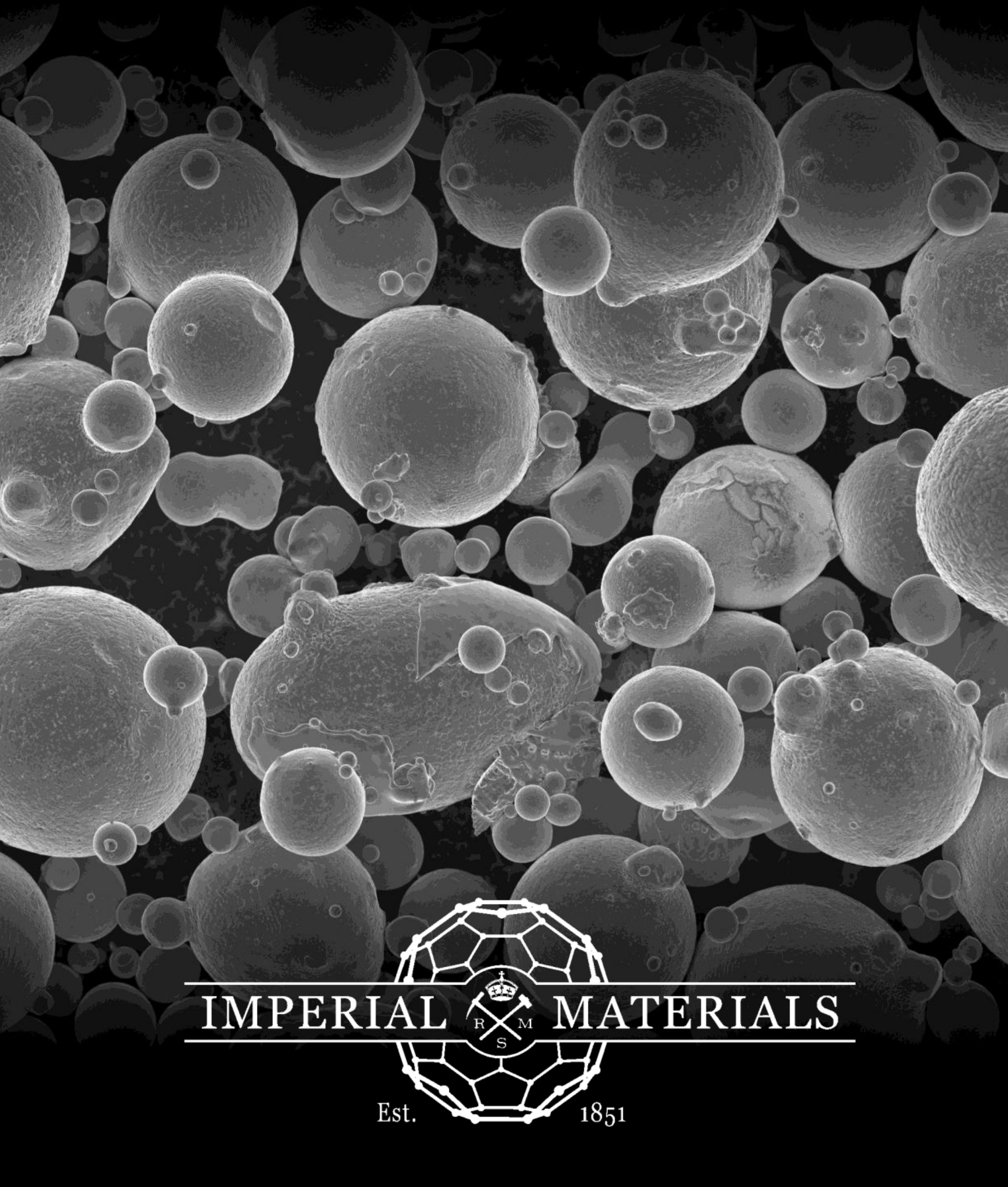
MatSocMagazine

Winter 2019/20



IMPERIAL MATERIALS

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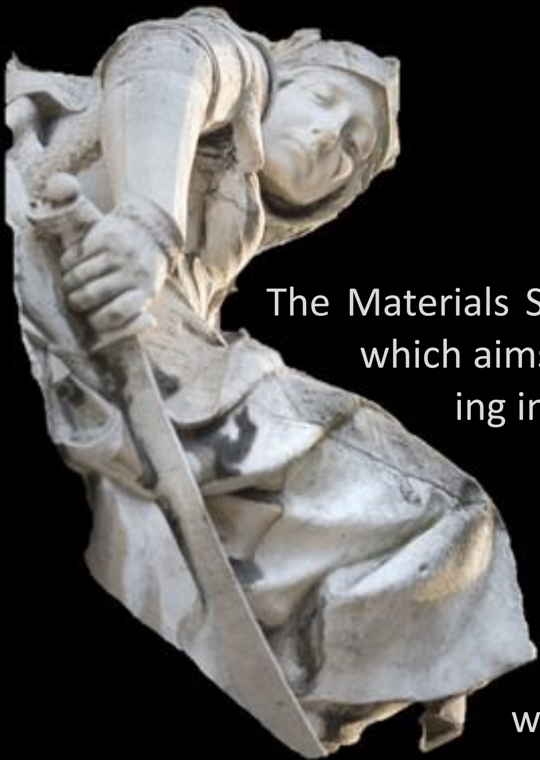
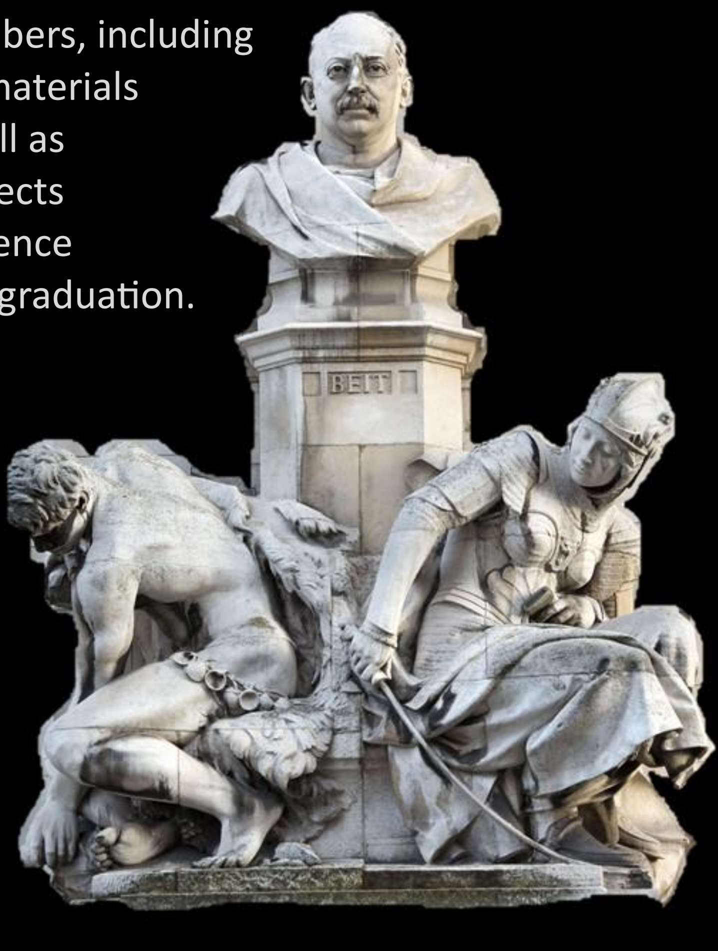


The Materials Society (MatSoc) is a student run organisation which aims to enhance the experience of students studying in this department at Imperial College London, and to promote Materials Science and Engineering both at university and in industry. We achieve this goal through collaborative events, social functions, extra-curricular lecture series, and industrial visits to engage with materials science beyond an academic environment.

Our society currently has 762 members, including undergraduate and postgraduate materials science students at Imperial, as well as other students studying other subjects who are interested in materials science and working in related areas upon graduation.



Contents

Welcome to the MatSoc Magazine:

Editors Foreword and Introduction

Disha Bandyopadhyay (Magazine Officer) and Schan Christopher Perera (President) introduce this edition of the MatSoc Magazine.

Welcome to the Winter 2019 edition of the MatSoc magazine!

After a term's worth of gruelling work, I hope this collection of articles provides you with moments of respite and you can enjoy glimpses of all that has happened in our first term. We have attempted to give an idea of what more you can get involved with in the coming terms and encourage you all to start a conversation with the fabulous writers featured here.

In my first term acting as magazine officer, I was ably supported by everyone's excellent quality of submissions and contributions. We have accounts of MatSoc's lunchtime lectures, UROPs, as well as an article from Shell addressing climate change. I've tried to incorporate the voices of everyone across the department, from current students, alumni and PhDs (and even a visiting student!); so this edition is really a reflection of our extended materials community.

Amidst environmental chaos we're facing now, the number of submissions addressing climate change reflect the views of our community and makes me proud to present a collection of such thoughtful articles. I hope this edition does justice to the high standards set by Amy in the past.

I thank everyone who got involved in creating this edition of the magazine. Without further ado, presenting your thoughts, written by you, for you!

Alloy a pleasure,

Disha Bandyopadhyay

MatSoc Magazine Officer 2019/20

Hi everyone,

Well done for making it to the end of the term! I expect the last few months have had their ups and downs, whether you are settling in to Imperial life for the first time or getting back into your Uni routine, but hopefully a quick perusal of the new MatSoc magazine will help you reflect on lots of happy memories with your Materials family ☺.

I've had the pleasure of seeing the MatSoc magazine evolve; from the release of the first digital edition when I was a fresher to the creation of a new committee role in my second year and the emergence of slick printed editions in the years to follow. Although it makes me feel a bit old looking back, I'm immensely proud to have been a small part of its history and to see it become a large part of MatSoc's contribution to student life. Big credit to Disha for carrying on the torch and doing a great job of independently managing everything to do with this prestigious publication (New Scientist watch out!).

I hope you feel inspired to contribute to the next edition of the Magazine, it is immensely satisfying to see your work in such a professional looking format and who knows, it might open up some journalistic doors for you down the road.

Have a wonderful Christmas and we'll see you in January!

Materials love,

Schan D-Perera

MatSoc President 2019/2020

MatSoc Career’s Fair:

The materials world beyond university

Arinjay Jadeja (Vice President) gives an overview of the MatSoc Career’s Fair

MatSoc held the third Careers fair this October, with sponsors and organisations close to our department coming to talk more about the different industries materials lead to. The event was a showcase to the huge range of applications our degree can be applied to.

With recent news of the 2 Hour mile being smashed by Eliud Kipchoge, it was amazing to discover that Zotefoams materials had been crucial to the unbelievable feat achieved. Talking to Angela and Wassim, I had the pleasure to learn more about how Zotefoams, a leader in cellular material technology, had their product used to make the shoes Eliud ran in for the race.

If that hadn’t been enough endorsement for the organisation’s leap in materials technology, a close competitor went as far to call its use in the shoe unfair, describing it as “having an extra limb”.

Another organisation that attended the fair was Element 6, a global leader in design, development and production of synthetic diamond and tungsten carbide super materials. Personally, learning from Richard about how a single carat (200 milligrams) of synthetic diamond cost £6000 was staggering, with the pressure required to create them being equal to the Eiffel tower, tip-down, on a coke can. It was remarkable to learn how broad the range of industries the diamonds can be used in, from oil drills to tweeters for surround sound speakers.

Career’s fair stands

Career's Fair in full swing in G01

It was great to meet Martyn Chapman and Benjamin Moorhouse from BP too, understanding the vast career pathways available at BP. The organisation does everything, from finding and producing oil and gas on land, moving energy around the globe to manufacturing raw materials used in mobile phones to food packaging. Mr. Moorhouse had also been the RSM Rugby captain and it was great to meet alumni who had great stories about Imperial and of bottle match.

Learning more about Jill Hodges, Fire Tech founder, was a great inspiration. He described how, when facing a widening skills gap in an increasingly technology-based world, provided a place where kids could get their hands dirty and experiment with a wide range of technological concepts. Imperial College was the first place she ran these courses, and now Fire Tech has expanded, offering a year-round programme across the UK, Europe, Caribbean, Australia and the Middle East.

We also had a chance to talk to Hansa, one of the co-founders of ComfortBreak, an Imperial based start-up. The issues the organisation highlighted was how women in impoverished areas have limited access to healthcare, forced to deal with incontinence using only leaves and rags, leading to daily embarrassment, discomfort, and high risk of infection. ComfortBreak works in tackling these issues by helping those affected to build an innovative bio-recyclable hygiene product, a crucial application of materials theory with huge and rewarding impacts, to empower these women and disrupt the status quo decades before it might otherwise happen.

Introducing a new aspect to the career's fair, this year we included an opportunity for students to explore further study at Imperial. Two of the materials department's PhD student Gloria and Catherine had kindly given up their time to answer any burning questions about paths to doctorates and research. We really appreciated their work in giving a rounded picture to students about our degree.

It was a such a pleasure to have organised the fair alongside the committee. I want to say a big thank you to our sponsors, all the organisations that attended, and to our MatSoc members for coming. The event wouldn't have been the same without your support, and we look forward to working with you all over the coming year.

Hosting UROP:

Experience of a visiting student

Alexandra Stuer, a 3rd year Natural Sciences student at UCL describes her experience of participating in a UROP in Imperial over the summer.

Over the summer, I spent 8 weeks in the materials department while doing my UROP on water, capacitors and tight binding and I can honestly say it was a life changing experience. My project was computational and was focused on applying Van der Waals forces on the water molecules in order to keep them together when heated, as part of a larger research project conducted by Dr. Horsfield's' research group.

The project was very interesting, and insightful. It gave me hands on experience on programming and how to use that to learn more about the properties of molecules. The requirements and background reading were very specific, which allowed me to develop my research skills as-well as my knowledge on the topics previously addressed in my lectures at UCL. Although that was the purpose of my stay at the University, I gained so much more in my time there.

Having a purely scientific background, I was surprised by the technologically advanced department, the equipment and facilities provided to the undergrads, to make it as easy and interesting as possible for them to excel in their studies. A highlight would be the reception of the laser cutter and the use of it, something out of my field but very interesting to observe and work with. What surprised me the most during my stay, was the sense of belonging and community. From my first meeting with Dr. Horsfield to the last day with my fellow researchers, there was no point when I felt alone, vulnerable or incapable of doing what I was asked to as everyone was by my side. Coming from a big university with over 40,000 students, this is a quality I always seek for as it is what keeps you sane.

Alexandra, now a part of our materials community.

I got to work in a great scientific environment, where students, researchers and professors work, converse and enjoy themselves all in a positive and uplifting environment. While at the university I made some of my current closest friends, with whom I got to explore London, make new memories with and make work fun. Overall, I believe this UROP developed me personally but also as an ambitious researcher.

MatSoc Lunchtime Lecture:

Stella Pedrazzini's Corrosion Lecture

Louise Rosset, a 2nd year student recounts Dr Pedrazzini's lunchtime lecture

On Tuesday, October 15th, Stella Pedrazzini inaugurated a whole new year of MatSoc Lunch Lectures. The lecture focused on her research on corrosion, and mostly on the work of her tutees over the summer. Her team, composed of Artem Khobnya, Ming Pek, Jessica Tjandra, Elisa Anzini and Adam Cliff, studied "Corrosion and Radiation Damage of Engineering Materials". Two main projects emerged: irradiation of superconductors and aero-engines alloy development.

The first project was centred around fusion and work on superconducting tape. As superconductors get irradiated in thermonuclear environments, they are damaged by radiation and slowly lose their properties. Most notably, magnetic measurements show a decrease by tenfold in carried current. Artem was in charge of this project and researched into a possible recovery process for the superconductors. He looked into thermo-recovery with copper and was given the opportunity to test his samples at the University of Huddersfield. He found partial recovery using copper, which is a promising start with great potential.

The second project, worked on by Adam, Elisa, Jessica and Ming, revolved around nickel superalloys, which are high temperature structural alloys, and developing their resistance to corrosion. This team separated into two pairs: Adam and Elisa studied nickel superalloys in turbine discs, while Jessica and Ming investigated turbine blades. Both pairs worked in partnership with Rolls Royce.

Adam investigated the creation of dual superlattices in the nickel alloys. This considerable change in morphology greatly affects properties and could possibly enhance properties of the alloys used in the discs. Adam had to gauge the quantities of dopant to ad in order to perfect the properties. He then heat treated his samples and used a Differential Scanning Calorimeter to study the changes in the γ, γ' and γ". His results were particularly interesting with the γ" phase, where the dissolving of dopants was promising.

Elisa studied alloying for corrosion resistance, on 3 alloys given to her by Rolls Royce. She tested the effect of different exposure conditions, particularly in sea salt and sulfur, on corrosion resistance, as tu-

Stella Pedrazzini.

Photo by Jason Alden, Imperial College London rbine discs are often exposed to such hostile environments.

She established that alloying with silicon had a beneficial effect on oxidation resistance, and that the silicon alloy performed much better than the manganese one in terms of corrosion resistance.

Jessica's project was centered around the Trent 700, which is a turbofan aircraft engine developed by Rolls Royce. It is majorly used in powering Airbus A330 planes. Jessica focused on blade failure. Two of the main reasons for blade failure are exposure to salt and exposure to stress, which is why she looked at salt exposure. Jessica used XRD and SEM characterization to establish the presence of various oxides in the nickel samples. The effects of this exposure to salt and exposure to stress, which is why she looked at salt exposure. Jessica used XRD and SEM characterization to establish the presence of various oxides in the nickel samples. The effects of this exposure were mixed: some alloys gained weight while others lost weight. In the continuity of this project, these results now have to be compared to the behaviour of the alloys in real-life application.

Ming developed coatings to protect pure nickel from surface contamination. His work consisted in coating the nickel with manganese for salt resistance, then heat treating the alloys. This enabled him to test whether the coating improved or worsened the actual performance of the nickel alloy. One of the difficulties he faced was making a relatively even and flat coating layer on the alloy to test the surface.

This insight into the summer projects was particularly striking in the context of UG lab sessions. It showed how the machines we learn about in lectures and the techniques we use in labs are regularly used in real research. Overall, this was a very interesting and fun lecture.

Here's to a whole new academic year of lunch lectures (and free pizza!)

Stella and her summer research group.

Sense and sensor-ability:

Using thin films for devices

Sion De Souza, a 4th year student shares his findings from his masters project about optoelectronic sensors.

As engineering advances, the main aims are to allow devices to become more efficient, durable, lighter and more compact, thus, areas such as thin film production have become increasingly popular. Thin films are described as films smaller than 100 µm in thickness. These films have use in a myriad of applications; coatings, electronics, drug delivery and solar cells.

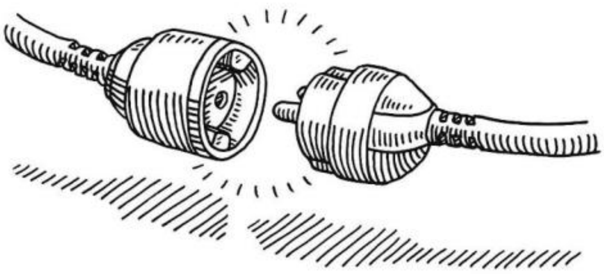


Illustration by Frank Ramspott via [https://photos.com/featured/unplugged-power-cable-drawing-frankramspott.html]

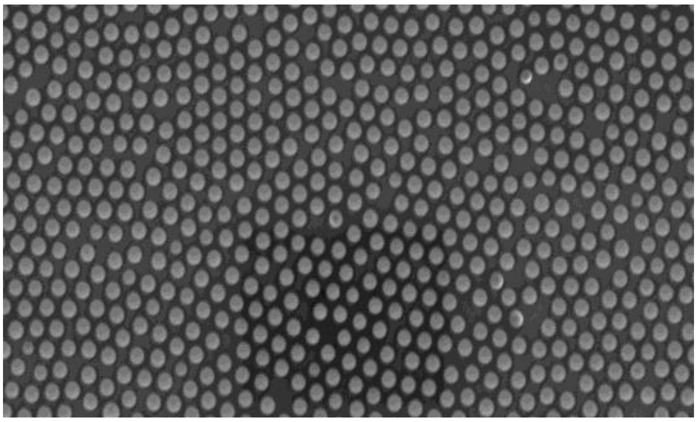
To construct interfacial sensors, only those that are thin and flexible are useful. This restriction reduces the number of materials that can be chosen to make these sensors. Specifically, these materials must be at least 5mm thick and be able to withstand sufficient deflection. This classification removes hydraulic and pneumatic branches in sensor technology, since these types of sensors are usually quite bulky.

Piezoelectric sensors are a viable option, however, due to leakage currents associated with this method, only dynamic measurements are accurate. Thus, only piezo-resistive and piezo-capacitive methods can be analysed.

Piezo-resistive pressure sensors are sensors that produce a change in resistance in response to an external stimulus (generally pressure) resulting in a strain to material.

In most touch technology, piezo capacitive sensors are used. These consist of two electrodes/plates with a dielectric between them, for which when these plates are pushed closer together, due to the decrease in distance, a change in capacitance is obtained. This change in capacitance is recorded as a change in voltage by an external system. However, these technologies mostly allow for positional accuracy, and don't detect the force used.

PEDOT:PSS (poly(3,4-ethylenedioxythiophene) and polystyrene sulfonate acid) is a low cost, conductive polymer with decent mechanical properties.3 The grains of the polymer consist of a conductive PEDOT concentrated core surrounded by an insulating, hydrophilic PSS shell. PEDOT while having high conductivity, has a low solubility, thus PSS is used as a counter ion to stabilize doped PEDOT and provide a matrix by which PEDOT can be aqueously dispersed. The method of thin film production has been well studied and multiple variations exist, within which, the properties of the polymer can be tailored to specific purposes. For example, the conductivity of the film can be increased in a multitude of methods, such as; Cruz-Cruz et al.6 performed experiments which used dimethyl sulfoxide as an additive to tai-



SEM image of the inverse of the mould of the thin film (Sion).

lor the thickness of the insulating PSS shell. The additive allowed a thinning of the shell, until an optimal concentration is reached, resulting in a minimum thickness being obtainable for the grains. A. Yoshida et al.7 increased the conductivity the polymer by adding gold nanospheres.

Similarly, Ziyang Yiu et al.9 produced organic thin film transistors using a composite of polyethylene glycol, and polyacrylic acid. This composite was used as a dielectric for tactile use, and registered pressures up to 453 KPa. While exhibiting excessively high sensitivities with regard to pressure (as compared to the needs for this experiment), the preparation process for these capacitive thin films is also a lot more complicated, requiring strict concentration control of the polymers for the dielectric and a lengthy procedure for the completion of the pressure sensor. The relative ease of the PEDOT:PSS film preparation, increased its suitably as a material choice.

The relative humidity has been found to affect the mechanical properties of PEDOT: PSS films due to the hydrophilic nature of PSS, increasing water uptake, resulting in lengthening and thus weakening of the hydrogen bonds between the molecules. This results in a change in the crack mechanism from brittle trans granular cracking to ductile intergranular cracking. Temperature is highly related to the humidity, as increasing temperatures causes water evaporation from the film, however, the grains of the film also begin to overlap, resulting in a decrease of effective surface area and thus sensitivity to changes in resistance.

These stimuli, including strain, can be influenced by methods of processing, such as the incorporation of additives that affect the hydrophobicity of the films, and external methods to reduce the effect of temperature on the polymer. It is important to note that there are many polymers with properties that allow them to be used for more intensive applications.

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3. *Lang U, Müller E, Naujoks N, Dual J. Microscopical Investigations of PEDOT:PSS Thin Films. 2008. doi:10.1002/adfm.200801258*

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9. *Liu Z, Yin Z, Wang J, Zheng Q. Polyelectrolyte Dielectrics for Flexible Low-Voltage Organic Thin-Film Transistors in Highly Sensitive Pressure Sensing. Adv Funct Mater. 2019;29(1):1806092. doi:10.1002/adfm.201806092*

More Energy, Fewer Emissions

A perspective of a Shell Materials Engineer

Dr Boris Thomas, Senior Materials and Corrosion Engineer in Shell UK Ltd. and Imperial College Campus Ambassador reflects on how Shell is addressing the environmental challenge.

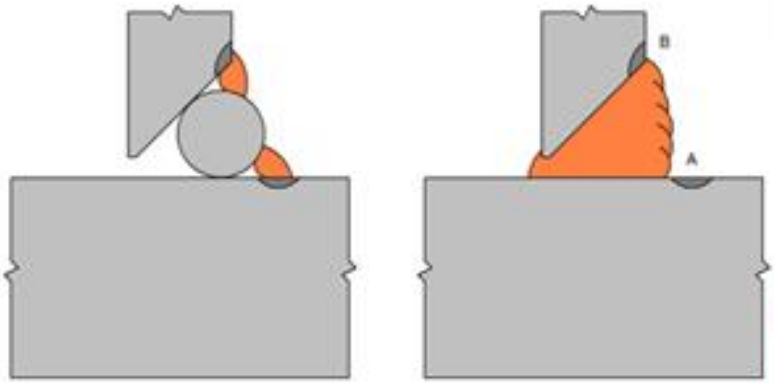
Not a small-scale pile

With the signature of the Paris Climate agreement in 2016, governments, companies as well as the general public around the world have since been able to set out their own vision on how to limit the increase in global temperature to 1.5ºC. In 2017, Shell set the ambition to reduce the Net Carbon Footprint of the energy products it sells, expressed as a measure of carbon intensity, taking into account their full life-cycle emissions, including its own operations. Shell aims to reduce the Net Carbon Footprint of its energy products by around half by 2050, and by around 20% by 2035, in step with society's drive to meet the goals of the Paris Agreement.

Shell's Southern North Sea Operation has been actively commissioning projects that will directly contribute to company emission targets. Some of its existing gas platforms, constructed as far back as the 1970s and split between the British and Dutch sectors, have obtained investment to increase the electrification of its gas- or diesel-powered equipment in the harsh North Sea environment. This exercise includes the installation of new power umbilicals from shore as well as replacement of multimillion-pound gas turbines or compressors. Newly designed offshore facilities with minimal gas separation will often have integrated renewable power generation or be directly powered from shore some 25+km away.

More significantly, joining the Blauwwind consortium and funding of the Borssele Windfarm in the Dutch sector represents a more substantial change to the company energy portfolio in Europe. The project is building 77 9.5MW turbines which will generate power to 825,000 households when it comes online in 2021. As a Materials Engineer for the project, our main contribution is to assure the robustness of the design and to support the fabrication of the structures for the wind turbines.

There is also an element of incorporating the lessons learned by the Oil and Gas industry over some 50 years of operation in the North Sea to a relatively young wind energy industry with regards to marine



Typical joining plan and onsite welding preparation of a stab in guide

corrosion mitigation or fatigue design for instance.

Although the collapse of a wind turbine may not be as dramatic as the release and ignition of a methane gas cloud, it could have severe impact on the operational costs and overall economics. Indeed, performing any sort of offshore work is expensive, let alone the loss revenues associated with any equipment downtime.

For that reason, the Offshore Oil and Gas industry aims at getting it right first time. Passing on this philosophy to the offshore renewable sector will be important to assure its competitiveness.

As young engineers and researchers, when major funding takes place in machine learning or novel manufacturing techniques like additive manufacturing, it is important to recognise that engineering companies from all sectors still use traditional materials and fabrication methods. They currently form the vast majority of the engineering materials and joining/welding them together remain a specialist trade and skill very much sought after across industries. In addition, the Materials Engineer's role in influencing the move towards the maximum 1.5ºC limit should consider the overall environmental impact and recyclability of materials that is recommended when engineering a component. Plastics, composites and "smart" materials are rarely recyclable, for instance, which potentially puts additional burden on disposal decades down the line.

The author would like to acknowledge Kevin Millican, Sn Materials and Corrosion Eng in Shell UK, for sharing his experience and for his contributions for the content of this article.

Leading investors back Shell's climate targets. (2019). Retrieved 19 September 2019, from https://www.shell.com/media/news-and-media-releases/2018/leading-investors-back-shells-climate-targets.html

Packaging Innovations Fair:

Shopping for ideas to cut down plastic

Enora Saule and Inga van den Bossche take a trip to the Packaging Innovations Fair in London Olympia and share their experience.

A random Google search on materials-related events led us to attend Packaging Innovations festival 2 hours after in London Olympia. Entering the vast hall, 180 stands awaited with different packaging solutions, debates, panel talks and a free champagne hour:) Exhibitors ranged from patented designs to luxurious eco-friendly packaging, while also introducing innovative solutions such as compostable packaging film or sustainable coatings for food-barrier packaging. In a professional atmosphere where companies searched for ideal packaging solutions, wandering around as students was an intriguing experience. Going from stand to stand, however, few of the salespeople were really able to explain the scientific principles upon which designs were based, which ignites one's curiosity to further look into these processes by ourself. Nonetheless, there were so many interesting stands! But you can only list so many; below are some of the more innovative packaging solutions we have come across:

- Ecovaganza: a German-based company producing luxury paper for packaging made from a blend of grass pulp and normal paper. Also introduces more biodegradable plastic-free coatings, glitter and textures to enhance the designs.
- Futamura: a Japanese company which developed Nature-Flex, a compostable packing film made from cellulose.
- The Sherwood Group: it has patented a biodegradable coating called Puracoat to act as a plastic-free food barrier. Its main application is for on-the-go food boxes which become entirely compostable. Even the see-through lid is made from transparent cellulose so no plastic/carton separation is necessary.
- Seufert Gesellschaft : a German company involved making foldable plastic boxes and sleeves from R-PET pellets, they are also using R-PET Blue Ocean, which is recycled, blue-tinted yet transparent plastic suitable for food products.
- Bag Maverick: this company is replacing the average plastic shopping bag with cotton, canvas, jute or R-PET alternatives. It also has a large design department.

As well as stands everywhere, the main stage also hosted various speakers. First, a panel talk on circular economy: a placid discussion on the difficulty in closing the circle and obtaining the material once again to start a new cycle. As one of the guests stated, 74% of PET bottles enter the recycling system, but only 8% come out as bottles again (according to the Ellen MacArthur Foundation). The range of guests was quite varied: from Just Eat takeaways to a Manchester University Professor in Polymer Science, as well as a representative from WRAP and the foundress of the Beauty Kitchen company.

Another interesting speech was delivered by a

Pictures of the stands. From left to right: The Futamura Group, The Sherwood Group and The Ecovaganza Group.

Labour MP on the relationship between industries, government and climate change. Dedicating its topic to the innovative steps packaging industries are taking, it noted both their advantages and disadvantages. One which particularly struck us was the lack of facilities and infrastructures to properly recycle existing packaging.

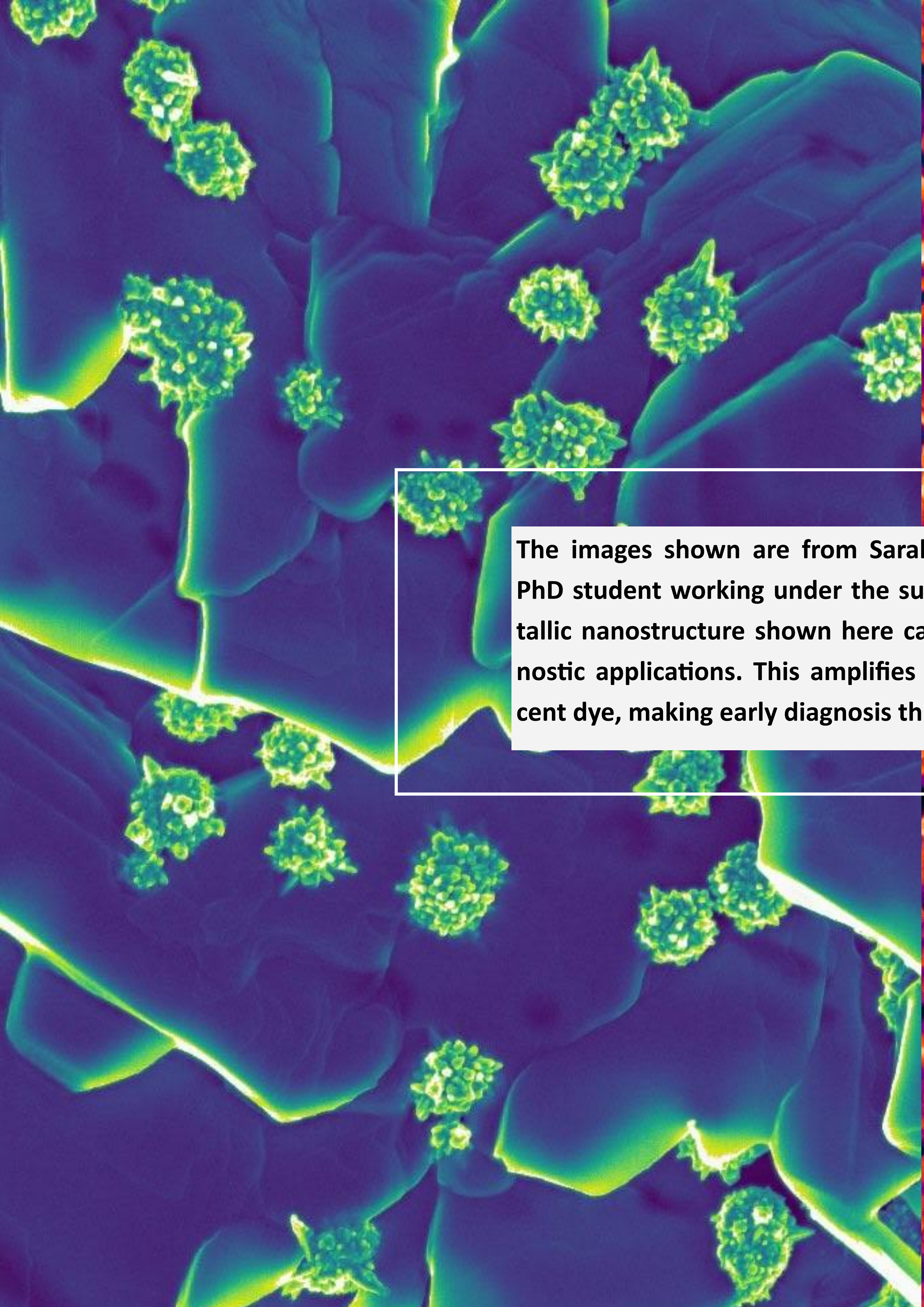
Despite consumers willing to recycle more, a growing awareness of climate change, and multiple campaigns surrounding waste reduction, the recycling system remains a mystery to the public.

Separating packaging correctly is crucial. Yet currently, it is almost impossible to distinguish between an unrecyclable film and a cellulose-based compostable one. For this, new legislation must be instore to regulate packaging display. One suggestion is to equally distribute space between indications regarding allergens and nutritive information, and recycling instructions on products. To stand out, the design must be clear and concise, and understandable by all.

The key takeaway however, and what it essentially all comes down to, is limiting climate change. Recycling is still a costly and energy demanding process; it is only an intermediate step towards a goal of a zero-waste society. This means stopping to produce waste at the source, instead of figuring out ways to re-use it. Single-use objects are the ones most highlighted, as the amount of waste they represent is considerable. A description of the German ”pfand” system to reuse bottles followed.

Tip: Bring your own cutlery! Keep a knife/spoon/ fork/chopsticks in your bag; make recycling fashionable and have the fanciest picnic yet! Drawing conclusions as material engineers, recycling is nowhere near perfect yet. So what does this mean? A whole lot of opportunities to crystallise and create, recycle and reduce, polymerise and produce the most compostable and environmentally sustainable materials out there yet!

Note: this event is held every year; make sure to post it into your calendars! Check IOM3 for further information on dates and secure your free glass of inspiring champagne!



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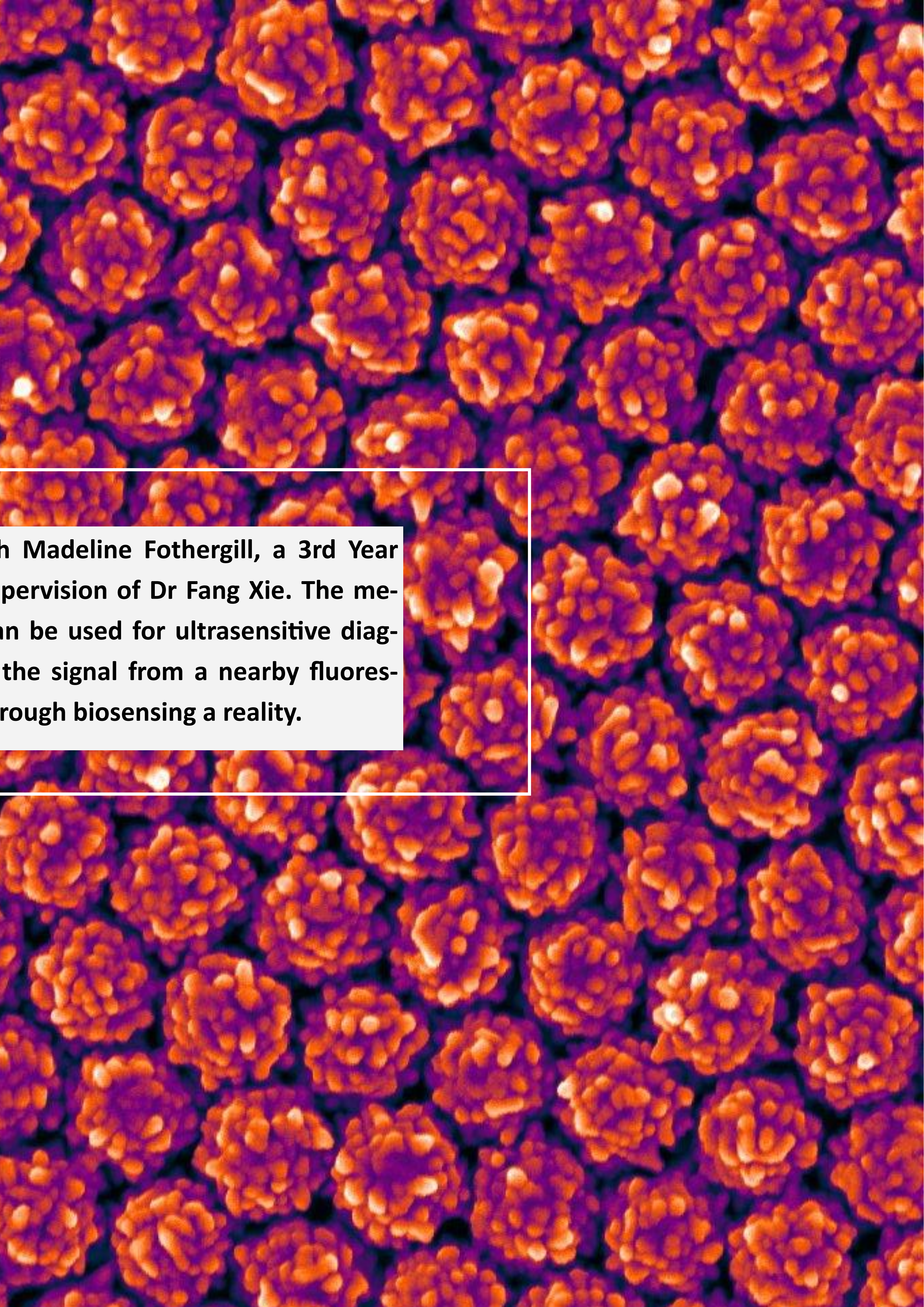

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Research Experience:

Rolls Royce at Imperial

Jessica Tjandra, a 4th year student shares details of her summer UROP experience working with Dr Stella Pedrazzini.

Spending the summer in College was such a different experience. For most of us, summer is normally spent either at home, on vacation or being a summer intern elsewhere. As this was my third summer since coming to Uni, I thought I would do something interesting instead of how I usually spend my summers -lazily watching Netflix in bed for 13 weeks.

On the first day of my UROP, I went to Rolls-Royce Materials Engineering division in Derby with Dr Stella Pedrazzini (my lovely supervisor) and other UROP students to discuss our projects and their relevance to Rolls-Royce. My project offered a systematic approach in determining the low-temperature corrosion mechanism in a nickel superalloy that is used in the turbine blades of Rolls-Royce Trent 700 engines. In simple terms, blades corrode, but they have been corroding faster than they should (and at lower temperatures than expected), and no one knows exactly why and how. Common hypotheses include air particulates (think sand particles, salt crystals and 'dirt' in the atmosphere hitting the blades at high velocities), humidity (think flying over oceans vs deserts), SO2/ SO3 gas (think flying over volcanic regions in Hawaii/ Japan), or a combination of these.

The first few weeks of my summer was spent on laboratory safety inductions and trainings, reading papers and PhD theses related to the topic and constructing my experiment matrix. My laboratory work involved spraying salt solutions on the alloy and heat treating them at various times and temperatures, after which I individually analysed each sample with x-ray diffraction (XRD) and scanning electron microscopy (SEM) to characterise the oxide layers.

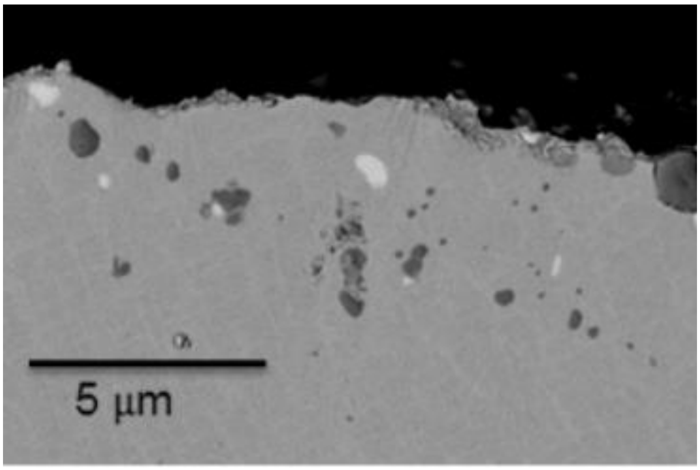
End-of-UROP review at Rolls Royce, Derby. From left to right: Dr Stella Pedrazzini (supervisor), me, Ming En Pek (2nd year UROP student), Adam Cliff (1st year UROP student) and our respective Lego characters.

I even got to use a very fancy SEM that has better resolution than the ordinary tungsten filament SEM. Sadly, even at 22,000x magnification, the oxide layers are barely visible.

At the end of my twelve-week UROP, we went back to Rolls-Royce to present our findings. It was really rewarding (and a little scary) to present my work, a lowly third-year student, to a panel consisting of experts in turbine blades and corrosion. The comments I received were positive and encouraging, which was awesome!

The research experience completely surpassed my expectations. Firstly, it allowed me to link concepts taught in the lectures across different modules. For example, when matching XRD peaks to possible oxides, I utilised Ellingham diagrams to determine which oxides are thermodynamically stable (e.g. oxide of cobalt: CoO or Co3O4?). Some of the peaks also overlap, hence there is a need to deconvolute the peaks, such as using Reitveld refinement. When learning about these in lectures, we seldom think how each concept relates to another, so this gives me a completely new perspective. Things I learnt make sense now.

Secondly, my supervisor is super approachable and has an open-door policy -90% of the time she is in her office so I can just knock and talk to her whenever I need guidance and/or help (massive shoutout to Stella!). As part of the Engineering Alloys group, there were also many social events which allowed me to get to know PhD students and post-doc staff better.



SEM image of a cross section of one of my samples, taken with a field emission ZEISS SEM at 22,000x magnification.

Aftermath of one of the many, many saw blades broken in the lab.

Lastly, these past twelve weeks have given me a taste of what working in a lab is like. I can honestly say that it is nothing like the lab sessions during my first two years, where all the instructions and materials are already provided and you just come in and follow instructions. Things like waiting for weeks for a shipment of materials you need (super frustrating) and going to the ChemStores to get consumables such as gloves and sample bags (it was like Tesco's for scientists and engineers!). Within the first two weeks there was already a competition on how many precision saw blades each of us broke - who knew breaking saw blades is a rite of passage.

'Forever Young':

The Promise of Regenerative Medicine

Aishwarya Varanasi, a 2nd year student gives an introduction to thermoresponsive block copolymers based on her UROP with Dr. Theoni K. Georgiou.

It can be unanimously agreed upon that no one is immune to the ravages of time. But, what if we can turn back the clock and replace diseased and damaged body parts with brand new ones? Imagine a future where no one waits on an organ transplant list, where the incurable can be cured and victims devastating diseases like ALS can receive effective treatment and most importantly, hope.

Science has long known that the human body responds to injury and disease by attempting to heal itself. Regenerative medicine accelerates this natural healing process by harnessing advances in biology and engineering to restore health and function to damaged tissues and organs. An emerging field in regenerative medicine is the use of artificial polymeric scaffolds to support damaged organs or organ systems. Thermoresponsive (Temperature-responsive) polymers are an excellent choice of material for these.

A class of polymeric materials called 'thermoresponsive polymers' undergo a drastic change in their physical structure in response to an increase or decrease in temperature. In solution, this means a change in solubility.

In tissue engineering applications, stem cells are mixed with a polymer solution at room temperature. When this solution is injected into the patient, the gel is formed in situ due to temperature increase. Thus, for this application it is crucial that the gel is

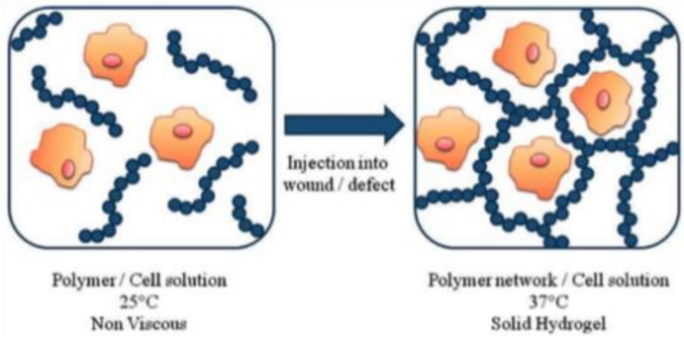


Figure 1: In situ formation of a scaffold in tissue engineering.

Source: Ward, MA.; Georgiou, T.K. Thermoresponsive polymers for biomedical applications. Polymers 2011, 3, 1215-1242

formed just below the body temperature, i.e., 37°C.

A gel in-situ is a soluble liquid which contains the stem cells and various biomaterials. Once injected into the body, the injected gel will solidify due to an increase in temperature and form a scaffold to keep the structure of the organ in place as shown in Figure 1. The stem cells will then differentiate into the required cells.

The solution-gel (sol-gel) transition is thermo-reversible and thus these gels are also often called thermally-reversible gels as well as thermoresponsive gels (TRGs). This transition can be observed via the formation of a gel (the solution no longer flows upon tube inversion).

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longer flows upon tube inversion).

Only few polymers can exhibit thermoresponsive behaviour. This is due to two reasons. Firstly, they can self-assemble into well-ordered structures like micelles. The most conventional type of micelles in aqueous solution are spherical shaped that consist of a hydrophobic core and a hydrophilic corona as shown in Figure 2. The shape and size of the micelle depend on the overall length of the polymer and the length ratio of the blocks.

Secondly, block copolymer structures can facilitate the microphase separation within gels (either physical or covalently linked gels). This microphase separation enables the formation (depending on the block ratio) of channels, which in tissue engineering are important for the transfer of water and nutrients to the cells.

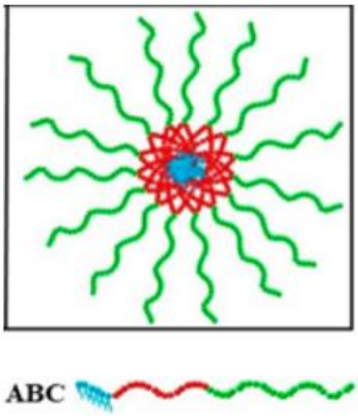

Figure 2: Self-assembly of micelles, a property of block copolymers. (Dr. Anna P. Constantinou)

In TRGs applications it is highly important to be able to control gelation point, i.e. the temperature that the polymer solution becomes a gel, Tgel. Ideally this transition should be clear and sharp and instead of occurring over a range of temperatures.

The gelation point is influenced by many factors like molar mass, composition and architecture. For an instance, an increase in the molar mass meant that the polymer chain got longer. The longer the polymer chain, the easier the interconnection of the micelles via bridging. Thus, this leads to gelation.

Composition also has a significant impact on the thermoresponsive ability of polymers. So, increasing hydrophobic content or decreasing the hydrophilic component decreases the Tgel.

The Georgiou Polymer Group at Imperial studies thermoresponsive polymers in order to enhance their sol-gel transition. In this group, Dr. Theoni K. Georgiou is an expert in Group Transfer Polymerisation (GTP), a technique that produces polymers with controlled molar mass distribution (MMD). Last summer, I had the opportunity to do an UROP in the Georgiou Polymer Group and work with thermoresponsive triblock copolymers. I studied 4 novel thermoresponsive polymers, based on the non-ionic hydrophilic methoxy poly(ethylene glycol) methacrylate (PEGMA), non-ionic hydrophobic n-butyl methacrylate (BuMA) and methoxy di-(ethylene glycol) methacrylate (DEGMA) using dynamic light scattering and visual testing. In my UROP, I characterised thermoresponsive polymers so that I could eventually optimize their sol-gel transition window by varying structural characteristics like the molar mass and composition.

Thermoresponsive block copolymers are an exciting class of biopolymers with a number of applications in regenerative medicine applications. By using thermoresponsive materials to make cell scaffolds and curing the incurable, we are not only creating a better quality of life but also advancing regenerative medicine.

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Absorbing Aluminium, Gaseous Glasses and Carbonated Cheetos:

What do all the following materials have in common?

Inga van den Bossche, a 2nd year student explores the wonders of gas.

That's right: gas! It is gas that takes up the most volume in our atmosphere yet is constantly hiding. The most abundant class of materials, it is simultaneously the most invisible class. Nitrogen may be the most abundant element on earth, but we literally look through it and as such, sometimes forget effects and advantages gasses may have.

And advantages there are. Manipulating gas evolution in industrial processes can lead to amazing new materials. Absorbing aluminium, more commonly referred to as an ultra-light porous metal foam is the secret to super fast formula 1 cars. Melted from its pellet form with titanium dihydride, a sudden release of hydrogen gas foams the entire structure.

Depending on bubble size, the material is strengthened; as such, once cooled a very low-density alloy of high strength is created.

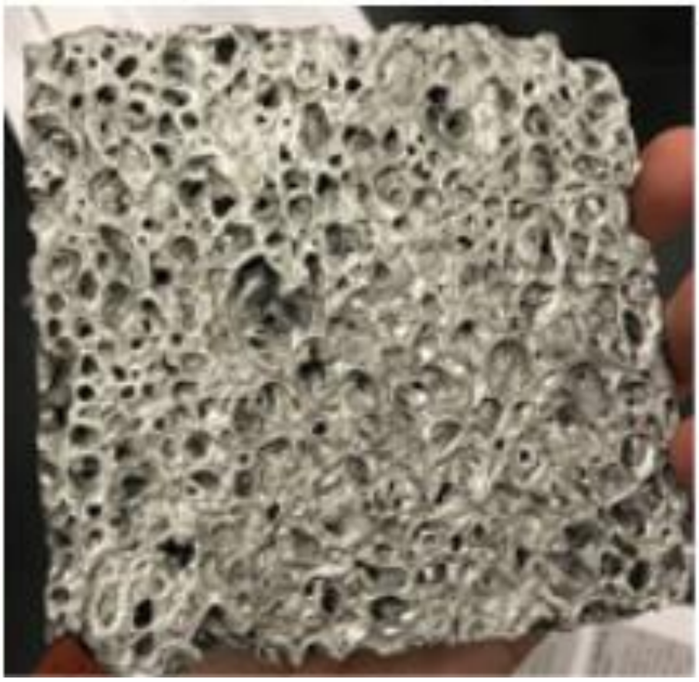
But materials are not necessarily always created in controlled environments. Glass for example is a material naturally produced, as is the case with desert glass. When lighting hits sand at a high enough temperature, silica is molten, and glass can form. Evidently, this random process cannot produce all the glass we need with its desired properties. Used for clothing skyscrapers, containing wine, and covering our smartphone and laptop screens, the key to this material is its controlled processing. Having a 71.5% SiO2 network type glass allows for inertness (for the most part), optical transparency, and strength. Lowering the SiO2 content to 46.1% allows for it to be biodegradable. Hence what if we created a glass of 99.99% air?

Via [https://www.hiclipart.com/free-transparent-background-png-clipart-ygvhg]

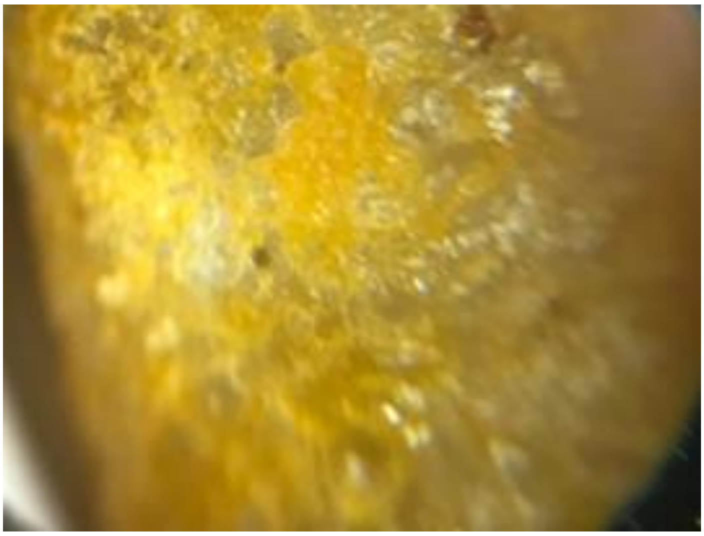
Such is the case with aerogels. An entirely new class of materials altogether, it was Hench's discovery of silica aerogels in 1969 that spurred a generation of modern, high functional glasses. And again, in the process of making aerogels, it all bubbles down to gasses again.

By creative combination of carbon and the sol-gel mechanism, whereby a material is bubbled through an inert gas such as nitrogen, scientists at the University in Hangzhou developed a carbon aerogel. Similar in nanostructure to a porous sponge, it is their high surface area ratios that allow for great electrical conductivity and storage capacities (1).

So, will the next generation of batteries be carbon aerogel derived - as opposed to lithium batteries? Not quite yet. Requiring supercritical drying by heating to a temperature of 600°C, perhaps more energy is required in its production than storage capacities.



Aluminium metal foam sample (Inga)



3x Magnification of max. zoom of iPhone 6 camera of a Cheetos crisp (Inga)

And speaking of storage, it was the storing of 'crunch' that gave chips manufacturers and brands much difficulty. When Cheetos and chips were first produced, the biggest concern for manufacturers was keeping their 'crispness'. Often, the solution to many a problem is simply found on your doorstep. In this case, the secret was again a gaseous one, coming in the form of Nitrogen gas. By inflating crisp packets with pure nitrogen gas as opposed to oxygen, spoilage by staleness was prevented.

So, from gaseous aerogel glasses to prevention of stale crisps, it was by spending an afternoon at the Institute of Materials at UCL that allowed me to see the invisible and appreciate more what continuously surrounds me. So just take a moment to visualise all the molecules of oxygen and nitrogen bouncing around and off of you. And next time someone opens a packet of crisps, try blowing out a candle with the invisible power of nitrogen gas.

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MatSoc Lunchtime Lecture:

Some like it hot: materials for use above 2000°C

Louise Rosset reports on Professor Luc Vandeperre's lunchtime lecture about ceramics at high temperatures as well as the obstacles faced in research.

On Tuesday October 29th, Professor Luc Vandeperre was invited by MatSoc to host the second lecture of the MatSoc Lunchtime Lectures. He presented his work as the co-director of the Centre for Advanced Structural Materials at Imperial in a presentation called "Some like it hot: materials for use above 2000 °C".

First, Prof Vandeperre started with explaining how ceramics can be structural materials and be used, for example, in the aerospace industry. Ceramics are known to be brittle materials, but they are more than just that. They have been widely used in aerospace for their thermal properties, particularly since the European Space Agency and Airbus Defence and Space developed the Herschel mirror in 2001. This mirror was to be used in an astronomical telescope, and its huge dimensions were not suited for a metal or a glass, but rather a lightweight material. Silicon carbide proved to be the perfect match for this project, with its light weight as well as its excellent structural ability. It was very stiff, not very dense, had low thermal expansion and high thermal conductivity. This last aspect would be crucial as it meant that the temperature could easily equalize over the whole instrument when irradiated by sunlight. Moreover, it could be optically polished to act as a perfect mirror. All of these properties lead to using SiC as the material for the Herschel mirror. Further work was conducted on SiC in 2010 with the Gaia project, a structure made essentially of ceramic to count plummets and stars on the horizon.

Research on SiC applications is still ongoing, as shown by a final-year student's research project at the Centre on using SiC fibre and BMAS glass to make a high performance ceramic.

Professor Vandeperre then focused on high temperature applications for ceramics, particularly on ceramics that can be used for re-entry on earth from space. Few materials have suitable properties to withstand such high temperature, and they are usually metals like tungsten, rhenium

and tantalum. However, silicon boride, silicon carbide and silicon nitride which are all ceramics also have very high resistance to heat. Moreover, they are also quite stiff, and their decay is therefore quite small at high temperature. One of their most important properties is their very thermal conductivity, which leads to fast propagation of heat in the sample; if one part of the material is heated, then the rest easily reaches that same temperature. These ceramics are quite hard and relatively strong, which are both effects of their dual phase nature. Such properties are of particular interest as the material has to be very resistant to crack growth. On the other hand, these ceramics fail quite easily at low temperature with increasing applied stress. At higher temperature with increasing applied stress, creep fracture can be expected.

To better understand the damage formation on these ceramics under intense heating, Luc Vandeperre's research led him to test the samples under high heat flux with Al_2O_3 balls and a thermocouple.

Great attendance at the lecture!

A first test at 25 MWm^{-2} for 30 seconds showed some oxidation of the samples. Other tests at much higher flux showed more oxidation as well as some melting (from the Gaussian distribution of light during the test). Such tests were performed for very short periods of time but prolonging the testing time would only lead to more oxidation more melting, and the destruction of the edges. Essentially, these ceramics lost all shape under very intense and prolonged heating.

To unlock the full potential of these ceramics, a method called transpiration cooling was carried out on the samples. Transpiration cooling is the use of a gas film to protect the surface from the high heat and intensity of the flux. The sample is protected from oxidation as the gas film hinders the access to oxygen, and upon cooling, the gas also hinders the heat transfer to the solid. Using partially hot pressed ZrB_2, the particles were glued together and permeable enough for this application.

The efficiency of the method was evaluated using plasma testing in Stuttgart. It was found that there was indeed formation of a film and that the method worked. It was noted however that with transpiration cooling, the sample had slightly grown under the intense heat flux. Some problems arose from the gas film. The permeability was still too low and needed to be increased. Moreover, the sample would sinter further if it was pushed even more, which needed to be prevented. One of the possible solutions to these problems was stabilizing the material by coarsening without densification. These still need to be implemented and researched into, but the transpiration cooling method showed a very promising start.

Overall, this lecture presented the development of a project, and how research is all about overcoming different obstacles to perfect said project. The development of transpiration cooling to protect ceramics from oxidation at high temperatures still has a lot of options to explore. It was also interesting to delve into the work of a specific research centre at Imperial, in this case the Centre for Advanced Structural Ceramics.

Thanks again to Professor Vandeperre for taking time to share his work with us.

Light pollution:

From misty skies to hazy sunrise

Disha Bandyopadhyay, a 2nd year student writes about light pollution as an under-reported form of pollution.

My roommate once woke up at 3am to get ready for her 9am lecture. Light seeped in from a party next door and lit up our room enough to seem like an early winter morning in London. This is an example of unnecessary lighting that forms light pollution, a growing problem as cities grow bigger, denser and indiscriminate lighting is offered as easy but sub-optimal solution.

Light pollution stems from extravagant non-essential lighting that make buildings look pretty, but leave animals confused, cause behavioural changes in humans and add an extra fifteen million tonnes of carbon dioxide into the atmosphere [1]. Studies now show that no amount of street lighting can actually deter a motivated criminal [2].

The ill effects of light pollution are startling. Shifted circadian clocks (the body's 24-hour day/night cycle) from artificial lighting are causing insomnia, depression and even obesity [3]. In response to artificial lights, animals change their feeding, locomotion and reproductive systems. Turtle hatchlings who were previously guided to the sea by moonlight are now being guided to beachside carousels by twinkling horses [4]. A third of the world's population cannot see the Milky Way in the sky, 26% of the population of UK [5] don't even ever get to use their night-time vision and 10,000 migratory birds fatally collide with buildings annually [6].

Every year thousands of animals are killed on roads as streetlight glares distort their vision, blinding them temporarily. Artificial light harms melatonin in the human eye, damaging diurnal and nocturnal vision. The cultural significance of skies is lost [7]. The celestial wonder Van Gogh once painted in The Starry Night is now becoming history. Ergo, not all our lighting is useful, and light pollution is a serious environmental problem requiring immediate attention. Materials science can provide effective solutions to limit this problem.

Building illustration via [https://www.l

Bird illustration by Brnnyvki via [ht

One measure towards controlling excessive artificial lighting is use of light sensors in electrical systems to automatically turn on and off lights and control brightness appropriate to the surrounding environment. Such switches use photoelectric sensors to detect changes in light intensity. These light sensors convert light energy to electrical signals that can be used for favourable responses. These devices can be categorised through their response mechanism. They either generate electricity when triggered by light (photovoltaics or photoemissives) or change electrical properties in response to light (photoresistors or photoconductors).

A contemporary solution for building light sensors harnesses changes in material properties under influence of light. Light dependent resistors (LDR) are photoresistors with an exposed piece of semiconductor material that changes resistance by orders of magnitude in response to light. Light energy excites valence band electrons of the material raising them to the conduction level. Here, they create hole-electron pairs in the material which increases conductivity and reduces resistance [8]. Cadmium sulphate (CdSO4) is one such semiconducting material used for its spectral response, which detects wavelengths similar as the human eye. Therefore, it can be used for its sensitivity to relevant levels of light. CdSO4's peak sensitivity lies between 560-600nm, within the visible spectral range.

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When LDRs are connected in a cell, unilluminated, the resistance is high at around ranges of the order of 100MW, but illuminated, the order is reduced to merely 100W. Connecting this system to a DC supply voltage in series with a standard resistor means that a different level of voltage will be available depending on the light stimulus, controlling lighting necessities [9].

Using different combinations of semiconductors and components in circuits, light sensing systems can be manufactured which can be used to either turn lights on and off or to control brightness to reduce excessive lighting. Furthermore, optical and electronic responses in the photoresistor can be modified for more favourable responses. For example, doping cadmium sulphate with n type dopants introduce various interband transitions for spin up and intraband transitions for spin down which increase absorption coefficients, meaning the spectral response widens to infrared, visible and ultraviolet, a handy technique to adjust light responses to requirements for different activities [10]. What this means is that a sensor can be created which knows the maximum lighting needed in a room, so it can dim lights once illumination reaches maximum. Professor Stefan Maier's research group at Imperial studies nanoplasmonics, an extension of this problem to understand how light interacts with matter (particularly nanostructures) and how this can be used to produce localised electromagnetic fields [11].

Another aspect of artificial light that contributes to light pollution is the colour of light. In recent years, the quest to reduce energy consumption has led to the popularity of white LED light usage over conventional lightbulbs. Although LED bulbs are 75% more efficient [12], they are approximately eight times the brightness of low-pressure sodium bulbs [13] which means they increase luminance of the night sky, or skyglow.

LED bulbs produce white light with shorter wavelengths (in the blue-green spectrum) than incandescent lightbulbs. These shorter wavelengths scatter more by Rayleigh scattering (scatter from bumping into oxygen and nitrogen molecules) and aerosols through Mie theory (a solution of Maxwell's equations which indicates that the size of scattering particles is directly related to the wavelength of light [14]. Despite this, the energy savings, cost and fairly environmentally friendly composition (doesn't contain any hazardous wastes) outweighs the blue hazard for most people [15]. As LEDs cannot be eliminated, their properties can be utilised for more

Illustration via [https://www.freepik.com/premium-vector/concept-lamp-that-emits-white-light-modern-yellow-background-add-your-message_4854992.htm#page=1&query=lamp&position=11]

more efficient handling to reduce light pollution.

LEDs are highly directional which means that they can just be pointed to where they're needed [16]. Their high illuminance means that specific areas can be targeted for lighting, reducing waste lighting. Light use can be optimised this way to reduce glare by effective shielding of LED light sources. Glare is when intense light sources reduce visibility due to uncomfortable or painful brightness. One way to reduce this effect is by increasing mounting height of the source so that a higher fraction of the light is useful and there is less spillage [17]. Special light fixtures are also used to shield portions of the lamp in a way that the path of light is only useful.

To minimize pollution, diffuse reflection needs to be minimised by either changing the surface of the light source, i.e. the lamppost itself, or the surface intended to be lit, the pavement. Additionally, if the path of light can be carefully calculated, tuning specular reflection on certain parts of the pavement can reduce the number of necessary streetlights. One possibility of this is adding reflective pigments to painted road signs to better distribute light on roads, increasing distance between streetlights. Despite car headlights not being a continuous source of light, this is sufficient for regions with continuous high traffic.

The smoother the surface of the material, the more metallic surfaces behave like a mirror. Hence, by manufacturing light fixtures with smoother surfaces there is less random scattering and consequently less light pollution. Similarly, other potential solutions to light pollution emerge from colour changing materials which change transparency when supplied by a voltage.

Materials science offers a variety of solutions whether that entails improving existing systems and devices with more directed materials, or revolutionising light distribution by coming up with sustainable, greener alternatives.

Using these different ideas can reduce, if not eliminate, light pollution and create clearer skies. By implanting these changes perhaps, the next astronomical photo can possibly yield a clearer black hole picture, or less frequent confused birds crashing dangerously into skyscrapers.

Solving light pollution saves the environment, money, psychological well-being of all living creatures and helps us see well beyond our periphery into the starry depths of the universe. Implementing solutions offered by materials science can reduce the negative impacts of light pollution and help save the environment. However, the greatest challenge lies in creating awareness of this environmental problem and to galvanize people to initiate preventative actions.

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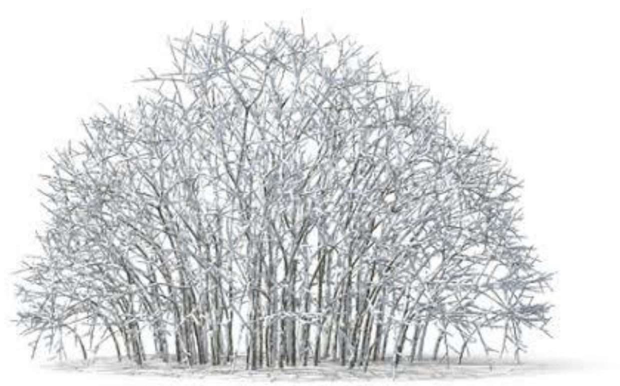

Image via [https://www.pixelsquid.com/png/bare-tree-covered-in-snow-1015382789630989938?image=I01]

Season's greetings:

A festive end of term for MatSoc

Jake Sidhu, a 3rd year student, recaps the traditional end of term trip to Brick Lane.

Twas the twelfth night of the twelfth month and a group of brave souls from the Materials Department took on a perilous journey that took them from the confines of South Kensington to the treacherous lands of Aldgate, for it was time for the annual Christmas Curry in Brick Lane. Armed with only our holiday attire, our wits and certain bottles (see Guala closures for how the lids are manufactured), we entered the famed 'Cinnamon' Restaurant, eager for the arrival of the food so that the real festivities could begin.

Upon arrival of the starters, our Most Celebrated and Regal President™ Schan Christopher Perera stood up and delivered his speech, toasting to the Queen and publicly shaming those who did not adhere to the strict policy of wearing something festive. (The author would like to point out to certain members that wearing a turkey hat on your head doesn't really scream Christmas to me, but nonetheless it was very creative and certainly better than some other efforts—they will not be named for their own safety).

The curious nature of this event was that it coincided exactly with day of the General Election—for those of you are reading this past 2020, see 'Brexit Election'. Once again, those who did not exercise their democratic right to vote were publicly shamed (I would write their names but I have conveniently forgotten them). But it also meant that our beloved Seif Mehanna was doing his best David Dimbleby impression; indeed, our main course delivered alongside regular updates on the exit polls from IC Radio. Regardless of your political stance, however, the mood was jovial and good natured, with a fantastic turnout from the freshers and, curiously, members who were not Materials students, including, but not limited to, the members of the public who joined in with our singing of 'Last Christmas'.

Can you find the author?

Eventually, the time had come for us to return to our natural habitat of West London, where the group was split according to the calling of the night. Some chose to celebrate the end of another term with their choice of tipple; others, however, were perhaps mourning their election losses (there are unconfirmed reports of the Regalia officer looking very sad with a 'Vote Labour' sticker peeling off his head). Overall, great fun was had by all and another fine event organised by our highly esteemed officer Adam Cliff. Which brings us nicely onto the New Year Dinner; an event which proved to be a huge success when it was done for the first time last year (some of you may remember the celebrated author Mark Miodownik attending and giving a speech), it returns this January (Friday 31st). We hope to see as many of you there as possible!

On behalf of the MatSoc committee, we hope that you all enjoy the Christmas holidays and look forward to seeing you back in next term in the New Year!

IMPERIAL MATERIALS

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Cover Image by Jalal Al-Lami:

Scanning electron microscopy (SEM) image of Inconel 718 powder particles used for additive manufacturing by powder bed fusion. The quality of additively manufactured parts is influenced by the characteristics of the printing powder. These characteristics include the powder composition, size distribution and surface morphology.