CRAIG E. BANKS

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Craig is currently a Professor in Electrochemical and Nanotechnology at Manchester Metropolitan University with research focused on Electrochemistry, both Fundamental and Applied. Craig has published over 500 papers (*h*-index = 80; Citations: >28K), 4 books and 22 book chapters. He is the lead inventor on 21 patents and has, in the last 2 years brought in over £14 M in external grant income. Craig is globally leading in the field of electrochemical science and analytical science and has been elected as a "Highly Cited Researcher" by Thomson Reuters putting him in the Top 1% of his field and is consequently listed in the 'World's Most Influential Scientific Minds 2014 and 2019'. CB has spun out 2 companies from his research, one using screen-printed electrode as the basis for drug driving and the second for medical diagnosis of diseases in breath via the measurement of chemical markers using electrochemical sensing technology. CB was awarded the Royal Society of Chemistry's Harrison–Meldola Memorial Prize (2011). Craig was recently a REF2021 Output Assessor for General Engineering (UoA 12).

Craig has various research interests, summarised as:

- **The design and development of next generation screen-printed and additive manufactured electrochemical platforms for sensing disease markers and electrocatalysis of key electrochemical reactions.**
  Craig has published over 200 papers in the design and fabrication of sensor technology, founded upon physical science research into next generation screen-printing and additive manufacturing sensing platforms. Craig has pushed the boundaries of screen-printing electrodes (SPEs) and has designed and developed never seen before next generation electrochemical sensing platforms Through intelligent design of the geometry and the surface composition of the SPEs, significant advancements in the electroanalytical outputs of the underlying sensing platform can be achieved, realising significantly improved electrochemical sensors which are cost-effective but yet have reduced signal-to-noise ratio, increased sensitivity and lower limits of detection. Examples of prior work include the first reports of: microbands, screen-printed back-to-back electroanalytical sensors, shallow recessed arrays, novel metallic electrode surfaces never reported before, P24-HIV protein detection based on graphene quantum dot modified SPEs, rapid antibiotic susceptibility sensors based on resazurin modified bulk SPEs, and all-in-one additive manufactured electroanalytical sensing platforms.

- **Studying the fundamental electrochemical understanding of 2D materials.**
  Craig was the first to report pristine graphene was not electrochemically useful and rather multi-layer/defect graphene is more optimal. Work was extended to understand how other 2D materials function, for example, 2D hexagonal boron nitride, previously was reported to be "inert" by the University of Manchester, however, to the contrary, we demonstrated that it had useful electrochemical properties. In other work we were the first in the world to report the beneficial use of 2D material, Antimonene, as a supercapacitor material [*Advanced Energy Materials* 8, 1702606]

  Work on 2D materials using in-situ electrochemical-AFM-nanoRaman co-localised measurements and Tip-Enhanced Raman Spectroscopy allowed us to undertake physicochemical characterisation during electrochemical perturbation towards the hydrogen and oxygen evolution reaction revealing, for the first time, that the integrity of graphene is structurally compromised in both cases for mono-layer graphene but less so for multi-layer graphene allowing more efficient fuel cells and electrolysers to be realized [*Sci Rep*, 2019, 9, 15961; *ChemElectroChem*, 2019, 6, 5446]

- **The innovative use of additive manufacturing (3D printing) to produce next generation batteries and supercapacitors.**
  An EPSRC funded project: EP/N001877/1 allowed the development of additive manufactured batteries to be realised for the first time. In this approach, the underlying technology is based upon the ability to readily produce bespoke additive manufacturing filaments. Utilising fused filament fabrication (FFF) printing, the additive manufacturing of freestanding anodes removing the requirement for a current collector in Li-ion coin cells, thus offering *a simpler and cheaper alternative* to traditional Li-ion based setups [*Sci Rep* 2017, 7 42233]. This work was extended to the FFF printing of Li-ion anodes with a chemically induced porosity step giving rise to a significant improvement in the battery performance where a 200-fold increase was observed [*Batteries & Supercaps* 2019, *2*, 488; *highlighted on the journals front cover and one of the most cited in the journal*]. Recent work in this area on the development of bespoke filaments realised the **world's first** completely FFF printed free-standing additive manufactured Na-ion battery [*Adv. Energy Mater.* 2019, 9, 1803019] which demonstrated a respectable performance noting that the structure is typically comprised of 80% thermoplastic, but yet, still works and functions as an energy-storage platform. The complete additively manufactured battery compared similarly to an ink-based/doctor-bladed counterpart and represents a paradigm shift in the technological and design considerations in battery and energy-storage architectures.

  This work has been extended to the development of additively manufactured graphene electrodes comprised of graphene and polylactic acid where different % compositions can be readily fabricated and tested. We demonstrated that graphene (20 wt%) incorporated into polylactic acid (80 wt%), fabricated into electrodes via FFF printing acts as a *generic template* for the electrodeposition of various metals/metal oxides. In our recent example, MoO_2 nanowires were deposited to act as a supercapacitor within ionic liquids displaying an optimal and highly competitive supercapacitance of 1212 F g^{-1}. [*Adv. Energy Mater., 2021, 11, 2100433*] New research has developed a completely new 3D printable conductive resin – a patent was filled in 2021.

- **New insights into supercapacitors and battery development.**
  Work in this area explores new materials, such as the synthesis of carbon quantum dots for the large production in the use of 3D porous frameworks in sodium storage properties with ultralong cycle life and ultrahigh rate capability, comparable to state-of-the-art carbon anode materials for sodium-ion batteries. [*Adv. Mat., 2015, 27, 7861*] Other work explores the use of RuO_2 for supercapacitors [*Energy Environ. Sci, 2013, 6, 3665*] and TiO_2 tuned by carbon dots for high performance sodium storage. [*Adv. Mat. 2016, 28, 9391*]

- **Electrochemical based sensors for unmet clinical needs.**
  The development of multi-analyte electrochemical biosensors based upon screen-printed electrode for measuring key blood markers that can identify SEPSIS and Traumatic Brain Injury has been developed. [*Anal. Chem, 2021, 93, 5931]* A patent has been filled in 2022. Commercially, Craig worked with Nemaura Medical, developing novel SPEs that allow the rapid determination of glucose via the skin (interstitial fluid) – this has been taken through to market and has had FDA approval. Lastly, Craig is CI on a BBSRC grant (BB/V017632/1) developing electrochemical sensors as a non-invasive diagnostic tool for the presence of fungal pathogens. Work in this area involves the design and development of Molecular Imprinted Polymers, a polymeric alternative to antibodies for sensing disease markers.

- **Working towards a net zero future.**
  This work involves developing new materials and fundamental understanding to develop clean, sustainable and green technologies for a Net Zero future, focusing on electrochemical water splitting. Recent work has reported the development of a facile synthesis for Ni/NiO nanocomposites for the OER where, through controlling the Ni:NiO ratio, optimal OER electrocatalytic activity can be achieved with the electrochemical mechanism deduced from detailed Tafel analysis and presented in a way that future materials scientists can easily utilise in the development of new OER catalysts. [*RSC Adv, 2021, 11, 14654*]. More recently, via an EPSRC funded grant, we have been able to showcase the world's first completely 3D printed electrolyser, in both metal and plastic, which at the end of life is deconstructed and returned into 3D printing feedstocks and manufactured into new electrolyser thereby establishing a closed loop system.

PUBLICATIONS

- Total number of papers: >500 (Source: Scopus); *h*-index, 80, >28K citations, i10-index: 422. A full list is available in Scopus.
- 20 Book Chapters; 4 Books; 21 Patents. Another new book and an updated version of Understanding Voltammetry in preparation in 2022.

RECENT FUNDING BIDS AND AWARDS

Awarded / Live:

- **TRANSFORM- CE - Transforming single use plastic waste into 3D printable / additive manufacturing and Intrusion moulding feedstocks and creating a new circular economy model; WorkTribe ID:** 170682; **Funder**: European Union Government Interreg Europe; **Amount**: 1.9M Euros. Note we are project lead; the total project is 9.6M Euros (5.7M Euros from the funder) with 36 partners over 4 countries. Started Jan 2020. Craig is PI.
- **Developing and Implementing Sustainability-Based Solutions for Bio-Based Plastic Production and Use to Preserve Land and Sea Environmental Quality in Europe; Funder**: Horizon 2020; **Amount**: £450K; Started 1 Oct 2019. Craig is the PI.
- **CIRMAP: Circular economy via customisable furniture with Recycled MAterials for public Places; Funder**: European Union Government Interreg Europe; **Amount**: 1M Euros. Starts July 2020. Craig is PI.
- **SHAREPAIR (Digital Support Infrastructure for Citizens in the Repair Economy); Funder**: European Union Government Interreg Europe; **Amount**: £300K. Started Jan 2020. Craig is PI.
- **Print City Network**; **Funder**: European Union Government Interreg Europe; **Amount**: £1.6M. Starts: 30 Sep 2020 for three year. Craig is PI.
- **2 Live KTPs**. Craig is PI.
- **EPSRC funding: Additive Manufacturing Complete Water Splitting Devices: A Pathway to Scalable Zero Emission Hydrogen Production (Additive-H2);** £252,330.40. Ranked 3rd out of 42 applications. Craig is PI.
- **Knowledge Exchange, project with the US ARMY DEVCOM:** Arsenic and Lead handheld portable electrochemical sensor for drinking water (US Army water diagnostic). £66,666.25.
- Match funded PhD cutting new edge electrochemical based technology to solve a range of substantial issues the water industry face. £48,962.00. Craig is PI.

INDICATORS OF ESTEEM

- Output assessor for REF2021for General Engineering (UoA 12) – June – Dec 2021 (over 700 papers accessed for quality);
- External examiner for the Czech Academy of Sciences (2021) accessing the quality of research conducted in 4 research institutions;
- In 2015 and 2018 named in the **Top 1% of the World** for citations;
- Royal Society of Chemistry Harrison-Meldola Memorial Prize and award (2011) for contributions to carbon nanotube and graphene electrochemistry.
- Fellow of the Royal Society of Chemistry (FRSC ; appointed at the age of 29);
- Advisory Board Member of RSC journal *Analytical Methods* (originally **Associate Editor** for 9 years, the longest that can be held);
- **Editorial board member** of: 1) *Journal of Nanostructure in Chemistry* (Springer); 2) *Inventions* (MDPI - Open Access journal); 3) *SOP Transactions on Analytical Chemistry*; 4) *Applied Chemistry*; 5) *The Open Electrochemistry Journal*;
- Editorial Board of *ChemElectroChem* (2019 – ongoing);
- **Editor in Chief and founding editor**: *Journal of Carbon Research*, (Sept 2014 - ongoing);
- Lead editor of the *RSC Specialist Reports in Electrochemistry* (July 2014-).
- Founding Editor Board member of the new Elsevier Journal, *Talanta Open*. Only UK person.

- Outstanding peer reviewer for Analytical Methods (2021; out of over 51,000 peer reviewers from more than 120 countries, one of only 500 to be recognized).
- Placed #49,634 in the publishing world by Mendelay report which ranks the first 500,000 of the world's 8 million scientists.

SUMMARY OF CAREER

- **October 2016 – June 2019, Manchester Metropolitan University:** *Faculty Head of Research and Knowledge Exchange*
- **September 2016 – February 2017, Manchester Metropolitan University:** *Acting Dean for Faculty of Science and Engineering (with David Lambrick)*
- **March 2015 – to September 2016, Manchester Metropolitan University:** *Associate Dean of Research, Faculty of Science and Engineering (role moved to Faculty Head of RKE).*
- **Jan 2016 – October 2018, Manchester Metropolitan University:** *Head of School of Healthcare Science, Faculty of Science and Engineering (rotational)*
- **June 2014 – to present, Manchester Metropolitan University:** *Professor / Personal Chair in Electrochemical and Nanotechnology*
- **Honorary Professor** at: 1) Central South University, Changsha, China; 2) Xiangtan University, Hunan, China; 3) Thapar University, Patiala, India; 4) Henan University of Technology, Henan, China; 5) Xinyang Normal University, Henan, China; 6) Jianghan University, Wuhan, China.
- **June 2011 – June 2014, Manchester Metropolitan University:** *Reader (Associate Professor) in Electrochemical and Nanotechnology*
- **Jan 2008 – to June 2011, Manchester Metropolitan University:** *Senior Lecturer in Analytical Chemistry*
- **October 2006 – to Dec 2007, Nottingham Trent University, Chemistry, School of Science and Technology**, **Nottingham:** *Lecturer in Analytical Chemistry*
- **July 2006 – Sept 2006, Schlumberger Cambridge Research, Cambridge:** *Research Scientist*
- **Oct 2004 – June 2006, University of Oxford, Physical Chem Laboratory, Oxford:** *Post-Doc*

SUMMARY OF EDUCATION

- **September 2006 – September 2007, Nottingham Trent University:** *PGCHE*,
- **September 2001 – September 2004, University of Oxford, UK:** *DPhil in Physical Chemistry,*
- **September 1998 – September 2001, Coventry University, UK:** *B.Sc. (Hons) in Applied Chemistry,*