Institution:
The University of Manchester

Unit of Assessment:
UoA08 Chemistry

Title of case study:
Organic Materials Innovation Centre (OMIC)

1. Summary of the impact

The activities of the Organic Materials Innovation Centre (OMIC) at the University of Manchester generate impact from its research activities through knowledge transfer to industry. This is exemplified by:

- Enabled UK SME ACAL Energy, through technology transfer and development, to create in excess of 20 jobs, raise £15m of venture capital investment to develop their FlowCath® fuel-cell technology.
- Enabled UK SME Byotrol, through improved understanding to develop novel anti-microbial technology which has been licensed to global fast moving consumer goods companies with sales of £2.19m per annum.

Provision of research-based training in the field of printed electronics and sensors to over 250 people from 2008 onwards.

2. Underpinning research

The impact is based on research that took place at the University of Manchester between the following key researchers:

- Professor Michael Turner (2004-date)
- Professor Stephen Yeates (2004-date)
- Dr Colin Booth (1993-1999)
- Dr Iain May (2000-2006) - lecturer
- Professor David Collison (1993-date)
- Professor David Procter (2004-date)
- Dr Andromachi Malandraki (2009) -PDRA

Electronic nose (1): Demonstration that arrays of organic field effect transistors can selectively detect airborne analytes in real time. The use of multiple parameters – on resistance, off current and mobility – collected from multiple transistors coated with different semiconducting polymers gives dramatic improvements in the sensitivity, specificity and speed of sensing.

Polyoxometallate chemistry (2): Research on the coordination chemistry of polymolybdate anions with zirconium, lanthanide or actinide heteroatoms. Careful manipulation of the Keggin ion structure $[PMo_{12}O_{40}]^{3-}$ lead to loss of $\{M{=}O\}^{4+}$ and gave the monovacant lacunary anion $[PMo_{11}O_{39}]^{7-}$, which has four unsaturated oxygen atoms available for coordination to a positive metal centre. This was confirmed in the solid state by single-crystal and powder X-ray diffraction studies and in solution by NMR, FT-IR and UV-VIS spectroscopy.

Micellisation and gelation behaviour of mixed surfactants (3): Investigation of the nature of the interaction of surfactant mixtures in aqueous solution on formation of hierarchical structures and subsequent gelation behavior.

Materials for organic electronics (4): The synthesis of substituted pentacene derivatives having optimised crystal structure for high hole mobility and their subsequent use in organic field effect transistors.

Heterocyclic chemistry (5): Central to the chemistry described in [4] is a new Pummerer process that provided rapid access to fluorous-tagged, heterocyclic frameworks that can be modified using a variety of approaches, easily purified by retention on fluorous-silica and the fluorous-tag cleaved reductively or oxidatively to give access to a diverse range of *N*-heterocyclic systems.

Effect of polymer additives on drug solubilisation in micellar systems (6): Investigation of the effect water soluble polymers on the uptake of hydrophobic drugs in micellar solutions. Increased drug uptake is rationalized in terms of synergistic interaction between the water soluble polymer and the micelle corona.

3. References to the research

Publications are in leading journals in the respective fields, having led to invitations to speak at international conferences. Citations are from Google Scholar.

Key Publications

1. Real-time vapour sensing using an OFET-based electronic nose and genetic programming. D.C. Wedge, A. Das, R. Dost, J. Kettle, M-B. Madec, J.J. Morrison, M. Grell, D.B. Kell, T.H. Richardson, S.G. Yeates, M.L. Turner, Sensors and Actuators, B: Chemical (2009), B143(1), 365-372. [citations = 11] DOI 10.1016/j.snb.2009.09.030
2. A rare structural characterisation of the phosphomolybdate lacunary anion, $[PMo_{11}O_{39}]^{7-}$. Crystal structures of the Ln(III) complexes, A.J. Gaunt, I. May, M. J. Sarsfield, D. Collison, M. Helliwell, and I. S. Denniss, Dalton Trans., 2003, 2767. [citations = 55] DOI 10.1039/B301995K
3. Micellisation and Gelation of Mixed Copolymers P123 and F127 in Aqueous Solution. C. Chaibundit, N.M.P.S. Ricardo, F. de M.L.L.C. Costa, S.G. Yeates, C. Booth, Langmuir (2007), 23(18), 9229-9236. [citations = 47] DOI: 10.1021/la701157j

Other Publications

4. High performance, Acene-Based Organic Thin Film Transistors, G. Rincon Llorente, M-B Dufourg-Madec, D.J. Crouch, R.G. Pritchard, S. Ogier and S.G. Yeates, Chem.Comm., (2009), (21), 3059-3061. [citations = 25] DOI: 10.1039/B901448A
5. A Fluorous, Pummerer Cyclative-Capture Strategy for the Synthesis of N-Heterocycles, L. A. McAllister, R. A. McCormick, K. M. James, S. Brand, N. Willetts, and D. J. Procter, Chem. Eur. J., 2007, **13**, 1032–1046. [citations = 25] DOI: 10.1002/chem.200601429
6. The effect of polymeric additives on the solubilisation of a poorly-soluble drug in micellar solutions of Pluronic F127. C.P. Oliveira, L.C.G. Vasconcellos, M.E.N.P. Ribeiro, N.M.P.S. Ricardo, T.V. de P. Souza, F. de M.L.L.C. Costa, C. Chaibundit, S.G. Yeates, and D. Attwood, International Journal of Pharmaceutics (2011), 409(1-2), 206-208. [citations = 9] DOI: 10.1016/j.ijpharm.2011.02.025

4. Details of the impact

The following exemplifies OMIC impact in teems of policy and up skilling industry as well as two examples of economic impact based upon research with SME deriving from basic research performed within the UoA.

OMIC [A,B,C,D]

Context: The Organic Materials Innovation Centre (OMIC) was established by initial funding of £4.25m from the Department of Trade and Industry in 2002 to the University of Manchester for work on knowledge transfer from academe to industry in the thematic areas of *Complex Fluids*, *Organic Electronics*, *Biomaterials* and *High Performance Materials*. Its success [A] led to an award from the North West Development Agency of over £8m (*ca.* £3m to Manchester) in October 2008 to start the North West Knowledge Centre for Materials Chemistry (KCMC, 2008-2012) [B]. In the first four years of operation (2008-12), the KCMC in Manchester has carried out 100 projects with industry for a value of over £5.4m which includes over £3.2M of industry income [C].

Pathways to Impact: OMIC enables effective knowledge transfer to industry through a flexible engagement model, which is attractive for the smallest SME through to the largest multinational. Flexibility is enabled through the ability to engage in projects as short as a few weeks with the ability through UoM procedures to put in place agreements between parties on a very short time scale. Projects have included embedding industrial researchers in the OMIC laboratories as well as OMIC scientists into industrial laboratories. Knowledge transfer is also facilitated through tailored

CPD and training events for industry in thematic areas where OMIC has recognized academic excellence.

Impact: Through its position as one of the UK's four academic, plastic electronics centres of excellence, as recognised in the House of Commons Select Report in 2008 [D], OMIC is a founding member of the Plastic Electronics Leadership Group and these activities are helping to advocate and shape the UK strategy in this emerging field and direct TSB funding in the area. Internationally, OMIC through Professor Yeates was invited to contribute as experts to the international White Paper from the Chemical Sciences and Society Summit (CS3) on 'Organic Electronics for a Better Tomorrow: Innovation, Accessibility, Sustainability' 2012 and also the EU project on developing the roadmap for digital fabrication 'Diginova'. As part of this advocacy, OMIC has hosted inward investment missions from Finland, Korea and Belgium as well as providing training to over 250 people in industry since 2008. Events have included 'Future generation solar cells' in 2008, 'Opportunities in printed solar cells', 2009, and 'Chemicals and materials for printed electronics', 2011. A recent survey by the Plastic Electronics Leadership Group confirmed that while the industry is still in its infancy, there are now over 150 businesses in the UK with activities in this field, more than double that of four years ago. Most of those are SMEs developing materials and devices but there are already some end-users such as De La Rue and Reckitt-Benckiser working to apply the technology in their products.

ACAL Energy [E]

Context: Fuel cells produce electrical power directly from chemicals and offer the potential to be a more efficient and clean way to generate power when compared to the combustion of fuels. Hydrogen-fuelled 10-100 kW fuel cells provide a cost-effective method for power production particularly at sites where lower life-cycle costs, cleaner and quieter operation, longer runtimes, and lower maintenance requirements are important. However concerns over cost and lifetime have limited their adoption. ACAL Energy is an UK SME developing a novel approach to the fuel cell cathode - the FlowCath® technology.

Pathways to Impact: ACAL Energy collaborated with the Collison and May (2) group by embedding a company scientist within the group and by consultancy from 2006, because of their expertise on polyoxometallates. This research led to the initial FlowCath® technology. Collaboration with the Turner and Proctor groups (5) through a combination of the flexible OMIC model, KTP and PhD funding on novel nitrogen-containing ligands is enabling more efficient fuel cells to be developed.

Impact: Since 2008 ACAL Energy has received £15m of venture capital investment, created in excess of 20 jobs and won the Carbon Trust's Polymer Fuel Cell Challenge. ACAL Energy's patented FlowCath® technology is the first example of a non-Pt based fuel cell cathode system and the first installation is now located in at the Solvay Interox Chemical Plant, UK. ACAL Energy fuel cells using a polyoxometallate catalyst compete with conventional electricity generators by reducing the platinum content by up to 80% which represents 20-25 % of the total cost of a system. These fuel cells show no deterioration in performance after 10,000 hrs of rigorous automotive test cycles (equivalent to 300,000 miles). This is comparable to the best light-weight diesel engines (100kW equivalent to a 2 L diesel engine) and exceeds the 2017 US Department of Energy (DoE) industry target for fuel cell powered vehicles. The durability of the fuel cells allows the system to be applied to stationary power applications where 40,000 hrs (10 years of product lifetime) operation is required. As a result ACAL Energy fuel cell units will be installed at the UK's first open access H_2 refuelling station to be located at Honda's manufacturing site in Swindon.

Byotrol [F]

Context: Cleaning products, such as bleach and alcohol-based products, stop working as soon as they dry, which allows bacteria and other microbes to quickly recolonize; a single surviving bacterium can produce up to 8 million descendants by the next day. In contrast, Byotrol technology which is based upon surfactant-polymer mixtures kills and destroys instantaneously bacteria and viruses and then dries to form a long-lasting antimicrobial barrier that stops germs from re-populating for up to 24 hrs.

Pathways to Impact: In 2007, Byotrol approached the University of Manchester based upon our previous work in the area of complex aqueous surfactant mixtures [3], and our then unpublished work on complex aqueous polymer-surfactant mixtures [6] with the aim of understanding the mechanism of long-lasting antimicrobial performance and of developing more effective and reproducible formulations which in turn could lead to a stronger IP position in this highly competitive market. This resulted in the filing of patent WO2010043863, which covers and exemplifies novel formulation classes, addressing the dual challenges of effective antimicrobial kill coupled with long term follow-on performance. This was continued by a one year Molecular Engineering Translational Research Centre (METRC) proof of concept grant in 2009-2010 and supported by a direct funded iCASE PhD 2009-13.

Impact: The research performed under the above engagement modes has contributed to the technology being further developed and optimized to provide reproducible, fast acting and powerful performance across all microbial classes [E]: bacteria, viruses, fungi, moulds & algae killing up to 99.99% of germs in 30 seconds when tested against the most stringent test methodologies including BS:EN 1276 Standard, BS:EN 13697 Standard, BS:EN 1650 Standard, BS:EN 14476 Standard and Residual Abrasion Testing methodologies. In 2013, Byotrol reported sales of £2.19m with a year-on-year growth of 12% per annum. Byotrol technology has been introduced into a wide range of consumer products across the healthcare, food and beverage and consumer goods sectors [E], through both direct sales and partnership with some of the world's leading brands including Boots, PZ Cussons, Heinz, Kimberley Clark, Marks and Spencer and Rentokil Initial Group (UltraProtect™).

5. Sources to corroborate the impact

A) Evaluation of University Innovation Centre's, Report for BERR, Tribal Consulting, March 2009. Independent report on success of OMIC over the funding period 2004-2008.

B) NW Science Strategy 2007-2010, NWDA, 2010. Establishment of KCMC and key partner role of OMIC.

C) KCMC report.2012. Report on performance of KCMC against agreed metrics from 2009-2012.

D) House of Commons Select Committee report on Plastic Electronics 2008. Recognition of OMIC of one of four UK centre's of excellence in printed electronics.

E) ACAL Energy, Chief Technology Officer. Corroboration of UoM and OMIC technology translation and support to ACAL Energy and ensuing impact.

F) Byotrol, Chief Scientist. Corroboration of UoM and OMIC technology translation and support to Byotrol and ensuing impact.