Early Career Conference in Energy

8 November 2024

Institute of Physics, London, UK

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Programme

9:30 AM - 10:00 AM	**Registration and Refreshments**
10:00 AM - 10:05 AM	**Welcome**
10:05 AM - 11:25 AM	**Theme 1: Other Energy** **10:05 AM - 10:55 AM Gary Hayes (Invited Speaker)** Fuel Cells for power supply and storage **10:55 AM - 11:25 AM Bianca Constandache** The Triple Helix of Innovation in Energy: Navigating Science-Industry-Government Collaborations for Advancing Energy Research
11:25 AM - 11:55 AM	**Morning Break**
11:55 AM - 12:55 PM	**Theme 2: Other Renewables** **11:55 AM - 12:25 PM Lu Tian** Ammonia as a fuel? Perspectives on emission mitigation and modelling considerations **12:25 PM - 12:55 PM Yuan Zhang** Hybrid energy harvester integrating ZnO piezoelectric nanogenerator with perovskite solar cell demonstrating the piezo-phototronic effect
12:55 PM - 2:00 PM	**Lunch and Poster Presentations** **Mashael Albuqami** Fabrication of flexible triboelectric nanogenerator on textiles by integration of two-dimensional WS2 as triboelectric layers **Max Court** Ferroelectric – photocatalyst nanocomposites for enhanced solar fuel generation
2:00 PM - 3:00 PM	**Theme 3: Solar** **2:00 PM - 2:30 PM Francisco Jose Cabrera** Optical and Electrical Analysis of an Innovative NW Design Reducing Costs and Maximizing PCE by mimicking ARC layers **2:30 PM - 3:00 PM Daniel McDermott** Coupled in-situ optoelectronic characterisation of accelerated aging in thin-film solar cells
3:00 PM - 3:30 PM	**Afternoon Break**
3:30 PM - 4:00 PM	**Theme 4: Hydrogen** **3:30 PM - 4:00 PM John Gordon** Experimental Investigation of NOx Mitigation in Two-Stage Hydrogen Combustion
4:00 PM - 4:30 PM	**Open Discussion, Final Remarks and Certificate Award**
4:30 PM - 5:30 PM	**IOP Green Economy Networking Reception (optional session)**

Invited Talk

Fuel Cells for power supply and storage

Gary Hayes

Fuel Cells (FC) invented by Sir William Grove in 1837 employ redox reactions to create electricity, heat and potable water when hydrogen is the fuel and oxygen is the oxidant. Today they are used in spacecraft, cars, ships, aircraft, domestic and commercial buildings. Pure hydrogen and oxygen systems with heat recovery achieve overall efficiency north of 80% and as component nanomaterials and gas supply become ubiquitous through the hydrogen/hythane distribution networks, pricing of energy will drive investment into global infrastructure for security of supply.

Contributed Talks

Hybrid energy harvester integrating ZnO piezoelectric nanogenerator with perovskite solar cell demonstrating the piezo-phototronic effect

Yuan Zhang[1], Joe Briscoe[1]
[1]Queen Mary University of London, United Kingdom

A hybrid energy harvester (HEH) comprising a piezoelectric nanogenerator and a perovskite solar cell was designed, fabricated, and analysed. The HEH device can simultaneously and separately harvest both mechanical and solar energy. The piezoelectric output of the HEH exhibits variation between dark and illuminated conditions, attributed to the differing electrical conductivity of ZnO and perovskite under these respective conditions varying the screening conditions. The operational mechanisms of the HEH were explored, and the synergistic effects between the perovskite and piezoelectric ZnO nanorods, known as the piezo-phototronic effect was observed. The photovoltaic (PV) output can be altered by mechanically bending the devices, because of the strain-induced shifting of the energy band in ZnO. The output of the HEH under light and oscillation conditions therefore consisted of a combination of the PV output variation due to the piezo-phototronic effect and piezoelectric output arising from the ZnO nanorods. The impact of morphological variations in ZnO nanorods on the performance of the HEH was also assessed, offering insights into optimizing nanostructured components for improved multi-source energy harvesting performance.

Ammonia as a fuel? Perspectives on emission mitigation and modelling considerations

<u>Dr Lu Tian</u>[1,2], Professor Peter Lindstedt[2]
[1]Loughborough University, United Kingdom, [2]Imperial College London, United Kingdom

Ammonia, a hydrogen carrier, has recently gained significant global interest as a potential transportation fuel. However, challenges remain in its implementation, such as different flame dynamics and high nitrogen oxide (NOx) emissions. This presentation addresses:

1. A systematically evaluated reduced-size mechanism for ammonia oxidation and its application to turbulent flame simulations.
2. The impact of ammonia on soot formation when blended with carbon-containing fuels.
3. The role of diffusion effects in cracked ammonia at elevated pressures.

The study employs a joint-scalar transported probability density function method. Modelling of turbulent, auto-ignition-stabilised ammonia/hydrogen flames reveals a distinct flame structure and highlights the advantages of operating within the Selective Non-Catalytic Reduction (SNCR) regime for NOx reduction. Further computations of ethylene-ammonia blends in both laminar and turbulent flows elucidate the mechanisms behind soot suppression through ammonia substitution. Results from cracked ammonia simulations at elevated pressures indicate that diffusion effects become increasingly significant as pressure rises.

These findings on ammonia combustion contribute to the advancement of computational methods for ammonia flame modelling and offer key insights into ammonia's practical deployment as a clean fuel.

Experimental Investigation of NOx Mitigation in Two-Stage Hydrogen Combustion

John Gordon[1], Dr Lu Tian
[1] *Loughborough University, United Kingdom*

Hydrogen is receiving considerable attention in the pursuit of net-zero carbon goals. Burning renewable hydrogen offers high energy efficiency without carbon emissions; however, nitrogen oxides (NOx) formation remains a major concern. Two-stage combustion, consisting of a primary and a secondary stage, has been employed in applications like gas turbines, boilers, and furnaces to mitigate NOx emissions. This study investigates the feasibility of applying the two-stage combustion concept to hydrogen combustion using dual fuel-staged diffusion flames.

The primary stage diffusion flame is generated from a 0.4 mm burner orifice drilled into a stainless-steel pipe with a diameter of 15mm, while the secondary stage uses a porous nickel-based foam positioned on top of a venturi tube that channels flue gas from the primary stage. Hydrogen fuel is supplied to both stages, with air entrained from the ambient environment. NOx emissions are measured using a Horiba VA-5112 and VS-5003 multi-component gas analyser system with an accuracy of +/- 1.0% full scale range repeatability. The study explores the effects of varying hydrogen flow rates at the primary stage, the pore size of the nickel foam, and variations in venturi designs on NOx reduction, while maintaining a constant hydrogen flow rate of 0.10g/min at the secondary stage. Experimental results indicate that increasing the hydrogen flow rate at the primary stage and the pore size of the nickel foam reduces NOx emissions from the secondary stage. Surface skin temperature measurements of the nickel foam help explain this trend, with lower temperatures correlating to reduced NOx levels.

Coupled in-situ optoelectronic characterisation of accelerated aging in thin-film solar cells

Daniel McDermott[1,4], Alexandra Levtchenko[2], Arthur Julien[1,2], Baptiste Berenguier[1], Jean-Baptiste Puel[3], Daniel Ory[3], Jean-François Guillemoles[1], Frédérique Ducroquet[4], Daniel Suchet[1]
[1] Institut Photovoltaïque d'Ile-de-France (IPVF), École Polytechnique - IP Paris, France, [2] Institut Photovoltaïque d'Ile-de-France (IPVF), France, [3] Électricité de France (EDF) R&D, France, [4] Centre de Radiofréquences, Optique et Micro-nanoélectronique des Alpes (CROMA), France

A key consideration for upscaling renewable energy technologies is device lifetime. For photovoltaics (PV), the durability of mass-deployed silicon technology exceeds 30 years. However, novel thin-film solar cells are still an unknown quantity, particularly in niche environments like floating PV and agrivoltaics. Previous approaches investigating degradation in these technologies usually focus on one characterisation technique and pre-/post-mortem analysis surrounding accelerated ageing tests, making it difficult to pinpoint the causes and kinetics of degradation. In-situ characterisation using several complementary techniques allows degradation to be tracked in real-time and the pathways to be fully explored, giving insight into the physio-chemical processes taking place. Consequently, a coupled IV-photoluminescence (PL) characterisation bench has been developed inside a climate chamber, facilitating the periodic acquisition of PL spectra and IV curves during accelerated ageing. Using this, it was possible to observe disparities between the evolution of a solar cell's optical and electrical performance.

It then becomes imperative to relate accelerated ageing to outdoor kinetics. This was achieved using time-independent parameter-space analysis, where experimental degradation signatures were compared to simulated degradation processes. Finally, time-resolved characterisation of defect states was explored as an addition to the bench. Modulated PL (MPL) and admittance spectroscopy (AS) optically and electrically probe carrier traps in thin-film solar cells. It was seen that MPL is better suited to characterising minority carrier traps in the absorber material, while AS focusses on deep traps, probing various depths of the device and its interfaces. Thus, it was possible to characterise different defect states in thin-film devices.

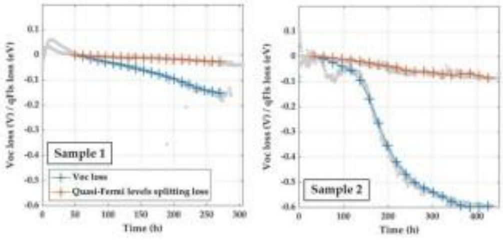

Figure 1: Evolution of VOC (electrical) and quasi-Fermi level splitting (optical) for two perovskite samples during accelerated ageing.

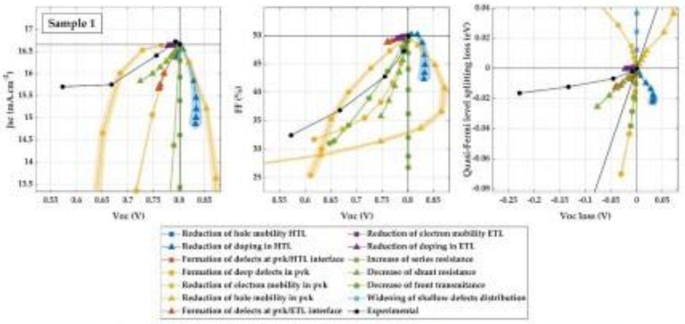

Figure 2: Experimental and simulated degradation pathways for sample 1. A formation of shunts (green triangles) is compatible with experimental results, as it closely follows this pathway on all planes. A formation of defects at the ETL-perovskite interface (red triangles) is also compatible with the beginning of the degradation.

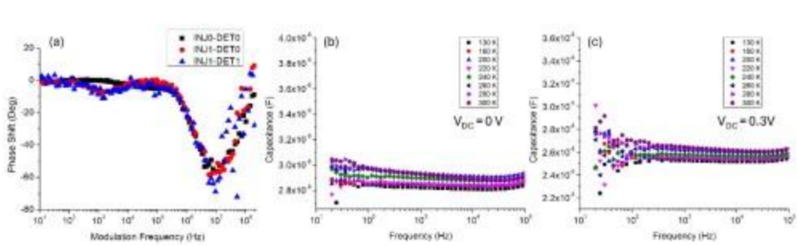

Figure 3: MPL Phase plot (a) displaying distinct 'V-shapes' indicating defect states at several levels of illumination. AS phase plots at Dc offsets of 0 V (b) and 0.3 V (c) displaying no defect related phenomena. Both measurements were recorded on the same CIGS sample.

The Triple Helix of Innovation in Energy: Navigating Science-Industry-Government Collaborations for Advancing Energy Research

Miss Bianca Constandache[1]
[1]University Of Cambridge, United Kingdom, [2]Lancaster University, United Kingdom

Historically, science, government and industry collaborations have stood at the forefront of economic and technological growth. However, amidst these collaborations rose numerous challenges, which today strongly impact the Energy Transition. Differences in language, timelines, processes and expectations could create bottlenecks for scientists thus hindering progress. These challenges resulted in unmet climate goals, lack of funding in R&D, a slow climate startup ecosystem and strict regulations that often inhibit growth.

This talk sets out to present the landscape in which Physics Energy research is currently evolving, from policies, industry demands and scientific challenges. The Triple Helix framework is a model developed by Henry Etzkowitz and Loet Leydesdorff used to explain innovation dynamics. To provide clear insights, the talk will use examples from the IPCC reports, UK Clean Growth Strategy and the IOP Physics Powering the Green Economy report, to describe each interaction in the model.

The aim is to equip the early career researcher with the tools needed to navigate these complex dynamics, thus furthering scientific progress and technological development in Energy.

Optical and Electrical Analysis of an Innovative NW Design Reducing Costs and Maximizing PCE by mimicking ARC layers

Dr Francisco Jose Cabrera España[1]
[1]City, United Kingdom

The use of textured surfaces to minimize the reflection from PV solar cells is a conventional way to increase the power conversion efficiency (PCE) of a solar cell. There are some traditional and well known textured patterns such as micropillars and nanowires to enhance light absorption. In this work it is also additionally considered the concept of mimicking the antireflection coating of single or multiple layers in minimizing the reflectance and thus enhancing the total absorptance further. By doing so, a new and ultra thin texturing pattern can outperform a standard NW of 4270 nm height, which needs less material and can also be fabricated at a reduced cost. This design also suffers from less surface recombination due to a significantly lower surface-to-volume ratio. This design has been analysed comprehensively by optimizing first its optical absorption and then completing the electrical simulations for different scenarios of PN junctions.

Poster Presentations

Ferroelectric – photocatalyst nanocomposites for enhanced solar fuel generation

Max Court[1], Chloe Forrester[1], Joe Briscoe[1]
[1]*Queen Mary University of London, United Kingdom*

Metal oxide semiconductors can be utilized in photoelectrochemical (PEC) water splitting to produce green hydrogen. The key redox reaction to make hydrogen is bottle-necked by the sluggish kinetics of oxidation at the photo-anode, and large rates of charge recombination can reduce solar to hydrogen efficiencies. A potential avenue to raising efficiencies is to integrate ferroelectrics into the photo-anode. Ferroelectrics possess internal fields which can be used to improve charge separation. This poster presents a proof of concept where a ferroelectric material Barium Titanate (BTO) is combined with a metal oxide photo-catalyst suffering from large recombination rates (Bismuth Vanadate, BVO), to create a nanocomposite ferroelectrically coupled system.

The research discussed centers on determining the best method to produce the nanocomposite film. Three different deposition methods are compared: chemical vapor deposition, spin-coating, and electrodeposition. The BTO layer is porous possessing a high resistance, so the deposited BVO layer needs to completely penetrate through the BTO to reach the electrical contact. Additionally, the photocatalyst should strongly couple to the ferroelectric, such that the material maintains high photocurrent. In depth studies are also presented on the difference due to electrochemically poling, the technique used to favorably align dipoles and the intrinsic field. Electrodeposited BVO is found to be the best across all quantifiers, with poling resulting in a current density percentage increase at 1.23 VRHE of 14%. Photoanodes consisting of just BTO see an increase of 33% after poling, indicating that BVO can be further optimized in the future of the project.

Fabrication of flexible triboelectric nanogenerator on textiles by integration of two-dimensional WS2 as triboelectric layers

Mashael Albuqami, Evgeniya Kovalskaa, Kavya Sadanandan, Mashael Alghamdi, Ana Nevesa, Saverio Russo, Monica Craciun

Triboelectric nanogenerators (TENGs) offer great potential for self powered sensing in wearables, but creating high performance, textile based flexible TENGs remains a challenge. Two dimensional (2D) Tungsten disulfide (WS2) is a promising triboelectric material for textile integration, due to its triboelectric properties, layered structure, chemical stability, and compatibility with textiles, making it ideal for flexible textile TENGs.

This study developed a flexible single electrode TENG on textile by integrating 2DWS2 on polyester, using Polyvinyl Chloride (PVC) as the triboelectric pair and copper electrode. Three deposition methods—drop casting, immersion coating, and ultrasonic spray coating—of WS2 films were employed. Results showed that while all methods produced comparable TENG outputs, drop casting slightly outperformed the others. Comprehensive testing was conducted using various materials (Kapton, Nitrile, Polyester, Meta Aramid, Paper, Rubber, PET, PVC, NYLON) with similar volumes of WS2 solution to evaluate device performance on flat textile substrates. We also conducted bending tests with varying radii to evaluate the flexibility of TENG performance. Notably, spray coated TENGs showed minimal performance change after bending, outperforming drop casting and immersion methods in flexibility. These devices also adapted well to different bending radii.

The superior performance of TENG devices produced using different methods demonstrates the effectiveness of these fabrication techniques in enhancing textile TENG functionality. This study paves the way for cost effective sensor fabrication and highlights WS2's value as a triboelectric layer. The findings suggest that WS2 based TENGs are promising for flexible, wearable technology, enabling advances in self-powered sensing and energy harvesting applications.

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