IoP PGS Printing for the Future 2022:

Scientific Conference and Early Career Researchers workshop

28 June 2022
Institute of Physics, London, UK

Programme

10:30	**Arrival and refreshments**
11:00	**Welcome Presentation by IOP PGS**
11:15 11:30 11:45 12:00 12:15 12:30	**Session 1:** Scientific Conference Presentations: **Alex Jenkins,** University of Edinburgh Phase changes of complex fluid droplets on ultra-smooth surfaces **Weidong Xu**, Imperial College London Quantification of the charge carrier losses in perovskite solar cells via voltage-dependent photoluminescence spectroscopy **Sam Cressall**, Swansea University Mechanical testing of 3D printed components subject to radiation **Chengning Yao**, Imperial College London Dielectric inks for ultrathin printable electronics **Ffyon Moody**, Swansea University Barrier Technologies for Food Packaging **Thomas Sykes**, University of Oxford Mixing between coalescing droplets
12:45	**Lunch and posters**
13:30	**Workshop:** Invited Speakers on Career Development **Dr Mario Moustras**, ACC CSci CChem FRSCMAZAMO limited Generating impact from your research and Leveraging your strengths **Stewart Edmondson**, CEO, UK Electronics Skills Foundation Tackling the Skills Shortage in the Electronics Industry: opportunities for the future
15:00	**Afternoon break**

	Session 2: Scientific Conference Presentations:
15:15	**Mr Alaa Alaizoki**, Swansea University Surface Modification of Open-cell Polymeric Foam for Improved Liquid Uptake in Food Packaging
15:30	**Waqas Kamal**, University of Oxford Pattern Printed Polymer Dispersed Liquid Crystals for Image-Integrated Smart Windows
15:45	**Thomas Fone**, Swansea University Electrochemical testing of carbons for supercapacitors
16:00	**Mr Kieran Fagg**, Nottingham Trent University Evaporation of Printed Multiple-Droplet Arrays
16:15	**Regana Vasanthanayagam**, University of Cambridge Direct-writing and embedding of functional materials into porcelain ceramic tiles to enable Smart Cities
16:30	**Closure and prizes**
16:40	**Event concludes and delegates depart**

Session 1: Scientific Conference

Phase changes of complex fluid droplets on ultra-smooth surfaces

Alex Jenkins[1]
[1] *University of Edinburgh, Edinburgh, UK*

The evaporation dynamics of complex fluid droplets is a key factor in many applications. In this study, we evaluate the evaporation of such droplets on pinning-free surfaces that cannot be assumed to have no surface contact. We investigate the role of temperature and humidity on the lifetime of respiratory fluids, however unlike previous works our study doesn't rely on lotus effects. Typically when achieving constant contact angle evaporation of fluids on surfaces, the contact of the droplet is assumed to be negligible as the contact angle of the droplet approaches $\sim 180^{\circ}$. Our study uses slippery omniphobic covalently attached liquid like surfaces (SOCAL), capable of CCA evaporation whilst maintaining a contact angle of $\sim 105^{\circ}$ allowing for the effect of contact line pinning on the droplet evaporation to be evaluated. Our results show that the evaporation of respiratory droplets on SOCAL is much different to on untreated surfaces and superhydrophobic surfaces. We also observed previously unseen responsiveness to humidity, even when away from the deliquescence limit of the salts within the fluid. The removal of contact line pinning on evaporation presents an alternative approach to evaluating the lifetime of complex fluid droplets and new understanding of non-pure liquid evaporations on SOCAL surfaces.

Quantification of the charge carrier losses in perovskite solar cells via voltage-dependent photoluminescence spectroscopy

Weidong Xu[1]
[1] *Imperial College London, London, UK*

Understanding the loss mechanisms in perovskite solar cells (PSCs) is the key to further improve their efficiencies towards the theoretical limit. Photoluminescence (PL) is a non-contact, non-destructive method of probing perovskite materials and can be used as an indicator of the free charge concentration in the perovskite bulk. It is noticeable that PL in a PSC is voltage-dependent and it has strong connections with device performance. We first demonstrated PL measurement on a complete PSC at both open circuit and short circuit as an assay for indicating the recombination passes and charge extraction efficiency. This method has also been successfully applied to many other PSCs with varied bulk modification, surface passivation and contact layer engineering. Moreover, we further employed an operando PL system for comparing the charge recombination and charge extraction in operating PSCs with varied electron transport layers. The results suggest that there are still considerable current losses in our devices due to sever charge accumulation at short circuit caused by ion migration.

Mechanical testing of 3D printed components subject to radiation

Sam Cressall[1], and Davide Deganello[1]
[1]*Swansea University, Swansea, UK*

3D printing has a wide range of potential applications, this can be limited by the material properties of the material itself, for example, applications subject to high-level radiation (nuclear).

The research presented here investigates the effect gamma radiation has on the mechanical properties of 3D printed polymers. Mechanical testing methods will be discussed. Early results for PLA and PETG will be presented, underlining the substantial difference in mechanical behaviour as a result of radiation exposure, with significant degradation of PLA vs relative resilience of PETG.

Dielectric inks for ultrathin printable electronics

Chengning Yao[1], Benji Fenech-Salerno[1], and Felice Torrisi[1]
[1]*Imperial College London, London, UK*

Printable dielectric inks with desired dielectric properties are in high demand to enable high-performance printed electronics. Two-dimensional (2D) dielectric materials such as h-BN and BiOCl, have relatively high dielectric constant value and can offer better chemical stability against organic or polymer dielectrics. 2D dielectric nanosheets can be obtained by liquid phase exfoliation, which is a cost-effective technique with a prospect for mass production. 2D dielectrics-based printed electronics have been demonstrated to outperform standard printed electronics, promising high-mobility devices for printed integrated circuits.

Here we report an optimized dielectric inks based on h-BN and BiOCl. Inks are produced by probe sonication and purified by centrifugation. Inks were characterized using AFM and Raman, and proved the successful exfoliation. A metal-insulator-metal parallel plate capacitor configuration is designed to investigate the dielectric properties. Results showed that, compared to traditional polymer-based dielectric materials, capacitor performance using our dielectric inks is improved, revealing a dielectric constant of up to 9.68 based on h-BN, and 23.91 based on BiOCl. Increasing h-BN weight ratio against the polymers or adding high-κ dielectric additives could futher improve the dielectric constant and lower the leakage current density in electroncis. This is beneficial to ultrathin printable electronics development with cost-effective dielectric inks.

Barrier Technologies for Food Packaging

Ffyon Moody[1], Davide Deganello[1], and Christopher Phillips[1]
[1]*Swansea University, Swansea, UK*

The food packaging industry is under pressure to increase the recyclability of plastic packaging. While the majority of food packaging trays, can be made from a mono-material such as PET, the rigid trays for products with a longer shelf life is currently made from a laminate. Different plastics and adhesives are laminated together to reduce the permeability to gases and vapours, maintain a high seal strength and hold together the various layers. Such combinations of materials are impractical to separate so the whole tray is often rejected upon recycling. Mono-PET is currently widely recyclable, however it is highly permeable to Oxygen. The key challenge of this work is to improve the barrier properties of a mono-PET tray by addressing the gas permeability of PET. An overview of current barrier technologies will be presented, discussing their current field of application & development, their potential application in food packaging: potential advantages and limitations. The overview will cover also testing methodologies and technical challenges in their use. The goal will be to develop a novel modification to PET to achieve good barrier properties, recyclable through current infrastructure whilst being scalable for mass production and ensuring there is minimal impact to manufacturing line speed.

Mixing between coalescing droplets

Thomas Sykes[1], Alfonso Castrejon-Pita[1], and Mark Wilson[2]
[1]*University Of Oxford, UK,* [2]*University of Leeds, UK*

When printed droplets coalesce, internal flows determine the extent of fluid mixing on short time scales. Mixing may be desirable, such as to bring chemical reactants (e.g. in reactive inkjet printing) or biological agents together, but may also lead to undesirable colour bleeding in graphical printing. We will summarise the key results of our research, which reveals a variety of ways to assess and tune the amount of mixing between droplets deposited on solid surfaces. Surprisingly, lateral separation can have a non-trivial effect on mixing between successively-deposited droplets; large separations can lead to localised free surface flows that may enhance colour bleed. Surface tension gradients (Marangoni flow) can either enhance or supress mixing, whilst substrate wettability (dynamic contact angles) can significantly alter the resulting internal flow structures. We demonstrate the latter both experimentally and numerically (using OpenFOAM). Experimentally, we show how colour-change reactions can be used to reveal internal flow structures and the real-time extent of fluid mixing.

Workshop: Invited Speakers on Career Development

Generating impact from your research

Dr Mario Moustras
ACC CSci CChem FRSCMAZAMO limited

This session will introduce you to the concept of research impact and help you understand what it is. You will explore tools for how to plan and create impact, and also look at how to evaluate impact. This session will help you to understand what research impact is and explore how to create your own research impact.

Leveraging your strengths

Dr Mario Moustras
ACC CSci CChem FRSCMAZAMO limited

This session is designed to give you practical tools and techniques that you can apply immediately to help you use and develop your strengths. By developing your strengths, you will be able to improve your performance and move forward with your goals. This session will help you identify your strengths and provide you with tips to use and improve your strengths.

Tackling the Skills Shortage in the Electronics Industry: opportunities for the future

Stewart Edmondson
CEO, UK Electronics Skills Foundation

There is a fundamental problem for the UK. Our participation in, and leadership of, technological advances is being limited by a chronic skills shortage in Electronic Engineering. Over a number of years, too few students have been studying Electrical & Electronic Engineering and this means that there are insufficient Electronics graduates to drive forward innovation and progress. This shortage is particularly acute in the sphere of 'chip' design and verification, where the situation is compounded be a lack of awareness among students. The UKESF is working with higher education institutions, industry and schools to tackle this problem.

Session 2: Scientific Conference

Surface Modification of Open-cell Polymeric Foam for Improved Liquid Uptake in Food Packaging

Alaa Alaizoki[1,2], Davide Deganello[1], and Christopher Phillips[1]
[1]*Faculty of Science and Engineering, Swansea University, Swansea, UK,* [2]*Exponent International Ltd, Harrogate, UK*

Plastic food packaging of fresh meat products still suffers from accumulation of liquid residue (exudate). Various packaging solutions have been developed to enable the isolation of exudate within food packaging, such as plastic trays with incorporated absorbent pads and plastic foam trays. These approaches have limited liquid isolation capacity and the use of open-cell polymeric foam tray also requires the addition of chemical wetting agents to facilitate liquid absorption. These chemicals can accumulate in the food supply chain with potential toxic effects on human health. Therefore, an innovative solution has been developed to facilitate liquid uptake into open-cell food packaging foam via oxygen plasma treatment of the foam porous structure. The plasma treatment introduced polar oxygen groups (e.g. C-OH, C=O) onto the pore walls and improved their surface hydrophilicity. This increased the capillary pressure acting on the foam pores, imparting instant liquid absorption capabilities, with capacity about 8 times higher than untreated foam (~ 8 g liquid/g foam), and without the need for chemical wetting agents. The improved absorption capacity persisted even 60 days post treatment, making this technology viable for producing meat foam trays with high capacity to isolate meat exudate and minimise the environmental footprint of plastic packaging.

Pattern Printed Polymer Dispersed Liquid Crystals for Image-Integrated Smart Windows

Waqas Kamal[1], Stephen Morris[1], Steve Elston[1], and Alfonso A. Castrejón-Pita[1]
[1]*Department of Engineering Science, University of Oxford, Oxford, UK*

Polymer dispersed liquid crystals (PDLCs) belong to a class of electro-optic materials that have found application as an electrically-switchable alternative to conventional blinds or curtains as they can be switched between an opaque and transparent state with the application of a voltage. Their compatibility with cost-effective production processes such as roll-to-roll processing has ensured their successful deployment as a “smart window” technology. Even though such manufacturing techniques provide flexibility however a drawback lies in the inherent homogeneity of the PDLC films. To obtain PDLC films with spatially varying properties, film manufacturing has to be performed with an additional step to create patterns or variations in the film morphology and it is not feasible for large area PDLC films. Drop-on-demand (DoD) inkjet printing, which is a form of additive manufacturing, is a digital fabrication process that allows for small volumes of a fluid to be deposited at well-defined locations on a substrate. In this work, we demonstrate new patterned PDLC films that are fabricated using DoD inkjet printing process and have shown that these printed materials could be used to form a smart window technology with logos and images that can be made to disappear with the application of a voltage.

Electrochemical testing of carbons for supercapacitors

Thomas Fone[1], Supervisor Davide Deganello, Daniel Jones, and Christopher Philips
[1]*Swansea University, Swansea, UK*

Supercapacitors are a highly power dense electronic component that can be used to reduce the burning of fossil fuels by distributing energy at peak moments when needed. Activated carbon is often used to make supercapacitor electrodes due to the large specific surface area and natural capacitance. This presentation will discuss electrochemical techniques for characterisation of electrochemical properties of printed activated carbon and challenges in their application

Evaporation of Printed Multiple-Droplet Arrays

Kieran Fagg[1], Fouzia Ouali[1], Joey Kilbride[1], and David Fairhurst[1]
[1]*SOFT Group, School of Science and Technology, Nottingham Trent University, Nottingham, UK*

Multiple-droplet evaporation is ubiquitous in natural phenomena such as raindrops and is of importance in industrial applications such as inkjet printing and spray coating. It is therefore imperative to understand how droplets evaporate in the presence of neighbouring droplets. A particular interest is in the occurrence of the so-called "shielding effect", namely each droplet experiences an increased vapour concentration due to the presence of neighbouring droplets, in turn reducing the overall evaporation rate compared to isolated ones. This shielding effect has been subject of a lot of interest recently theoretically (Wray et al, 2020; Masoud et al, 2021).

In this work, we have developed an automated droplet printing system to remotely deposit millimetre-sized water droplets in various 2D array geometries to allow an experimental investigation of the evaporation dynamics of each droplet within the array, enabling a validation of the recent theory of Masoud (Masoud et al, 2021).

The shielding effect was visually and quantitatively confirmed in 1D arrays whereby outer droplets evaporated faster than those confined in the centre of an array. Relative evaporation rates were also tested experimentally in a triangular array. A good agreement was found between theory and experiment, demonstrating the ability of the model to predict relative evaporation rates in 2D arrays.

Masoud, H., Howell, P.D. and Stone, H.A., 2021. Evaporation of multiple droplets. Journal of Fluid Mechanics, 927.
Wray, A.W., Duffy, B.R. and Wilson, S.K., 2020. Competitive evaporation of multiple sessile droplets. Journal of Fluid Mechanics, 884

Direct-writing and embedding of functional materials into porcelain ceramic tiles to enable Smart Cities

Regana Vasanthanayagam[1,2], and Ronan Daly[2]
[1]Cambridge Graphene Centre, University of Cambridge, UK, [2]Institute for Manufacturing, Department of Engineering, University of Cambridge, UK

Control of 2D patterns of nanomaterials by inkjet printing has already shown the potential to create devices and functional surfaces for emerging product technologies such as printed sensors and energy storage. Here we describe the embedding of functional materials into the near-surface regions and within the bulk of the ceramic tiles whilst ensuring stability and long product lifetimes. Porcelain ceramic tiles are commonly used as building materials for architectural applications, so the delivered functions can be used to support initiatives in smart cities. Porcelain ceramics have challenging surfaces for controlled material integration and have to-date been neglected from detailed functional printing research. We show here the importance of understanding the interdependencies between the advanced functionality of emerging materials and their associated manufacturing technologies, and in understanding how to ensure the functionality of the materials are not compromised during the harsh pressing and firing techniques endured throughout the ceramic tile fabrication process.

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