. Several IDMs and foundries in MEMS such as APM, Neostones and tMt provide foundry services for popular commercial MEMS products, such as pressure sensors and inkjet heads. Some of them are also developing their own components and subsystems in optical or RF communication. In universities, several projects focus on innovative products achieved through CMOS MEMS technology, which are provided by TSMC and UMC. They are:

1. Monolithic wireless biomedical sensor network system aimed at providing a vehicle to fully integrate the technologies of RFMEMS, bio-sensing, IC design, and communication protocol design.
2. Nanojet Technology developed a system-on-a-chip packaged nanojet print head. CMOS and MEMS dry–etch processes are applied to a wafer to make nanojet hole, cavities, refill-proof micro-channel, inlet, and driving wave generator circuits on the same side of the wafer. Finally, a nickel vibration membrane and piezoelectric thick film are aligned and bonded to the silicon wafer to assemble the complete PZT nano-inkjet head.
3. CMOS-MEMS Probe Arrays, including micro-probe array for EFM-based Tb/in^2 data storage, scanning tip oxidation array for nanolithography, MFM probe array, and probe card with probe force feedback.

REPORT ON SESSION 3

In addition to making use of local MEMS fabrication facilities in Scotland, Professor Uttamchandani has made extensive use of commercial MEMS foundry services in America. (His own institution does not have any silicon processing capability.) He has found it to be a cost-effective route to carrying out world-class research without having to invest money in the purchase and upkeep of equipment, or spend time in process development. Effort can be concentrated on innovative design and on testing. The foundry he uses offers a range of multi-user processes (all-metal, bulk machined SOI, and surface machined polysilicon) for research, and these processes are also available for commercial customers. By developing devices using these processes, there is an automatic route to manufacturing on a commercial scale.

The fact that the processes are open to everyone does mean that ingenuity has to be used in order to create novel work with them. Professor Uttamchandani described pioneering work done on analysing air damping effects on comb drives made by a foundry process. He also highlighted an rf bandpass filter that had been manufactured with state-of-the-art performance.

Professor Huang explained that Taiwan's foundry and design houses were undergoing a change in emphasis. Until recently they had concentrated on achieving efficient manufacture of products with a low profit margin and now they wished to add value to the products through innovation and developing IP. A contribution to this aim is being made by two foundries offering integrated CMOS and MEMS processing. One of them, the Chip Implementation Center (CIC), is a government-funded resource made available free to universities that provides 0.35 μm and 0.18 μm CMOS plus a 2 μm resolution MEMS process. The other is TSMC, a commercial operation due to be on-line in 2006.

A major theme for MNT research in Taiwain is to be biomedical and environmental applications, as illustrated by the work on a biomedical sensor network system that Professor Huang described. The remote monitoring of blood glucose and ECG has been demonstrated.

The nanojet print head was notable for achieving a smaller nozzle size (down from the 15 μm diameter of conventional manufacturing to 1 μm diameter) that allows a smaller droplet size (in the femtolitre range). Apart from conventional printing the head could also be used for other liquid dispensing applications, eg photoresist deposition. Another significant outcome was that a greater degree of integration of components was achieved, reducing the number of components that had to be assembled to form the print head.

Professor Huang thought that MEMS devices containing arrays of probes will be a significant market. He described research into arrays carrying out functions associated with scanning probe microscopes (magnetic and thermal imaging), as well as memory and bio-assay applications (detecting the change in mass when a bio-molecules attaches to a functionalised probe tip).

The CIC foundry service proved to be of interest to Scottish delegates. Dr Desmulliez asked if it might be made available to Scottish institutions. Professor Huang thought that this might be possible, although probably only via a collaborative Scotland-Taiwan project.

Session 4
Challenges in Micronanomanufacturing

Chair: **Professor Jenn-Gwo Hwu, National Taiwan University**

Assessing and Packaging of MEMS

Dr Marc Desmulliez, Heriot-Watt University

Most electronic industry experts agree that today's market demand for increasingly smaller products and the push for greater functional power can only be met through advances in packaging technologies. A recent market survey from the Consultant Services BPA predicts that, by the year 2006, 63% (10.4 billion) of all electronic systems will be portable. The same company also calculates that 65% of an electronic product's added value comes from packaging.

In the optoelectronic and microengineering sectors, packaging is a nascent technology; standards, design tools and manufacturing processes are still being developed. A country that could capture and enhance this know-how in the electronics sector, and develop it in the photonics and microengineering markets could rapidly reach a dominant position in fostering unprecedented economic development in high technology.

This talk presented the latest technological advances made by MISEC (MicroSystems Engineering Centre) in assembly and packaging of MEMS. The presentation focused on the integration of DC-DC micro-power converters, new flip-chip bonding methods for MEMS, the development of sub-100 microns pitch stencil printing, the sub-micron alignment of monomode fibre arrays and laser-assisted bonding and sealing of packages.

Development of Nanometer Resolution Working Stages

Professor Wen-Yuh Jwye, National Formosa University

Ultra-high precision stages have been developed for micro and nano-manufacturing. For different demands of positioning techniques in manufacturing, a heavy-load-capable 5-axis hinge-type working stage and a compact 5-axis working stage, with 1 nanometer resolution and travelling ranges of some micrometers, were presented. Techniques of employing laser interferometers and capacitance sensors for nano-contouring and positioning were also described. Finally, a 2-axis long working stage, with 330 mm x 300 mm travelling range with 10 nanometers resolution was introduced with a 5-axis self-compensation measurement system.

REPORT ON SESSION 4

In his presentation Dr Desmulliez highlighted the importance of the role of packaging in developing a device from demonstration in the lab to full commercialisation. Among the techniques for packaging that his research group has developed is an electrostatic fibre aligner that can be integrated into a device, allowing the fibre to be hermetically sealed in place once aligned. His group is investigating the use of laser-cured glue as a medium for creating patterns. This light sensitive glue can be used for encapsulating devices by depositing a bead of glue around the device, placing a transparent lid on top and directing a laser beam through the lid in order to cure the glue.

Open Forum and Panel Discussion

Chair: Professor John Mavor FREng, FRSE, Vice-President, The Royal Society of Edinburgh

Panel members
Professor Jenn-Gwo Hwu, National Taiwan University
Professor Wen-Yuh Jwye, National Formosa University
Professor Anthony Walton FRSE, University of Edinburgh
Professor Deepak Uttamchandani, University of Strathclyde

The desire for co-operation in research between Taiwan and Scotland was strongly in evidence during this session. Related strands of research had been outlined earlier in the pairs of presentations and further commonality was explored. Researchers from both regions share the aims of achieving personal fulfilment and benefit to their region and wider humanity through the fruits of their endeavours, enhancing the quality of life and developing trade. Both communities of researchers also experience the struggle of securing funding and even more difficulty in obtaining follow-on funding for projects.

Professor Walton was pragmatic in highlighting the fact that both partners must identify what benefits would accrue from a cooperative venture. They would need to identify what complementary skills/processes/equipment the pairing would possess.

It was agreed that the ultimate aim is to establish new joint projects between Scottish and Taiwanese institutions but it was recognised that there were various structural problems to be overcome, and this would take some time. A more immediate prospect is to allow exchange visits under the auspices of existing projects. Some discussion took place as to the appropriate level for those participating in the exchanges. It was agreed that most benefit would be obtained by exchanges that lasted several weeks so that participants could 'find their feet' and begin to make a contribution to the project they were visiting. Principal investigators could probably not spare this amount of time and opinion was divided on whether post-graduate students or post-doc researchers would be more suited.

Some mechanisms already exist to allow exchanges at various levels. PhD students in Taiwan can be sent aboard for one year of their studies and this scheme could be extended to include Masters students (a two-year course, rather than the one-year course that is usual in Scotland). At present some postgraduate students from Taiwan carry out their studies in the UK, but very few do so in Scotland. This may indicate that a greater recruitment effort could be made by Scottish institutions in Taiwan. Currently, the Royal Society of Edinburgh's joint funding scheme with the National Science Council of Taiwan is restricted to postdoctoral researchers (or equivalent). A similar scheme is in place between the National Science Council of Taiwan and the Royal Society (of London), which complements the RSE–NSC bilateral programme.

Students from Taiwan could be accepted as visitors in Scottish universities for periods up to six months with no fees being charged, provided the students were not seeking a qualification from the Scottish institution. Visits at the level of principal investigator can be supported through ESPRC, which has a scheme that allows UK academics to apply to fund a visit by world-class academics from overseas.

For extended visits in the opposite direction (ie from Scotland to Taiwan), exploration of funding mechanisms for postgraduate students is needed, as it is unlikely that there will be specific funding within their projects to support such visits. In addition to the Royal Society scheme described above, travel grants are also available for post-docs from EPSRC. It is possible that the RSE may reconsider the eligibility criteria for its bilateral exchange programme and extend it to postgraduate students, although this is within a context of limited funding. Dr Chang-Tze Hu (Science Division of the Taipei Representative's office in the UK) suggested that it might be possible for NSC to support the visit of Scottish postgraduate students to Taiwan.

The delegates then discussed the importance of involving industrial partners, such as the large Taiwanese silicon foundries, in collaborative research. They would gain competitive advantage from the results of research and their support would be useful when applying for research funding. A number of representatives from Scottish industry had been present through the day and much interest in this field was generated with these delegates during informal private discussions. However, it was recognised that efforts had to be made to make industry in general more aware of the benefits from early exploitation of a breakthrough technology such as micronanotechnolgy. Within Scotland, Scottish Enterprise could have a role in linking academia with industry.

The establishing of new collaborative projects would pose challenges in securing funding. In general, there is no coordination between UK and Taiwanese National Research Councils and they tend to fund projects taking place within their own region. A joint project would require applications to be made to both the Scottish and Taiwanese councils on an independent basis. Researchers from both countries commented on the low success rate of grant applications; an even lower success rate might be expected for twinned applications. However, there was some encouraging news: Professor Uttamchandani reported that a precedent had been set for collaboration between two national research councils. A joint US/UK call for materials research is currently underway. This came about as a direct result of pressure applied by scientists from both participating countries, serving as an example of what the delegates could achieve.

CLOSED DISCUSSION

Professor D Uttamchandani, Professor of Microsystems Engineering, University of Strathclyde

Further discussions were held over a post-conference dinner hosted by the Taiwanese delegation. All agreed that the event had been successful by way of introducing leading Taiwanese and Scottish scientists working in the field to one another. It was recommended that the following actions should be followed:

A. A visit to Taiwan by Professor Deepak Uttamachandani (Strathclyde University) and Professor Anthony Walton (Edinburgh University) any time before March 2006. Their visit would be hosted by Professor K.B Lee (National Cheng Kung University), Professor J. G. Hwu (National Taiwan University). It is hoped that the visit of the Scottish academics would:
   - encourage joint projects or collaborations to be initiated;
   - allow the Scottish visitors to gain direct exposure to academic and commercial MNT activities in Taiwan;
   - help generate more interest from young Taiwanese researchers to visit Scotland with the National Science Council's scholarship, and for reciprocal visits with RSE support to be made by Scottish researchers.

B. It was once again reiterated that such visits by young researchers would yield fruitful results if the duration of the visits was at least several months.

Professor Durrani wrapped up the day's proceedings with a toast thanking all the organisers for their efforts in making the event a success and wishing a safe journey to all.

Biographies

Professor Jon Cooper FREng, FRSE, University of Glasgow

Professor Jon Cooper has interests in exploring the benefits of miniaturisation in biology using both micro and nanotechnologies. Recent examples of his work include the use of nanoparticle sensors in DNA diagnostics and the development of lab-on-a-chip formats for real-time monitoring of cellular events. He was a member of the DTI-Foresight Lab-on-a-Chip (LOAC) Consortium and is currently a principal applicant in the Interdisciplinary Research Collaboration (IRC) in Bionanotechnology (2001-2007) and the IRC in Proteomic Technologies (2005-2011), see http://www.rasor.org.uk. He is on the Editorial board of *Biosensors and Bioelectronics*, and the *IEEE Transactions in Biological Nanoscience*, as well as being Editor-in-Chief of *IEE Proceedings in Bionanotechnology*. He was elected a Fellow of the Royal Society of Edinburgh in 2001 and a Fellow of the Royal Academy of Engineering in 2005.

See http://www.elec.gla.ac.uk/groups/bio/staff/jcooper/index.htm for more details.

Dr Marc Desmulliez, Heriot-Watt University

Dr Marc Desmulliez was born in France in 1963 and graduated from the Ecole Superieure d'Electricite of Paris in 1987. He also obtained two MScs in modern optics and theoretical physics from University College London (1987) and the University of Cambridge (1991), respectively. He finally obtained a PhD in Optoelectronics from Heriot-Watt University (1995). Dr Desmulliez is currently the Director of the Microsystems Engineering Centre (MISEC) at Heriot Watt University, which has seven permanent members of staff and over twenty PhDs and RAs all working in the field of MEMS. Dr Desmulliez has published over 110 articles, holds two patents and is the director of a spin-out company MicroStencil. He has two visiting professorships from ESME- Sudira (Paris) and Vestfold College (Norway) and is presently the holder of the Royal Society of London/Kan Tan Po visiting professorship award to the City University of Hong Kong. His research interests are in MEMS integration and packaging.

Professor Tariq Durrani OBE, FREng, FRSE

Professor Tariq Durrani is Deputy Principal at the University of Strathclyde with oversight responsibility for Staff Development, Lifelong Learning and Information Technology Strategy. He is an electronics engineer by training and is Professor of Signal Processing. He has published over 300 papers and is author/co-author of six books.

He is a member of the Scottish Funding Council; and a Director of the UK Leadership Foundation for Higher Education, the Glasgow Chamber of Commerce, the Institute for System Level Integration and the Kelvin Institute. He has acted as Advisor to higher education and research organisations in the UK, EU, the Middle East and the South East Asia.

He is active in professional circles, being a Member of the Council for The Royal Society of Edinburgh and its International Committee, Executive Vice-President of the IEEE Engineering Management Society, and Chairman of the Advisory Board of the West of Scotland Knowledge Transfer Partnership.

Professor Jung-Tang Huang, National Taipei University of Technology

Professor Jung-Tang Huang received a degree in Mechanical Engineering from National Taipei University of Technology in 1981, his MSc degree from Tsing Hua University, Taiwan, in 1986 and a PhD on Mechanical Engineering from University of California Los Angeles in 1992. He then joined the faculty of National Taipei University of Technology, where he is now a Professor. Since 1998, he has served as a division leader for NSC Northern MEMS center to promote Industry-Academy Research Collaboration. He has served as a consultant or conducted industrial projects with several companies on innovated MEMS products. His research interests include the RFMEMS, BIOMEMS and packaging technology, especially on design and modelling, integrated MEMS manufactured in CMOS processes. He holds three US patents and 28 Taiwan patents.

Professor Jenn-Gwo Hwu, National Taiwan University

Professor Jenn-Gwo Hwu was born in Tainan, Taiwan, on August 29, 1955. He received a BSc degree in electronic engineering from National Chiao-Tung University, in 1977, and MSc and PhD degrees in electrical engineering from National Taiwan University in 1979 and 1985, respectively.

He joined the faculty of National Taiwan University in 1981. He is now a Professor in the Department of Electrical Engineering and the Graduate Institute of Electronics Engineering, National Taiwan University. From 1997 to 1998, he was the Vice-Chairman of the Department of Electrical Engineering, National Taiwan University. From February 1, 2004, he was appointed Dean of the College of Electrical Engineering and Computer Science, National United University, Miaoli, Taiwan. His research work is mainly on ultra-thin gate oxide and its related Si MOS devices. He has experience in teaching the courses of Circuits, Electronics, Solid-State Electronics, Semiconductor Engineering, MOS Capacitor Devices, Radiation Effects on MOS System, and Special Topic on Oxide Reliability.

He was qualified to be a licensed Professional Technique Experts on Electrical and Electronics Engineering, Taiwan, in 1978 and 1980, respectively. He was honored with an Outstanding Teaching Award in 1991 by The Ministry of Education and in 1987 and 2003 by the National Taiwan University. He was also awarded the Excellent Teaching Award in 1988, 1989, 1990, 1991, and 1993 by the College of Engineering, National Taiwan University, and in 1999, 2000, and 2002 by National Taiwan University. In 1999, he was the recipient of Jan Ten-You Paper Award by The Chinese Institute of Engineering, Taiwan. In 2005, he was the recipient of Best Paper Award by Far Eastern Y.Z.Hsu Science and Technology Memory Foundation, Taiwan.

Professor Wen-Yuh Jwye, National Formosa University

Professor Wen-Yuh Jywe, born in 1962 in Taiwan, gained his Master and PhD degrees from the University of Manchester Institute of Science and Technology in 1987 and 1992 respectively. He is a Professor at the National Formosa University. He has carried out more than 20 research projects in developing techniques in dimensional metrology and various short and long micro/ nano working stages for micro and nano-manufacturing. He has published more than 40 journal papers and 30 patents in the last five years. He is also Dean of R&D office in charge of research and development affairs and international cooperation affairs at National Formosa University.

Professor Gwo-Bin Lee, Professor, Department of Engineering Science, National Cheng Kung University

Professor Gwo-Bin Lee received his BSc and MSc degrees from the Department of Mechanical Engineering at the National Taiwan University in 1989 and 1991, respectively. He received his PhD in Mechanical & Aerospace Engineering from the University of California, Los Angeles, USA in 1998. He is currently a Professor in the Department of Engineering Science at National Cheng Kung University. His research interests lie in nano-biotechnology, microfluidics and its biomedical applications, micro flow sensors, micro-actuators and their optical applications. He received the Distinguished Researcher Award from NCKU in 2002, the Distinguished Young Engineer Award from the Chinese Engineer Society in 2003, the Distinguished Mechanical Engineer Award in 2004, and the K. T. Lee Research Award in 2004. He has published over 80 referred journal papers and 160 conference papers and owned 17 patents. He is the director of MEMS Design and Microfabrication Lab and Microfluidic Biochip Lab. Dr. Lee is IEEE/ASME member.

Dr Edgar Lin, Taipei Representative in the United Kingdom

Dr Edgar Lin's distinguished career started with his studying English at Taiwan University, then moving to Ecology, studying at Indiana University in the United States of America. His career has taken him all over the world, working in Israel, Thailand, Haiwaii, becoming a representative for Taipei in 2001 in The Gambia. London is his second posting in this capacity.

Dr Kwang-Lung Lin, Director General of the International Cooperation, the National Science Council of Taiwan

Dr Kwang-Lung Lin took up his position as Director General of the International Cooperation for the National Science Council in January 2005. His PhD is in metallurgy, which he read at Pennsylvania State University. He has worked subsequently in a number of roles at National Cheng Kung University, including as Director of the Institute of Nano Science and Technology and most recently Chairman of the Institute of Micro Electromechanical System.

Professor John Mavor FREng, FRSE, Vice-President of The Royal Society of Edinburgh

Born in Ayrshire, John Mavor was an undergraduate at City University, London, from where he graduated in Electrical Engineering in 1964. After graduation he worked in the Blackheath Research Laboratory of AEI evaluating a first generation of transistors in telecommunications. Thereafter, in 1965 he read for a PhD at London University, which was awarded in 1968 for a thesis on the electronic noise properties of MOS transistors. Thereafter, he devoted 25 years to researching novel MOS/CCD integrated circuits for strategic signal processing and infra-red applications. He has published 150 papers and several books, for which he was awarded a DSc(Eng) in 1990 from London University. During the period 1991–93 he was an IEEE Distinguished Lecturer to the Circuits & Systems Society (USA).

Professor Mavor was the first holder of the Lothian Chair of Microelectronics for five years at the University of Edinburgh; this was translated to the Chair of Electrical Engineering in 1986. During 1984-89 he was Head of the Department of Electrical Engineering and, in 1989, he was elected Dean, Faculty of Science & Engineering. In

1994, he was appointed Principal & Vice-Chancellor of Napier University from which he retired in 2002.

He was appointed Vice-President (Physical Science & Engineering) of The Royal Society Edinburgh in 2004.

Dr Ching-Jyh Shieh, the Deputy Minister of the National Science Council of Taiwan

Dr Ching-Jyh Shieh's area of scientific interest is aerospace engineering. Prior to taking up his current post in 2000, he worked for the National Space Program in Taiwan, having been employed previously at the Aerospace Corporation, El Segundo, California.

In his current position, Dr Shieh has, amongst other key achievements, accelerated the globalization of Taiwan's R&D efforts by establishing three Science and Technology (S&T) Divisions in Vietnam, Australia and Russia over the past three years. He has also promoted the self-reliant capabilities of Taiwan's space technology, with the completion of the research, design, construction and evaluation of the Pico satellite, YAMSAT, and the Image Process System (IPS), a software program for ROCSAT-II image processing.

Professor Wilson Sibbett CBE, FRS, FRSE, Chairman of the Scottish Science Advisory Committee

Professor Wilson Sibbett CBE, FRS, FRSE, is Chair of the Scottish Science Advisory Committee and Wardlaw Professor of Physics, University of St Andrews. Professor Sibbett is recognised as a pioneer and world authority in ultrafast lasers, nonlinear optics and optoelectronics/photonics and he has published over 300 scientific journal papers in these areas. His work has wide-ranging applications in the field of ultrafast science and technology, including optical communications and photobiology. He is presently the Co-Technical Director of the St Andrews *Photonics Innovation Centre* that promotes the linkage of academic research to applications in industry, Director of an EPSRC-funded Interdisciplinary Research Collaboration - *Ultrafast Photonics Collaboration* on ultrahigh speed data-communications and Co-Director of a SHEFC-funded Strategic Research Development Grant on the application of photonics to biology and medicine. He received the Rank Prize for Optoelectronics in 1997, the Mitutoyo–NPL Frontier Science and Measurement Award in 1998 and the Rumford Medal of the Royal Society for "Research into Ultrashort-Pulse Laser Science and Technology" in 2000. In 2002 he was awarded the Quantum Electronics Prize by the European Physical Society in recognition of the 'excellence and enduring impact' of his major research contributions.

Professor Deepak Uttamchandani, University of Strathclyde

Professor Deepak Uttamchandani is Professor of Microsystems Engineering and leads the MEMS and Microsystems activity at the Centre for Microsystems and Photonics. He has worked in the field of micromachining and MEMS since the late 1980s. His activities have included R&D in microsensors and microactuators, thin film property measurements in micromechanics, MOEMS, RF-MEMS and general MEMS design. His team has extensive experience of using commercial foundries for MEMS R&D.

Professor Anthony Walton FRSE, University of Edinburgh

Professor Anthony J. Walton is Professor of Microelectronic Manufacturing in the School of Engineering and Electronics at the University of Edinburgh. He has been actively involved with the semiconductor industry in a number of areas associated with silicon processing, which includes both IC technology and micro-systems. This includes microelectronic test structures, yield improvement, Design for Manufacturability (DFM) and Technology Computer Aided Design (TCAD). His present interests also include the applications of micro and nanotechnology to biotechnology, organometallic materials for semiconductor applications, sensors and interconnect technology. He also has had a long interest in integrating new technologies (such as MEMS) and materials with foundry CMOS.

He played a key role in setting up the Scottish Microelectronics Centre (SMC), which is a purpose-built facility for R&D and incubation. It consists of approximately 300m^2 of class 10 cleanrooms with a comprehensive set of CMOS and MEMS equipment and 1000m2 of office and laboratory space. Since its opening in 2005 it has been involved with the incubation of companies such as MED, Ice Robotics, Critical Blue and Point 35.

He has published over 200 papers and has won the best paper awards for the *IEEE Transactions on Semiconductor Manufacturing*, *Proceedings of the International Society for Hybrid Manufacturers* (ISHM) and the International Conference on Microelectronic Test Structures (ICMTS). He has served as the chairman for a number of conferences, including the European Solid-State Devices Research Conference (ESSDERC) and the IEEE International Conference on Microelectronic Test Structures (ICMTS). He also serves on numerous technical committees and is an associate editor of the *IEEE Transactions on Semiconductor Manufacturing* and the *Journal of Nanoengineering and Nanosystems*.

LIST OF POSTERS

SCOTTISH CONTRIBUTIONS

Droplet Manipulation using electrowetting

Y Li, Scottish Microelectronics Centre, School of Engineering and Electronics, University of Edinburgh

As a post-CMOS processing procedure, an array of electrodes is coated with parylene. Application of potential to electrodes changes the wetting behaviour of droplets of liquid placed on the parylene layer, allowing manipulation.

Engineering Nanoliquid Systems: Fluid Dynamic Phenomena and Simulation Techniques

G Macpherson and J M. Reese, Department of Mechanical Engineering, University of Strathclyde

Micro-extrusion of ultrafine grained aluminium

A Rosochowski (Department of Design, Manufacture and Engineering Management, University of Strathclyde), W Presz (Warsaw University of Technology, Poland), L Olejnik (Warsaw University of Technology, Poland), M Richert (AGH University of Science and Technology, Krakow, Poland)

Micronanophotonics at Glasgow

C Jin, H Chong, P Pottier, M Sorel, N Johnson, R De La Rue, Department of Electronics & Electrical Engineering, University of Glasgow

Examples of processing carried out for micronanophotonic applications illustrated, including 3D photonic crystals and components with drilled holes down to 0.2 μm diameter.

Monomode Fibre Array Manufacture using Microengineering Techniques

D Weiland, M P Y Desmulliez, M Luetzelschwab – MicroSystems Engineering Centre, School of Engineering & Physical Sciences, Heriot-Watt University, Edinburgh

Fibre positioner illustrated. Tips of fibre were coated with metal and then manipulated electrostatically by applying orthogonal electric fields.

Manufacture and Characterisation of Microscale Magnetic Components

D Flynn, M P Y Desmulliez, T Toon, MicroSystems Engineering Centre, School of Engineering & Physical Sciences, Heriot-Watt University, Edinburgh

Overview of Microsystems Engineering Centre projects at Heriot-Watt University

M Desmulliez, M Luetzelschwab, MicroSystems Engineering Centre, School of Engineering & Physical Sciences, Heriot-Watt University, Edinburgh

Piezo-Electric Tool System for Producing Surface Micro-Geometries (SMG's)
M Rosochowska, K Chodnikiewicz, R Balendra, Department of Design, Manufacture and Engineering Management, University of Strathclyde

The micro-pits can be created in materials that can act as small reservoirs of lubricant for applications such as ball joints in hips. The pits increase the surface area so they also have application for drug delivery (increasing surface to volume ratio).

The fluid dynamics of gas microflows
L O'Hare & J M Reese, Department of Mechanical Engineering, University of Strathclyde

The SCUBA-2 detector for the JCM telescope
W Parkes, Scottish Microelectronics Centre, School of Engineering and Electronics, University of Edinburgh

TAIWANESE CONTRIBUTIONS

Compatibility of Material Processing and Fabrication of Sol-Gel Derived PZT Devices
J-C Yu (Department of Mechanical and Automation Engineering, National Kaohsiung First University of Science and Technology) and C-C Chou (Department of Mechanical Engineering, National Taiwan University of Science and Technology)

Low temperature annealing of PZT through CO_2 laser processing, allowing accelerometers to be produced with better sensitivity and noise.

Contact Mechanism of Rough Surfaces
Y-R Jeng, National Chung Cheng University

Theoretical study of chemo-mechanical polishing. Nanomechanics of thin films and nanotubes, with an investigation of dislocation emission around nanoindentations.

Development of Novel Micro/Nano Stages and Measuring Techniques
W-Y Jwye, C-H Liu, National Formosa University

Device Degradation Modelling and Circuit Reliability for CMOS RFIS; Digital Output Pixel Sensor with 1-Bit Memory and Wide Dynamic Range; Low Voltage Transient Voltage Suppressor (LV-TVS); Reliability and Memory Characteristics of Sequential Laterally Solidified Low Temperature Poly-Si TFT with ONO Stack Gate Dielectric
Y-C King, Institute of Electronics Engineering, National Tsing-Hua University

By locating an analogue to digital converter of the imaging chip at the pixel site, higher SNR is obtained.

MEMS for Nano-biotechnology – Manipulation, Replication, Separation and Detection of Nano-Scale DNA
G-B Lee, Department of Engineering Science, National Cheng Kung University
(not presented)

Nanolithography with Scanning Probe Microscopy
T-Hua Fang, Institute of Mechanical and Electronmechanical Engineering, National Formosa University

Research on the Fabrication Mechanism of Nano-scale Curve
S-C Lin, J-C Huang, C-B Yang, Department of Mechanical Engineering, National Taiwan University of Science and Technology
(not presented)

SiGe-Buffer-Free Schottky Barrier –Germanium p-MOSFET
F Yuan (Department of Engineering, National Taiwan University), M H Lee (Industrial Technology Research Institute), C-Y Yu (Department of Engineering, National Taiwan University), S Maikap (Industrial Technology Research Institute), S T Chang (Department of Engineering, National Taiwan University), C-Y Peng (Department of Engineering, National Taiwan University), P-S Kuo (Department of Engineering, National Taiwan University), C C Lee (Department of Engineering, National Taiwan University), M-J Tsai (Industrial Technology Research Institute), C W Liu (Department of Engineering, National Taiwan University)

Enhanced transport mobility of Ge was obtained through optimising a thin epigeal layer of Ge on Si in a CMOS compatible process.

Silicon-Carbide based Microscale Detectors for Extreme Environments
M-H Weng, University of Newcastle

Silicon carbide Schottky diodes allow room-temperature radiation detectors to be constructed for space applications. Modelling and experimental results presented.

The impact of Uniaxial Strain Engineering on Channel Backscattering in Nanoscale
Institute of Electronics, National Chiao-Tung University

Acknowledgements

The Royal Society of Edinburgh would like to thank the following people:

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The Royal Society of Edinburgh would also like to thank Scottish Development International for their generous sponsorship of the reception on 11 October 2005.

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PARTNER INFORMATION

The Royal Society of Edinburgh

The Royal Society of Edinburgh (RSE) is an educational charity, registered in Scotland. Independent and non-party-political, we are working to provide public benefit throughout Scotland and by means of a growing international programme. The RSE has a peer-elected, multidisciplinary Fellowship of 1400 men and women who are experts within their fields. We seek to provide public benefit in today's Scotland by:

- Organising lectures, debates and conferences on topical issues of lasting importance
- Conducting independent inquiries on matters of national and international importance
- Providing educational activities for primary and secondary school students throughout Scotland
- Distributing over £1.7 million to top researchers and entrepreneurs working in Scotland
- Showcasing the best of Scotland's research and development capabilities to the rest of the World
- Facilitating Scotland's international collaboration in research and enterprise
- Awarding prizes and medals

RSE International Programme

The Royal Society of Edinburgh (RSE) initiates and supports a wide range of activities which enhance Scotland's involvement in global collaboration. Through events, strategic partnerships and publications, the RSE promotes the reputation of the nation's research, innovation and culture. By forging effective partnerships with equivalent national academies overseas, amongst others, the RSE is helping to:

- Facilitate two-way international exchange programmes, enabling top Scottish-based researchers, in any field, to collaborate with the best of their counterparts anywhere in the world
- Raise awareness overseas of some of the best of the research and innovation being undertaken in Scotland
- Stimulate collaboration between centres of excellence through joint international events
- Provide a forum for discussion of international issues in science, the arts and letters, technology, industry and commerce.

This successful programme, which has grown since its inception in 1998, is delivered in partnership by the Society's professional staff and the International Committee of the RSE, which comprises eminent Fellows of the Society.

International Events

Examples of Other Recent International Events include:
Languages in Scotland: what's the problem (One-day conference: March 2006) ~ exploring the current state of language learning and teaching in Scotland, considering its impact on the nation's economy and cultural awareness of its people

The RSE China Reception (Evening Reception: February 2006) ~ an opportunity for postdoctoral researchers, based in Scottish research institutions, interested in working with the best of their counterparts in China to gain awareness of the opportunities available through the RSE's bilateral exchange programme with the Chinese Academy of Sciences.

Nanomedicines of the Future (One-day meeting: November 2005) ~ a focused joint workshop with the Academy of Sciences of the Czech Republic (hosted by the University of Strathclyde) looking at new drug delivery systems.

Agreements with Sister Academies

The RSE has bilateral, or formal agreements with:

- the Chinese Academy of Sciences
- the Academy of Sciences of the Czech Republic
- the Hungarian Academy of Sciences
- the Polish Academy of Sciences
- the National Science Council of Taiwan
- The Slovenian Academy of Sciences and Arts

These agreements set out the basis for cooperation, mainly through bilateral funding programmes and joint events.

The RSE also has informal agreements with:

- the Royal Danish Academy of Sciences and Letters,
- the Norwegian Academy of Science and Letters,
- the Cuban Academy of Sciences, and
- The Royal Swedish Academy of Sciences

These agreements establish a willingness to cooperate between the two academies, through the sharing of publications and organising of joint events.

International Exchange Programmes:

The Royal Society of Edinburgh is keen to support research collaboration in all areas between Scottish and overseas research groups. The object of the International Exchange Programmes, funded by the Scottish Executive, is to enable postdoctoral scholars and researchers to come to Scotland or to visit overseas from their Scottish academic base for a short period of time (1-4 weeks), to establishing ongoing collaboration. (The RSE is not in a position to establish contacts on behalf of applicants). Both the Bilateral and Open Programme are open to Fellows and non-Fellows of the RSE.

Bilateral Programme

The **Bilateral Programme** facilitates the collaboration between researchers from Scotland and those based in institutions with which the RSE has a formal agreement. Exchange Programme grants are for short-term visits of one to four weeks duration, the key objectives being to enhance the research capabilities of individual researchers, develop international collaborative links, and enable participation in international research programmes.

For visits to Scotland, the RSE meets the cost of accommodation and subsistence in Scotland, and international travel is covered by the partner academy. For visits from Scotland, the RSE covers the international travel, and the partner academy provides for accommodation and subsistence.

Both visitors and hosts should have established contact before submitting an application, either by previous collaboration or by scientific correspondence.

Open Programme

The **Open Programme** was launched in 2003 to allow researchers to initiate further collaborations with research groups in countries (non-UK) or institutes not covered by the bilateral programme. The RSE meets the costs of international travel, accommodation and subsistence.

Further Information

Application details, eligibility criteria, closing dates and application forms are available on the International section of the RSE's website: www.royalsoced.org.uk/international/. Or for more information, please contact international@royalsoced.org.uk.

行政院國家科學委員會
National Science Council

The National Science Council of Taiwan

The NSC (http://web.nsc.gov.tw/) is a cabinet-level organization of the Republic of China (R.O.C.) in Taiwan charged to manage research and development affairs in science and technology. Major missions of the NSC include promoting national science and technology development, supporting academic research and developing science-based industrial parks.

The Department of International Programs (DIP) (http://www.nsc.gov.tw/int/english/) serves as the window for international scientific cooperation within the NSC. DIP supports international cooperation through two different mechanisms of operation :-

1. One system relies upon relationships established with foreign funding agencies or research institutes to promote bilateral research visits, support joint research projects and fund joint seminars.
2. The other system is used to fund unilateral subsidy programs, which may be freely applied for by academic scientists or research experts with Taiwan citizenship.

Current International Cooperation Programs :-

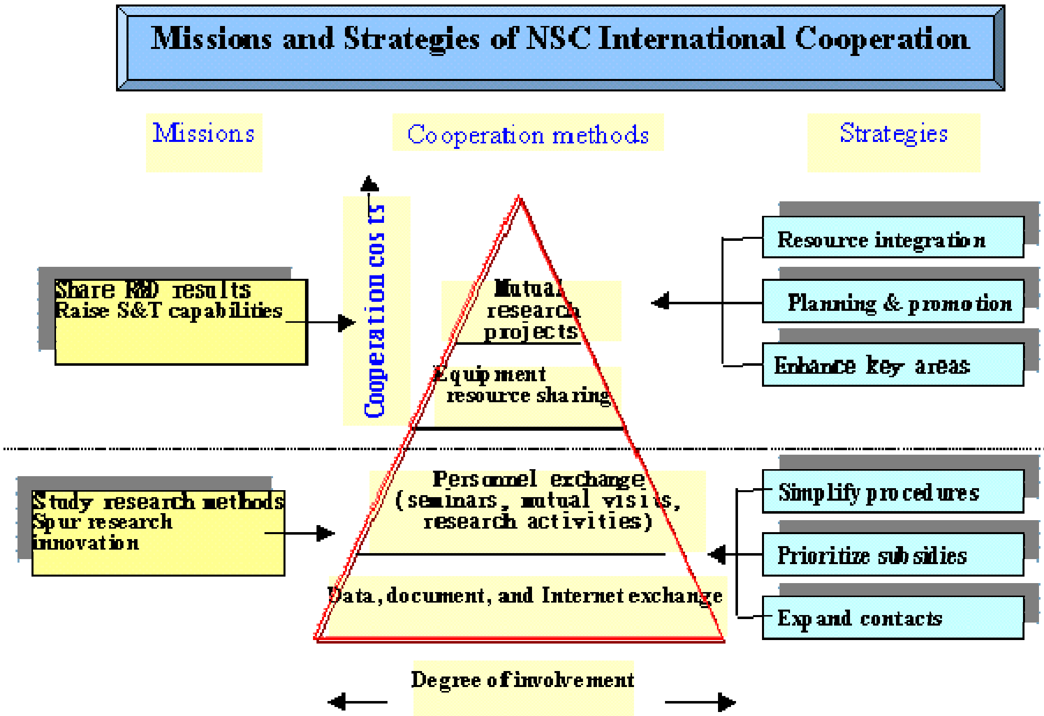
Bilateral Cooperation :-

For years, the NSC has signed Memoranda of Understanding (MOU) or agreements for bilateral cooperation with science and technology organizations in different countries. In the United Kingdom, the NSC has signed MOUs with

1. British Academy
2. Engineering and Physical Sciences Research Council (EPSRC)
3. Royal Society of Edinburgh
4. Royal Society London

Unilateral Programs :-

1. Elite Scholarship Program (http://studyabroad.ntust.edu.tw/abroad/studyabroad.nsf)
2. Graduate Student Study Abroad program
3. Post Doc. Fellowship
4. Taiwan Scholarships Program (http://www.edu.tw/EDU_WEB/EDU_MGT/BICER/EDUANDY001/english/TS_intro.htm?open)



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