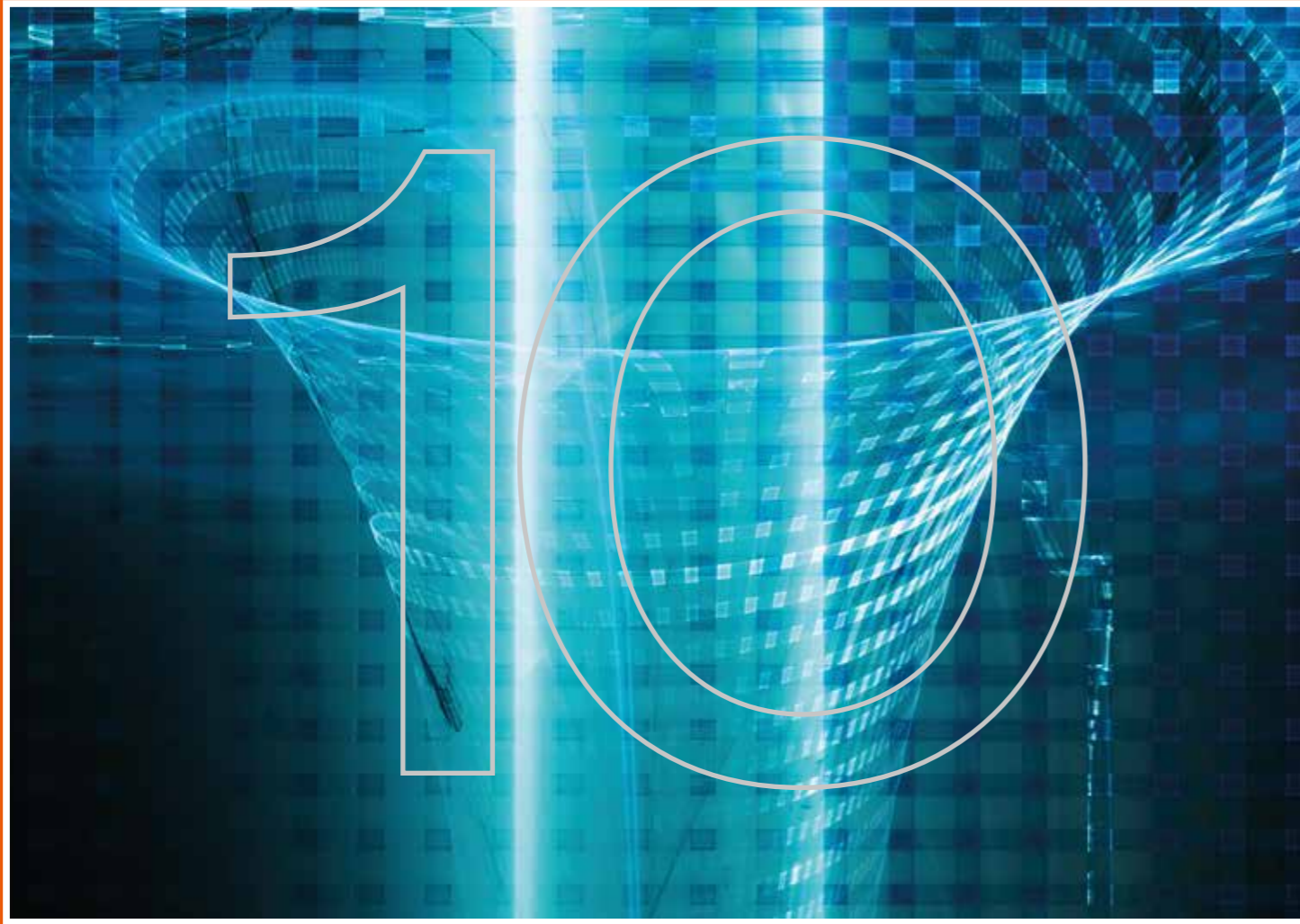




# ERC at Newcastle University







# Introduction

The European Research Council (ERC) is part of Horizon 2020, the EU's Framework Programme for Research and Innovation, and for the period 2014-2020 the ERC's budget is €13 billion (roughly £11 billion).

First established in 2007, the ERC's mission is to encourage excellent frontier research in Europe through competitive funding and by supporting top researchers across all fields and from anywhere in the world.

Since then, the ERC has had a considerable impact on the European research landscape. In ten years:

- The ERC has funded 7,000 excellent researchers, who have employed a further 30,000 young researchers on their teams
- The ERC's support has been acknowledged in around 100,000 international scientific journal articles
- Completed ERC funded projects have led to scientific breakthroughs in 21% of cases and major advances in 71% of cases
- ERC funded researchers have been awarded 6 Nobel Prizes, 5 Wolf Prizes and 4 Field Medals

This year the ERC marks its 10th anniversary, which is an important milestone towards making Europe a global centre of excellence in research. Celebrations are taking place in Brussels and all across Europe, providing an opportunity for reflection on the past decade and on the future of this prestigious scheme.

Newcastle University is very proud of its 20 ERC grant holders and is delighted to celebrate the ERC's 10th anniversary by showcasing some of them in this brochure. We hope you enjoy reading about the wide variety of exciting research they are carrying out and join us in wishing them every success in their future research careers.



# SEEV:

## Self-enforcing e-voting: trustworthy elections in the presence of corrupt authorities

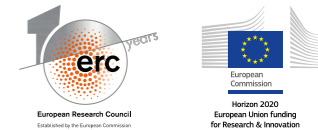
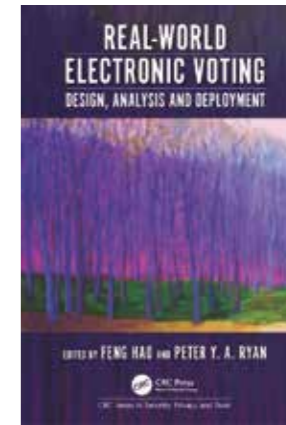
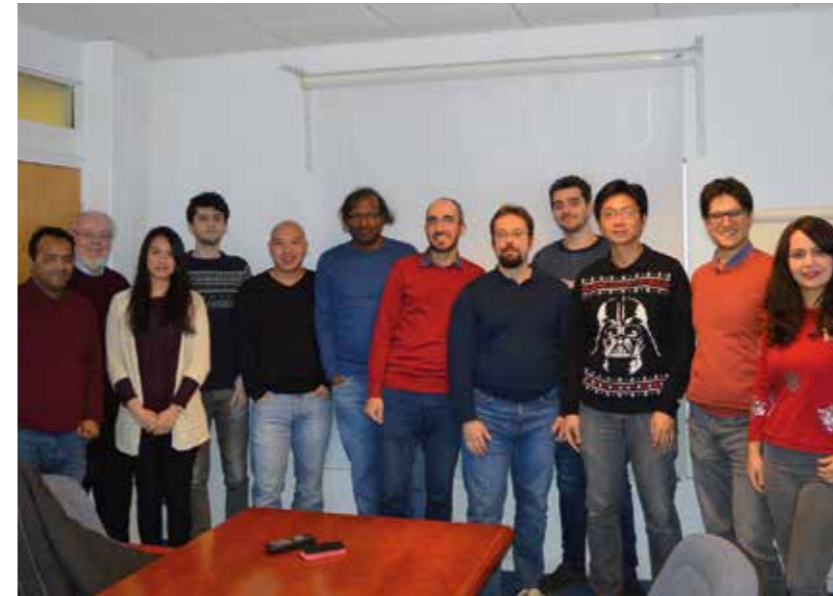
ERC Starting Grant, 2013-2017  
Value: £1,060,510

Dr Feng Hao,  
Reader in Security Engineering,  
School of Computing Science  
<http://homepages.cs.ncl.ac.uk/feng.hao>

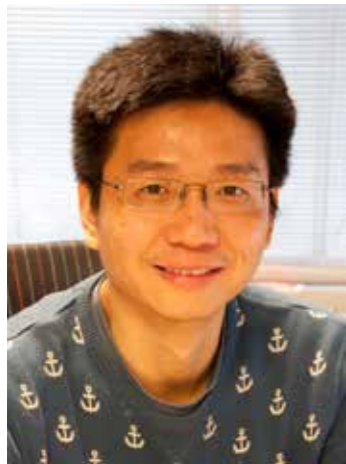
# SEEVCA:

## Self-enforcing e-voting for commercial applications

ERC Proof-of-Concept Grant, 2016-2017  
Value: £107,042



## In SEEV, we envision a new paradigm of voting systems for future elections that are fully verifiable yet without requiring any trusted tallying authorities (TAs).

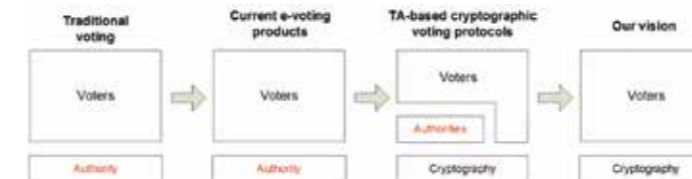


Throughout the history of democratic voting, trusted authorities have been playing a critical role in ensuring the integrity of the tallying process in all voting systems, let it be paper-based or DRE-based. The state-of-the-art in the e-voting research is voting systems that are End-to-End (E2E) verifiable,

meaning that the voter is able to verify the integrity of the tallying process from the moment of casting the vote to receiving the tally in the end. However, previously proposed E2E voting systems all require a

set of Tallying Authorities (TAs) who are cryptographic experts tasked to perform the decryption and tallying operations. These TAs mimic the role of trusted counting staff in traditional paper voting. However, implementing such TAs in practice has proved particularly difficult. After 20 years' extensive research, only few E2E voting systems have actually been implemented, and none of them is used in real-world national elections. The vision in the SEEV project is to develop a whole new type of voting systems that are E2E verifiable, but without any tallying authorities. In other words, the systems are "self-enforcing". A prototype of the self-enforcing e-voting system, based on the DRE-i protocol, has been developed and used in the Newcastle University campus for classroom voting<sup>1</sup>. The prototype is currently being extended for public use outside Newcastle University, supported by an ERC Proof-of-Concept Grant.

### Highlighted outputs to date (2013-2016):



- An edited book "Real-World Electronic Voting: Design, Analysis and Deployment" published by CRC Press, Taylor & Francis, 2017<sup>2</sup>
- International patent filed on a new SEEV system for polling station voting based on the DRE-ip protocol.
- Ranked 3rd place in 2016 Economist Cybersecurity Challenge on digital voting over the blockchain (the only UK university in the top three finalists among 19 university teams from the UK and USA)<sup>3</sup>
- A prototype of verifiable classroom voting based on SEEV that has been used regularly in classroom voting and student awards competition in the campus since 2013

- 25 papers published in high-ranking conferences and journals

### ERC project team:

The ERC Starting and Proof-of-Concept grants support a truly international team of researchers with great diversity in cultural and educational backgrounds, expertise and skills. They have recruited 12 members from 9 nationalities: China, UK, India, Portugal, Australia, Iran, Italy, Ireland and Pakistan. The diversity has proved a particular strength in the team and an important contributing factor for its successful outputs.

### References

1. <https://evoting.ncl.ac.uk/>. Anyone with a Newcastle University campus account can logon as a coordinator and create elections for classroom voting.
2. <https://www.crcpress.com/Real-World-Electronic-Voting-Design-Analysis-and-Deployment/Hao-Ryan/p/book/9781498714693>
3. <http://www.economist.com/whichmba/mba-case-studies/cyber-security-case-study-competition-2016>





# COMSTAR:

## The effects of early-life adversity on cognition: A comparative approach

Professor Daniel Nettle,  
Institute of Neuroscience  
[www.danielnettle.org.uk/comstar](http://www.danielnettle.org.uk/comstar)  
ERC Advanced Grant, 2015-2020  
Value: £1,540,770



### How might you think as an adult if your childhood had been stressful, deprived and unpredictable?

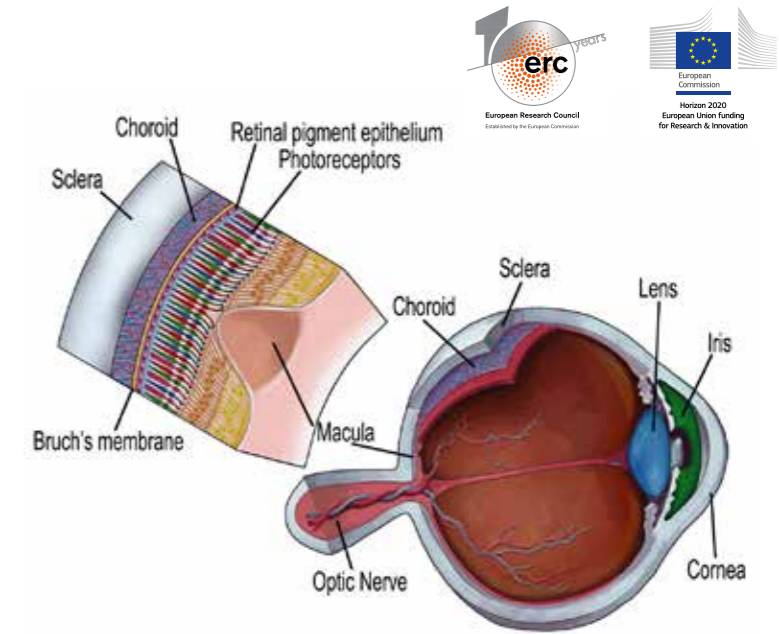
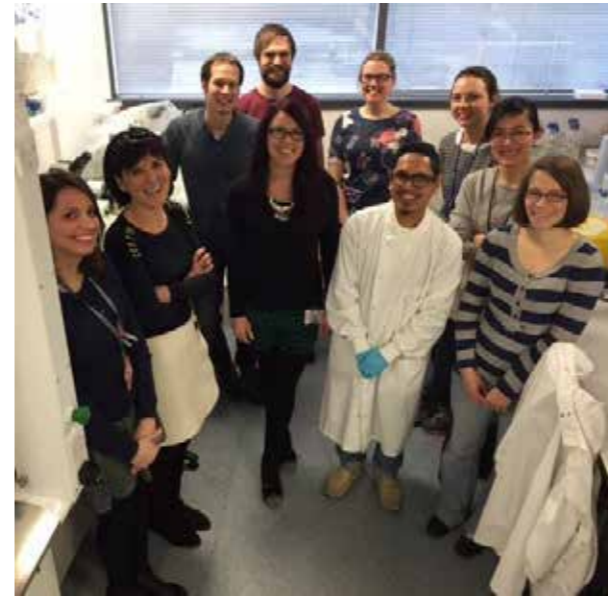
You might well become impulsive or anxious. We know that there are associations between early-life experience and adult psychology, but we don't really know how or why they come about. Our goal in this project is to understand this. But the project is very unusual: we are asking the same question in humans, and also in a bird, the starling. Starlings like humans live a long time and are raised by two parents. We also had some evidence that birds with a stressful start in life were more impulsive. In this project, we proposed to ask the very same questions about early life and adulthood we can ask in humans. Moreover, in the starlings, we can experimentally control the kind of early life an individual had, by fostering birds around different nests in our breeding colonies in Northumberland. Whilst starlings are certainly not the same as humans, we think there is a lot we can learn by comparing how behaviour develops in the starling to ourselves.

As well as understanding how early-life experience might relate to adult behaviour, we are interested in how early-life stress gets 'under the skin'. One of the key ideas we are investigating is that early-life stress speeds up bodily ageing. You can measure ageing with biological markers such as an individual's level of inflammation, or the length of their telomeres, the DNA caps on the ends of the chromosomes in every cell. Thus, we are interested to know whether, in both humans and birds, individuals who have a more stressful start are in a real sense 'old for their years' by the time they are adults; whilst individuals who have a more benign growth period are protected from ageing and all the problems that go with it.



# RET-iPSC: Retinal Stem Cell Research – the fight against blindness

Professor Majlinda Lako,  
Institute of Genetic Medicine  
ERC Consolidator Grant, 2014-2018  
Value: £1,185,077



**Our mission is to exploit developmental, genetic and cellular information to better understand inherited and age related retinal disease and to work towards new treatments for patients with retinal disease.**

Studying the developmental biology and disease of the eye is a core activity of the Retinal Stem Cell Research group (RSCR), led by Prof. Majlinda Lako in the Institute of Genetic Medicine at Newcastle University.

The retina is a thin sheet of central nervous tissue which covers the back of the eye and is responsible for converting light into electrochemical signals that can be transmitted to the brain via the optic nerve, whereupon they will be processed to give the sensation we understand as vision.

The light conversion process begins when light enters the eye through the pupil and passes through the lens which causes it to focus on the retina. When the light shines on specialised cells known as photoreceptors, it causes pigments called rhodopsin/opsin to trigger a

cascade of chemical changes that cause the cell to lose sodium ions and become "polarised".

This is a bit like a chemical battery - the polarised cells now have enough potential energy to transmit a signal to the next group of cells that in turn will pass this signal to the cells that form the optic nerve. This is a complex process, which of course means that there are lots of opportunities for things to go wrong.

Dysfunction of any of the cell types that reside in the retina or supporting cells, the retinal pigmented epithelium (RPE), which is vital for the health of the retina, will disrupt vision - *our aim is to determine the mechanisms that cause such disruption and find ways to repair the damage.*

## Pluripotent stem cells - our primary weapon

Pluripotent stem cells are able to grow indefinitely while retaining the ability to turn into any of the cell types found in the adult body.

A few years ago, the only way we could obtain cells with these characteristics was, with appropriate patient consent, to extract embryonic stem cells from spare human embryos created for the purpose of in vitro fertilisation, but that were no longer needed. These days we don't need to do this since we can obtain cells with embryonic stem cell-like properties from many adult cell types via a process called reprogramming.

We can perform this technique on adult cells which can be easily collected from patients; a few millilitres of blood or even a few hairs are all we need to make these reprogrammed cells, which are called "induced pluripotent stem cells" (iPSC for short). Just like their

embryonic stem cell counterparts, these will grow indefinitely and can turn into any type of adult cell we want.

Naturally, this includes most of the cells of the retina, so iPSCs are a great resource for learning more about how the retina is assembled in the embryo - but also for understanding how retinal disease can occur. We can do this by making iPSCs from patients affected by retinal disease and examining the genetic and functional differences between retinal cells made from the patient's iPSCs and those made from iPSCs which were created from healthy donors.

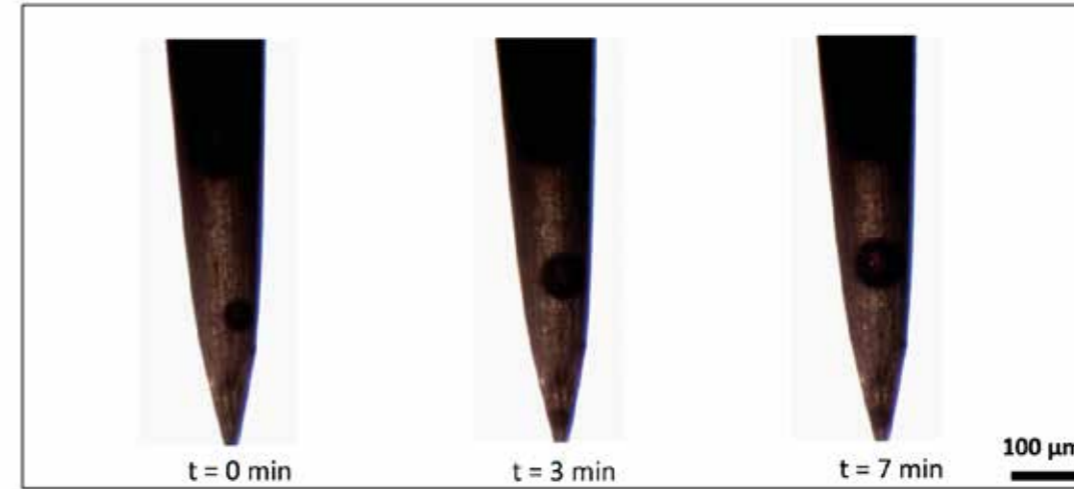




# SPEED:

## Single Pore Engineering for Membrane Development

Professor Ian Metcalfe,  
School of Chemical Engineering & Advanced Materials  
ERC Advanced Grant, 2013-2018  
Value: £1,485,714



*Watching a CO<sub>2</sub> bubble grow inside a working membrane: We are looking through a single crystal oxide (which is optically transparent even though it is a solid) at a temperature of 575°C into a pore that contains a molten salt. We can see a CO<sub>2</sub> bubble growing in size as a function of time.*

This ERC grant is enabling me and my team to develop completely novel high temperature artificial membranes for the separation of gases such as carbon dioxide, hydrogen and oxygen.

A membrane is a barrier that is selectively permeable, i.e. it only allows certain substances to cross it. The problem is that currently available membranes use pores to attempt to differentially separate tiny molecules such as carbon dioxide, hydrogen and oxygen. And pores don't do this very well. Unless the size of the pore is controlled very precisely (something we cannot yet do) then if oxygen crosses the membrane carbon dioxide probably will too. So here our approach is to fill the pores with an additional material that helps improve our membrane selectivity. So, for example, we can use a molten carbonate (a common chemical heated to high temperature such that it melts) within the pores to provide a pathway for carbonate ions (which are easily formed from carbon dioxide) while blocking other molecules.

Successful membrane separations of this kind would allow fundamentally different, and more efficient, industrial process plants to be built, in a variety of sectors and in particular the energy sector, such as carbon dioxide capture and hydrogen production. More efficient plants would be more economic and environmentally-friendly as they would use less energy, fewer materials and produce less toxic waste.

My work uses ground-breaking techniques to probe membrane behaviour at the microscale, which will allow accurate prediction of membrane properties and logical membrane design for the first time. For example we use single crystals to build membranes. The interesting thing about single crystals is that we can see through them. So we can actually look inside a working membrane and watch what is happening.

Firstly, my team will design and make model single pore systems and develop micro-analytical techniques to follow molecules as they permeate the membrane via the pores.

Secondly, these model systems will be used to screen novel combinations of materials to create hybrid membranes and to determine the movement (kinetics) of molecules with a degree of control not previously available in this field.

Thirdly, our improved understanding of membrane kinetics will be used to influence real membrane design and fabrication.

We will then investigate how the performance of the new real membranes has an impact on process design.

ERC Advanced Grants are fellowships awarded to established world-leading researchers.



# CPFTMW: New Applications of Broadband Rotational Spectroscopy

Dr Nicholas R. Walker,  
School of Chemistry  
ERC Starting Grant, 2012-2017  
Value: £1,069,901

The European Starting Investigator programme, “New Applications of Broadband Rotational Spectroscopy” is capitalising on recent technological advances to apply microwave spectroscopy to research challenges that lie outside the traditional boundaries of the field.



Figure 1 –  
Susanna  
Stephens (top)  
and Dan Zaleski  
(bottom) at  
work in the lab.



Established at Newcastle University in 2012, the program has supported the training of two postgraduate students, three postdoctoral researchers and the teaching of many Newcastle undergraduates. Within the last few years, team members and visiting collaborators have arrived from Spain, Belgium, Germany, the USA and Australia.

When performed using microwave radiation (between 3 and 300 Gigahertz), molecular spectroscopy provides a wealth of information about the physical structure of molecules and materials. The lengths and orientations of chemical bonds, the positions of atoms and the strengths of electric fields within molecules can be selectively isolated and measured. The results of experiments are used by researchers modelling complex chemical systems, such as Earth's atmosphere or the human metabolism, to test and improve the accuracy of their models. Many chemicals generated during our experiments are also found in the interstellar medium. In this context, our experiments provide the accurate and reliable spectral “fingerprints” that allow interstellar and circumstellar chemicals to be identified from their microwave emissions.

## Instruments and Methods

The broadband rotational spectrometer at Newcastle University is globally-unique in respect of its capabilities for the study of molecules containing metal atoms and/or non-volatile organic substances. It benefits from new technology provided by the ongoing electronics and telecommunications revolution. Experiments can be performed at higher speeds than previously and with a very high level of automation. In practice, this means that we can now perform experiments on challenging but important molecular targets that are either structurally complex or which tend to disintegrate on very short timescales.

A mixture of gases is passed over the surface of a solid target from which material is vaporised using a laser. The resulting mixture is introduced into a vacuum chamber and the sample rapidly expands and cools, allowing for the spontaneous formation of a wide range of molecules and complexes which we can then probe by microwave spectroscopy.

## Recent Projects<sup>(1)</sup>: Isolation and Characterisation of a Dimer of Imidazole

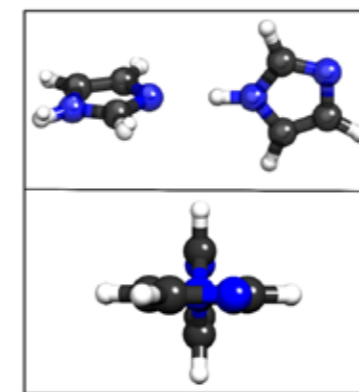


Figure 2 – Top  
and side views  
showing the  
geometry of  
the interaction  
between  
two isolated  
imidazole  
monomers.

Imidazole is a component unit of adenine and guanine, two important building blocks of DNA, and many other biologically-active molecules. It is also an important unit in photochemistry, the process by which light is

converted into useful energy by living organisms. An understanding of the nature of chemical bonds formed by the imidazole unit is fundamental to knowledge of how such molecules are generated, captured and processed by living organisms.

Our experiments prove that weak bonds between isolated imidazole molecules result in the geometrical arrangement of these units as shown in Figure 2. The significance of the work is the demonstration that isolated imidazole monomers tend to interact via relatively weak “hydrogen” bonds rather than “stacking” interactions in which imidazole rings sit on top of each other. Similar experiments are currently being performed on urea.

## Recent Projects<sup>(2)</sup>: Gas Phase Chemistry of Pt / Pd with Hydrocarbons

Microwave spectroscopy is a powerful means of exploring transient species and thus gaining insight into those molecular arrangements that are “intermediates” between the reactants and products of chemical reactions. An understanding of competition between chemical pathways allows for the development of more energy-efficient processes. Platinum and palladium are used as catalysts by the chemical industry with each metal atom known to prompt breaking of the C–H and C=C bonds of gaseous hydrocarbons. Chemical reactions that prompt such re-arrangements are vital to human use of petrochemicals for fuel, materials and drugs. The Newcastle group recently demonstrated that PtC<sub>3</sub> and PdC<sub>3</sub> molecules could be very easily generated from a wide range of different hydrocarbon precursors, including CH<sub>4</sub>, C<sub>3</sub>H<sub>4</sub> and C<sub>4</sub>H<sub>4</sub>O. Our observations thus suggest that PtC<sub>3</sub> and PdC<sub>3</sub> have an important role in the wider gas phase chemistry of platinum and palladium.

(1) Chem. Phys. Chem. 16, 2630-2634 (2015) (2) Angew. Chem. Int. Ed. 55, 3768-3771 (2016)

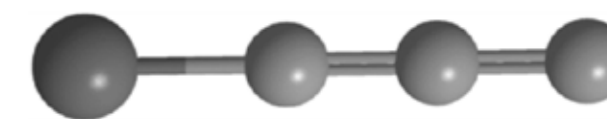


Figure 3 – The linear structure of PtC<sub>3</sub>

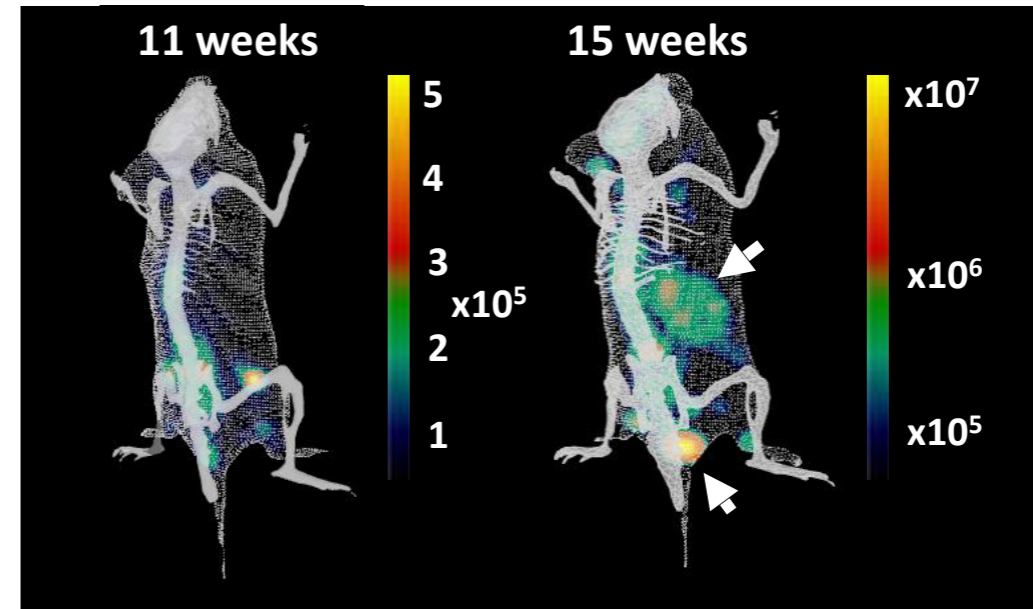




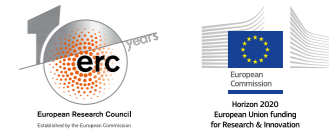
## ONCOGENOMICS:

Development of high throughput in vivo oncogenomic screening strategies in acute leukaemia

Professor Christine Harrison,  
Northern Institute for Cancer Research  
ERC Advanced Grant, 2010-2016  
Value: £1,484,012



Three dimensional reconstructions of live images of a mouse transplanted with human leukaemia cells labelled with a luminescent marker. Between weeks 11 and 15 changes in signal intensity revealed increased disease burden and its dissemination from the bone marrow to organs such as the testis and spleen (arrowed). Models of human leukaemia like these were used to identify novel tumour suppressor genes and oncogenes contributing to leukaemia.



The main aim of this project was to develop new ways to identify genes that contribute to childhood acute lymphoblastic leukaemia (ALL) through loss (tumour suppressor genes) or gain (oncogenes).

To this end we devised assays where effects on growth or survival of leukaemia cells of increasing expression, of candidate tumour suppressor genes, or of reducing expression of candidate oncogenes, was investigated. Initially we investigated genes on the long arm of chromosome 6 (6q) because although deletions of this region are seen in about 10% of childhood ALL, the tumour suppressor genes had not been identified. By increasing expression of pools of candidate genes, in an ALL cell line with a deletion of 6q, we identified two that produced very clear negative effects on cell growth. The effects were seen not only in tissue culture but also when the cells were grown in mice. We therefore had strong evidence that these two candidates are tumour suppressor genes that contribute to childhood ALL and have further investigated them to understand the mechanism by which their loss contributes to disease.

This data is currently being summarised in a manuscript for publication.

A PhD student on the project used similar assays to investigate candidate tumour suppressor genes on the short arm of chromosome 12 (12p) and candidate oncogenes on 11q, regions affected respectively by deletion or amplification in patients with acute myeloid leukaemia (AML). After defining a common region of deletion on 12p in patient material, the student tested a number of genes for their potential role as tumour suppressors, identifying one strong candidate. The role of this gene in AML was further investigated in patient samples and in other functional studies and has been summarised for publication. To identify oncogenes on 11q the approach was to use reagents (shRNAs) that reduced expression of candidate genes. However

this study produced only inconclusive results, possibly because the shRNA were not sufficiently active. The student completed his PhD graduating in 2015.

A major interest of our group is intrachromosomal amplification of chromosome 21 (iAMP21), a cytogenetic abnormality seen in about 2% of childhood ALL patients that have a poor response to standard therapy. These abnormalities have regions of chromosome 21 that are amplified or deleted in complex patterns that are unique to each patient. To identify candidate chromosome 21 oncogenes for analysis, in collaboration with the Sanger institute, we used a combination of state of the art techniques to characterise iAMP21 abnormalities in ALL patients. This preliminary analysis was published in the prestigious journal Nature. To create assays for the analysis of the candidate oncogenes, because no cell lines are available, we developed models, known as xenografts, by transplanting iAMP21-ALL patient cells into mice. The xenografts have been used to produce substantial stocks of cells which have been extensively characterised and shown to carry iAMP21 abnormalities

that closely resemble those in the patients from which they originated. Leukaemia in the xenografts has also been characterised by live imaging and histological analysis and we have summarised these data in a paper which is currently being submitted for publication. We have also performed assays in mice, using the xenograft cells and shRNAs that target the candidate chromosome 21 oncogenes. This approach did not identify any of the candidates as contributing to iAMP21 ALL, so we have adopted an alternative technique that makes use of CRISPR-cas9 'molecular scissors' to knock out these genes. Although there was insufficient time to perform these assays within the course of the grant, we have been awarded further funding to continue this work.

In summary, we have achieved our principal objective of developing a new type of assay for the identification of genes contributing to leukaemia. Thus far the assay has been more successful for the identification tumour suppressor genes than for oncogenes, but with further funding we will continue to refine these techniques and expect to overcome this problem.





# p-TYPE:

Transparent p-type semiconductors for efficient solar energy capture, conversion and storage

Dr Elizabeth A Gibson,  
Lecturer in Physical Chemistry, School of Chemistry  
<http://www.ncl.ac.uk/chemistry/staff/profile/elizabethgibson>  
ERC Starting Grant, 2017-2021  
Value: £967,638

p-TYPE addresses the scientific and technological challenges required to transform the use of solar energy by reducing payback time, improving manufacturability, innovating the technology for integration into buildings or devices and solving the energy storage issue.

We are developing tandem dye-sensitized solar cells (Figure 1), which are a unique way to make a step change in the efficiency of solar cells which function at a molecular level.<sup>1</sup> An efficient tandem DSC has not yet been developed because p-type DSCs are much less efficient than n-type cells. The goal of this project is to increase the efficiency from < 2% to > 20% by replacing the nickel oxide conventionally used with a new material which is optimised for dye-sensitized photocathodes: a wide band gap to allow the dye to absorb the light; better conductivity for higher photocurrent; a higher ionisation potential for higher voltage. By adding catalysts to the device (Figure 2), we can drive chemical reactions such as carbon dioxide reduction or hydrogen production from water to make fuel, so the dual challenges of energy conversion and storage are addressed.<sup>2</sup>

n-Type transparent conducting oxides are present in many devices but their p-type counterparts are not largely commercialized as they exhibit much lower conductivities. The core part of the project focuses on making libraries of mixed metal oxides and selecting those which are promising p-type semiconductors.<sup>3</sup> Our high-throughput synthesis and screening system will enable us to accelerate the discovery and optimisation processes. Promising materials are assembled in tandem DSCs and tested. Our objectives are: A) Improve the efficiency of p-type dye sensitized solar cells and water-splitting cells by incorporating new p-type semiconductors which, for the first time, combine good transparency and high conductivity. B) Drive innovative engineering for the fabrication of high-efficiency low-cost tandem devices incorporating new photocathodes as a means of converting the majority of solar radiation striking

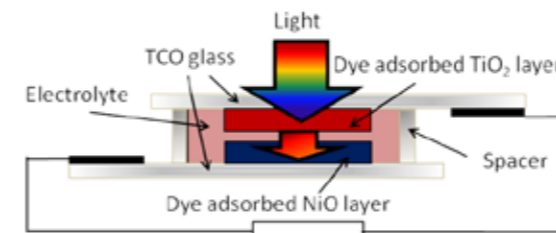


Figure 1. A Tandem dye-sensitized solar cell

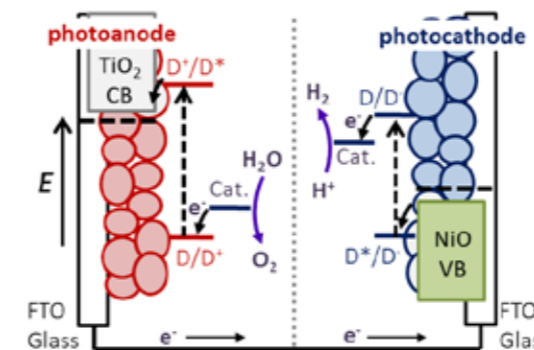


Figure 2. A photoelectrosynthesis cell for splitting H<sub>2</sub>O.

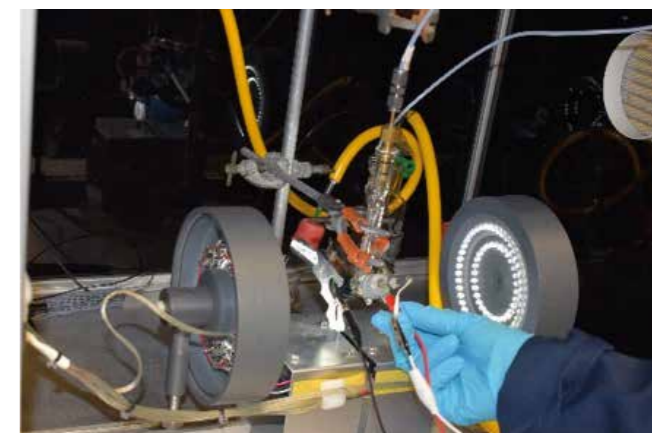
the Earth. C) Underpin our research with state-of-the-art techniques for solar cell characterization to connect the fundamental research carried out at the molecular level and the events that take place in the device as a whole.<sup>4</sup>

### ERC project team:

The ERC grant has supported the recruitment of three PhD students and two post-doctoral research assistants in the first year to join our international team of researchers (UK, China, Estonia, India). Each is responsible for a different aspect of the project (materials synthesis, spectroscopy, electrochemistry and/or device assembly and characterisation) but work together as a team to address the challenges to widespread utilisation of solar energy.

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2. *Phys. Chem. Chem. Phys.*, **2016**, 18, 10727 – 10738
3. *ACS Appl. Mater. Interfaces*, **2015**, 7, 24556–24565.
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## Contact

Dajana Dzanovic  
EU and International Research Funding Team Manager

Newcastle University  
Research & Enterprise Services  
Old Library Building  
Newcastle upon Tyne  
NE1 7RU

Tel: +44 (0)191 208 5373  
Email: [dajana.dzanovic@ncl.ac.uk](mailto:dajana.dzanovic@ncl.ac.uk)  
[www.ncl.ac.uk](http://www.ncl.ac.uk)



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