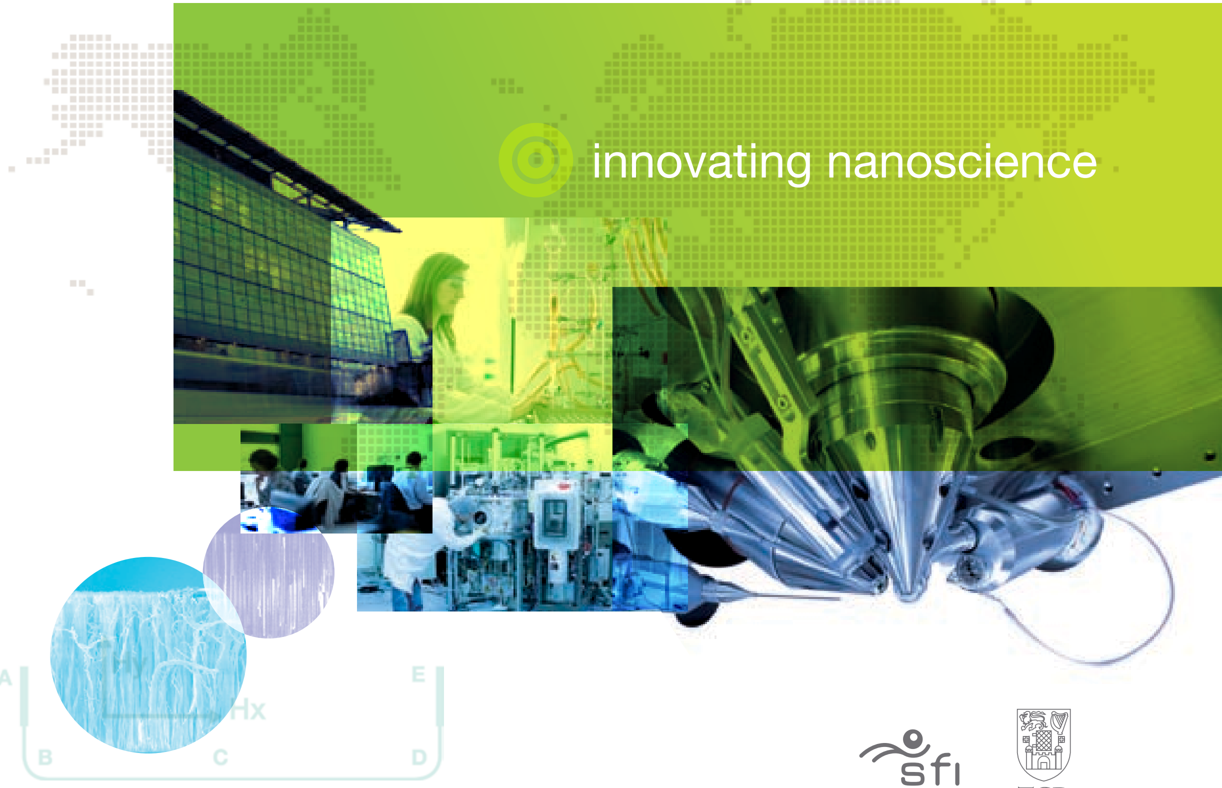
CRANN

innovating nanoscience



science foundation ireland
fondúireacht eolaíochta éireann

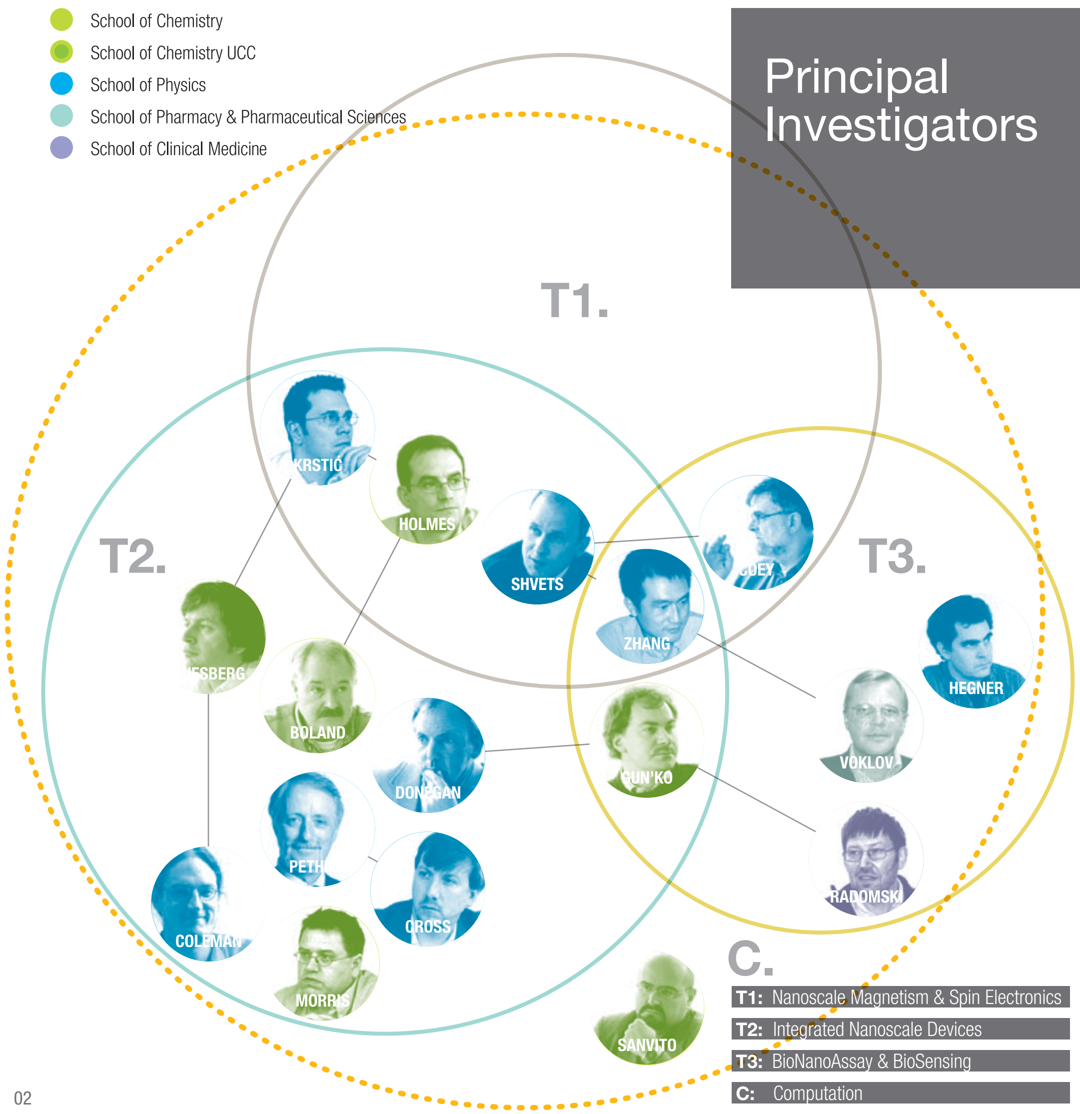
TCD

Nanoscience is the study of small scale matter, the minuscule building blocks of the material and biological worlds. While the physical properties of matter can be controlled by varying size and shape, nanoscience is more than the science of small sizes. It concerns the way nanoscale building blocks organise and assemble into larger functional units. Nanoscience views all matter from the same perspective regardless of whether it comprises the electrical circuits in a computer memory or the membrane that surrounds a human cell. What distinguishes them is how the blocks work together. It is a challenge to understand the rules that govern the assembly of hierarchical structures. The opportunities are immense, with nanoscience touching almost all areas of human endeavour: from advanced technologies and silicon chips to medical devices and new ways to diagnose and treat human disease.

Nanoscience therefore, underpins key sectors of our economy: ICT, biopharma and medical diagnostics. In 2007, Ireland exported €13.2B in goods of which it is estimated 10% were enabled by nanoscience and related nanotechnologies. The world market in nanoscience enabled products is expected to exceed €3 trillion by 2015. It is acknowledged that nanoscience will provide the impetus for the next wave of advanced technologies and it is essential that Ireland and CRANN fully participate in the global nanotechnology revolution.

With over 150 researchers, CRANN funded through Science Foundation Ireland is working at the forefront of nanoscience to develop new knowledge and to build links with industry. With Intel, CRANN is developing ways to manufacture computer chips using non-silicon materials that rely on the self-organisation of polymer building blocks to define device structure and size. Separately with Hewlett-Packard, CRANN is developing super-strong but flexible and transparent conducting films from assemblies of carbon nanotubes as a technology platform for future displays and hand-held devices such as electronic paper.

CRANN is also working at the nano-biology interface of nanoscience and biology, with the development of sensors for growth of micro-organisms such as MRSA, the evaluation of the diagnostic and therapeutic potential of nanoparticles, and the development of bar-coded nanowires for the multiplexed detection of bio-marker molecules for disease. All these exciting projects, led by expert teams, are designed to position CRANN as a leader, and to further boost Ireland's growing reputation in science and technology.



Principal Investigators

CRANN currently has 17 Principal Investigators based at Trinity College Dublin and University College Cork. They are linked to a broad range of disciplines including Chemistry, Physics, Medicine, Engineering & Pharmacy. All are recognised internationally in their area of expertise and together create a unique collaborative working environment focused on nanoscience research.

The PIs are the foundation upon which the CRANN Institute is built. Each has a faculty appointment in a partner school and is funded as a Principal Investigator through Science Foundation Ireland (SFI) and/ or the EU Framework, through which they deliver scientific excellence in specific areas of nanoscience. Collectively, this expertise defines the core competencies and the intellectual base of the Institute, and provides CRANN with both a competitive advantage in its engagement with industry partners and a source of new ideas and innovation.

All PIs participate and support the CRANN Centre for Science Engineering and Technology (CSET) which represents the collaborative industry interface of the Institute, through which critical masses of researchers are assembled to address grand challenges of nanoscience and of our industry partners. The CSET draws upon and leverages the PI base, particularly in terms of expertise, equipment and facilities. The large integrated projects funded through the CSET bring together researchers from different disciplines in a collaborative working environment, thus creating the ethos and culture that is essential to a successful and vibrant nanoscience institute.

CRANN PIs manage their own research groups, and play a full role in both the development of their School and the Institute. Across the PI groups at present we have in excess of 200 researchers working within CRANN. The research activity encompassed by this team of researchers can be broadly defined by four research strands:

– Integrated Nanoscale Devices
– Spin Electronics and Sensors
– BioNanoAssay and BioSensing
– Computation

Theme 1

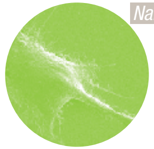
Nanoscale Magnetism & Spin Electronics

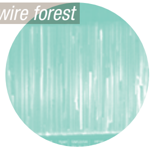
Conventional electronics has ignored the spin on the electron. Besides a fundamental unit of charge -*e*, electrons each have an intrinsic magnetic moment associated with their quantum of spin angular momentum $\hbar/2$. Devices based on spin-polarised electric currents in thin film stacks built up of layers 1–10 nm thick depend on giant magnetoresistance and tunnelling magnetoresistance, discovered in the 1980s. Tunnel junctions with coherent, spin-filtering MgO barriers are the active elements for novel devices being investigated in CRANN, where the angular momentum of the electron current is used to switch a free ferromagnetic layer in the stack.

These devices have potential for widespread application in sensors, nonvolatile random-access memory and programmable logic. A major challenge is to separate spin and charge currents in solids, so as to transmit information magnetically, without electrical dissipation.

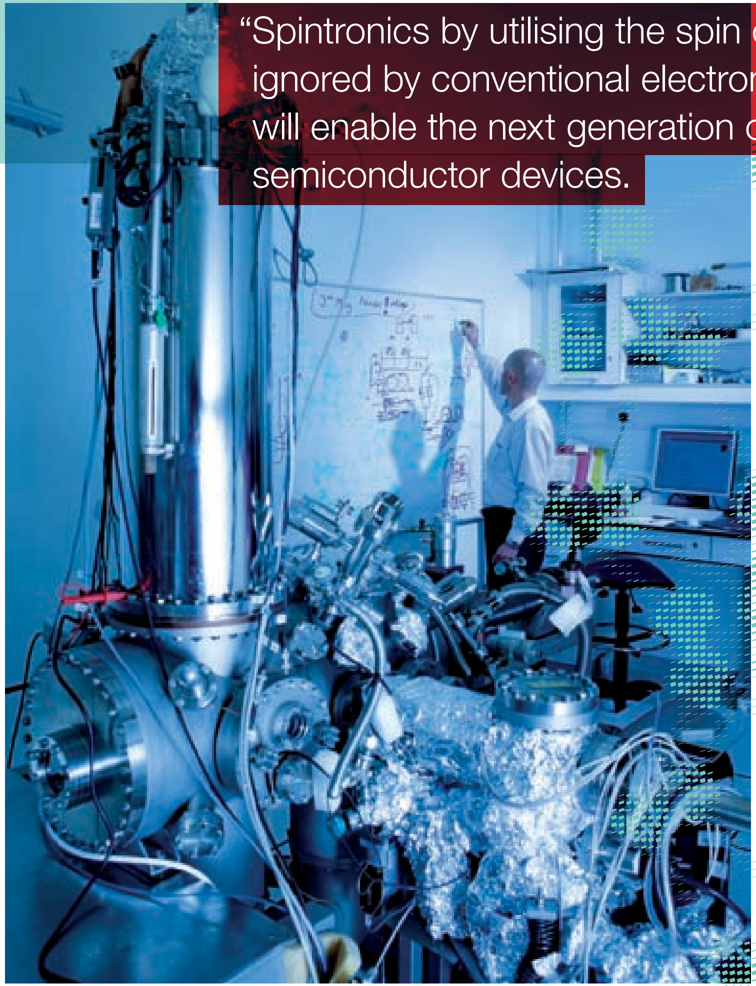
Magnetism, like many other physical properties, is different on the nanoscale. In CRANN, we have a particular interest in magnetic nanowires, and in the effects of the huge strains that can be created in suitable nanostructures, especially with atomic-scale point probe techniques.

Much innovation in device physics arises from the introduction of new materials. While spin-polarised electron transport in metals and insulators is fairly well understood, that in semiconductors, and especially in organic conductors, is an open question. An interlinked program of theory and experiment in CRANN is aiming to provide answers, and evaluate the potential of devices which include such new materials in the stacks.





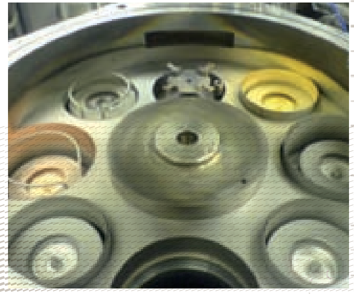
Nanowire forest

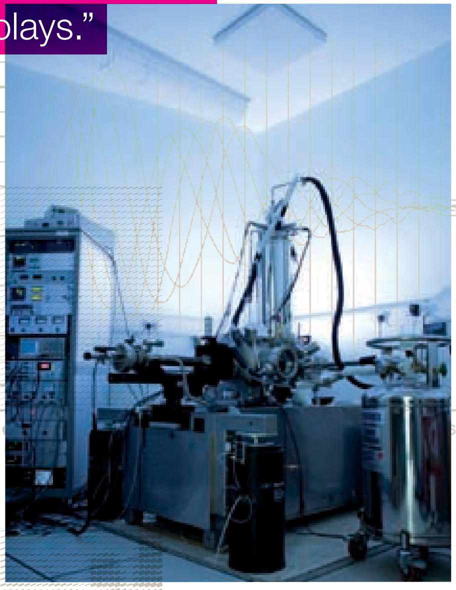


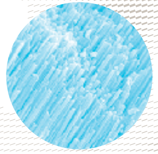
"Spintronics by utilising the spin of the electron, ignored by conventional electronics, will enable the next generation of semiconductor devices.

Theme 2
Integrated Nanoscale Devices

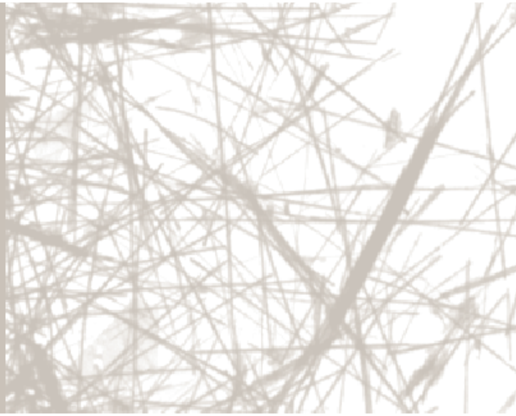
"Nanoscience research at CRANN is enabling the future – faster, lighter and more mobile computers and the next generation of flexible displays."







Carbon nanotube composite/ Metallic nanowires



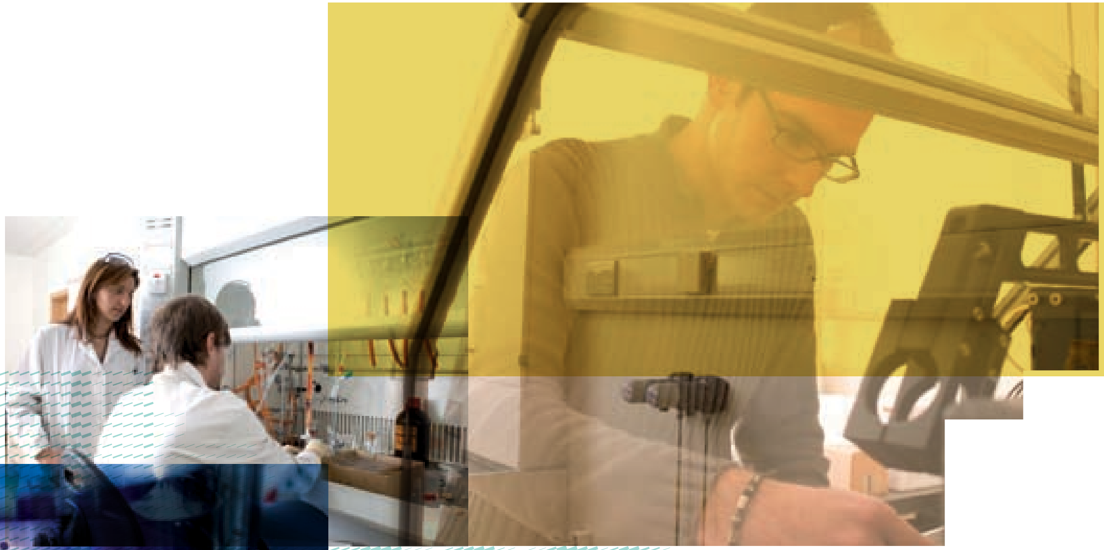
For over 30 years, computer processors have been continually improved by making the size of the electrical components smaller. This miniaturisation in design and manufacturing has enabled us to buy electronic goods that do more and cost less with each generation of technology. Ireland has played an important role in bringing this technology to the market. Intels largest fabrication facility outside the US is in Ireland manufacturing leading edge technology.

Now CRANN in partnership with Intel is enabling the future through research. Over 30 researchers work in collaboration with Intel investigating new materials and device concepts. We are studying nanowires made from carbon and silicon at dimensions less that 10 nm. These materials have extrodinary electrical properties and provide an opportunity to fabricate devices which will allow a paradigm shift in computation This research offers the opportunity for Ireland to play a role in of the future of semiconductor development and manufacturing.

CRANN is also utilising similar nanomaterials in collaboration with Hewlett-Packard. Together this research programme is investigating a transparent, flexible, highly conductive electrode which can be used for a flexible and transparent display. This technology could have profound implications – from true electronic paper, to ultra thin televisions which can be scrolled like a blind, to screens which can be built into the windscreen of an airplane or the helmet of a pilot.

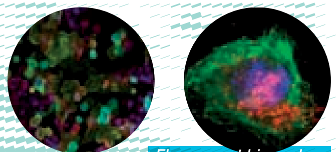
The project with HP harnesses the properties of carbon nanotubes. These tubes are thousands of times longer than they are wide (2nm) and have remarkable strength and electrical properties. CRANN has developed novel techniques to deposit them into super thin films, both alone and with polymers to achieve the highest reported electrical conductivities.

By using the novel properties of nanomaterials, CRANN is working to provide integrated solutions to the grand challenges of science and industry.



Theme 3
BioNanoAssay & BioSensing

> "Nanobiotechnology will have a deep impact on our daily lives translating laboratory research into products that will revolutionise healthcare."



Flourescent biomarkers
Nanoparticle cell interaction

Biosensors are devices that consist of a sensitive element, which is capable of detecting the presence of specific analytes (viruses, DNA, RNA) and transmuting this information into a measurable signal (e.g. mechanical, optical). The development of bio-sensing is closely related to advances in relevant technologies. As such, micro and nano-technologies have contributed to detecting sensors that allow the rapid detection of minute amounts of biological material. Among them, cantilever based sensors have raised considerable interest as they work in a label-free manner. These sensors are like springboards but are typically only 500 microns long and just 1 micrometer thick. They can be coated with particular receptors that will interact with specific analytes. As such, these sensors are versatile: they can be coated with single-strand DNA molecules for application in genomics, with antibodies for detection of proteins or with appropriate culture media for bacterial detection. Upon interaction, the tiny extra mass on the surface of cantilevers can be detected by measuring resonant frequency. Alternatively, such interactions induce a mechanical stress on the cantilevers than can also be measured.

In CRANN, Prof. Martin Hegner from the School of Physics, is working on such sensors. His team of researchers has already demonstrated the potential of such biosensors for the rapid and label-free detection of RNA transcripts. More recently, they have demonstrated the detection of viruses in buffer conditions. Although cantilever-based sensors are still in their infancy, they have significant future potentialfor use as a tool for personalised medical diagnostics.

Computational Studies

Computational research is viewed as a key to unlock the secrets of nanoscience. With the development of super-computers with improving power it is now possible to simulate, with tremendous accuracy, clusters of atoms and molecules. This capability allows, for the first time a direct comparison between experimental and simulated data on real nanostructures.

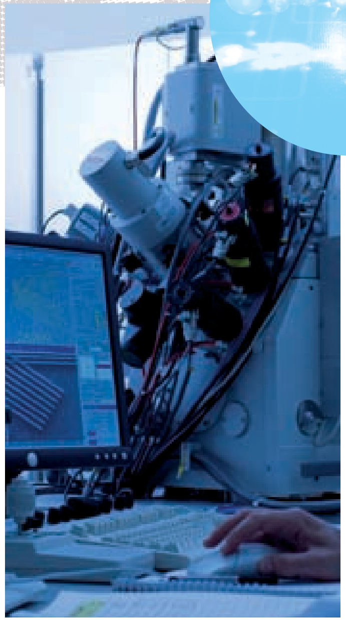
This new capability has significant impact in the design of new material systems such as drug molecules or semiconductor materials and their subsequent utilisation in devices. Advanced simulations allow CRANN's computational researchers to make quantitative predictions which provide the experimentalists with a better understanding and clear directions for modelling and designing atomic-scale devices and interfaces.

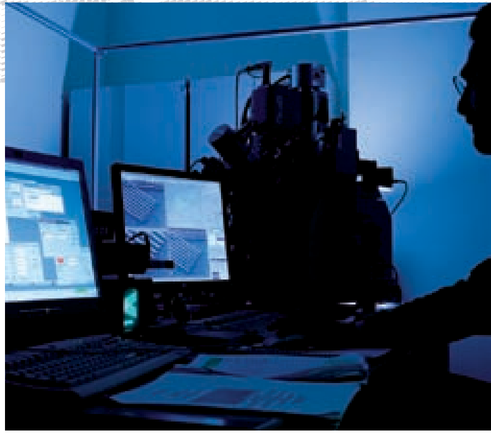
Computational research in CRANN is predominantly focused on the development of code for accurate simulation of systems that span length scales ranging from atomic dimensions to those that are relevant to macromolecular biological and physical problems. CRANN has a significant track record in this field, including the development of Smeagol (www.smeagol.tcd.ie), which is currently the most widely used code for quantum transport in the community.

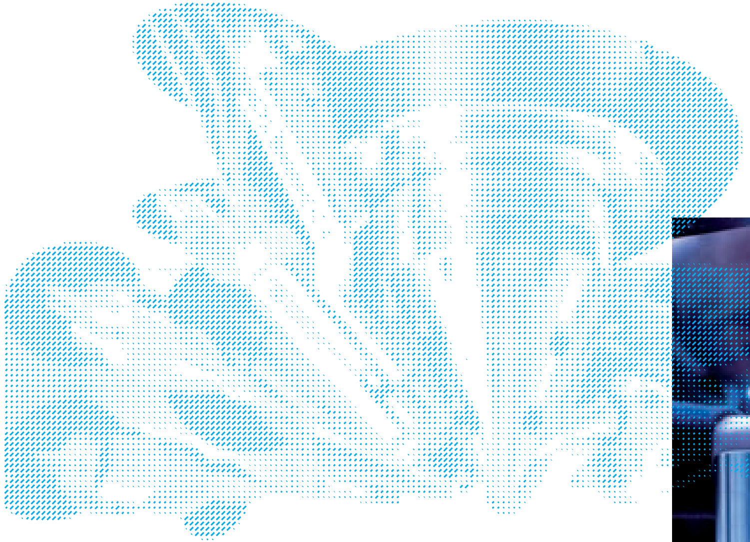
Looking forward, future spintronic and nanoelectronic research will require the construction and implementation of new computational tools and the development of advanced theoretical/algorithmic capabilities. Specifically, CRANN will focus on the implementation of Van der Waals interactions in density functional theory for large-scale simulation codes and on the construction of a quantum mechanical/molecular mechanical dynamics module for large-scale simulation codes which are necessary to deliver significant advances in nanoscale materials and interface modelling.

"Never has a computational science been so close to describing reality, now for the first time computation can seriously guide new technological developments."

Quantum molecular transport







"Research is driven by excellent people and facilities. CRANN has in place leading and unique infrastructure which is enabling innovation and discovery."

Infrastructure

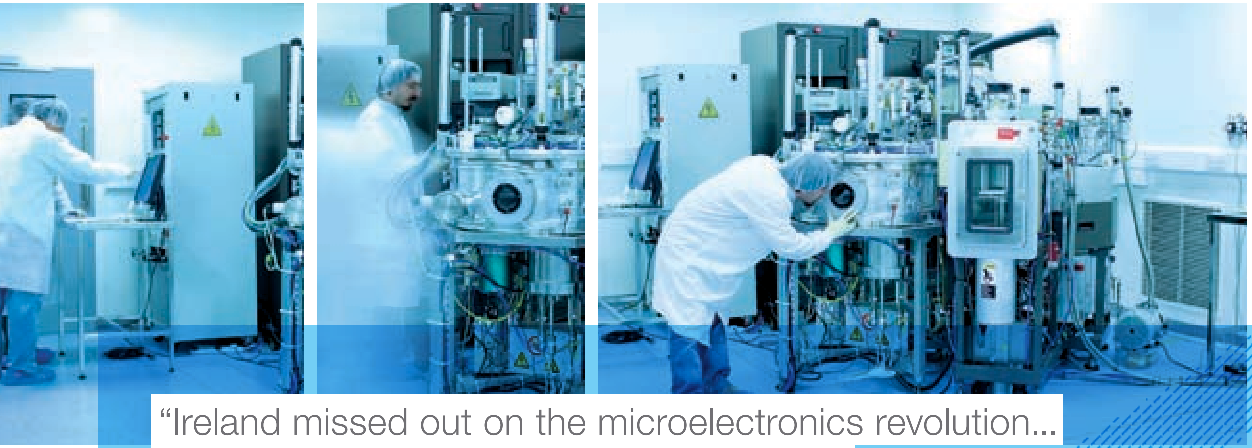
Innovating nanoscience depends on unique and powerful tools which enable researchers to grow, characterise, probe and manipulate matter at the atomic scale (there are about four atoms to a nanometer). The environment needs to be controlled and managed so as to eliminate, as far as possible vibrations, dust particles and electrical interference. CRANN is housed in a flagship building, the Naughton Institute which includes a central equipment facility with research tools that will place CRANN at the leading edge of nanoscience research internationally. The infrastructure in the central equipment facility covers four distinct areas:

Cleanroom: Our research Cleanroom allows the fabrication of research devices which feature sizes ranging from 10μm to sub 20nm. It has 210 m^2 of processing space, ranging from class 10 to class 10,000 for lithography deposition and patterning and characterisation.

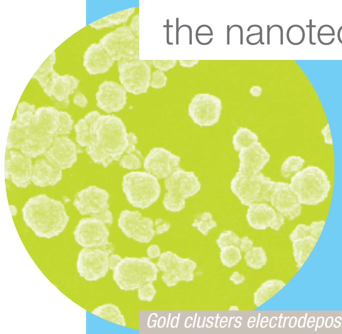
Ultra-fast photonics facility: CRANN's recently established photonics facility comprises some of the most advanced laser systems in Europe. It will be used for the characterisation of the optical and electrical properties of materials ranging from quantum dots for drug discovery to nanowires which may be used in next generation electronic devices.

Nanobio facility: A 100 m^2 type 2 biohazard facility for micro- and nano-scale manipulation, interaction and investigation of DNA, proteins and molecules in two and three dimensions. The facility will be used for toxicology research, nanoparticle fabrication, liquid AFM including high resolution microscopy, ultrasonic techniques, pulse magnetic stimulation and high-throughput diagnostic technologies.

Ultra-microscopy facility: A new 1000 m^2 facility is being established which will allow researchers to view and manipulate materials at the atomic scale. It will comprise high performance tools including a transmission electron microscope (TEM), numerous scanning electron microscopes (SEM), two focussed ion beam systems (FIB) and the latest He-ion micoscope. The combination of these tools is practically unique for a nanoscience research institute.



"Ireland missed out on the microelectronics revolution… we must now position ourselves to catch the nanotechnology wave"



Gold clusters electrodeposited on carbon nanotubes films

In the nanoworld as surface area increases relative to volume, a material takes on intriguing new properties. Insulators can become conductive, soft materials can display incredible strength and mechanical properties, colored materials can become transparent. These remarkable changes provide clear pathways for both traditional businesses to develop improved products or processes and for new enterprises to develop revolutionary products. Nanoscience is viewed as a key technology for a broad range of industrial sectors including; aerospace, automotive and transport; agrifood, chemistry and materials, construction, energy, environment, health, medicine and nanobio, ICT, security and textiles.

Industry

CRANN is open to industry engagement in various ways including: allowing access to our equipment base for test and characterisation measurements, carrying out proof of concept investigations on behalf of a company and the joint development of a research programme. We welcome opportunities to speak with industry regarding the value CRANN can add to your R&D programmes – be it from our metrology and characterisation capability, the novel material systems which we develop, the large interdisciplinary teams we can assemble or the specific expertise we can provide in areas ranging from electronics, magnetism, and computational modeling, to biological sensors and high throughput drug screening.

We have significant experience in partnering with industry and have been running independent research programmes with many companies including Intel and Hewlett Packard over the last five years.

CRANN will work in partnership with Science Foundation Ireland (SFI), the Industrial Development Agency (IDA) and Enterprise Ireland (EI) to put in place well-supported research programmes with industry to meet the specific needs of the company – be it a small proof of concept project or a grand research challenge.

Researchers
post docs & post grads

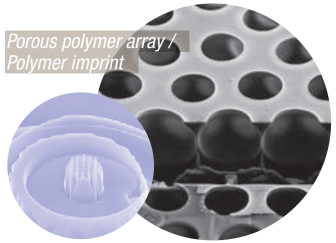
Ireland is fast becoming recognised as an international leader in nanoscience research. A 2006 Nature Nanotechnology article ranked Ireland sixth globally, based on the impact of its research as measured by citation levels.

"The way atoms merge together into nanoscale building blocks leads to new nanomaterials that will make our lives more enriched, safer, and greener."

CRANN was the key driver behind this success. The critical ingredient is the quality of postgraduate and postdoctoral researchers who have been attracted to Ireland, from over thirty nations. These researchers create a stimulating international environment to pursue a research career.

The CRANN Institute is based on the campus of Trinity College Dublin, a university recently ranked among the top 50 universities in the world, now in its fifth century of innovation in teaching and learning. CRANN, the newest jewel in Trinity's crown, is housed in a purpose-built state-of-the art research centre – the Naughton Institute.

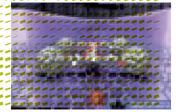
We provide a stimulating environment for our entire research staff encouraging interdisciplinary research by having biological, physical and chemical laboratories operating side by side. CRANN researchers are provided with training and access to state of the art research facilities. This training coupled with the structured teaching programme, provides an educational experience comparable to leading international institutions.

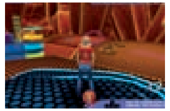


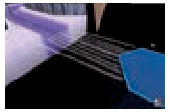
Porous polymer array / Polymer imprint

CRANN offers its researchers the opportunity to engage in science communication with both the general public and school children. CRANN has strong links with the Science Gallery, also based within the Naughton Institute. Our strong industry interface enables researchers to work side by side with industry professionals seconded to CRANN from our industry partners.

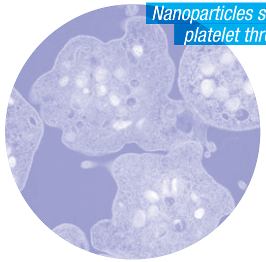
Altogether, CRANN offers an exceptional environment for research in nanoscience, whether it is to pursue a PhD or build a career in science.







“CRANN is committed to developing both a passion and understanding for science in Ireland – this is critical for our future success.”



Nanoparticles stimulate platelet thrombosis

There is a need both in Ireland and internationally to create an improved awareness and appreciation of science. Globally the number of students studying science at both school and university is declining. This decline is of serious concern as science is at the core of our civilisation, driving economic growth and providing the opportunity to improve the quality of our lives.

Education & Outreach

CRANN has a mission to stimulate interest in science across a range of audiences by developing engaging and innovative outreach programmes. The first achievement was the foundation of the Science Gallery (www.sciencegallery.com), the first science communication centre in Ireland which plays a critical role in raising awareness of science through the exhibitions and events it hosts. The Science Gallery has become a popular venue for scientific discussion, communication and debate, reflecting the new maturity and confidence with which Ireland can represent its scientific achievements to the broader international scientific community. The Gallery attracted 120,000 visitors in its first year of operation.

CRANN also delivers its own innovative outreach programmes. An example is the development of ‘Nanoquest’, a video game provided free of charge to every 13/14 year old schoolchild in Ireland. In addition to communicating through the schools, where we prepared a lesson plan to accompany the game, social networking websites, such as www.bebo.ie, were used to advertise the game and free copies were distributed in gaming stores. The success of this novel approach to communicating directly with a young audience is measured by the 200,000 visitors to the Nanoquest website since the games launch. This type of programme provides impact on a grand scale.

CRANN welcomes the opportunity to discuss new outreach initiatives with all stakeholders and is committed to communicating the role science is playing in both Irish and international life.

“CRANN is committed to delivering scientific excellence and partnering with industry to translate innovation into economic value for Ireland.”

TEM Cross Section / Thin film carbon nanotubes

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