University Alliance
Doctoral Training Alliance

DTA3/COFUND Programme Research Project Proforma

Page 1 – General Information

Project Code	UCEN02
Partner University	University of Central Lancashire The University of Manchester (External)
Faculty/School/Department/Research Centres	UCLan Faculty of Science and Technology: School of Physical Sciences and Computing (Karen Syres and Joe Smerdon) School of Engineering (Katerina Fragaki) The University of Manchester, School of Materials.
First supervisor Please provide name and weblink	Dr Karen Syres https://www.uclan.ac.uk/staff_profiles/karen_syres.php
Second supervisor Please provide name and weblink	Dr Joe Smerdon https://nanophysicsuclan.wordpress.com/
Third supervisor Please provide name and weblink	Dr Katerina Fragaki https://www.uclan.ac.uk/staff_profiles/dr_katerina_fragaki.php
Fourth (external) supervisor	Dr David Lewis https://www.research.manchester.ac.uk/portal/david.lewis-4.html
External/industrial supervisor	Dr Hayley Brown Plasma Quest Limited Unit 1B Rose Estate, Osborn Way, Hook, Hampshire, RG27 9UT
Which of the supervisors listed above is an early-career-researcher	Dr Karen Syres
Contact details for project for informal applicant queries	Karen Syres ksyres@uclan.ac.uk
DTA Programme	DTA Energy
Project title	Probing electron transport and nanoscale behaviour in perovskite solar cells

Co-funded by the Horizon 2020 programme of the European Union

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 801604.

Page 2 – Project Description

Scientific Excellence (500 words)	Perovskite-structured compounds were first used in solar cells in 2012 and since then have seen rapid increases in efficiencies. In just a few years efficiencies have reached over 22% [1], already higher than most competing photovoltaic technologies. Research into this new class of photovoltaics is still in its infancy and there is lots of fundamental physics still to learn about these materials. Perovskite solar cells use a perovskite-structured compound, usually a hybrid inorganic-organic metal halide-based material, as the light absorbing layer in the device. The absorbed light excites electrons in the perovskite material which subsequently travel to the cathode and round the external circuit to generate a current. Perovskite solar cells can be made from inexpensive materials and can often be manufactured using simple inexpensive methods, making them a particularly attractive alternative to other technologies. The major obstacle of perovskite solar cells is their long-term instability, particularly under UV light and in the presence of water. These problems must be overcome before these devices can be commercialised. Perovskite solar cells consist of an electron-transport layer (ETL) between the perovskite material and the cathode which helps with charge carrier separation [2]. However, in common ETL materials, the electrons are not transported efficiently to the cathode and have a tendency to recombine in the perovskite or become trapped. Recently, materials called ionic liquids have been used to modify the ETL. The bonding of the ionic liquid between the perovskite and ETL results in an efficient electron transport channel and significant improvements in cell efficiencies have been reported. [1] A. Kojima et al., Journal of the American Chemical Society (2009) 131, 6050–6051 [2]. Yang et al., Energy and Environmental Science (2016) 9, 3071—3078

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	Scientific excellence of supervisors and facilities: Dr Karen Syres (h-index 11) is a surface scientist specialising in molecular bonding, ordering and charge transfer at interfaces using spectroscopic techniques. She regularly wins experimental time at synchrotron facilities around Europe which will be exploited for the PhD project. She is the elected vice-chair of the Institute of Physics Thin Films and Surfaces Group committee and has chaired national and international conferences. She has published papers on charge transfer and ordering of molecules at photovoltaic interfaces. Dr Joe Smerdon (h-index 18) is a surface scientist specialising in nanoscale imaging techniques. He has state-of-the-art equipment at UCLan, partly funded by a Royal Society equipment grant, which will be vital for the project proposed. He has published papers in the area of molecular electronics. Dr Katerina Fragaki (h-index 8) is an engineer specialising in the effect of weather conditions on the long term performance of the photovoltaic systems. She has specialist equipment at UCLan for measuring the efficiency of photovoltaic devices and has published papers on the testing of photovoltaic systems. Dr David Lewis (h-index 22) is a leading materials scientist specialising in the growth of novel perovskite films. He has specialist equipment at Manchester which will be used to grow perovskite materials for the project.
Aim (400 words) You may wish to include headings – Hypothesis, Methodology and Innovations	Hypothesis We will use cutting edge techniques to probe electron transport and nanoscale behaviour at the interfaces of novel perovskite solar cells in order to improve the efficiency and long-term stability of these devices. Methodology The project is uniquely structured to equip the candidate with knowledge of every stage from growth of the active layer to the real-world performance of a device, leading to fantastic employment prospects in the academic/energy sector on graduation.

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	1. Probing fundamental physics of perovskite interfaces (Dr Karen Syres). We will determine the bonding, band energy alignment and charge-transfer properties at the interface using X-ray photoelectron spectroscopy and synchrotron radiation techniques (at external facilities). We will build perovskite solar cell devices using thin film deposition equipment at UCLan (funding won by Karen Syres in an internal equipment bid). Key outcome/thesis chapter: Charge transfer at interfaces 2. Microscopy of perovskite interfaces (Dr Joe Smerdon). We will use electron microscopy to measure the cross-sections of fabricated solar cells to analyse the interface quality, which is crucial to solar cell efficiency. We will use state-of-the-art atomic resolution cross-section STM (X-STM) to measure the per-atom morphology, interface quality and electronic structure of thin films of perovskite deposited on technologically relevant substrates, such as glass, ITO glass and silicon. Key outcome/thesis chapter: Interface nanomorphology 3. Constructing and testing perovskite solar cell devices (Dr Katerina Fragaki). Following device fabrication we will measure the efficiency of the perovskite devices under sunlight using specialist equipment. The long-term stability of the devices will be measured by taking measurements under different conditions over a period of weeks to months. Key outcome/thesis chapter: Assessing device performance 4. Growing novel perovskite materials (Dr David Lewis). The PhD student will work in David's group learning how to grow perovskite materials. Key outcome/thesis chapter: Active layer synthesis Industrial placement at Plasma Quest Limited (Dr Hayley Brown). The student will work on thin film deposition techniques of perovskite materials. Innovations Perovskite solar cells have seen rapid increases in efficiencies over just a few years and are already competing against other photovoltaic technologies. This is an exciting area to research

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	because there is still lots of fundamental physics to explore and innovative improvements to be made in the field of perovskites. Their long-term stability is an issue which must also be researched before these devices can be commercialised so there is lots of room for innovation in this area.
Strategic Relevance (300 words)	Global CO_2 emissions are increasing and contributing to climate change. This is arguably the biggest challenge facing society and if we can't find a way to reduce CO2 emissions it may be too late to reverse the effects. Our research efforts must be directed at this challenge of finding "greener" alternatives for our energy supply. Novel photovoltaics, such as perovskites, show great promise for meeting this energy demand. The research fits with the University's strategic research direction to develop Condensed Matter Physics at UCLan. In 2015 four new lecturers (including Karen Syres) were appointed to expand the university's research in this area and to complement the research of other recently appointed physicists at UCLan (including Joe Smerdon). This project will allow collaboration and expansion of research in this area.
Interdisciplinarity and fit with DTA3	The aim of the DTA3 programme is to develop early-stage researchers with interdisciplinary and inter-sectoral skills, ready for industrial employment, in the UK priority challenge areas. This PhD project will deliver on all of these aims as follows: • The PhD project is directly relevant to the DTA3 theme of Energy and hence the UK priority challenge area of clean energy. • This project covers multiple disciplines, from synthesis of novel perovskite materials (chemistry and materials science), nanoscale behaviour at surfaces and interfaces (physics), through to building and testing the efficiency of devices (engineering). The student will learn a variety of interdisciplinary skills leading to fantastic employment prospects on graduation. • The project involves an industrial placement at Plasma Quest Limited so the student will also learn inter-sectoral skills and be trained for industrial employment on graduation.

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	• The project will be led by a female early career researcher (Karen Syres). Joe Smerdon is also a relatively early career researcher (within 6 years of first academic post) so this project will aid the development of two dynamic early career physicists. The project also benefits from an experienced, high profile external supervisor at The University of Manchester.
Industrial Relevance (300 words) Detail external placement opportunities or collaborations available as part of the project	The PhD project will include a 1-3 month placement at Plasma Quest Limited (PQL) in Hampshire. PQL provides thin film materials and process solutions that cannot be met by current deposition technologies. PQL can be contracted to undertake design services, material trials and under confidentiality agreement be engaged with a client to do thin film material process development. Access to PQL's thin film deposition expertise can improve time to market and reduce internal costs. PQL often work with PhD, EngD and Masters students through their studies and are in strong support of students that have an opportunity to be linked to industry. The work that the student carries out at PQL will be directly relevant to their project in the area of perovskite solar cells and will give them a different perspective by working in an industrial environment rather than academia.
Economic and Societal Impact (300 words)	With CO_2 emissions contributing to climate change there is a societal need to find "greener" alternatives for our energy supply and to find ways to capture harmful emissions into the atmosphere. The UK government has a target that by 2050 they will reduce CO_2 emissions by at least 80% of the levels in 1990. Photovoltaics can at least partially fill this energy gap but to become a major player in the energy market they need to be more cost effective. Perovskite solar cells have seen rapid increases in efficiencies over just a few years and are already competing against other photovoltaic technologies. This project aims to study behaviour in these devices at the nanoscale to provide a foundation for the design of perovskite solar cells with enhanced charge transfer properties and improved stability. Any improvements on the efficiency of photovoltaic devices will have an economic impact.

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	UCLan has an Innovation and Enterprise department through which it would be possible to exploit any potential commercial opportunities arising from the project. We also have links to the Henry Royce Institute in Manchester which aims to work with materials scientists in the UK and link them with world leading companies to develop solutions and speed up the time between discovery and commercialisation. Since this is primarily a fundamental project in nature, large scale commercialisation is not expected within its duration. If efficiencies are improved and problems with instabilities are overcome, the industry could begin to incorporate perovskite solar cells into the national grid within 10 years.

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Page 3 – Admission Requirements

Specific Admission Requirements Detail any subject specific degree qualifications or disciplines, relevant skills, experience	The successful candidate would be expected to hold a good degree in Physics or a related field and meet the language requirements for postgraduate admission to UCLan.
Minimum IELTS score	IELTS 6.5/7.0, with a minimum of 6.0 in each sub-score or an equivalent acceptable qualification.

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