Institution: 10007857 Bangor University

Unit of Assessment: 08, Chemistry

a. Overview

Chemistry at Bangor focusses on **materials chemistry** and **chemistry at the life sciences interface**. Our ethos is to seek novel solutions to practical problems, and we operate in an openly collaborative and interdisciplinary manner – ensuring a critical mass of researchers much larger than the School of Chemistry's own research staff base. Our applied work is underpinned by boundary-spanning computational and theoretical research. The unit has been refreshed with considerable staff turnover, indicating a deep commitment by the institution, with 6 submitted staff having been recruited since 2007. Our work covers nanomaterials, photovoltaics, molecular electronics and sensors, to synthetic chemistry, chemical biology, bioactive natural substances and plant chemistry, immunology, drug delivery and clinical medicine.

b. Research Strategy

The School is relatively small for a UK School of Chemistry but we seek to transcend our size through specialisation in the twin foci noted above, and also through forging collaborations with researchers from other disciplines, such as biology, computer science, electronics and medicine. This provides a critical mass of research excellence far above the volume of the school itself. Bangor University is located in an economically disadvantaged region, which continues to qualify for EU economic Convergence assistance, and our strategy also includes working in partnership with government, agencies and businesses to bring our expertise to bear on issues of practical importance to the region and to encourage inward investment in developments of national and global significance.

Current position with reference to RAE2008.
We have maintained the overall strategy outlined in 2008, keeping our focus on materials science and chemistry at the life sciences interface. We have benefited from substantial investments in research facilities and infrastructure through University, HEFCW and other Welsh Government funding and have replaced staff who have retired or move with dynamic researchers in our core themes. Overall, we believe that this has allowed us to attain a critical mass of research staff of cognate expertise to achieve our long-term strategic vision for development. Our productivity has developed in our strategic priority areas, enabling us to increase the number and quality of publications: from ~140 peer reviewed journals papers in 2002-2007 to >170 papers during the (shorter) REF census period, with an increasing proportion of papers published in high profile journals. *e.g*. publications in journals with impact factors >4.0 has increased from 8% to 32%. We have maintained a substantial rate of grant capture from a wide range of sources and have a higher annual spend of both RCUK and EU framework funding than during the previous census period. Fundamental research which began in the RAE2008 period has now led to significant societal impacts (as exemplified by our two Case Studies). This has positioned us as a research centre of excellence for collaboration with industry, including regional companies, to aid economic development in Wales, the wider UK and institutions globally.

Achieving our strategic aims during the REF assessment period.
Our approach over the REF2014 census period has centred on building strength and depth in our two core themes. Recruitment of research-led staff in our areas of specialisation has refreshed and focused our staff base, with six submitted staff hired over the census period, indicating the continuing commitment of Bangor University to maintaining research excellence in Chemistry. This is further shown by our investment of ~£1M in laboratory equipment and infrastructure. Within this context, we have developed clear tactical approaches to implement our research strategy. We have ensured that new appointments are strongly research-led and fit with our chosen research themes and available infrastructure. We have prioritised the quality of our grant applications, to

enhance grant capture rates, through careful mentoring of applications. We have encouraged staff to raise their profile through publication, particularly in higher impact journals, using journal impact factors and article citations as important criteria in personal development plan analysis. To develop research expertise, international collaboration and to enhance the reputation of the School and University, we have actively encouraged outgoing (sabbatical leave, secondment) and incoming (visiting scholars) staff exchanges, presentations at international conferences and through lectures and seminars in other institutions in the UK and abroad. These developments are realised through discussion at staff meetings, personal planning with mentors are performance development reviews and by allocation of resources by the School Executive committee.

Our Future strategic aims.
Over the next 5 years, our major strategic goal is raising the international profile of the School and the University: we intend to enhance our reputation through strengthening international links and collaborations including wider participation in European programmes (Horizon 2020), and through greater engagement with RCUK and 'blue chip' charities. The long-term prospects of sustaining our research strategy are exemplified by its excellent fit with two of the four pillars of the Welsh Government's strategy laid out in *For our Future: The 21st Century Higher Education Strategy and Plan for Wales*: "Low Carbon Economy" and "Health and Biosciences". We believe that we will remain well-placed to continue to access structural funds in collaborative programmes. We plan to recruit one new academic member of staff in the near future. Additionally, we have appointed Dr. Leigh Jones (supramolecular chemistry) from National University of Ireland, Galway, who will start in Jan. 2014. Bangor University's Estates strategy envisions construction of a new chemistry building due for completion in 2017, demonstrating institutional commitment to the discipline and providing us with the opportunity to optimise our laboratories and other infrastructure. The £10M Welsh Government investment in a Bangor University-led Science Park, due for completion in 2014 will provide an environment for exploiting university research, as will the establishment by the university of the £46M Arts and Innovation Centre 'Pontio' which is due to open in May 2014.

c. People, including:

i. Staffing strategy and staff development

The underlying theme of our staffing strategy has been the recruitment and development of well-rounded academics that recognise opportunities in research, teaching and third mission activities. We have made a conscious effort to sustain critical mass in the two identified research themes, and compared to RAE2008, we have increased academic staff numbers from 14 to 15. As a relatively small research unit, we are unable to cover the entire field of chemistry. Therefore, in recent staff recruitment special care was taken to effect an alignment of appointees with the defined physical infrastructure and main themes of research in the School.

Three Professorial staff left during the REF2014 census period: Irvine, 2008, to take a post of Director of the Centre for Solar Energy Research at OpTIC, St Asaph (2008); Kalaji to full-time consultancy (2009); Ashwell to Lancaster University (2010). Other academics moving on were Drs Chass (2011, to Queen Mary, London) and Croft (2013, to Nottingham University).

These vacated positions were successfully filled with appointments at Professorial (Perepichka 2010, Paizs 2012) and Lecturer level (Davies 2008, Gwenin 2009, Tai 2009, Thomas 2012). Paizs, a world renowned researcher in the study of protein /peptide fragmentation pathways by mass-spectrometry, was appointed to lead the life science area. He previously held a double appointment at the Cancer Research Centre, Heidelberg and Arizona University. Gwenin and Tai also work in the Life Sciences area. Perepichka (University of Central Lancashire) was recruited to reinforce and strengthen research in materials, and specializes in Organic Electronics, allowing him to work as part of the pan-Wales Low Carbon Research Institute. Another materials scientist, specializing in inorganic nanomaterials, Thomas, came from Manchester. Davies specializes in computational chemistry and works closely with staff in the computer sciences department at

Bangor. Research in the two main themes is supported by a complement of technicians (6 FTE), who manage our instruments and facilities and provide general research support.

Staff career development.
All new staff appointees have been allocated reduced teaching responsibilities during their first two years of appointment to provide adequate time for the establishment of an independent research programme. Start-up funding totalling £95k with assistance to secure PhD studentships has been provided to new appointees. Special support and attention has been given to career development of early career researchers, encouraging them to collaborate with senior academics in the School and to develop their recognition outside the University at national and international levels. For example, Tai has worked with Baird, and currently leads the Bangor University component of a major INTERREG grant, while Gwenin collaborating with Kalaji and Baird, has achieved exciting progress in research on sensors for explosives and tuberculosis diagnostics, with substantial funding for industrial collaborative work.

The University achieved the European Commission HR Research Excellence Award in 2012, which acknowledges our alignment with the principles of the European Charter for Researchers and Code of Conduct for their Recruitment. The **Researcher Development and Concordant Group** oversees researcher development and addresses the standards of the Concordat to ensure that researchers are effectively supported in the University. To further enhance our provision for researchers, professional development opportunites for established staff are available in-house, monitored by the School's Research Committee. Several members of our staff have been promoted as recognition of their activity and success in research during the REF2014 period. These include Beckett, Chass, Holliman and P. J. Murphy to Reader, and Croft, Hughes, Lahmann and L. M. Murphy to Senior Lecturer. Davies was appointed to a lectureship from a temporary post. We encourage our staff to visit other institutions to enhance their expertise and to spread the reputation of Chemistry at Bangor. For example, Croft spent 6 months on sabbatical at MIT (to research ionic liquids), Holliman had two secondments at TATA Steel to work on dye-sensitized solar cells (2011-2013, see Case Study) and Thoss spent 2 months in Ghana on a RSC Analytical Chemistry Trust Fund Outreach Fellowship for studies in plant chemistry.

Equality and Diversity.
In accordance with Equality Act 2010, Bangor University has introduced its Strategic Equality Plan (http://www.bangor.ac.uk/hr/equalitydiversity/). The University has an active Athena SWAN group that is developing interventions to better support women working in sciences in the University: the University achieved a Bronze Award in 2011. This also helps enhancement of support for all staff, and since 2011 the University has developed a new senior academic promotions policy and process, agreed a new policy to improve gender representation on decision groups, and is now looking at enhancing career-break provision for academic staff. Currently female staff representation amongst School's academic staff is 33%, with 40% of our female staff in senior positions.

ii. Research students

PGR recruitment.
Doctoral training is a major focus and commitment in the School. Emphasis has been given to providing studentships for newly appointed staff members as a strategic priority, although all students have an experienced co-supervisor. In total we have recruited 48 PhD students over the census period from the following sources: 4 RCUK, 9 EU-funded, 28 from International Governments, 3 with Bangor University Scholarships and 4 self-funded. The RCUK funded students were supported by EPSRC-industrial CASE awards in collaboration with Morvus and TATA, and EPSRC-EngD with TATA and a DTA. EU-funded studentships were facilitated by the Bangor-led pan-Wales ESF-funded *Knowledge Economy Skills Scholarships* (KESS) Scheme. The KESS project delivers collaborative research projects and higher-level skills training in partnership with employers based in the Convergence area of Wales.

Total FTE of PhD student registrations in the School of Chemistry, were as follows:
29.0 (2008/09), 34.0 (2009/10), 32.0 (2010/11), 34.0 (2011/12), 26.5 (2012/13).

Our **training and progression** requirements are frequently reviewed, not least because our success in obtaining studentships through diverse routes with their own emphases and training needs. A flexible approach to the provision of training maintains a cohesive and integrated postgraduate research body, and ensures consistency in access to high-quality training opportunities and monitoring procedures. All PGR students have access to a broad spectrum of training provided centrally by the University, and by the School, including courses for those engaged in laboratory supervision. Training needs are identified by the student and supervisory panel during the annual reporting round. The School has effective measures in place to support the induction and orientation of research students. All PGR students have full access to all research facilities and equipment in the School and training is provided by qualified technicians and trained members of research groups. Support mechanisms for PGR students also include access to equipment available in research groups in other units at BU *e.g*. School of Electronic Engineering and the Biocomposites Centre (see below for details). Within the Aberystwyth-Bangor CAFMaD collaboration (2006-2011) annual conferences have been organised at which students made presentations and prepared proceedings papers. PGR students also make presentations annually at the Chemistry PGR conference, the Young Scientists Symposium (RSC sponsored local section, Bangor-Glyndwr Universities), and at national and international scientific conferences. The development of journal-paper writing skills is emphasised and all students submitting their PhDs are expected to have published at least one peer-reviewed journal paper.

PGR progress monitoring.
The University and the School of Chemistry use a variety of mechanisms to monitor its postgraduate research students and their programmes. Each student has a named supervisor and a Research Committee (2 academic staff) who monitor and review the students progress each year in accordance with University procedures. Monitoring mechanisms are robust and include: (i) fortnightly supervisory checks on engagement and progress, (ii) annual written reports on the progress of research, which are reviewed by the research committee with an independent chair and internal examiner, (iii) a probationary first year and at the end of the year the committee decides whether a student has the ability to continue with the PhD or be re-registered as MPhil. The efficacy of these procedures is evidenced by the fact that over the census period the School had a 98% pass rate and 75% of PhD students completed within 4 years, excluding those with extenuating personal circumstances.

d. Income, infrastructure and facilities

Research funding portfolio.
Our research funding portfolio (total spend £5.4M) includes RCUK, charity foundations, and EU framework funding. EPSRC-funded work in progress includes a grant to P.J.Murphy for work on synthesis of cylindrospermopsin alkaloids (£185k, 2012-2014). Holliman is part of a £5M EPSRC-funded consortium (SPECIFIC) developing innovative functional industrial coatings for buildings, and recently also worked with Prof Freeman (Biological Sciences, Bangor) on a major (£430k) NERC-funded study of the public health implications of rising Dissolved Organic Carbon in water supplies as a result of environmental change. A BBSRC-DTI grant (£202k) has supported collaborative work with Excelcyn Ltd on coupled biochemical processes. Baird obtained awards from the Wellcome Trust (£286k, 2009-2012) and Asthma UK (£184, 2008-2011) for work on biologically active synthetic mycolic acids.

The unit is particularly successful in obtaining funding from collaborative programmes through the European Regional Development Fund (ERDF), which are designed to build up the Welsh economy through industrial-academic collaboration. Over £3.2M has been awarded through this route during the census period. We have also been awarded Welsh Government Academic Expertise for Business (A4B) funding of £277k (2012-2014) for research and implementation of

methods for detection of tuberculosis.

Investments in infrastructure and facilities.
During the REF census period we have benefitted from approximately £1M in expenditure on new equipment and laboratory facilities. Two new NMR spectrometers, 400 and 500 MHz, were bought in 2012 for £440k. The 500MHz instrument is equipped with an off-line liquid chromatography facility, worth £60k. A suite of instruments has been bought through £155k Welsh Government funding for the Low-Carbon Research Institute for research on renewable energy technologies, supplying advanced absorption / photoluminescence spectrometers, electrochemical workstation, MW reactor, flash chromatograph, freeze dryer and other equipment. We have invested over £110k in refurbishment to expand the laboratory space for research, particularly to accommodate the expanding research groups of new staff members to lead the research in materials chemistry and chemistry at life interface.

Operation of specialist infrastructure and facilities.
The School's research benefits from excellent facilities and is well equipped for modern chemistry research including key infrastructure facilities: LC-NMR, GC, HPLC, GPC, GC-MS & LC-MS (EI, ESI, MALDI), TGA, DSC, pXRD, FTIR, AFM, SCM, ICP, AA, Cat2 biological lab, glove box facilities. These are all freely available to all staff, PGRs and contracted researchers. Through strong collaboration with other units in the University, access to a wider range of facilities is provided for research in both materials chemistry and chemistry at the life science interface, for example: Class1000 clean room, vacuum deposition facilities, facilities for testing solar cells, light-emitting devices, organic transistors and memory logic circuits, Raman microscope, AFMs, and other facilities for materials and surface studies at School of Electronic Engineering; preparative HPLC, GPC, BET, SEM, microcalorimeter and high-pressure reactors, small and pilot scale extraction reactors, and other facilities at the Biocomposites Centre, College of Natural Sciences. This has supported productive collaborations with industry regionally and nationally.

e. Collaboration and contribution to the discipline or research base

Research collaboration.
A range of collaborative activities are in place at regional, UK, inter-regional, and international levels, and all staff are involved in collaborative research with other institutions and companies in the UK or abroad. Some examples of high-profile collaborations are: **Baird's** international collaborations in Belgium (Pasteur Institute of Infectious Diseases, Brussels & University of Ghent), France (CNRS University of Montpellier II), Germany (University of Bonn), South Africa (University of Pretoria) and with the World Health Organisation (Geneva) on health-related research. Within the UK there are cross-disciplinary collaborations with Cardiff, Essex, Oxford and Strathclyde Universities, Public Health England & Wales, Southampton Hospital and Public Health England. In plant polymer research there is a productive link to Beijing Forestry University. **Perepichka's** research on organic electronics involves strong collaborations with researchers in Canada (McGill University), China (South China University of Technology), France (Angers University), Germany (Erlangen-Nürnberg University), Israel (Weizmann Institute of Science), The Netherlands (University of Groningen), Russia (Moscow State University and Russian Academy of Sciences), Spain (Universities of Malaga and Valencia), Ukraine (National Academy of Sciences) and USA (University of Texas). **Paizs** has collaborations with Oxford, Paris, Lausanne and US institutions (Universities of Indiana, North Carolina, Arizona, Washington) exploiting his ground breaking research into mass-spectrometric fragmentation of peptides and proteins. **Tai** has established strong joint research with the University of Ireland Galway on stimuli responsive polymers and she also collaborates with Utrecht and Washington Universities.

Exemplars of interdisciplinary research.
Many of the projects discussed already as interdisciplinary, but further examples are given below. We are actively involved in pan-Wales multidisciplinary research collaborations with other Welsh institutions in developing the low energy economy and in health care. BEACON (A Biorefining

Centre of Excellence for Wales: 2012-2015) - is a partnership between the Universities of Aberystwyth (Agricultural researchers), Bangor (Chemistry, forestry and materials scientists) and Swansea (Life Scientists) to jointly exploit 'bulk' and 'fine' chemicals from bio-based materials. The Centre for Advanced Materials and Devices (CAFMaD) integrates Chemists and Engineers at Bangor with Physicists at Aberystwyth, along with researchers in Singapore (National University of Singapore and Nanyang Technical University), supporting workshops and exchange visits. We participate in the HEFCW-funded pan-Wales program for developing the low carbon economy, the Low Carbon Research Institute, leading the photovoltaics theme (Perepichka, Holliman). Welsh Government A4B funding supports our chemistry researchers to work with companies such as Biocheck and AET for develop systems for detection of tuberculosis, while the €11M FP6 Nanosecure grant brought our chemistry expertise into a consortium 30 partners across Europe working to develop materials, sensors and methodologies to promote public security. Finally, the £5M EPSRC SPECIFIC consortium brings together engineers and chemists from Swansea, Imperial College London, Bath, Bangor and Glyndwr together with 15 industrial and governmental partners to work on developing novel coating materials to put on metals and glass that can be manufactured by industry in large volumes to produce, store and release energy at point of use.

Academic leadership and esteem within the School has been demonstrated by international awards, fellowships, visiting scholarships, consultancies, journal editorships, conference organization and lectures (plenary, keynote, invited) at international conferences.

Awards

Paizs has been awarded the ***Biemann Medal*** (American Society for Mass Spectrometry, 2011) "*for his seminal contributions to a comprehensive understanding of peptide ion fragmentation*" (http://link.springer.com/article/10.1007/s13361-011-0314-6). This is the highest ***world award in mass-spectrometry*** (the only other UK recipient is Prof. Dame Carol Robinson, DBE FRS at Oxford). **Baird** was honoured with a title of Extraordinary Professor by Pretoria University in 2008. **Perepichka** is a co-editor of the 2-volume *Handbook of thiophenes-based materials. Applications in Organic Electronics and Photonics* (Wiley, 2009). **Beckett** has been elected as Titular Member of IUPAC (Division VIII, Structure & Nomenclature, 2012-2013; re-elected for 2014-2015). He is Chair of an international Task Group (project titled 'Nomenclature for Polyhedral Boranes and Related Compounds', #2012-045-1-800) with the aim of revising boron-hydride nomenclature for future IUPAC approval.

Staff research fellowships.

Paizs was awarded a prestigious ***Heisenberg Fellowship*** (2009-2012, €250K) by the German Research Foundation (DFG). **Tai** won an EPSRC Life Science Interface Fellowship (2007-2011; £134k when in Bangor) and **Thomas** held a RCUK Fellowship (2006-2012).

Staff provide a broad range of consultancies and professional services to companies and within the materials chemistry theme include Johnson-Matthey, Polartech, Whitford, Pilkingtons (**Beckett**); TATA, Telsol (**Holliman**). Within the life science theme help has been given to Reckitt Benckiser (**Thoss**), Greener Polymers, and Covatec (**Tai**).

Journal Editorship.

School staff are members of editorial boards of international journals, e.g. *J. Am. Soc. Mass Spectrometry*, *Open Materials Science J, Plos One, Tuberculosis Research Treatment*. Our staff have also acted as Guest Editors for journal special issues *e.g. J. Am. Soc. Mass Spectrometry* (2008, **Paizs**), *Int. J. Mass Spectrometry* (2011, **Paizs**), *Isr. J. Chem.* (2014, **Perepichka**).

Organising Conferences.

Staff are active in the organisation of symposia and conferences at national and international levels, *e.g*. **Paizs** was an organiser of the 23rd ASMS Sanibel Conference of Mass Spectrometry (Florida, 2011), workshop at the 41st Annual meeting of German Society for Mass Spectrometry (Giessen, 2009) and the 18th International Mass Spectrometry Conference (Bremen, 2009); **Perepichka** was a co-organiser of a Symposium on Organic Electronics at the 21th International Materials Research Congress (Cancun, Mexico, 2012); **Chass** was a co-organiser of two UK-

Singapore two INYS Workshops (International Network of Young Scientists) on "Advanced materials and devices" (Singapore 2009, Aberystwyth 2010) supported by British Council; **Thoss** organised two National Conferences "Plants as providers of Fine Chemicals" (Bangor 2011, 2012); **Hughes** was a co-organiser of a Conference on Molecular Structure and Dynamics (Austin, 2009); **Beckett** is a member of the International Scientific Committee for International Meetings on Boron Chemistry (Imeboron), and is involved in planning Imeboron-XV (Czech Republic 2014).

Plenary/Invited lectures on International Symposia.

Baird gave a plenary lecture at 1st South Africa TB Conference (Durban, 2008,) and **Perepichka** gave a keynote lecture at the 2nd Symposium on Organic Chemistry (Sofia, 2008). Staff have also given invited lectures at the 11th International Conference on Electrical & Related Properties of Organic Solids (Piechowice, Poland 2008, **Perepichka**); the 1st South Africa TB Conference (Durban 2008, **Gwenin**); the 56th and the 59th ASMS Conferences (Denver 2008 and 2011, **Paizs**); the 8th International Electrochemistry Meeting (Antalya 2009, Perepichka); the 24th Asimolar Conference on Mass Spectrometry (Pacific Grove 2009, **Paizs**); the 7th IUPAC NMS-FCFP Conference (Shanghai 2011, **Perepichka**); the 21st International Symposium on Glycoconjugates (Vienna 2011, **Lahmann**); the IX International Krytun Summer School "Frontiers in Advanced Organic Materials for Next Generation Electronics" (Krytun, Poland 2012, **Perepichka**); the Gordon Research Conference on Gaseous Ions (Galveston 2012, **Paizs**); WUT International Symposium on Advanced Optoelectronic Materials and Devices (Wuhan, China 2013, **Perepichka**).