Project Call for 2021 ERBE Cohort

MaREI Supervisor	Prof. Brian Norton, TU Dublin and Tyndall National Institute Dr. Philippe Lemarchand, TU Dublin Professor John Cassidy, TU Dublin, Applied Electrochemistry Group
Institution	TU Dublin
Co-Supervisor & Institution	Dr. Sourav Ghosh, Loughborough University
PhD Proposal Title:	**S**witchable **W**indows for **I**ndoor **T**hermal and lighting **C**omfort, **H**ealth, **E**nergy-efficiency and **S**afety **(SWITCHES)**
Alignment with ERBE Themes:	**Switchable Windows have the potential to improve:** **Comfort** 1. Natural indoor lighting is adapted to outdoor conditions and occupants comfort level 2. Modulated opacity prevents glare to occupants 3. Solar Heat Gain is dynamically modulated to meet desired thermal comfort **Health and Well-being** 4. Quality of light has been demonstrated to improve circadian rhythm, alleviate tiredness and improve physical and mental health **Smart Heating & Fuel Poverty** 5. Building energy consumption and associated cost reduce up to 20% 6. Costs associated with heating, ventilation and air-conditioning (HVAC) systems reduces up to 30% 7. Lighting cost reduces up to 60% 8. Building operating cost reduces by up to 20%

PhD Proposal Abstract:

Motivation

The EU greenhouse gas (GHG) emissions reduction target is 55% by 2030. The EU building stock represents the largest single energy consumer accounting for 40% of energy consumption and 36% of EU GHG emissions.

Windows are the only components of a building that can modulate both free solar heat and natural indoor lighting. They are key to providing the desired thermal and lighting comfort to occupants, while minimise energy losses through the building fabric and lower energy consumption for heating, cooling and lighting. More than 30% of the building energy use is associated with windows.

Switchable Windows are chromogenic (optically switchable) devices that can switch between (i) a fully or partially absorptive state and (ii) a fully or partially reflective state resulting in modulation of light transmission. Dynamically adapting their thermal and light transmission properties they provide considerable energy savings and the desired indoor conditions. Benefits are listed in the ERBE theme box above.

Cost Barriers: Cost remains stubbornly high, with tungsten (WO_3) devices ~€500/m^2 to the end user without frame and control unit.

Performance Barriers: Organic polymeric electrochromic (EC) materials like PANI and PEDOT have peak to peak transmission modulation of 42-44%, with the fastest switching time (30 seconds) for small (4cm^2) sample areas. Figure 1 demonstrate large transmission modulation over the visible and

infrared light range using bilayer EC devices. A large size ($1200cm^2$) non-tungsten-based device using niobium pentoxide switches in 180 seconds.

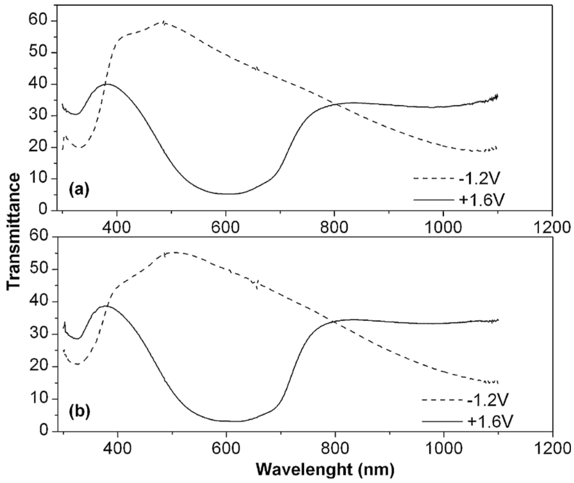

Figure 1: Transmittance spectra at -1.2V/+1.6V for (a) PPy/PAni-PEDOT and (b) PAni/PPy-PEDOT bilayer ECDs (Abaci et al 2014)..

EC devices have great advantages that if developments of appropriate ionic and electronic materials succeed at improving their switching cycle-ability this would make EC devices ideal switching devices. Other areas of improvement include the transmission modulation range and switching speed.

Project Objectives

This project will design, simulate, prototype and characterise a novel lab-scale (~$5x5cm^2$) low-cost organic electrochromic devices (ECD) using a range of electrochromic materials in conjunction with a novel Polymer Gel and/or similar conductive electrolytes. The research aims to tackle the cost and performance drawbacks of switchable windows namely by demonstrating 3-10 fold cost reduction compared to WO_3 devices, increase life cycle of PEDOT ECD by 1 or 2 order of magnitude, increase transmission modulation range and faster switching speed.

Methodology and Scope

Polymer gel electrolytes (PGEs) beneficial properties are reasonable ionic conductivities, wide electrochemical potential windows, negligible volatility, increased charge-discharge cycle stability, improved Faradaic efficiency and substantially reduced sensitivity to moisture. They can be tailored to specific applications.

Deep Eutectic Solvents (DES) are a non-toxic, affordable subclass of ionic liquids. Apart from lower cost they are also characterized by simple one-pot synthesis with 100% atom economy.

Electrochemical performance of PEDOT/DES systems has been studied. PGE are a suitable source of dopants for PEDOT film with no degradation of polymeric films observed. We propose to extend this methodology to PGE's based on DES electrolytes. Inexpensive electrolyte chemicals and ions doping PEDOT film are selected.

Electrochemical methods will be used to ascertain the performances of new electrochromic devices (ECD) such as cycling behaviour and stability. Spectroscopy and microscopy techniques will be used for surface characterisation and ascertain the transmittance characteristics similarly to Figure 1.

Microgravimetric studies are key to determine the switching cycle-ability performances. A novel acoustic approach to investigate the redox behaviour of electrolytes will provide much accurate results compared to the typical Sauerbrey method as shown in Figure 2.

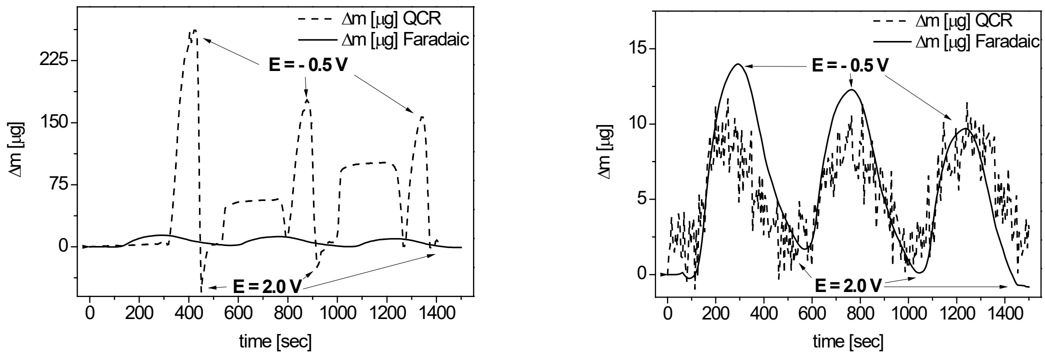

Figure 2: Efficiency of Al deposition in a polymer gel electrolyte redox cycled between 2.0 V (oxidation potential = mass loss) and reduction potential – 0.5 V (reduction potential = mass gain) measured acoustically using Sauerbrey equation (left) and using Loughborough's high amplitude drive method with resonance frequency shift adjustment due to viscosity-related resonance frequency shift (right). Close agreement between acoustically measured and Faradaic mass can be observed when the novel method developed at Loughborough University is applied.

Aims tackled by:

(i) Using organic material such as PEDOT as they are low-cost and recyclable material and provide the potential large scale roll-to-roll manufacturing process.

(ii) Tuning the formulation and thickness to optimise the solar transmission modulation range.

(iii) Holistically optimising the ionic conductivities, charge-discharge cycle stability, and viscosity of PGEs.

(iv) Using purchased transparent ITO conductor with high optical transparency.

(v) Demonstrating the acoustic sensor monitoring method can be used for the live characterisation of PGEs to meet the formation objectives of a single device and the in-line production of such device.

Project summary and PhD Candidate Profile:

This 4-years project will be based in TU Dublin with 6 months in Loughborough University. It will tackle cross disciplinary challenges using advanced technologies and processes. The supervisory board bring strong cross-disciplinary expertise in adaptive building façade technologies, switchable glazing technologies, solar energy, polymer gel electrolyte, chromogenic material, development of switchable film prototypes, electrical and environmental characterizations, and will connect the student to various international organisations. An advisory board of academic and industrial collaborators including other PhD students in related fields will further support the research. The candidate will gain technical and soft skills and knowledge, including project management and collaboration with international teams, and the opportunity for industry exposure.

The desired candidate would have at least a 2.1 degree in chemistry or materials science, a keen interest on polymers, and with a knowledge of analytical science; working with instruments for measurements/characterisation and software for data analysis. The candidate will be fluent in English, shall have a dynamic problem-solving attitude, demonstrate scientific rigour, excellent communication (oral and written) skills, creativity, ambition and with multidisciplinary interests and a goal-oriented outlook.

References

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