Understanding and controlling the processes occurring at electrode/electrolyte interface are key factors in optimising fuel cells and electrolysers. Metal particles supported on oxide surfaces promote many of the reactions and processes that underpin the global chemical industry and are key to many emergent clean energy technologies. At present, particles are generally prepared by deposition or assembly methods which, although versatile, usually offer limited control over several key particle characteristics, including size, coverage, and especially metal-surface linkage. In a new approach, metal particles are grown directly from the oxide support through in situ redox exsolution. We demonstrate that by understanding and manipulating the surface chemistry of an oxide support with adequately designed bulk (non)stoichiometry, one can control the size, distribution and surface coverage of produced particles. We also reveal that exsolved particles are generally epitaxially socketed in the parent perovskite which appears to be the underlying origin of their remarkable stability, including unique resistance of Ni particles to agglomeration and to hydrocarbon coking, whilst retaining catalytic activity.

John Irvine FRSE, FRSC (St Andrews) is well recognised for world-leading activity in energy materials, fuel cell and energy conversion technologies. He has 400 refereed publications with h-index of 53, has successfully trained over 50 PhD students and was awarded the RSC Sustainable Energy Award in 2015, previously being awarded RSC Materials Chemistry (09), Bacon (03) and Beilby (99) awards/medals as well as many International Awards and Fellowships. He has 10 high level Nature publications. He was re-elected European Councillor of the International Society for Solid State Ionics in 2015. He has led two EU research training networks, 1 ESF programme and 1 EU project. He led the Scottish Hydrogen and Fuel Association for 6 years to 2013 and is co-Director of the Energy Technology Partnership. He has won 3 EPSRC platform grants, led the Delivery of Sustainable Hydrogen Supergen and is Co-director of the current Supergen Hydrogen and Fuel Cell hub. He was an EPSRC Senior Fellow 2006-11, is PI or CoI on 10 current EPSRC related grants including co-writing the St Andrews Advanced Materials Capital for Great Technologies award. There is also very significant Industry, EU and government funding with a total overall current portfolio of around £18M
Do SOFCs still have a future?

John Zhu
School of Chemical engineering, the University of Queensland, Australia

In this talk, I will have a brief introduction on the SOFC research in our group, followed by some personal points of view on the future of SOFCs.

Dr. John Zhu is a Professor in School of Chemical Engineering, the University of Queensland. His research interests and expertise exist in advanced catalysis, gas/liquid adsorption and separation, direct carbon fuel cells and solid oxide fuel cells with strong application focus on clean energy and environment. His publications include one edited book, 8 book chapters, over 190 journal papers and many international conference papers. He holds 6 patents, and 3 patents have been licensed to the industrial sponsor. He has won and successfully led 18 ARC (Australian Research Council) grants with himself as sole or first chief investigator, with a total funding from government and industries in excess of $15 million. He is the recipient of a number of awards and fellowships, including RK Murphy Medal 2013, Freehills Award IChemE 2011, 2nd place Innovator of the Year Award IChemE 2011 (announced in Birmingham UK), the University of Queensland Foundation Research Excellence Award in 2007, an ARC Future Fellowship (FT3) from 2012-2016, an ARC Queen Elizabeth II Fellowship from 2008 to 2012, an ARC Postdoctoral Fellowship from 2003 – 2005. In May 2012, John Zhu's long term collaborative research with Eden Energy since 2005 was recognised by Thomson Reuters Innovation Award for Innovative Collaboration between the University of Queensland and Eden Energy.
Biomass carbon fueled tubular solid oxide fuel cells with molten antimony anode

Jian Li
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Tubular direct carbon solid oxide fuel cells (SOFCs) supported by Y$_2$O$_3$ stabilized ZrO$_2$ (YSZ) electrolyte were fabricated by slurry-casting, slurry-dipping and sintering processes with La$_{0.6}$Sr$_{0.4}$Co$_{0.2}$Fe$_{0.8}$O$_3$-10 mol.% Gd$_2$O$_3$ doped CeO$_2$ (LSCF-10GDC) as the cathode. Their electrochemical performance was examined at temperatures from 700 to 800 °C using molten antimony (Sb) anode and biomass fuel. The ohmic resistance of the cell was between 1.01 and 0.37 Ω cm$^2$ mainly originated from the thick YSZ electrolyte (150 μm); the polarization resistance ranged from 0.22 to 0.06 Ω cm$^2$. The maximum power density at 800 °C was 304 mW cm$^{-2}$ and could be greatly increased by using a thinner and/or more conductive electrolyte. With cocoanut active charcoal (CAC) as the fuel, the cell performance was stable at 200 mW cm$^{-2}$ at 800 °C by chemical consumption (oxidization) of the carbon, which reduces the electrochemically formed Sb$_2$O$_3$ to Sb; and the cell performance decreases as the fuel is used up and is recovered by refueling. The cells with 1 gram of CAC (Cell-II) and pyrolysed corn starch (PCS) (Cell-III) carbon fuels stably performed for 7.2 and 0.6 h at 750 °C and 5.6 and 7.1 h at 800 °C, respectively; the fuel utilization was above 50% in all cases except Cell-III at 750 °C. The electrical efficiency of Cell-II and Cell-III was below 34% at 750 and 800 °C, which was limited by the low Nernst voltage of the reaction of Sb oxidation, thick YSZ electrolyte used and significant amount of heat generated during the reduction of Sb$_2$O$_3$.

Dr. Jian Li joined Central Iron and Steel Research (Beijing) as an Engineer in 1989 after earning his Ph. D. in this institute, working on metal injection molding. In 1990, he went to the US as a post doctor, studying shape memory materials in Prof. C. M. Wayman's group. After earning his Ph. D. in ceramic engineering in 1995, he joined Prof. R. D. James of University of Minnesota at Twin Cities as a post doctor, doing research on magnetic shape memory materials. From 1996 to 2001, he was a Materials Engineer/Senior Materials Engineer at FuelCell Energy Inc. (then Energy Research Corporation), developing materials and processes for molten carbonate fuel cells. From 2001 to 2004, as a senior scientist, he worked for Versa Power Systems, Inc. (then Global Thermoelectric, Inc.) in Canada and was responsible for interconnect and contact development for solid oxide fuel cells (SOFC). Since Feb 2004, he has been a full time professor in the School of Materials Science and Engineering of Huazhong University of Science and Technology in Wuhan China, continuing his research on SOFCs, high-strength steels for automobiles and Li-air battery. He has authored more than 150 scientific publications, received 6 US patents and 10 Chinese patents.
Materials selection/R&D for commercial fuel cells

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Materials selection/R&D hold the key for commercial success of fuel cells by controlling critical parameters such as performance lifetime and costs. Fuel cells are electricity generators, and technologies for producing electricity (stationary applications), or electricity + motion (mobile applications) have been known for over hundred years. In order for fuel cells to replace these technologies, they have to offer significant advantages in performance as well as being cost competitive (operating and lifetime costs). For stationary devices costs of up to $1000-3000 per kW (depending on system size) may be tolerable, but for automotive applications about $50/kW need to be achieved.

The focus of R&D has to be development of materials for improved performance, yielding smaller and more compact fuel cell stacks, as well as minimising expensive materials or replacing them for cheaper ones. This applies for both the fuel cell stack components – cells (membranes + electrodes), catalysts, flow plates/interconnectors, end plates, “clamping” devices etc – as well as system components. Complexity of manufacturing of components with the selected materials constitutes a further challenge for commercialisation of fuel cells.

The presentation will focus on examples – with particular emphasis on SOFC – that demonstrate how the interaction between performance, lifetime and costs influence the commercial viability of fuel cells.

Dr Karl Föger was one of the founders of Ceramic Fuel Cells Ltd (CFCL), and Chief Technology Officer until his retirement in August 2014. In this role he has managed development of CFCL's technology from the beginning as member of the Executive Management Team. Under his technical leadership CFCL has demonstrated the potential of solid oxide fuel cell technology, and developed BlueGen, the world’s most efficient electrical generator. Earlier on his role as Chief Technology Officer was full operative responsibility of all technology and product development. Since 2005 the role has become more strategic. He was responsible for corporate technology and product strategy, advised the CEO and Board on technical matters, managed CFCL's extensive IP portfolio and gave credibility of CFC's technology to investors and partners. He was also a member of CFC’s European management team.

From 1975 to 1999 Dr Föger worked for CSIRO, Australia’s premier government R&D organisation, where he held various research and management positions culminating in his appointment as Chief Research Scientist.

Dr Föger is a Fellow of the Australian Chemical Institute, a Member of the American Chemical Institute and the American Ceramics Society, and was Adjunct Professor at RMIT and Swinburne Universities.

Dr Föger obtained a PhD in Physical Chemistry at Innsbruck University, Austria. He has worked over 35 years in the energy/fuels field, in diverse areas such as alternative fuels, catalysts for efficient fuel processing, environmental catalysis, materials in energy and fuels applications and fuel cells, and he is an international recognised authority. He has published several book chapters, over 200 scientific papers and is inventor on 6 patents.
Solid oxide fuel cells (SOFCs) have been considered as promising electrochemical energy conversion devices because of their high energy conversion efficiencies, excellent fuel flexibility and low environmental pollution. The conventional Ni-YSZ cermet anodes with YSZ electrolyte have an excellent catalytic activity and electrical conductivity. These Ni cermet anodes, however, have several drawbacks in hydrocarbon fuels such as carbon build-up (carbon coking), sulfur poisoning and low tolerance to redox cycling, which severely damages the anode microstructure and reduces the cell performance. To overcome these problems, extensive efforts have been devoted to develop Ni-free anode materials or surface modification technology for the anode backbone. In recently years, among the surface modification methods, an exsolution has been received attention due to \textit{in-situ} fabrication of catalysts. The exsolution evenly produces catalyst nanoparticles on the electrode surface, which can reduce carbon coking and increase redox stability. We previously reported the layered perovskite material, PrBaMn$_2$O$_{5+\delta}$, as fuel electrode with superior electrochemical performance. In this study, fuel oxidation catalyst doping into the layered perovskite material employed as a potential ceramic fuel electrode for SOFC with dense La$_{0.9}$Sr$_{0.1}$Ga$_{0.8}$Mg$_{0.2}$O$_3$ (LSGM) electrolyte, which can show high performance and good redox stability.

In 2005 \textbf{Guntae Kim} received his PhD in Chemistry from the University of Houston. He was a postdoctoral fellow in Prof. Raymond J. Gorte’s group at University of Pennsylvania from 2007 to 2009.

He is currently Associate Professor in School of Energy and Chemical Engineering, Ulsan National Institute of Science and Technology (UNIST), Republic of Korea. He has published more than 60 journal in the area of electrode materials for solid oxide fuel cells (SOFCs).

His research interests include materials for new energy technologies and their applicability in powering or conversion, storage devices. A particular field of interest is the development of layered perovskite oxides as electrode for fuel cell applications, metal-air batteries, proton conducting oxides for solid oxide cells, oxygen membrane reactor, and polymer electrolyte membrane fuel cells (PEMFCs).

Guntae Kim received the following awards: Texas Public Education Grant-International (2002-2003), Robert A. Welch Research Foundation Fellowship (2005-2007), Best 50 research award of Ministry of Education in Korea (2015), Best 100 research award of Ministry of Science, ICT and Future Planning in Korea (2015), and Certificate of Merit Industrial Technology of the Month, Minister’s Award of Ministry of Trade, Industry and Energy in Korea (2015).
Improved Chemical and Electrochemical Stability on Perovskite Oxides by Oxidizing Cations at the Surface

Nikolai Tsvetkov\textsuperscript{1,2,†}, Qiyang Lu\textsuperscript{1,3†}, Lixin Sun\textsuperscript{1,2}, Ethan Crumlin\textsuperscript{4}, and Bilge Yildiz\textsuperscript{1,2,3,*}

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Segregation and phase separation of aliovalent dopants on perovskite oxide (ABO\textsubscript{3}) surfaces is detrimental to the performance of energy conversion systems such as solid oxide fuel/electrolysis cells and catalysts for thermochemical \textit{H\textsubscript{2}O} and \textit{CO\textsubscript{2}} splitting. One key reason behind the instability of perovskite oxide surfaces is the electrostatic attraction of the negatively charged A-site dopants (Sr\textsubscript{La}′) by the positively charged oxygen vacancies (V\textsubscript{O}∙∙) enriched at the surface. Here we show that making the surface more oxidizes improves the oxygen surface exchange kinetics and stability, albeit contrary to the well-established understanding that surface oxygen vacancies facilitate reactions with O\textsubscript{2} molecules. We take La\textsubscript{0.8}Sr\textsubscript{0.2}CoO\textsubscript{3} (LSC) as a model perovskite oxide, and modify its surface with additive cations that are more and less oxidizing than Co. We utilized ambient pressure X-ray absorption and photoelectron spectroscopy to prove that the dominant role of the oxidizing surface additives is to suppress the enrichment and phase separation of Sr\textsubscript{La}′ while reducing the concentration of V\textsubscript{O}∙∙ at the surface. Consequently, we found the effect of these oxidizing cations to be significantly improved stability, with up to 30x acceleration of the oxygen exchange kinetics after 54 hours in air at 550 °C. This result highlights the existence of an optimum surface oxygen vacancy concentration that balances the gain in oxygen surface exchange kinetics and the chemical stability loss.

Bilge Yildiz is an associate professor in the Nuclear Science and Engineering and the Materials Science and Engineering Departments at Massachusetts Institute of Technology (MIT), where she leads the Laboratory for Electrochemical Interfaces. She received her PhD degree at MIT in 2003 and her BSc degree from Hacettepe University in Turkey in 1999. After working at Argonne National Laboratory as research staff, she returned to MIT as an assistant professor in 2007. Her research centers on molecular-level studies of oxygen exchange kinetics on surfaces at elevated temperatures, under stress and in reactive gases, by combining in situ surface sensitive experiments with first-principles calculations and novel atomistic simulations. The scientific insights derived from her research impact the design of novel surface chemistries for efficient and durable solid oxide fuel/electrolysis cells, and for corrosion resistant films in a wide range of extreme environments as in nuclear energy generation and oil exploration. She was the recipient of the Charles Tobias Young Investigator Award of the Electrochemical Society in 2012, the Somiya Award of the International Union of Materials Research Societies for international collaboration in 2012, and an NSF CAREER award in 2011.
Metal-Free and Nonprecious Metal Electrocatalysts for Energy Conversion

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Replacement of precious metal catalysts by commercially available alternatives is of great importance among both fundamental and practical catalysis research. Nanostructured carbon-based and transition metal materials have demonstrated promising catalytic properties in a wide range of energy generation/storage applications. Specifically engineering graphene/porous carbon with guest metals/metal-free atoms can improve its catalytic activity for electrochemical oxygen reduction reaction (ORR), oxygen evolution reaction (OER) and hydrogen evolution reaction (HER), thus can be considered as potential substitutes for the expensive Pt/C or IrO₂ catalysts in fuel cells, metal-air batteries and water splitting process. In this presentation, we will talk about the synthesis of nonprecious metal and metal free elements-doped graphene/porous carbon, and their application on electrocatalysis [1-9]. The excellent ORR, OER and HER performance (high catalytic activity and efficiency) and reliable stability (much better than the commercial Pt/C or IrO₂) indicate that new materials are promising highly efficient electrocatalysts for clean energy conversion.

References:

Figure 1 Electroctatalysis processes of ORR, OER and HER on hybrid atoms-doped graphene and porous carbon materials.
Professor Shi-Zhang Qiao received his PhD degree in chemical engineering from Hong Kong University of Science and Technology in 2000, and is currently a professor (Chair of Nanotechnology) at School of Chemical Engineering of the University of Adelaide, and an Honorary Professor at The University of Queensland, Australia. His research expertise is in nanomaterials and nanoporous materials for drug/gene delivery and new energy technologies. He has co-authored more than 220 papers in refereed journals (over 12000 citations with h-index 60), including Nature, Nature Materials, Nature Communications, J. Am. Chem. Soc, Angew. Chem., Adv. Mater., and has filed several patents on novel nanomaterials that are promising for drug/gene delivery, fuel cells, photocatalysis and lithium ion battery.

Professor Qiao was honoured with a prestigious ARC Discovery Outstanding Researcher Award (DORA, 2013), a Emerging Researcher Award (2013, ENFL Division of the American Chemical Society) and a UQ Foundation Research Excellence Award (2008). He has also been awarded an ARC ARF Fellowship, an ARC APD Fellowship and an inaugural UQ Mid-Career Research Fellowship. Professor Qiao is currently an Associate Editor of Journal of Materials Chemistry A.
Iron Carbide Nanoparticles Encased in Graphitic Layers as Oxygen Reduction Catalysts for Fuel Cells

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Development of non-precious metal catalysts (NPMCs) for the oxygen reduction reaction (ORR) has been a foremost subject of low temperature fuel cell research. Among the investigated materials is the carbon-supported transition metal/nitrogen composite of most interest. The active sites are always involving the surface nitrogen coordinated with the metals. In this talk a novel catalyst is presented consisting of uniform Fe₃C nanoparticles wrapped by graphitic layers. Volatile precursors, e.g. cyanamide and ferrocene are used and the synthesis was performed by high pressure pyrolysis. The catalyst in form of hollow porous microspheres is a result of the atom-reorganization process from the vapor phase. More detailed studies are carried out in terms of synthetic parameters, nanostructure formation, Mossbauer spectra and ORR active sites. Below 500°C, melamine-rich microspheres are first formed with uniformly dispersed amorphous metallic species. At elevated temperatures, the spheric structure remains and confines the following growth of the graphitic phases as well as the encapsulated Fe₃C nanoparticles. Simultaneous formation of carbide nanoparticles and electronically conductive graphitic phases occurred at above 700°C. The synthesized catalysts, with very low surface nitrogen or metallic functionalities, exhibit superior ORR activity and stability. A new type of ORR active sites is proposed originating from the synergies between the carbide nanoparticles and protective graphitic layers.

Qingfeng Li, Dr. Techn. Professor in Department of Energy Conversion and Storage, Technical University of Denmark, received his Ph.D. at Northeastern University of China in 1990 and was in 2006 awarded the Doctor of Technices in Denmark. He has initialized / coordinated / participated 7 EU and more than 20 Nordic research projects in the field of electrochemical energy conversion technologies including a Danish-Chinese Research Centre on Proton Conducting Systems. For the time being Professor Li is leading a Danish center, 4M Centre funded by Innovation Fund Denmark, devoted to fundamental research on high temperature polymer fuel cells.
Solar Fuel Generation on Semiconductor Metal Oxides

Lianzhou Wang
Nanomaterials Centre, School of Chemical Engineering and AIBN, The University of Queensland, Australia

The capability to design functional nanomaterials with desirable structures and properties remains an important challenge to R&D sectors. In this talk, we give a brief overview on our recent progresses in designing semiconductor metal oxide materials for photoelectrochemical energy conversion. In more details, we have been focusing the following three aspects; 1) new types of photoelectrochemical reactor design which can simultaneously deliver dual-function with not only solar fuel generated but also toxic/pollutant removed from the reactors; 2) stimuli driven switchable photoelectodes that can convert between cathodic and anodic photocurrent; and 3) new photoelectodes for improved conversion efficiency in dye-sensitized solar cells and new generation perovskite solar cells.

Lianzhou Wang is currently Professor and ARC Future Fellow in School of Chemical Engineering and Director of Nanomaterials Centre, the University of Queensland, Australia. His research focuses on the design and development of functional semiconductor metal oxides and two-dimensional nanomaterials for energy conversions including photocatalysis, low cost solar cells and rechargeable batteries In the past years, as a Chief Investigator, he has succeeded in winning a large number of competitive research grants from governments and industry, totaling >$AUD 18 million and has contributed > 200 peer-reviewed journal publications, 11 patents and delivered over 50 plenary/keynote/invited talks. Lianzhou has won some prestigious Fellowships/Awards including ARC QEII Fellowship, UQ Research Excellence Award, Scopus Young Researcher Award of 2011, ARC Future Fellowship of 2012, and was elected to ARC College of Experts in 2015.
In this presentation, I will discuss our recent progress toward design of advanced colloidal carbon spheres for energy applications.

We have developed carbon nanostructured electrode materials, including novel microporous carbon spheres, mesoporous carbon spheres, core shell and yolk shell carbon spheres with hierarchical porous structures. Specifically, (i) We recently developed a strategy to synthesise monodisperse polymer spheres from resorcinol–formaldehyde (RF) resin and carbon “Stöber” spheres.1 (ii) In addition, modified carbon spheres have been prepared through a bottom up self-assembly by using different functional precursors, or post-synthesis modification method. Furthermore, we have applied this method to produce uniform carbon core–shell spheres with adjustable shell thickness, carbon@metal, carbon@silica, metal@carbon, silica@carbon, or metal oxide@carbon materials.2 (iii) We also extended the synthesis method of mesoporous silica nanospheres to enable the preparation of ordered mesoporous resorcinol formaldehyde nanospheres with particle size from 80 to 400 nm and mesopores of ~3.5 nm in diameter.3

Our synthesis strategies provide a new benchmark for fabricating well-defined porous carbonaceous nanospheres with a great promise for energy storage and conversion applications.4

References:


silicas nanocomposites, colloidal polymer and carbon spheres, anisotropic particles with patchy, multicompartment and Janus architectures. In April 2013, Dr Liu joined Curtin University as a Lecturer, was promoted to Senior Lecturer in December 2014. He will further advance the nanoporous and hollow materials as nanoreactor and drug delivery vehicles, particularly for nanobiocatalysis. Dr. Liu has been CI on over $2.2 M in sponsored research (including two ARC DP grants, one ARC LP grant, two international linkage grant from the Australian Academy of Sciences, and four UQ major grants) in the last five years, and as of November 2015, has published more than 102 peer reviewed journal articles including top ranking journals such as *Nature Mater.*, *Nature Commun.*, *NPG Asia Mater.*, *Angew. Chem. Int. Ed.*, *Adv. Mater.*, *JACS*, *Nano Today*, *Adv. Funct. Mater.*, *Small*, *Chem. Commun.*, *Chem. Eur. J.*, *Chem. Mater.*, *J. Mater. Chem.*, *J. Phys. Chem. C.*, et al. 5 book chapters, and held one authorized Chinese patent and three Chinese Provisional patents, and delivered over 30 presentations/seminars in scientific meetings and congresses. A recent search (November 2015) of ISI Web of Science shows his entire publications have been cited for over 5100 times. He has an H-index of 37 and his research has been featured on 12 Cover pages of scientific journals. His research works were also highlighted by Chemistry World, Angew. Chem. Int. Ed. and Nature Materials. He is the Associate Editor of RSC Advances, and Editor for Asia-Pacific Journal of Chemical Engineering. As recognition of his achievements in research, he was honoured with a prestigious UQ Foundation Research Excellence Award, Australian Postdoctoral Fellowship (APD), JSPS Invitation Fellowships, UQ Postdoctoral Research Fellowship, President Award (Chinese Academy of Sciences) and a Young Scientists Award of the 14th International Congress on Catalysis.
Graphene materials attract increasing interest in clean energy applications, such as solar cells, supercapacitors, lithium ion batteries, Li-S batteries, and OLED devices.

For supercapacitors and lithium ion batteries, it is found that graphene composites have a significant improvement in their capacity, rate capability and cycling stability. The roles of graphene are found mainly to form a conductive network, increase electron and lithium ion conductivity, and anchor and trap electrode materials, and their efficiency is dependent upon how strong the interaction between graphene and electrode materials is.

Graphene materials can be used in Li-S batteries. A unique sandwich structure with pure sulfur sandwiched between two graphene membranes was designed for a Li-S battery to trap polysulfides. Furthermore, a graphene membrane was used as both current collector and buffer layer on a polymer separator. These batteries show significant improvement in cyclability and capacity, because the electrode with the graphene membrane can provide rapid ion and electron transport paths, accommodate sulfur volumetric expansion, and store and reuse migrated polysulfides to alleviate the shuttling effect. By incorporating a graphene foam (GF) fabricated by template-directed CVD with reduced graphene oxide aerogel, a three-dimensional hybrid nested hierarchic graphene macrostructure was used as a current collector to solve the low sulfur loading and sulfur content issues of Li-S batteries.

Graphene materials can also be widely used in flexible energy storage devices. For example, a graphene/PANI composite membrane is good electrode material for flexible supercapacitors; by coating active materials on GF, an anode and cathode were made to assemble a thin, lightweight and flexible lithium ion battery and Li-S battery, which show high rate capability and capacity, and excellent flexibility.

Finally, high-quality graphene transparent conducting films by CVD can be used as transparent electrode to assemble flexible OLEDs with excellent performance.

Dr. Hui-Ming Cheng is Professor and Director of Advanced Carbon Research Division of Shenyang National Laboratory for Materials Science, Institute of Metal Research, the Chinese Academy of Sciences.

His research activities focus on the synthesis, properties and applications of carbon nanotubes, graphene, energy storage materials, photocatalytic semiconducting materials, and high-performance bulk carbon materials. He has published over 480 papers with citation >34000 and an H index of 86, and is recognized as one of the Highly Cited Researchers in both materials science and chemistry fields in 2014 and 2015 by Thomson Reuters. He has received several international and national awards, including the 2nd class National Natural Science Prize, the Charles E. Pettinos Award, the Felcht Award, and the Prize for Scientific and Technological Progress of Ho Leung Ho Lee Foundation. He has given more than 80 plenary/keynote/invited talks in international conferences and symposia, and was the Editor of Carbon from 2000 to 2015, Editor-in-Chief of New Carbon Materials from 1998 to 2015, and is the founding Editor-in-Chief of Energy Storage Materials since 2015. He is also a member of the Chinese Academy of Sciences and fellow of the World Academy of Sciences (TWAS).

Yusuke Yamauchi1,2*

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Polymeric micelles are formed in solution when the hydrophobic portions are driven to an interior structure while hydrophilic portions are turned outward facing toward the water. Recently, we have focused on the polymeric micelles as stable and rigid templates for obtaining mesoporous materials with ultra large pore sizes.[1-3] Our ‘polymeric micelle assembly’ approach is highly useful for preparation of novel mesoporous materials which are not easily obtained by general synthetic approaches. As one example, mesoporous gold (Au) films with tunable pores are expected to provide fascinating optical properties stimulated by the mesospaces, but they have not been realized yet because of the difficulty of controlling the Au crystal growth. Very recently, we reported a reliable synthesis of mesoporous Au films using stable micelles of polystyrene-block-poly(oxyethylene) (PS-b-PEO) diblock copolymers, with electrochemical deposition advantageous for precise control of Au crystal growth.[3] In the electrolyte solution, HAuCl4 is dissolved into H3O+ and AuCl4- ions and then interacts with the EO shells of the micelles through hydrogen bonding. This interaction favours H3O+ rather than AuCl4-, and consequently creates positively charged micelles that can be directed to the working electrode surfaces, where the AuCl4- ions are reduced to metallic Au with the electrochemical deposition of the micelles. The resultant mesoporous Au films actually exhibit high scattering performance and thus high activity for molecular sensing. Significantly, enhanced electric field (E-field) amplitude is clearly seen inside or at the perimeter of the mesopores. In this presentation, we would like to introduce our recent progress on new mesoporous/nanoporous materials as well.[4-7]

References


Fig. 1 | (a) Schematic illustration for the fabrication of mesoporous Au films by using polymer micelle assemblies. (b, c) TEM images of PS-b-PEO micelles formed in aqueous solution (b) without and (c) with HAuCl4 source. The Tyndall effect is also shown as an inset image.
Prof. Yusuke Yamauchi received his bachelor’s degree in 2003, master’s degree in 2004, and Ph.D. in 2007 from Waseda University in Japan. After receiving his Ph.D., he joined NIMS as permanent staff. Since 2008, he started his own research group: the ‘Inorganic Materials Laboratory’. He has published more than 350 papers in international refereed journals with more than 10,000 citations (h-index 51). He concurrently serves as a visiting professor in several universities (Tianjin Univ. in China, Wollongong Univ. in Australia, King Saud Univ. in Saudi Arabia, and Waseda Univ. in Japan), an associate editor of APL Materials published by the American Institute of Physics (AIP), and an editorial board member of Scientific Reports published by the Nature Publishing Group (NPG). He has received many outstanding awards, such as the CSJ Award for Young Chemists, the Chemical Society of Japan (CSJ) in 2014, the Young Scientists’ Prize of the Commendation for Science and Technology by MEXT in 2013, the PCCP Prize by the Royal Society of Chemistry in 2013, the Tsukuba Encouragement Prize in 2012, the Ceramic Society of Japan (CerSJ) Award in 2010, and the Inoue Research Award for Young Scientists in 2010. His major research interest is tailored design of novel nanoporous materials with various shapes and compositions toward practical applications.
ORGANIC IONIC PLASTIC CRYSTALS – NOVEL IONIC ELECTROLYTES FOR ALKALI METAL ELECTRODES

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The electrolyte is one of the key components of an energy storage device required to achieve, for example, high reliability and safety as well as high energy density. There are numerous battery chemistries possible, although lithium-ion has become one of the most common technologies for portable electronics and is making its way increasingly into electric vehicles and stationary storage.

We have found that pyrrolidinium and phosphonium based organic ionic plastic crystals (OIPCs), made entirely of ions, can be applied as attractive, high safety, solid-state electrolytes for lithium batteries.[1] These electrolytes offer attractive stable electrolyte properties and unique interfacial properties, key to the use of high energy density electrodes such as lithium metal. These materials allow flexibility of design and can remove the safety risks associated with leakage and ignition of commonly used volatile liquid electrolytes. They can be classed as fast ion conductors, where one type of ion (i.e., Li⁺ for lithium batteries) is able to move rapidly against a background of a relatively static matrix.

However, in most cases the ionic conductivity of OIPCs is too low for application in devices at ambient temperatures. In this presentation, the use of an electrospun polymer nanofibres as an additive and mechanical support matrix has been investigated. The obtained composite materials exhibit enhanced mechanical and ion transport properties and our efforts to understand these improvements and to control the composite properties by manipulation of the OIPC and nanofibre chemistry will be described.[2,3]

References:

Associate Professor Patrick Howlett is a Senior Research Academic within the Institute of Frontier Materials at Deakin University. His research seeks to apply novel materials science principles, design and methodology to the development of new electromaterials. This mainly relates to electrochemical devices (e.g., batteries) and surface engineering through the manipulation of passivity for application in corrosion engineering. The materials focus of A/Prof Howlett’s research includes ionic liquid and plastic crystal electrolytes as well as a specific focus on the corrosion and electrochemical properties of reactive metals such as lithium and magnesium. His work also includes the use
and development of advanced surface characterisation techniques including synchrotron based sources.

His research has resulted in over 90 refereed journal papers and 2 patents. He was the lead author on a manuscript and PCT entitled “High lithium metal cycling efficiency in a room temperature ionic liquid” published in 2004, which helped to initiate a worldwide and ongoing effort to develop batteries based on these electrolytes. Some of his current projects include; new electrolyte and electrode materials for advanced metal-air and flow batteries, organic ionic plastic crystal and ionic liquid electrolytes for advanced batteries, corrosion resistant ionic liquid coatings for light metal (Mg & Al) alloys and ionic liquid lubricants for steel-aluminium systems. He is a CI within the ARC Centre of Excellence for Electromaterials Science, 2 ARC Discovery Projects and an ARC Linkage Project as well as various industry funded projects.
Thermoelectric materials directly convert thermal energy into electrical energy, offering a green and sustainable alternative for the global energy market. Here, Dr Chen developed inexpensive, abundant, and low-toxic thermoelectrics for high-efficiency energy conversion using novel industry-level approach, coupled with nanostructure and band engineering strategies. Through effective design of thermoelectric materials with engineered chemistry and unique structure, and advanced manufacturing, high-performance thermoelectrics has been realised by Dr Chen in lab scale. Such innovative technology can be used for harvesting electricity from waste heat or body heat, which will pioneer the QLD position at the forefront of energy technologies and bring tremendous economic and environmental benefits to the QLD community.

Dr Zhi-Gang Chen received his Ph.D in Materials Science and Engineering from the Institute of Metal Research, Chinese Academy of Science, in 2008. After his Ph.D, he joined the University of Queensland as an Australian Postdoctoral Fellow, and continued as a Queensland Smart State Future Fellow. In 2012, he won a Queensland International Fellowship to undertake a collaborative research at California Institute of Technology. His research has been concentrating on manufacturing high-performance smart functional nanomaterials for thermoelectric and nanoelectronic applications, and on understanding their underlying physics and chemistry for better designing the manufacturing. As a Chief Investigator, Dr Chen has succeeded in winning many competitive research grants including 5 ARC grants, 2 Queensland smart future funds, 1 industry investment, 1 international linkage grant from the Australian Academy of Sciences, and 4 UQ grants. Dr Chen has contributed more than 115 original journal publications, 4 patents, and over 30 invited talks or oral presentations. His publications have been cited > 4500 times (ISI web) with H index of 36.
Polarization induced interface and its implication in the development of solid oxide cells technologies

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In high temperature solid oxide cells (SOCs) either in the form of solid oxide fuel cells (SOFCs) for electricity generation or solid oxide electrolysis cells (SOECs) for electricity storage, electrode/electrolyte interfaces play a critical role in the electrocatalytic activity and durability of the cells. Traditionally, electrode/electrolyte interface has been formed ex situ by high temperature sintering typically in the range of 1100-1400°C. However, we have found that electrode/electrolyte interfaces can be formed in situ by electrochemical polarization treatment. The atomic force microscopy (AFM) analysis results indicate that thermally induced interface is characterized by convex contact rings with depth of 100-400 nm and diameter in agreement with the particle size of pre-sintered \((La_{0.8}Sr_{0.2})_{0.90}MnO_3\) (LSM) and \(La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8-\delta}O_3\) (LSCF) electrodes, while the electrochemically induced interfaces under cathodic polarization conditions on in situ assembled electrodes are characterized by particle-shaped contact marks or clusters (50-100 nm in diameter). Electrochemically, the electrocatalytic activity of electrochemically induced electrode/electrolyte interfaces is comparable to the thermally induced interfaces for the \(O_2\) reduction reaction under SOFC operation conditions. The polarization induced interface has a significant implication in the development of truly reversible and stable SOCs under cyclic SOEC and SOFC modes. We show that the deterioration of LSM oxygen electrodes caused by the anodic polarization can be partially or completely recovered by the subsequent cathodic polarization. The fundamental reason for the reversibility of SOCs is self-healing and regeneration of the LSM/YSZ interface under cathodic polarization conditions.

Dr San Ping Jiang obtained his BEng from South China University of Technology and PhD from The City University, London. He is Professor at the Department of Chemical Engineering and Deputy Director of Fuels and Energy Technology Institute, Curtin University and Adjunct Professor of the University of Sunshine Coast University, Australia. He also holds Guest Professorships of number of Chinese Universities including Central South University, Guangzhou University, Harbin Institute of Technology, Huazhong University of Science and Technology, Wuhan University of Technology. Before joining Curtin University in 2010, Dr. Jiang worked at Essex University in UK, CSIRO Materials Science and Manufacturing Division, Ceramic Fuel Cells Ltd in Melbourne, Australia and Nanyang Technological University in Singapore. His research interests encompass solid oxide fuel cells, proton exchange membrane fuel cells, water splitting, supercapacitors, solid oxide electrolyser, electrocatalysis and nano-structured functional materials. Professor Jiang has published ~305 journal papers, which have accrued over 10,500 citations and \(h\)-index of 58. He has authored and co-authored ten book chapters, four books on fuel cells and delivered over 70 invited public seminars.
Our recent research focuses on understanding the interfacial binding of metal oxide materials with functionalized graphene materials via the so-called Oxygen-bridge. We have investigated the electrocatalytic properties of these hybrid graphene-metal oxide electrode materials for oxygen reduction reaction. Our results showed the interface locking effect in a Mn3O4-graphene oxide electrode which contributed substantially to preserving the structural integrity and enabling high activity. This interfacial effect is attributed to the interface C-O-Mn(III) bond. The catalytic nature of the interface C-O-Mn bridge was explored. Our detailed structure analysis revealed the C-O-Mn(III) structure in the new system, and successfully correlated the structure with the electrocatalytic behaviors. Inspired by these O-enabling carbon-metal interactions, we extended the concept to directly using functionalized nanocarbon materials as cation storage electrodes, such as zinc ions.

Da-Wei Wang is a Lecturer at the University of New South Wales. He received PhD in Materials Science at the Institute of Metal Research, Chinese Academy of Sciences in 2009. He worked as a research fellow at University of Queensland from 2009 to 2013. He is interested in electrochemical energy materials and engineering. He received a 2012 UQ Foundation Research Excellence Award and The 2013 Scopus Young Researcher Awards for his research to develop advanced batteries. He has published around 60 peer-reviewed journal papers and several book chapters, with an h-index of 30 and total citations of over 6000.
Nitrogen-enriched carbon electrodes for supercapacitors

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Nitrogen-doped carbons are considered promising electrode materials for supercapicitors because of nitrogen-containing functional groups that are reported to provide beneficial pseudocapacitance. Combining the benefits of nitrogen-enriched carbons and hierarchical pore structures, however, is a challenge because the most common approaches used to introduce nitrogen groups involve the direct pyrolysis of nitrogen-containing precursors, such as melamine-derived precursors, hexamine or urea, or by carbonization and activation process using ammonia treatment. These methods typically produce carbons with a poorly developed pore structure, and therefore a secondary chemical or physical activation step may be required. In this presentation I will describe three approaches in UQ research to develop nitrogen-rich carbons with hierarchical pore structures: (1) chemical activation of waste coffee grounds, (2) direct pyrolysis of melamine resin and poly(vinylidene fluoride), and (3) synthesis of nitrogen-rich graphene nanosheets.

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Dr Tom Rufford is a Lecturer in the UQ School of Chemical Engineering and a holds an ARC Discovery Early Career Researcher Award. Tom completed his BE and PhD degrees in Chemical Engineering at the University of Queensland in 2000 and 2009, respectively. Tom’s PhD thesis investigated the use of porous carbon materials derived from waste coffee grounds for energy storage via hydrogen or supercapacitors on board electric vehicles. His research interests include natural gas process engineering, porous carbons, pressure swing adsorption, and solid-fluid interactions in coal seam gas reservoirs. Current and recent projects include studies on Helium recovery and nitrogen rejection from natural gas, low permeability coals, and the capture of methane emissions from liquefied natural gas (LNG) production plants. He has published more than 35 journal articles and edited a book titled Green Carbon Materials: Advances and Applications.