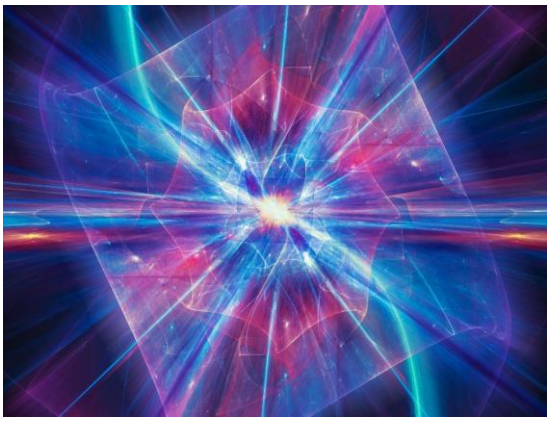
January 2022

Advanced Technology Institute Newsletter
Faculty of Engineering and Physical Sciences

News

FIRST-EVER OBSERVATION OF MULTI-PHOTON FANO EFFECT COULD LEAD TO BOOST IN QUANTUM COMPUTING



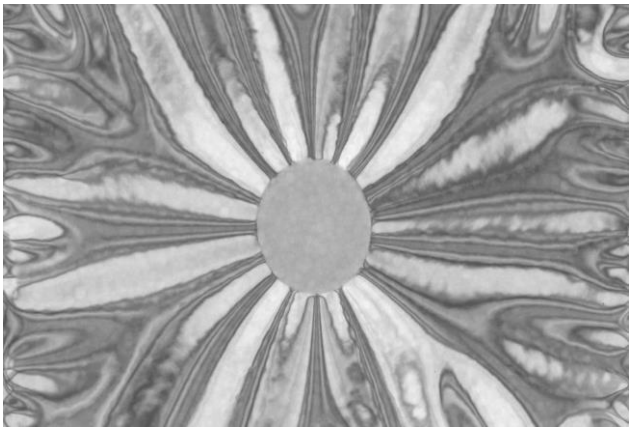
A breakthrough study has confirmed a 50-year-old theory and could boost the development of silicon-based quantum computers. Published by Nature Communications, an international team of researchers led by the University of Surrey has proven the existence of the fabled multi-photon Fano effect in an experiment. Ionisation is when electrons absorb photons to gain enough energy to escape the nucleus' electrical force. Einstein explained in his Nobel Prize-winning theory of the photoelectric effect that there is a threshold for the photon energy required to cause an escape. If a single photon's energy is not enough, there might be a convenient half-way step: ionisation can occur with two photons starting from the lowest energy state.

Led by the University of Surrey this complication was overcome by using impurity atoms where, due to the influence of the semiconductor host material, the electric field that determines the outer electron orbits is significantly reduced and, consequently, much less laser intensity is required to demonstrate the Fano effect. The team used ordinary computer chips that contain phosphorous atoms embedded in a silicon crystal. The team then used powerful laser beams at the free-electron laser facility (FELIX) in Radboud University, Holland, to ionise phosphorus atoms.

Dr Konstantin Litvinenko, co-author and Research Fellow at the University of Surrey, said: "We believe we have taken a very important step towards the implementation of novel and promising applications of ultrafast readout of silicon-based quantum computers; selective isotope-specific ionization; and a variety of new atomic and molecular physics spectroscopies."

IN THIS ISSUE

GROUNDBREAKING RESEARCH PRODUCES RECORD LEVELS OF STRAIN IN SINGLE-CRYSTAL SILICON



University of Surrey researchers have developed a single-step procedure to put single-crystal silicon under more strain than has been achieved before. The discovery, which has a patent pending, could be crucial to the future development of silicon photonics, which underpins the technologies behind the internet-of-things, and is currently constrained by the lack of cheap, efficient, and easily integrated optical emitters. Now, the Surrey-based researchers are transferring the same procedure to germanium.

If successful, they will open the door to creating germanium lasers, which are compatible with silicon-based computers, and could revolutionise communications systems by means of new opto-electronic devices. This would address the problem of overheating, which is becoming a threat to development in silicon-based computer systems and would eliminate the need to develop expensive and difficult to integrate III-V devices, a popular area of research to try to overcome overheating. The team from the University of Surrey's **Advanced Technology Institute** demonstrate that up to 3.1% biaxial strain and up to 8.5% uniaxial strain can be generated but point the way to even larger strains, achievable by varying the implant species and by exploiting the underlying crystal direction.

Dr David Cox, Senior Research Fellow at the Advanced Technology Institute at the University of Surrey, said: "What excites me about this is the simplicity of the method and that it can easily be transferred to production methods. It will be exciting to see if this can have as significant an impact on Group-IV semiconductor photonics as Alf Adam's long-standing legacy on the development of the strained-layer III-V based quantum-well lasers. **Mateus Masteghin**, the lead author of the study and Ph.D. student, said: "Seeing the wrinkles annihilation and the flattening of the membranes in real time was astonishing. This new technique promises to be highly disruptive to the field of photonics, and I am looking forward to continuing developing new devices based on this proposed technique."

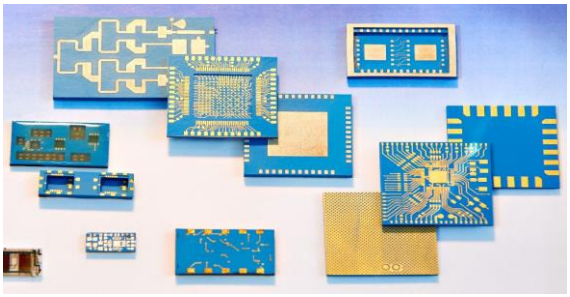
SURREY STUDENT WINS INSTITUTE OF PHYSICS PRIZE

Daisy Shearer, a PhD research student at our **Advanced Technology Institute**, has won a prestigious Institute of Physics (IoP) Early Career Physics Communicator Award. The prize is organised by the IoP's Physics Communicators Group and is awarded to people at the start of their careers. It celebrates those who organise activities to support and encourage the excellent communication of physics.

And that description certainly includes Daisy. She not only promotes physics through her outreach work – but, diagnosed with autism at 21, she's also a campaigner for neurodivergent people in science, technology, engineering, and maths (STEM) subjects. Daisy learnt she was on the four-strong shortlist for the IoP award in May this year. In the final, she and the other nominees had to give a 10-minute presentation to a panel of judges. "I talked about my science communication and outreach projects," says Daisy. "I started off by reading the essay about my journey into physics, which was part of the competition this year. Daisy's supervisor, Dr Steven Clowes said "This is great recognition."

TAKE A SECOND LOOK AT POOR PERFORMING THIN-FILM TRANSISTORS, SURREY EXPERTS URGE FELLOW RESEARCHERS

Researchers from the University of Surrey and the Max Planck Institute in Stuttgart, Germany, have arrived at a set of recommendations that may see an explosion in the research effort into unconventional electronic devices. Transistors are the small electronic switches and amplifiers that make up the electronic circuits that underpin all modern technologies. Thin-film transistors (TFTs) are made with low-cost materials and techniques, which means large-area circuits can be made economically.



Some characteristics of inefficient TFTs could be hallmarks of unoptimised source-gated transistor (SGT) behaviour. SGTs, a class of TFTs invented and perfected at the University of Surrey, score poorly in the usual metrics of TFT performance but have significant amplification and uniformity advantages, making them useful in an increasing number of emerging applications, for example imperceptible technologies and environmental sensors. In their recent publication in the Advanced Electronic Materials journal, the research team give numerous examples that demonstrate cases in which underwhelming TFT behaviour may be turned into high-performance SGT operation.

Dr Radu Sporea, Senior Lecturer at Surrey's **Advanced Technology Institute**, said: "The recent surge in publications that report source-gate transistors in varied material systems hints at how popular this type of transistor can become. It is very likely that many other experiments have been cut short when the expected thin-film transistor operation was not achieved, overlooking the opportunity for creating excellent SGTs in the process.

SURREY WINS BID FOR NEW MICROSCOPE WHICH CAN SEE ATOMS

Winning a £0.6m Core Equipment Award from the Engineering and Physical Sciences Research Council (EPSRC), Surrey's materials scientists have taken possession of a state-of-the-art transmission electron microscope. The new microscope allows users to see materials in three dimensions and to employ a host of other imaging techniques and fast chemical analysis, enabling new insights into the mechanisms and processes that happen within materials. Supporting materials research across the University, the new equipment will pave the way for the development of highly advanced materials in fields such as green energy, next generation computing and wearable technology. It will also help researchers to understand materials ageing and degradation, helping them to improve the lifetime of materials and thereby reduce environmental impact.

The Thermo Fisher Scientific Talos F-200i Scanning Transmission Electron Microscope – an investment of around £1m – has been purchased thanks to the EPSRC Core Equipment Award along with significant funding from industrial sponsors of the Micro and Nano-Materials and Technologies (MiNMaT) Centre for Doctoral Training

The bid was a collaboration between materials researchers in electrical and electronic engineering, chemistry, chemical and process engineering, mechanical engineering sciences, physics and civil engineering. It was led by Pro-Vice-Chancellor for Research and Innovation, Professor David Sampson, with co-investigators Dr Mark Whiting (Department of Mechanical Engineering Sciences), **Dr Vlad Stolojan (Advanced Technology Institute)** and Professor Joseph Keddie (Department of Physics).

NO EXCUSE TO CONTINUE RELIANCE ON FOSSIL FUELS, SAYS LEADING NANO-TECHNOLOGIST

A leading thinker in nanoscience has called on the energy materials community to help put an end to the world's reliance on fossil fuels. In a hard-hitting editorial published by *Energy and Environmental Materials*, **Professor Ravi Silva**, Director of the **Advanced Technology Institute (ATI)** argues that there are no coherent excuses left to justify the use of fossil fuels. In his paper, Professor Silva challenges the scientific community to lead the world away from a reality where fossil fuels still account for 80 per cent of the energy mix.

While the cost of clean energy generation has plummeted over recent years, Professor Silva argues that significant innovations in advanced batteries and energy storage technologies are needed to meet the International Energy Agency's goal of the planet being carbon net-zero by 2050. Professor Ravi Silva, Director of the ATI at the University of Surrey, said: “The pandemic has been a truly horrific experience. However, one of the few positives that I can gather from the past two years is that it has allowed me to take stock and refocus on the incredible challenge of combatting climate change. It is increasingly clear that the energy materials community has a crucial role to play in weaning the world off fossil fuels.

“The cost of green energy is falling all the time - in the UK, solar and wind generation is competitive with fossil fuels. But we need to look at improvements in thin-film technologies, new polymers and other hybrid materials that can boost energy capture capabilities while reducing the cost of production if we are to have a genuine green energy revolution."

SURREY STUDENT MAKES A DISCOVERY THAT COULD IMPROVE THE RELIABILITY OF FUTURE SMART ELECTRONICS

An undergraduate student from the University of Surrey has discovered a way to suppress hot-carrier effects that have plagued devices that use thin-film transistor architecture - such as smartwatches and solar panels. In her final-year project, Lea Motte studied a new device, the multimodal transistor, an alternative to conventional thin-film transistors, invented and developed by PhD candidate **Eva Bestelink** and supervisor **Dr Radu Sporea** at Surrey.

Lea used a defining feature of multimodal transistors, the separation of controls for introducing electrons into the device and allowing them to move across the transistor.

In a paper published in the journal Advanced Electronic Materials, PhD student Eva Bestelink systematically studies Lea's discovery of the unusual behaviour in multimodal transistors by confirming it with measurements in microcrystalline silicon transistors and performing extensive device simulations to understand the device physics that underpins its unique ability. Eva Bestelink, lead author of the study from the University of Surrey, said:

"We now have a better understanding of what the multimodal transistor can offer when made with materials that cause numerous challenges to regular devices. "For circuit designers, this work offers insight into how to operate the device for optimum performance. In the long term, the multimodal transistor offers an alternative for emerging high-performance materials, where traditional solutions are no longer applicable."

SURREY STUDENT WINS YOUNG SCHOLAR AWARD

Michal Delkowski, a collaborative PhD student at our **Advanced Technology Institute (ATI)** and Airbus, has won the Gold Young Scholar Award at the 31st International Conference on Diamond and Carbon Materials (ICDCM). This year, the conference – where scientists from all over the world meet to discuss and exchange the latest cutting-edge results – brought together delegates from 41 countries and hundreds of submitted works.

Michal presented his work, which is associated with a unique plasma-enhanced-chemical-vapour deposition (PECVD) system that helps provide the next-generation of composite and polymeric materials. These can be used in the building of structures, sub-components and devices that can survive in the harsh environment of space. At the ICDCM award ceremony at the end of the conference, Michal won the main prize, the Gold Young Scholar Award, receiving a certificate and a cash prize of 250 Euros.

FOR NEXT-GENERATION LED-BASED DATA COMMUNICATIONS

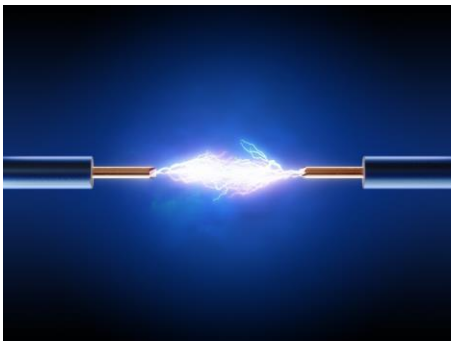
A new paper from the University of Surrey and the University of Cambridge has detailed how two relatively unexplored semiconducting materials can satisfy the telecommunication industry's hunger for enormous amounts of data at ever-greater speeds. Light-emitting diode (LED)-based communications techniques allow computing devices, including mobile phones, to communicate with one another by using infrared light. **Dr Aobo Ren**, the co-first author and visiting postdoctoral researcher at the University of Surrey, said: "There's excitement surrounding CQDs and perovskites because they offer great promise for low-power, cost-effective and scalable communications modules. Although the conventional inorganic thin-film technologies are likely to continue to play a dominant role in optical communications, we believe that LEDs based on these materials can play a complementary role that could have a sizeable impact of the industry."

SURREY RESEARCHERS BREATHE NEW LIFE INTO PAPER BOOKS WITH THE MAGIC BOOKMARK

The University of Surrey has developed a new, cost-effective, ecological solution for augmenting the printed page with rich, up-to-date digital content. The development overcomes one of the most significant advantages e-books have over paper books, helping paper maintain its strong position in its competition with electronic media. Researchers at the University of Surrey's **Advanced Technology Institute** and Digital World Research Centre have designed an elegant and intuitive electronic system that allows the readers of a paper book to access related multimedia content by simply placing a bookmark on a page. The Magic Bookmark uses optical contrast sensors to discern a pattern printed next to the book's spine on each page. Because no electronics are embedded in the paper book, costs are minimised, and end-of-life recycling is enabled.

The research, published in the peer-reviewed Advanced Intelligent Systems journal, explores several ways of making the system. After a series of prototypes, the optimised version uses an optical barcode printed along page margins near the spine of the book and a detachable physical bookmark with embedded sensors.

SURREY RESEARCHERS REVEAL THE HIDDEN BEHAVIOUR OF SUPERCAPACITOR MATERIALS

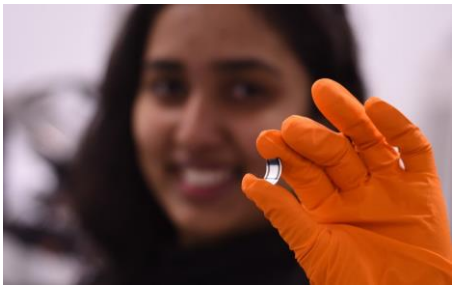


Researchers from the University of Surrey's **Advanced Technology Institute (ATI)** and the University of São Paulo have developed a new analysis technique that will help scientists improve renewable energy storage by making better supercapacitors. Improvements in energy storage are vital if countries are to deliver carbon reduction targets. The inherent unpredictability of energy from solar and wind means effective storage is required to ensure consistency in supply, and supercapacitors are seen as an important part of the solution. Supercapacitors could also be the answer to charging electric vehicles much faster than is possible using lithium-ion batteries.

Surrey's peer-reviewed paper, published in Electrochimica Acta, explains how the research team used a cheap polymer material called Polyaniline (PANI), which stores energy through a mechanism known as pseudocapacitance. PANI is conductive and can be used as the electrode in a supercapacitor device, storing charge by trapping ions. To maximise energy storage, the researchers have developed a novel method of depositing a thin layer of PANI onto a forest of conductive carbon nanotubes. **Professor Ravi Silva**, Director of the ATI and principal author, said: "Following on from world leaders pledging their support for green energy at COP26, our work shows researchers how to accelerate the development of high-performance materials for use as energy storage elements, a key component of solar or wind energy systems. This research brings us one step closer to a clean, cost-effective energy future."

SAFER X-RAYS AND RADIATION THERAPY A STEP CLOSER THANKS TO SURREY RESEARCH

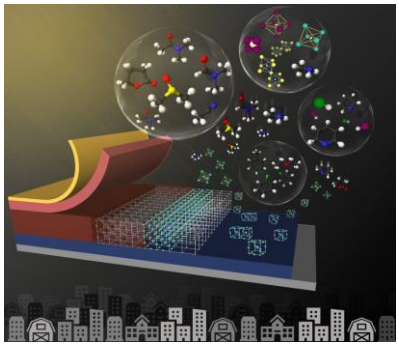
Researchers at the University of Surrey have identified key design rules for making curved X-ray detectors, bringing clearer and safer X-rays a step closer to reality.



Although the use of digital flat panel detectors has enabled radiographers to examine X-rays much more quickly compared with old-fashioned X-ray sensitive photographic films and to make quicker diagnoses, flat panels are ill-suited to the complex shape and geometry of the human body. The reliance purely on flat panels means there is unavoidable distortion around the edges of images. Flat panels also prevent an accurate registration of the X-ray dose delivered, a key feature towards enabling safer radiation therapy and minimizing secondary tumours.
However, in a study published in the peer-reviewed journal Advanced Science, researchers from the **Advanced Technology Institute** at the University of Surrey, in collaboration with Italy's University of Bologna, the National Physical Laboratory and Sheffield University, identify design rules for a special class of "inorganic in organic" semiconductors.

Prabodhi Nanayakkara, lead author of the study and PhD student at the University of Surrey, said: "Our curved detector concept has shown exceptional mechanical robustness and enables bending radii as small as 1.3mm. The use of organic or 'inorganic in organic' semiconductors is also far more cost effective than conventional inorganic semiconductors made from silicon or germanium, which require expensive crystal growth methods. Our approach potentially offers a significant commercial advantage."

UNIVERSITY OF SURREY RESEARCHERS PAVE THE WAY TOWARD FINDING SUITABLE SOLVENTS FOR PEROVSKITE INKS



Researchers from the University of Surrey have published a roadmap to boost the commercial viability of perovskite solar cells. Perovskite solar cells have gained attention in recent years because of their ability to deliver high photovoltaic performance under a low-cost and low-temperature solution-based fabrication processing, which allows materials to be dissolved in suitable solvents to produce inks.

In a paper published in the journal *Small,* researchers from Surrey's Advanced Technology Institute (ATI) reveal their progress in solvent engineering to help achieve the highest quality for perovskite light-absorbing layers.The review paper focuses on the essential characteristics of the developed solvent systems and the engineering methods for perovskite thin film preparation, thereby paving the way for future evolutions in how the solar-cell devices and their inks are produced. **Dr Ehsan Rezaee**, postdoctoral research fellow at the ATI at the University of Surrey, said: "The emergence of perovskite solar cells as the highly efficient new generation of solar harvesting technology is incredibly exciting.

Professor Ravi Silva, Director of the **ATI** at the University of Surrey, said: "Our organisation has always believed in the potential of solar panels to be a critical part of the energy mix that finally allows us all to move away from dangerous outdated energy sources. However, we must do more to improve the power conversion efficiency of these promising devices, and we hope this significant paper helps pave the way for those advancements."

UNIVERSITY OF SURREY MAPS PATH TO CARBON NEUTRALITY

Ahead of COP26 in Glasgow, the University of Surrey has published a paper in Sustainability detailing how it will reduce its carbon emissions and reach Net-Zero by 2030. In the paper, Surrey's researchers share ideas and provide guidance on how other universities can apply the Science-Based Targets Initiative (SBTi).

The University of Surrey is a leading UK university with an annual turnover of around £300m. Sustainability research is a vital part of research activity across the University, for example, at its Centre of Environment and Sustainability. Sustainability forms a central pillar across the teaching curriculum. Solar and renewable energies are a major theme within the research undertaken by the **Advanced Technology Institute** Actions the University will take to reduce its absolute carbon emissions by 46% over the next ten years (based on 2018/2019 emission levels) and achieve Net-Zero include on-site renewable energy generation, including building a solar farm. **Professor Ravi Silva**, Director of the Advanced Technology Institute at the University of Surrey, said: "There is a moral obligation for all deep-thinking organisations to champion change, and, with the expertise we have at the University of Surrey, we can lead the way in accurately calculating carbon emissions and developing robust plans to become carbon neutral.

On behalf of RAEng and CESAER, we hosted a very successful two-day meeting on meeting the SDGs in the next 30 years. Prof. Ravi Silva hosted the second day session on "Net Zero World in 30 years". Sir Jim McDonald, Professor Martin Green, Dr. Chad Frischmann from Drawdown etc. spoke at the event which was attended by a virtual audience of over 200. More information can be obtained from the web pages link here and here. An Editorial on meeting the Net Zero energy supply and storage obligations was written by **Prof. Ravi Silva** in the journal Energy and Environmental Materials. He is the Editor in Chief of this quartile one journal which received a recent impact factor of 15.12. For those interested in the Energy Supply trends please examine the following Editorial in full here.

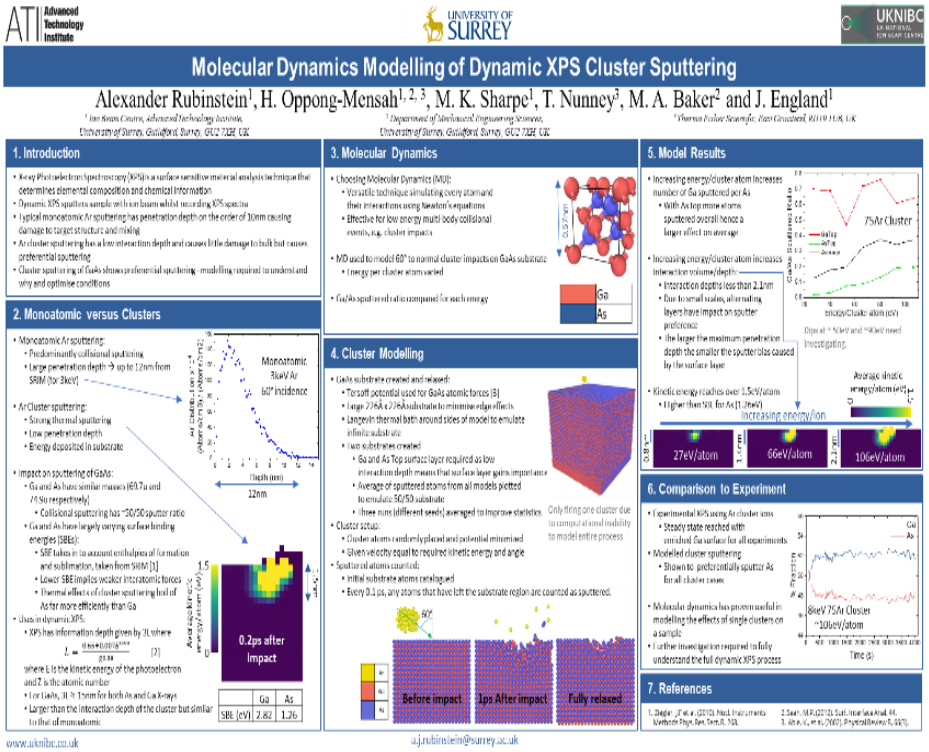
PhD News

Welcome - The ATI welcomes: **Surajit Kar** who joined our January 2021 cohort, **Shaoyin Li** who joined our April cohort, **Patryk Golec**, **Alex Teng**, **Toby Hawkins**, **Anthony Balchin**, **Toussaint Gervais,** and **Matthew Goodwin** who joined our July cohort, **Richard Banister**, **Raphael Viana**, **Lauren Tidmarsh**, **Apostolos Panagiotopoulos**, **Veronika Zelyk** and **Rucchi Ryan** joined in October. **Jed Lambert**, **Md Delowar Hussain**, and **Abayomi Oluwabi** who joined us this month. We wish them well in their research.

Well done to **Georgios Bairaktaris** for his publication at the CHI2021 conference, the biggest conference for human computer interactions. The publication can be found here.

Congratulations to **Eva Bestelink** on her win for IET Postgraduate Scholarship for an outstanding researcher. Prior to her BEng degree, Eva was a mature student undergoing a career change. Eva made the decision between a PhD in an unrelated field or start over. Eva quickly realised that semiconductor devices were her true calling and could see parallels between neural behaviour and unconventional ways of operating transistors.

Alex Rubinstein wins Best Poster at IoP Plasma Surfaces and Thin Films Meeting.
The Plasma Surfaces and Thin Films Meeting was a one-day meeting organised by the Ion and Plasma Surface interactions Group of the Institute of Physics (IoP) and had around 40 attendees. Under normal circumstances this event would have taken place in London however, this year it was held online. The poster presented, titled "Molecular Dynamics Modelling of Dynamic XPS Cluster Sputtering", was an overview of molecular dynamics work investigating the mechanisms involved in Ar cluster sputtering.



This project was undertaken with the aim of assisting in experimental work developing the technique of using Ar gas cluster ion beam sources with dynamic XPS.
The researched involved running numerous models and altering parameters such as the energy per cluster atom in order to ascertain the effect on preferential sputtering of the target.
Experimental data was used to glean a general idea of the expected preferential sputtering results.
Alex is in the first year of his PhD working at the Ion Beam Centre.

Staff News

The ATI welcomes **Dr Jae Sung Yun** who joined in September and will be working on powering off-grid portable IoT devices using efficient perovskite solar cells.