HENRY ROYCE INSTITUTE

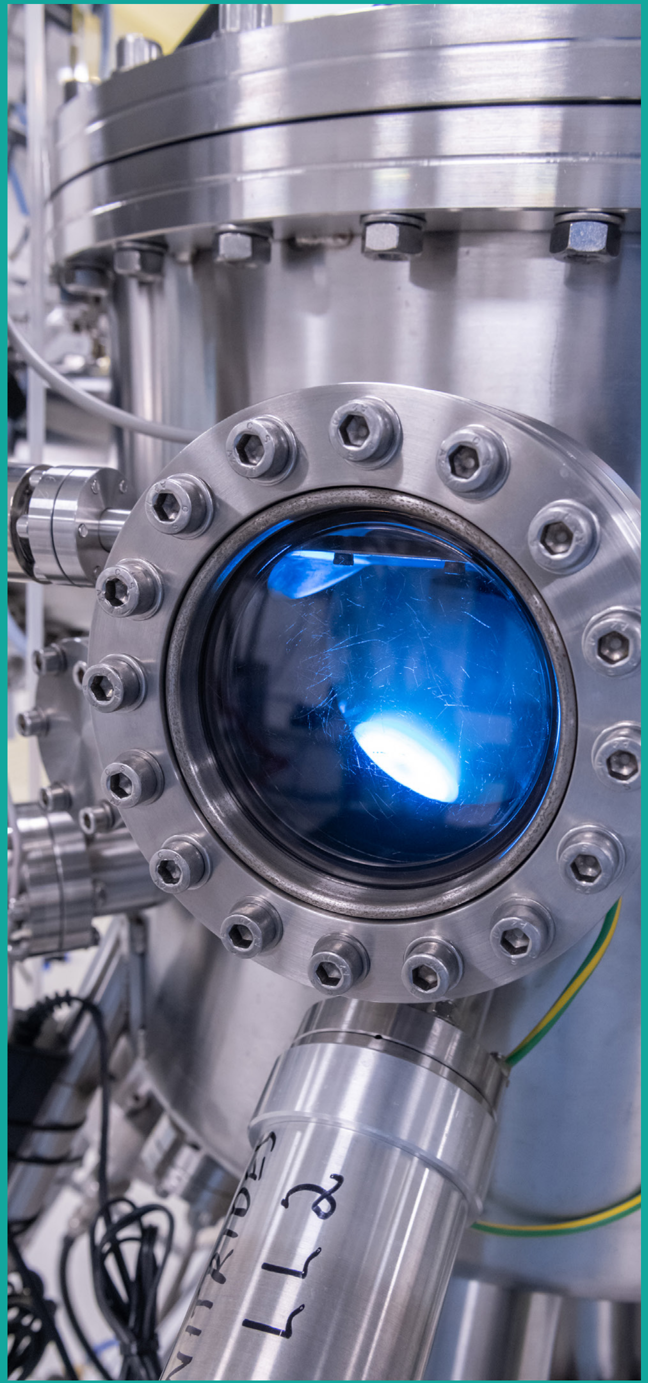
ADVANCED MATERIALS RESEARCH & INNOVATION

ATOMS TO DEVICES

FACILITIES

ROYCE

The Atoms to Devices Research Area has underpinning, cross-disciplinary facilities, that support the accelerated discovery and development of new device materials and device architecture.



VISION

The Henry Royce Institute Atoms to Devices (A2D) Research Area aims to provide underpinning, cross-disciplinary, technology platforms, which facilitate and support the accelerated discovery and development of new device materials and device architecture.

Building from a single atom up, A2D focusses on engineering materials at the nanoscale to support device application.

This includes deposition of precisely controlled thin films, interface engineering, providing the ability to control doping on the nanoscale, as well as characterising device properties, such as electrical conductivity and chemical composition, on nanometre length scales. This capability enables the design of new devices for *tomorrow's technologies* that will impact society.

A2D brings together national expertise and cutting-edge facilities to support discovery at the atomic scale and its translation into functional technologies. Through strong academic and industrial collaboration, we accelerate the development of advanced materials and devices through our access schemes and collaboration programmes.

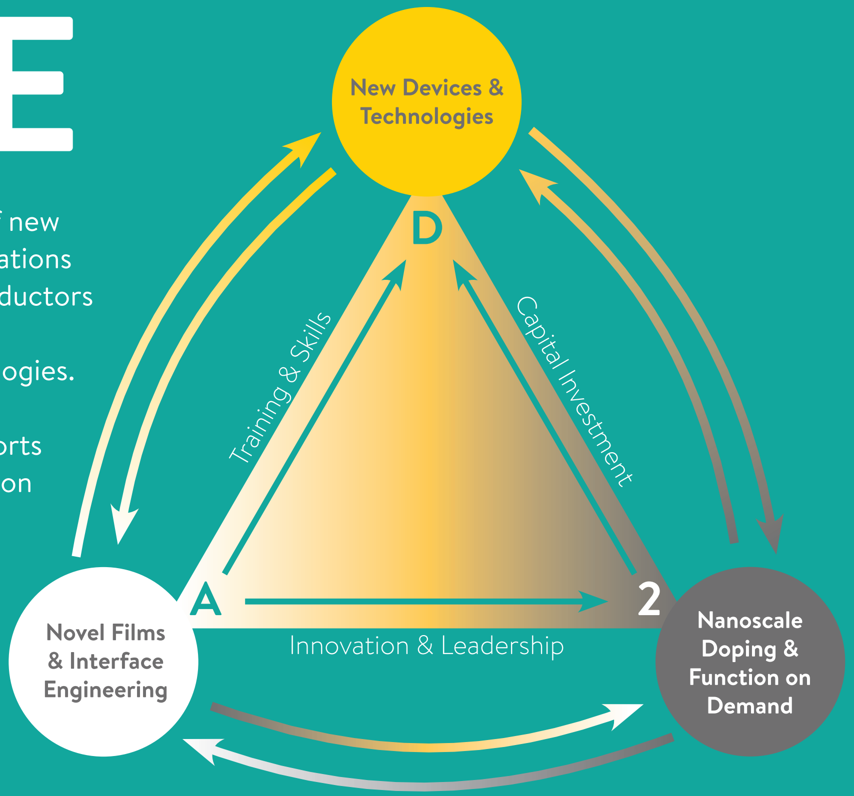
Our work is underpinned by a commitment to skills development, training, and outreach, ensuring that we equip the next generation and wider community to meet future materials challenges.

SCOPE

A2D supports atomic-scale engineering of new technologies that can translate into applications ranging from photonics, imaging, semiconductors and sensors, through to energy storage, biomedical materials and quantum technologies. We share many aspects of our remit and capabilities with 2D Materials, which supports the atomic-scale engineering and application of novel 2D materials. Between A2D and 2DM, Royce can offer the full range of nanoscale materials engineering.

Capabilities include modelling, design, growth, fabrication, characterisation, and testing of electronic, spintronic and opto-electronic devices, with facilities spanning four Royce Partners: the University of Manchester, Imperial College London, the University of Cambridge and the University of Leeds.

Our partnership is predicated upon the feedback loop between material optimisation and device performance. We optimise each step in the design process, from growth of novel materials into thin films and nanostructures, to the characterisation of chemical, structural and optoelectronic properties, and finally fabrication into devices, and device testing.



UNIVERSITY OF MANCHESTER

Atoms to Devices capabilities at the University of Manchester sit within the Photon Science Institute, which provides cohesive infrastructure, including multiscale structural characterisation (£20M of SEM/TEM, FIBs, nanoSIMS, XPS) and photonic (>£20M) capability. Manchester expertise focuses on engineering and characterising systems on nanometre length scales, hosting several unique national facilities, including the P-NAME facility for deterministic ion doping, and the CUSTOM near-field microscopy facility for nanoscale optoelectronic characterisation.

RESEARCH AREA LEAD

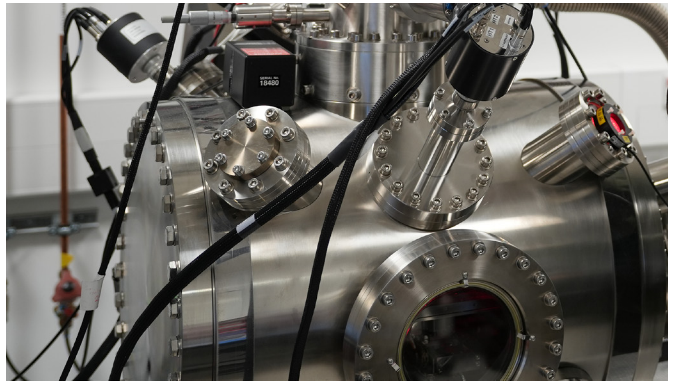
Dr Jessica Boland is a UKRI Future Leader Fellow and Senior Lecturer (Associate Professor) of Functional Materials. She is the director of the CUSTOM facility, which hosts a suite of scattering-type near-field microscopes enabling optoelectronic material characterisation at nanoscale length scales, sub-picosecond timescales and cryogenic temperatures.

FABRICATION

Platform for Nanoscale Advanced Materials Engineering (P-NAME)

The P-NAME tool provides the ability to engineer functionality into advanced materials on the nanoscale. Dopant ions can be selected with isotopic purity and implanted into precisely defined regions with sub-20 nanometre resolution.

The P-NAME tool has a focused ion beam (FIB), with over 20 ion species available. A secondary electron microscope can be used for sample imaging and co-alignment with the FIB. The key functionality of P-NAME lies in its ability to detect single ion implantation. With detection efficiencies of over 98%, this opens the possibility for single defect engineering.



CHARACTERISATION

Cryogenic Ultrafast Scattering-type Terahertz-probe Optical-pump Microscopy (CUSTOM)

The CUSTOM facility consists of a suite of scattering-type scanning near-field optical microscopy (s-SNOM) systems that can operate from the THz to the visible range. The systems offer material characterisation on nanometre length scales with ultrafast temporal resolution (80 fs) at temperatures as low as 10 K, enabling 2D mapping of local dielectric function and time-resolved dynamics.

CAPABILITIES:

- Flexibility to couple custom light sources to SNOM systems.
- Simultaneous imaging of amplitude, phase and topography
- Hyperspectral and 3D mapping
- Surface-sensitivity

APPLICATIONS INCLUDE:

- 3D conductivity mapping of semiconductor materials and devices
- Near-field mapping of metamaterial structures at telecom wavelengths
- Chemical composition mapping (nano-FTIR spectroscopy) of surface layers
- Nanoscale imaging and spectroscopy of biological cells

IMPERIAL COLLEGE LONDON

Imperial College London offers state-of-the-art facilities dedicated to the innovation of novel multifunctional devices. This includes facilities for nano-scale thin film deposition, device patterning and electrical characterisation and instrumentation able to analyse a wide range of surfaces, along with a range of tools for prototyping nano-devices.

RESEARCH AREA LEAD

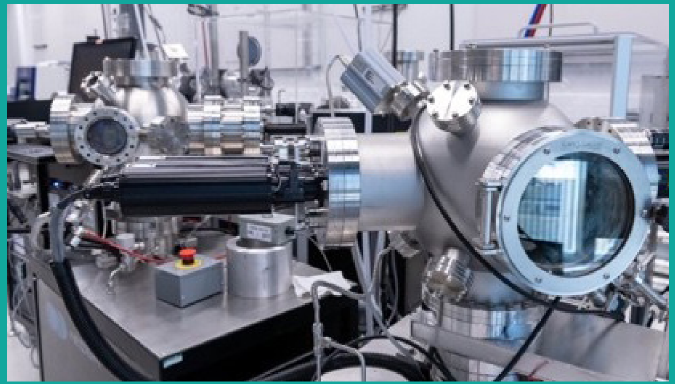
Professor Ifan Stephens' group aims to enable the large-scale electrochemical conversion of renewable energy to fuels and valuable chemicals and vice versa, processes critical to the increased uptake of renewable energy. His focus is on catalyst material, which defines the efficiency of electrochemical energy conversion devices, and has extensive experience with thin films as model electrodes for electrochemical devices.

FABRICATION

Thin Film Device Materials Platform
A Rapid Prototyping Fab

The Thin Film Device Materials Platform at Imperial College London provides a platform for the construction of bespoke thin film devices, from materials preparation to deposition and patterning, physical characterisation and device testing, embracing the entire research and development lifecycle.

The co-location of instruments to perform each step of this process enables us to repeat the research life cycle to generate proof of principle rapidly, essentially making the facility a rapid prototyping fab for technologies in the TRL 1-4 range.



CAPABILITIES:

Deposition

- Magnetron & RF Sputtering; Magnetron & RF
- HIPIMS
- E-Beam Evaporation
- Pulsed Laser Deposition

Characterisation

- Structural analysis:
- X-Ray Diffraction; powder and thin film
- Cryo Focused Ion Beam
- Scanning Electron Microscope;
- EDS and EDSB
- Raman Spectroscopy
- Scanning Laser Confocal Microscopy
- Electron Paramagnetic Resonance and
- SQUID magnetometry

Surface Analysis

- Atomic Force Microscopy (AFM)
- Stylus Profilometry
- Optical Thin Film Analysis

Patterning

- Photolithography
- Nano-Imprint Lithography
- E-beam lithography
- ICP-RIE
- Wide Beam Ion Etching

Device Testing

- Ambient, Cryo- and High-Temperature probe stations:
- Semiconductor analyser,
- Vector Network Analyser
- RF LCR Meter
- Ferroelectric Analyser
- Current/Voltage Source Measurement
- Thermal Analysis

UNIVERSITY OF CAMBRIDGE

Royce at Cambridge supports a wide range of deposition, fabrication and characterisation equipment with applications across materials systems. Royce at Cambridge acts as a gateway for industrial engagement across the University and supports a wide variety of industrial characterisation and research projects, as well as workshops to help industry better understand and define the solutions they need from Royce. Successes include working with large companies to develop new materials for sensing and telecommunication applications, supporting SMEs to advance new battery technologies, and supporting researchers develop and characterise new energy materials.

RESEARCH AREA LEAD

Prof Manish Chhowalla; Goldsmiths' Professor of Materials Science, studies atomically thin two-dimensional transition metal dichalcogenides (TMDs). He has demonstrated that it is possible to induce phase transformations in atomically thin materials and utilise phases with disparate properties for field effect transistors, catalysis, and energy storage.

FACILITIES

- Battery Manufacturing Facility
- Electron Microscopy Facility
- Physical Vapour Deposition and Characterisation Facility
- 3D Bioelectronics Facility
- Ambient Cluster Processing Facility

FABRICATION AND DEPOSITION

- Electron Beam Lithography
- Molecular Beam Epitaxy (MBE)
- Sputter Deposition
- UV Mask Aligned Lithography

CHARACTERISATION

- X-Ray Photoemission Spectroscopy (XPS)
- Electrical Characterisation Suite
- Wafer-Scale Atomic Force Microscopy (AFM)
- Nanoscale Quantum Sensing and Imaging
- High Frequency Antenna Measurement
- Magnetic Property Measurement System
- Wide Bore Magnet
- Thermoelectric Testing
- Solar Suite

Cambridge Ambient Cluster Processing Facility (CACTUS)

A custom-built glovebox tool that integrates different vacuum and liquid-based deposition technologies into a common inert glove box atmosphere. It comprises of ten glove box modules that are interconnected by a cutting-edge, semi-automated inert atmosphere transfer system. CACTUS has capabilities including deposition, thermal evaporation, printing, encapsulation and metrology.

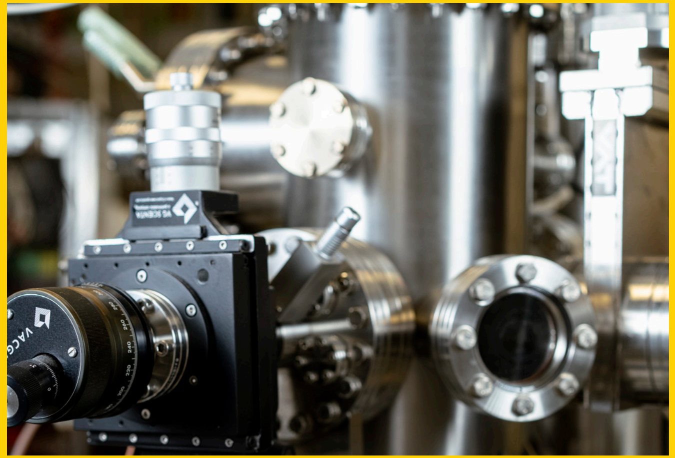
The facility provides users access to a wide range of functional materials, from transition metal oxides; organic and hybrid semiconductors; perovskites; photovoltaics; 2D materials; polymer composites; and beyond. The unique configuration allows for the integration of different classes of materials into novel hetero-architectures, as well as the fabrication of a wide-range of devices.

Royce at Cambridge Technology Platform: Physical Characterisation and Vapour Deposition Facility (PVCDF)

The Royce PVCDF is a state-of-the-art facility for thin-film deposition and device fabrication.

Capabilties include:

- AJA Sputterer
- SEM-FIB
- Custom Sputterer Systems
- PLD
- Ion-Miller
- SEM with Raith Elphy Quantum E-Beam
- AFM



UNIVERSITY OF LEEDS

The Bragg Centre for Materials Research aims to discover, create and design new materials and acts as a focus for Royce A2D activities at the University of Leeds.

The Bragg Centre has a state-of-the-art deposition and cleanroom facilities. This is supported by a breadth of analytical and characterisation facilities, including the Leeds Electron Microscopy and Spectroscopy Centre, X-ray Photoelectron Spectroscopy (XPS) Facility (including the Royce enviroESCA, an environmental near-ambient pressure system), and XRD and AFM capabilities.

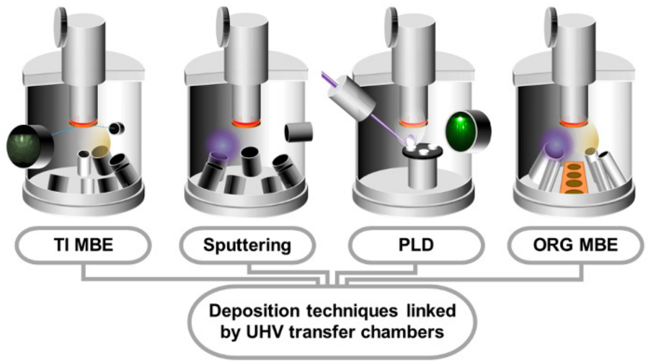
RESEARCH AREA LEAD

Prof Edmund Linfield's research explores the science and technology of the terahertz frequency region of the electromagnetic spectrum. Sitting between the radio and microwave regions at lower frequencies, and the infrared and visible regions at higher frequencies, terahertz occupies a fascinating and distinctive portion in the electromagnetic spectrum, lying at the interface between electronics and optics.

Royce Deposition System

The Royce Deposition System is a multi-chamber, multi-technique thin film deposition tool. The system includes a prep chamber and four deposition chambers that are linked together via an interconnected UHV transfer system:

- Topological Materials MBE Chamber Four dual-filament effusion cells, Low temperature effusion cell, Two valved-corrosive-metal-cracker-cells
- Pulsed Laser Deposition Chamber; Multi-target system for growth of complex multi-layers
- Sputtering Chamber; Eight DC/RF-magnetron sputter sources
- Organics Chamber; Four low temperature effusion cells, Four pocket e-beam evaporation, DC/RF magnetron sputtering gun



Leeds Nanotechnology Cleanroom

A leading facility for nano and micro-fabrication. Following its relaunch in January 2022, the cutting edge 800m^2 cleanroom has continued to expand, with over £3.5m in investment in the past two years, ensuring it stays at the forefront of research.

Equipped with an extensive array of advanced tools, and staffed by a team of specialised experts, the LNC promotes innovation, offers training and supports collaboration with industry and academics from around the world.

Capabilties include:

- Electron Beam Lithography
- Metrology Bay
- Wet Etch Bay
- Test and Packaging
- Photolithography Bay
- Deposition Bay
- Dry Etch Bay

Our extensive toolset, encompassing PVD, CVD, dry etch and metrology is underpinned by our highly adaptable lithographic capabilities, offering sub 10nm linewidths using our advanced ebeam system, to rapid prototyping using our maskless optical lithography system. This is supported by our comprehensive solutions for packaging, bonding and electrical testing and probing.

We specialise in supporting diverse production needs, ranging from short-loop process runs to full device flows, and in integrating non-standard materials, enabling seamless provision of small production volumes for new and innovative devices.

TRAINING

A2D offers a wide range of practical nano-fabrication training to both academia and the commercial sector, directly addressing the National Quantum and Semiconductors Strategies call for upskilling the UK workforce. These include:

Practical Cleanroom Skills

Universities of Leeds, Cambridge and Swansea

Annual training to provide basic practices and techniques for cleanroom use. Through a combination of taught lectures, discussion sessions, and practical training, participants gain fundamental skills for working in cleanrooms. The course develops theoretical and practical knowledge in a wide range of cleanroom techniques, including lithography, deposition, and etching; with participants using what they learn to fabricate a micron-scale Field Effect Transistor.

Thin-Film Deposition

University of Leeds

This course introduces thin-film deposition and analytical techniques for characterising thin films. The content explores physical vapour deposition techniques, and will cover deposition parameters, structural characterisation and the electrical behaviour of a simple device.

It includes basic lab skills for working with the ultra-high-vacuum environments needed for high quality thin film growth. Through the use of the Royce Deposition System participants gain hands-on experience of sputtering, molecular beam epitaxy (MBE) and pulsed laser deposition (PLD).

Thin-Film Device Manufacturing

Imperial College London

An introduction to the fundamentals of vacuum technologies and essential concepts in thin film deposition techniques. It provides a foundation in microfabrication methods, such as photolithography and ion milling, essential for advanced research and thin film device manufacturing.

Participantsgain theoretical knowledge and develop practical experience, preparing them for work in research and manufacturing environments. It also introduces the state-of-the-art equipment available at the Royce Thin Film Device Materials (TFDM) Facility at Imperial College London and supporting capabilities across the A2D Partners.

CASE STUDIES

DE-RISKING NEW TECHNOLOGY FOR SMES

Paragraf is creating next-gen electronics using graphene, a 2D material extremely sensitive to its local environment at the atomic length scale, by exploiting this behaviour to design molecular sensor devices with extreme sensitivity.

The facilities available through Royce at the Universities of Cambridge and Leeds enabled Paragraf to undertake important studies on new combinations of materials with graphene and associated devices, to expand its product offering to customers.

Royce Support

Paragraf used a wide range of Royce facilities, including the Ambient Processing Cluster, X-ray Photoelectron Spectroscopy, and Transmission Electron Microscope. The opportunity to access the Royce SME Access scheme through an efficient process ensured swift access and strong support.

"Royce offers invaluable opportunities for SMEs to undertake early exploratory or analysis work, strengthening their technology and boosting their offering to customers."

Dr Seb Dixon
Senior Scientist
Paragraf

CREATING ADVANCED MATERIALS

DZP Technologies develop advanced materials for printed flexible and stretchable electronics. Testing and validating these materials in specific use cases requires scientific equipment which is too expensive for a small company to invest in.

Using such equipment often requires specialist expertise and skills and years of scientific training. As a result, product development and market entry can be delayed because validating the materials becomes a lengthy and expensive process.

Royce Support

Using the Equipment Access Scheme, DZP Technologies gained access to a specialist screen printer at Cambridge, THz light source at Manchester, and characterisation facilities at Imperial. The company has already gained important knowledge which is helping to commercialise their novel materials.

"The support from Royce is crucial for our material innovation and product development, and helps to bring our products to market faster."

Dr Zlatka Stoeva
Founder
DZP Technologies Ltd

ATOMS TO DEVICES EQUIPMENT LOCATIONS

	CAPABILITY	IMPERIAL	LEEDS	CAMBRIDGE	MANCHESTER
Depositon	Sputtering	●	●	●	
	E-Beam Evaporation	●	●		
	Pulsed Laser Deposition	●	●	●	
	Thermal Evaporation	●	●	●	
	MBE		●	●	
	ALD		●	●	
	Organics	●	●	●	
	UHV Connected Systems		●	●	
Ion Implantation	P-NAME				●
Characterisation	XRD	●	●		●
	XPS		●	●	●
	XRCT			●	●
	HAXPES				●
	AFM	●	●	●	●
	SEM	●	●	●	●
	TEM		●	●	●
	FIB	●	●	●	●
	Thin Film Analysis	●	●	●	
	EPR	●			
	MPMS	●		●	
	Stylus Profilometry	●		●	●
Patterning	Dry/Wet Etching	●	●	●	
	Electron Beam Lithography	●	●	●	
	Nanoimprint Lithograpohy	●			
	Photo / Scanning Probe Lithography	●		●	
Device Testing	Cryo / Hi Temperature and Ambient Probe Stations	●		●	
	Electronic Characterisation	●	●	●	

ACCESS

Royce is open to businesses of all sizes, to tackle materials challenges and accelerate both innovation and technology translation.

From equipment access for commercially sensitive short-term research to long-term partnerships, Royce can work flexibly and support a range of approaches and needs.

Our team will provide clear options, including costings and available funding, enabling you to understand the model that fits your organisation's needs including wider training requirements.

Through our Equipment Access Schemes, Royce can provide funding to utilise its extensive portfolio of state-of-the-art materials science and engineering equipment.

Royce funded access schemes are open to researchers and students based at UK academic institutions, Research Technology Organisations, and UK-based SMEs.

Industrial Collaboration Programme

Funding for universities, RTOs and companies to explore innovative ideas with a focus on technology translation.

Researcher and Student Access Schemes

Funding for UK-based doctoral and research masters students, and researchers at all stages of their careers.

SME Access Scheme

Open to UK-based SMEs, spin-outs and start-ups, the scheme offers subsidised access to its extensive portfolio of equipment.

Designed to overcome cost barriers, de-risk experimental materials-based R&D, and complete proof-of-concept studies.

To access our services or engage with us, email info@royce.ac.uk and we'll be in touch to see how we might collaborate.

Or get in touch directly via:

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