EPSRC Standard Research Report - Chemistry National Services: Mass Spectrometry Grant GR/R70088/01 "Continuation of the EPSRC National Mass Spectrometry Service Centre at Swansea to 31 March 2007" (extended to 31 October 2007)

PREFACE

This grant financed a National Service Centre and not a standard research project. As a national centre, the role of the National Mass Spectrometry Service Centre (NMSSC) at Swansea is to support high quality research rather than conduct its own, and the criteria against which its work should be measured are not those normally used to judge research, but rather those set by EPSRC for national services. The NMSSC (with all the EPSRC Chemistry Programme national services) has been reviewed by an external panel annually for the last four years, and passed with flying colours.

It should be noted that the 2001 funding request was not granted in full, and therefore some items in the application do not appear in this report.

INTRODUCTION

This grant provided funds for continuation of the EPSRC National Mass Spectrometry Service Centre at Swansea from 2002 to 2007, with a seven-month extension in 2007 to synchronise national services (making the total period 5 years and 7 months). The underlying objective of the Centre is to underpin high-quality chemical research in the UK by provision of state-of-the-art mass spectrometry for EPSRC supported research groups. The success of the service over the grant period ensured that UK chemists could be assisted to compete at international level without disproportionate costs for analysis. Additionally, substantial mass spectrometry training services and general advice were provided.

All objectives expressed in the grant application of 2001, as well as EPSRC's conditions and a customer "wish list", were met within the specified budget, and on schedule. Minimal disruption to the service was experienced at any time, even during times of long-term staff illness and restructuring of the host department.

The work of the Centre has been comprehensively monitored throughout the grant period by the return of Annual Reports to EPSRC. Additionally, it has benefited from the scrutiny of an external EPSRC "Cross Services Review Panel" each year, a process instigated in 2004. These reviews assess community demand, quality of research supported, service management, performance, training, and publicity, as well as giving an "overall" score. The NMSSC has been unique in attaining "green lights" in all the seven categories examined for the last three years, with only one non-green light ever (one amber in the first year of these assessments).

The excellent performance and track record of the Swansea NMSSC from 2002-7 is further attested by its recent renewal for a further five years after a comprehensive and competitive process (EP/F014341/1) for the period 2007 to 2012, £2.82M). Feedback from the Renewal Panel confirms that the renewal was achieved largely because of the excellent track record of the service over the period discussed in this IGR.

A Management Advisory Panel (MAP) consisting of chemists and mass spectrometry experts has been closely involved in the administration of the NMSSC over the whole grant period. The membership has been regularly reviewed, with an increased MAP size for the grant application exercise and a substantial rotation of membership once the renewal was confirmed. Professor Jonathan Williams (Chemistry Department, Bath University) assumed the Chair from Professor John Todd (Canterbury) in early 2007 and together with his MAP members are essential participants in formulating policy over the coming five year term.

Key advances made during the funding period were:

- introduction of a MALDI (Matrix-assisted Laser Desorption/Ionization) service with a concomitant research and development programme (details in Appendix, at the end of this report);
- extended scope of applications, particularly into interface areas of chemistry with materials and biomedical science;
- assessment, development and application of new methods, additionally to MALDI, to significantly increase range and capability of the service;
- extension into a new, second laboratory to accommodate additional services and new instruments;
- introduction of an electronic customer interface;
- improved and extended publicity;
- extended collaboration network, both nationally and internationally.

OVERVIEW AND HIGHLIGHTS OF THE SERVICE FROM 2002 TO 2007

Key statistics and performance indicators of the NMSSC for the grant period are summarised in Table 1. In assessing these statistics it should be noted that, although the expressed ambition of the 2001 application was to significantly increase output, subsequent EPSRC policy directed operation from "routine analysis" to a focus on more "complex" work. Laboratory throughput and turnaround statistics reflect this. A "submission challenge" exercise was also conducted by NMSSC management from 2005 onwards in response to EPSRC concerns, to actively discourage unnecessary sample submissions, in particular requests for "low resolution" analysis or economically driven demands. Comprehensive examples of the necessary requirement for the EI/CI (electron and chemical ionization) service were also collected by NMSSC management to help reviewers understand the unexpected, ongoing need for this service and the replacement of the critical instrumentation used to deliver it.

As well as the service related elements of the National Centre, reflected in Table 1, and the "key advances" mentioned in the previous section, the Centre was also actively engaged in other work falling into its remit. Such activities include the extensive formal and informal training programmes (for the community and for its own staff),

assessment of new technologies and subsequent purchase when expedient, engagement with other relevant bodies, and active participation at conferences and meetings. Examples of activities of these types include:

- Summer Schools in 2004 and 2006, for approximately 40 participants on each occasion;
- visits by technicians and academics from other universities, for training or instrument assessment, including Bristol, Imperial and Manchester;
- accommodation of local scholars and students requiring work experience, and American exchange students;
- integration of recent automation technologies, e.g., the Advion Nanomate;
- assessment of "LIFDI" (liquid injection field desorption/ionization), including a visit and demonstration by the supplier, and subsequent exchange of customer samples;
- investigation of ICPMS (inductively-coupled plasma MS) instrumentation and applications in 2005, by manufacturer demonstrations and RSC seminar attendance;
- assessment of new external atmospheric sources such as "DESI" and "DART";
- assessment of accurate mass instrumentation in 2002 and 2006, by structured sample trials;
- assessment of EI/CI alternative inlet systems in 2005 by a structured sample trial;
- extensive, ongoing assessment of the ever-growing pool of software with potential use for the electronic customer interface;
- collaboration with the Computer Science Department Masters programme at Swansea for development of software for trials and experimentation;
- collaboration with the Laboratory of the Government Chemist (LGC) on MS-related initiatives, being key players in development of the "Guides" on both accurate mass[1] from 2002-4 and mass spectral generation[2] from 2005-7;
- active participation in the Accurate Mass workshop at the International Mass Spectrometry Conference (IMSC) in 2003, as part of the accurate mass initiative;
- presentation of the issue of "Mass spectral quality" to the RSC meeting on "Achieving Reliable Mass Spectrometry Data: Back to Basics", in 2006.
- collaboration with American Society of Mass Spectrometry (Washington-Baltimore Discussion Group) for training courses;
- collaboration with the American company "NanoSys" for assessment and development of surface-assisted laser desorption ionization (SALDI) using nano-structured surfaces;
- other collaborations driven by the MALDI research project and detailed in the appendix.

TABLE 1: SUMMARY of NMSSC PERFORMANCE 1/4/2002 to 31/10/2007 using KEY INDICATORS

Demand: # analyses requested	180,000
Operation and output:	
# analyses allocated	98,500
# analyses performed	90,000
# accurate mass measurements	24,324
# samples analysed	38,000
# institutions supported	>50
# researchers supported: average p.a.	900
# research groups allocated a regular quota: average p.a.	169
# projects allocated a regular quota: average p.a.	335
% of projects directly funded by EPSRC	80%
# publications (total)	>2000
% analyses done for RAE [5, 5*]	46%
% analyses done for RAE [4, 5, 5*]	>85%
Customer feedback: positive comments	>99%
Sample turnaround rate (average # days to final result)	6.3
% samples for which successful analysis achieved	>99%
Spectrometer downtime (average for 6 instruments; includes unscheduled and preventative maintenance time)	2.5%

RESEARCH QUALITY

The quality of research supported by the national services is evident from the profile of the service users (see Table 1) and the stringent mechanism of filtering of applications, documented in the annual report, which is heavily biased toward EPSRC-funded research (as per EPSRC guidelines). These statistics show that over 90% of service time was dedicated to EPSRC-approved projects from more than 50 UK institutions. 80% of this time was used by projects directly funded by EPSRC grants, and approximately 2.8% by projects funded by other research councils. The quality of supported work is thus amongst the top rated in the UK with concomitant major scientific impact and economic benefit. More than 85% of time was spent on work for researchers from institutions with RAE rating 4 and above (2001 RAE), with 46% of work from institutions with RAE 5 and 5*.

Quality of the service provided by the NMSSC is of paramount importance in its operation, and the very positive feedback of service users (requested annually from all users) over the whole grant period attests to customer satisfaction. As well as the mass spectral data, additional quality was provided to service users by commentary on results where these were ambiguous, and analysing samples by alternative techniques, if initial analysis failed. The Centre has developed a good reputation for achieving results where other laboratories have failed, with the introduction of new techniques over the grant period allowing more than 99% of samples submitted to the service to

give a meaningful result. The "new" techniques included reintroduction of "old" techniques such as negative ion CI, and development of increased range of accurate mass methods and reference compounds, as well as development of new technologies such as MALDI.

The NMSSC makes a conscious effort to stay at the forefront of technology so that new developments can be used to advantage to further improve the quality of service when possible. The purchase of the Nanomate is a good illustration of this philosophy successfully in action.

Quality of science is also safeguarded by the NMSSC, with new accurate mass tables implemented from 2002 to take the electron mass into account, when it was realised that the ones in use were disregarding this factor (as was common practice in MS at the time). This change also required customers and journals to be notified and educated. In 2003, errors were noticed in the manufacturer–provided "Rings and Double Bonds" table valence values that were subsequently rectified and the company alerted.

RESEARCH PLANNING AND PRACTICE

A variety of statistics have been taken over the grant period (and many years before this) to give a meaningful indication of the performance of the Centre (see Table 1). Additionally, feedback from the Annual Review Panels, in spite of being overwhelmingly positive in the assessment of management practice in the NMSSC, has been useful in leading to improvements. Customer satisfaction, expressed annually, has also continually been very positive, but with suggestions and criticisms taken seriously and acted upon.

Flexibility of management to meet targets but also respond creatively to EPSRC and customer feedback, coupled with exemplary diligence of staff, have led to the maintenance of an uninterrupted, good quality service throughout the grant period, even in the face of much adversity (disruptive building work and the incorporation of new instruments and staff, followed by two simultaneous long-term staff illnesses and a maternity, and then total restructuring of the host department).

The low percentage of instrument downtime (average 2.5% over 6 instruments) has assisted productivity, and is of further credit to staff skill, good laboratory practice and wise purchase choices of robust and productive instrumentation.

POTENTIAL SCIENTIFIC IMPACT

The publication statistics in Table 1 reflect a huge potential scientific impact of the NMSSC. The high percentage of service users with EPSRC-supported projects (80%) and from highly rated institutions (46% RAE 5 and 5*) is indicative of the quality of science supported by the MS Centre. The NMSSC's relevance in the research process is underpinned by its fast turnaround rate and the good quality data and commentary provided.

The training projects and collaborations also contribute to the scientific impact of the Service, helping other scientists to use their equipment and understand their data more effectively. This impact is extending into the international arena by the recent invitation of the Service Manager to the ASMS (American Society for Mass Spectrometry) team teaching "The Interpretation of Mass Spectra" at the annual society meeting.

The NMSSC widens its impact further through its assistance of other university department services by the free contribution of methods and knowledge, when requested. The MChem. projects conducted within the NMSSC's own research programme (see Appendix) are also relevant.

STAFF OUTPUT AND TRAINING

Apart from the rapid throughput of more routine samples, the staff took time to comment on ambiguous results, respond to customer queries by telephone, post or email and repeat analysis of samples where submitted mass spectral data (obtained in users' home laboratory) was poor. They also collaborated with customers on projects requiring attention beyond the scope of the standard service. Publications by Centre staff are listed below.

All staff were also involved in the two Summer Schools and other training projects for external academic staff, technicians, postgraduates and undergraduates provided by the service.

Development of the NMSSC staff themselves was also important in the programme of this report period. The technician (G. Llewellyn) trained by the NMSSC was promoted to Experimental Officer when he joined the NMSSC full time in 2002, and the Centre's Administrator also achieved promotion through the additional skills she developed with progressions of the Service, in particular the electronic customer interface and the summer school. All staff were also encouraged to attend university courses hosted by the Staff Development Unit.

Unfortunate incidents during this grant term were the long-term illnesses suffered by two staff members. However, these did lead to the training of four temporary staff brought into the Centre to cover their absence, and now productively using these skills in other employment.

The new MALDI research project has met its varied objectives and extended the scope of the service considerably, including into new and interface areas of science, in particular materials and biological science. More detailed information about this project is given in the appendix.

COMMUNICATION OF RESEARCH OUTPUTS

More than 2000 publications and 29 patents have been published over the grant period using data obtained by the NMSSC, many of which are in first class journals. A tiny sample of these publications is listed on the IGR form. Additionally much of the Centre's own research has been published in journals and is listed on our website and includes collaborative work with national and international groups.

Much of the Centre's own research, in particular the MALDI project, has been regularly presented at national and international conferences (see references 20-29 in the publication list at the end of the report for details).

Output from the NMSSC to customers is also important to the success of the service. Data obtained is returned to customers as rapidly as possible, after being processed by qualified and experienced analysts (rather than

automated processes) to ensure clear and meaningful display of results. Analyst commentary contributes additional quality and clarity to the result.

Electronic communication with the customer base was initiated in November 2004 for the 2005-6 application round, and the electronic annual application form is now well established in its fourth year of successful implementation. An electronic results system has been developed subsequently, by the additional IT consultant time purchased by virement of funds (see financial section below) and has been launched at the beginning of the new grant period. In the tradition of the NMSSC, alternative ways of undertaking this transition have been carefully researched, so as to optimise the final product, implement it seamlessly, and avoid the common pitfalls of electronic systems. The 2007-2012 grant application details the further progress planned for the electronic interface, for which the groundwork has now been done.

PUBLICITY

The publicity portfolio of the NMSSC has been considerably extended over the last few years, after the Centre was alerted to some potential deficiency in this area by an amber rating (the only "non-green" ever!) in the Cross Services Review in 2004. Subsequently the work done and services offered by the NMSSC have been more widely publicised through mailing shots, national societies, increased attendance and profile at meetings (MS as well as applications-based), and the publication of more suitable material for display (posters 2m high) and distribution (flyers). The new umbrella department (School of Medicine) in the University has been particularly helpful in this regard, and the posters are permanently and prominently displayed in the School when they are not "on a job". The Centre's website has also been developed as part of this project and includes *inter alia* publications, reports and a new "Application Notes" feature. However, this was the area to suffer when the staffing and other difficulties were experienced, and more ambitious development of the site will now be done in the new grant term.

POTENTIAL BENEFITS TO SOCIETY

Because of the high calibre and wide variety of research supported by the NMSSC, the potential benefit to society of the Centre's work is very far reaching indeed. The "Research Highlights" offered each year as part of the annual report give a flavour of some of the useful and interesting applications of the supported science.

Additionally, the Centre adds value to public investment in universities by providing technical training and advice free of charge, thus helping them make better choices when purchasing instruments, and promoting better use of equipment already purchased. Practical help such as provision of technical methods, reference tables or materials is also available. Examples include instrument demonstrations at Swansea for Manchester and Bristol, and distribution of material and methods for electrospray accurate mass measurement to Surrey and Manchester.

As well as supporting highly rated projects, the Centre also provides time for young researchers and those with minimal local facilities. Additionally the Centre assists departments whose local facilities experience temporary failure or difficulty, so that disruption to their research is minimised. An average of three universities has been helped each year through an acute crisis, with 10 institutions evidently suffering this condition almost permanently, in a spot check in 2006.

The Centre also offers formal training of researchers, postgraduate students and technical personnel through the Summer Schools, two of which were held (2004 and 2006), with attendance limited to ~40 at each, to allow live instrument demonstrations. Four Swansea project students and three postgraduate students (one external, in a BMSS collaboration) have been trained in the Centre.

The NMSSC evidently also has some international interactions (although these are strictly limited), with visits from South African colleagues wanting to establish their own national service, and an American Exchange student accommodated for 100 hours in 2007. Several local scholars and a Cardiff University undergraduate student were also accepted into the Centre for work experience, at different times, as part of a social outreach.

FINANCIAL CONSIDERATIONS

The NMSSC has achieved all the objectives stated in the grant application of 2001 on time and under budget in all categories, illustrating both the good management and cost-effective nature of the Centre. Permission was obtained from EPSRC to reallocate funds on two occasions during the five years, when this was considered to be advantageous, and both decisions have since been proven sound. One was the continued employment of the IT consultant in place of the previously anticipated hardware and software purchases; the other was the use of commercial earnings and savings on maintenance (due to robust instrument performance) to purchase a refurbished NanoMate in 2006, which has subsequently revolutionised the electrospray service and proved a good illustration of cost-effective practice.

A second (new, improved model) TriVersa NanoMate was purchased at the end of the grant term in 2007, when it was seen that funds would be available due to the exceptionally good instrument record and low requirement for engineer assistance over the grant period. This inlet will be used to enhance the accurate mass service and further develop interface applications.

The pre-planned purchase of an Uninterrupted Power Supply (UPS) proved a wise decision, as it protected the more vulnerable instruments through several power surges / failures and prevented more heavy expenditure being incurred.

Even with the shift from routine to more complex analyses such as MALDI, the cost per analysis by the end of the grant term has been maintained at a modest £25.44 based on total analyses of 90,000.

A few items listed in the 2001 application are not in this report because they were not funded. These include the post of Technician, two postgraduate project students, and some Equipment and Exceptional items; *viz*. automation software, EI/CI/GCMS instrument (originally planned for 2004), MALDI "sample preparation unit", and magnetic sector instrument service contracts.

FUTURE DEVELOPMENTS

Future developments planned for the NMSSC are detailed in the recent grant application that secured continued funding for the next 5 years. They are therefore not discussed further here.

OTHER ASPECTS

During the grant period the University met its obligations written into the grant. The recent restructuring into Schools led to extensive consultations of where to place mass spectrometry, including discussions between the NMSSC Management Advisory Panel (MAP) Chair and the Vice-Chancellor. It was decided that the best option for further development of mass spectrometry is in the School of Medicine (SoM) where mass spectrometry is a strong component of the School and University Business Plan. In 2007 an Institute of Mass Spectrometry (IMS) was established, under the leadership of Prof. Brenton, as an umbrella body for the NMSSC and all mass spectrometry in the School. Additional appointments of a new Chair and Lecturer of Mass Spectrometry and a technician post have been made to the IMS. It has a team of four academics undertaking MS research, a number in collaboration with SoM research progammes, and will deliver postgraduate courses and an MSc in analytical mass spectrometry (2010).

Additionally, major financial input has included SRIF funding (£3.2M) for a bio-analytical mass spectrometry laboratory within the IMS (a joint project between Chemistry, SoM and the School of Biological Sciences) and a GC/MS system for the SoM, under operational control of the NMSSC. The University has promised to invest overhead back into mass spectrometry over the next three years and, since the grant was renewed, has moved two contract staff (Dr A. Hunter and Mrs H. Hewitt) in the NMSSC to permanent posts. In the upcoming grant we outlined the planned move to a custom facility for the IMS, including new laboratories and dedicated facilities for the NMSSC, in a modern life sciences research building due for occupation in 2010.

APPENDIX Report on the MALDI Research and Development Programme, August 2002- October 2007

The introduction of the matrix-assisted laser desorption/ionization time-of-flight (MALDI-TOF) service in 2002 was a source of major development for the NMSSC. The technique has given the NMSSC the scope to support totally new areas of science, but required specialised research to achieve this goal, as the work of the Centre widely falls outside the traditional uses of MALDI-TOF, and new methods needed to be developed.

The NMSSC MALDI project was primarily to develop use of the technique for samples presently not able to be analysed in the Centre, especially higher mass species, and then to explore the continued need for fast-atom bombardment (FAB) in the presence of MALDI. Once successfully deployed, MALDI would also be required to do accurate mass measurements, so this was an additional area of research.

Dr Mark F. Wyatt, took up an RA appointment in August 2002, as a MALDI researcher. His time was divided equally between MALDI research and service related tasks, there obviously being a lot of overlap between the two activities. After extensive trials and careful deliberation in 2001 and early 2002 a Voyager DE-STR MALDI-TOF spectrometer was purchased from Applied Biosystems and brought into service in December 2002. A collaboration for the development of sample preparation methods was also established with Applied Biosystems, and Dr Wyatt visited their facility in Darmstadt in August 2003 with six representative samples to benefit from the company's experience. (Samples included a cyclic, hydrophobic peptide, and some "difficult" samples such as sodium polyphosphate and polyrotaxanes. Although 2`-(4-hydroxyphenylazo)benzoic acid (HABA) matrix was found to work very well for the cyclic peptide, data for the "difficult" samples was no better than that already achieved by the Centre, so further method development was done at Swansea.)

Following discovery of the aprotic, charge-transfer matrix, DCTB (2-[(2E)-3-(4-tert-butylphenyl)-2-methylprop-2-enylidene]malononitrile), to promote formation of radical analyte ions, the application of MALDI to the analysis of organometallic and non-polar species has been highly successful, with many examples of novel analytes reported in Analytical Chemistry[14]. The success of this research project has led to the use of MALDI rather than FAB for the analysis of most non-polar aromatic and metal compounds in the NMSSC (although FAB is still essential for some applications and far from redundant).

To increase our understanding of the MALDI mechanism as a means to further success, a more detailed fundamental study of the analysis of metal compounds by MALDI followed, comparing mass spectra of first-row transition metal acetylacetonate complexes in MALDI and other ionization techniques. This study formed part of an MChem. student project[3].

With MALDI now an integral part of the NMSSC service, accurate mass measurement needed investigation. Initial findings on accurate mass measurement of positive radical ions were published in the Journal of the American Society for Mass Spectrometry (JASMS)[12] and indicated the instrument to be capable of the required accuracy and precision. In order to establish a validated method, standard reference materials needed to be identified. Porphyrins have the correct chemical properties, but a variety of compounds with appropriate substituents to provide sufficient calibration points across the relevant mass range were not commercially available. A collaborative synthetic project was therefore undertaken by an MChem. student, in collaboration with Drs S. Kean and A.E. Graham, at Swansea, and the work submitted for publication. The use of these standards for MALDI-TOF accurate mass measurement will be submitted to JASMS in 2008.

The accurate mass measurement of negative radical ions was studied by a BMSS-funded summer student in 2007, with the measurement of functionalised fullerenes a specific application. Existing porphyrin standards could not be used, but perfluorinated analogues were found to be very effective, so were synthesised for use.

The analysis of insoluble compounds by mass spectrometry is challenging and currently a hot research topic. Several researchers have recently investigated solvent-free preparation methods for MALDI characterisation of insoluble polymers and biological samples. We undertook a complementary investigation of insoluble metal

compounds, assisted by an MChem. student. A very recent breakthrough has been published as a communication in The Analyst[4] and a full publication is currently being prepared for submission to Analytical Chemistry.

In addition to the NMSSC's research objectives, collaborations with several national and international research groups have been established. These include work with the materials groups of Prof. Steve Howdle (Nottingham University) and Prof. Andy Cooper (Liverpool University), resulting in joint publications[5-8,11], and a collaboration with Dr Mariette Pereira (Coimbra University, Portugal) to develop improved methods of porphyrin synthesis to modulate their amphiphilicity for improved cancer treatments. A collaboration is ongoing with Dr Hugh Daniels of Nanosys Inc., USA, investigating new applications of matrix-free sample targets (surface-assisted LDI).

LIST OF NMSSC PUBLICATIONS

Best Practice Guides (with LGC)

1. *Methodology for Accurate Mass Measurement of Small Molecules - Best Practice Guide* co-ordinating editors K. Webb, A. Bristow, M. Sargent and B.K. Stein; LGC Ltd 2004, ISBN: 0-948926-22-8. http://www.bmss.org.uk/Docs/VIMMS_guide.pdf

2. *Best practice guide for generating mass spectra* V. Barwick, J.L. Langley, Tony Mallet, B.K. Stein, Ken Webb; LGC Ltd 2007, ISBN: 978 0 948926 24 2. www.vam.org.uk/publications/publications_item.asp?intPublicationID=1328

Refereed Journal Articles

3. *Analysis of transition-metal acetylacetonate complexes by matrix-assisted laser desorption/ionization time-of-flight mass spectrometry,* M.F. Wyatt, S. Havard, B.K. Stein and A.G. Brenton, **Rapid Communications in Mass Spectrometry,** 2008, 22, 11-18.

4. *Characterisation of organometallic and coordination compounds by solvent-free matrix-assisted laser desorption/ionisation time-of-flight mass spectrometry,* M.F. Wyatt, B.K. Stein and A.G. Brenton, **Analyst,** 2008, 133, 47-48.

5. *Strategies for the analysis of poly(methacrylic acid) by matrix-assisted laser desorption/ionization time-of-flight mass spectrometry*, M.F. Wyatt, N. Schaeffer, B. Tan, and A.I. Cooper, **Journal of the American Society for Mass Spectrometry,** 2007, 18, 1507-1510.

6. *Design of Polymeric Stabilizers for Size-Controlled Synthesis of Monodisperse Gold Nanoparticles in Water*, Z. Wang, B. Tan, I. Hussain, N. Schaeffer, M.F. Wyatt, M. Brust, and A.I. Cooper, **Langmuir**, 2007, 23, 885-895.

7. *Kinetics of Enzymatic Ring-Opening Polymerization of ε-Caprolactone in Supercritical Carbon Dioxide,* K.J. Thurecht, A. Heise, M. deGeus, S. Villarroya, J. Zhou, M.F. Wyatt, and S.M. Howdle, **Macromolecules**, 2006, 39, 7967-7972.

8. *One-Step Chemoenzymatic Synthesis of Poly(-caprolactone-block-methyl methacrylate) in Supercritical CO_2*, J. Zhou, S. Villarroya, W. Wang, M.F. Wyatt, C.J. Duxbury, K.J. Thurecht, and S.M. Howdle, **Macromolecules**, 2007, 40, 2276 (Addition/Correction).

9. *Synthesis, structures and mass spectrometry of lanthanide nitrate complexes with tricyclohexylphosphine oxide,* A.P. Hunter, A.M.J. Lees, A.W.G. Platt, **Polyhedron**, 2007, 26, 4865–4876.

10. *A homologous series of eunicellin-based diterpenes from Acalycigorgia sp. characterised by tandem mass spectrometry,* K. Kyeremeh, T. C. Baddeley, B.K. Stein and M. Jaspars, **Tetrahedron,** 2006, 62, 8770-8778.

11. *One-Step Chemoenzymatic Synthesis of Poly(ε-caprolactone-block-methyl methacrylate) in Supercritical CO_2,* J. Zhou, S. Villarroya, W. Wang, M.F. Wyatt, C.J. Duxbury, K.J. Thurecht, and S.M. Howdle, **Macromolecules,** 2006, 39, 5352-5358.

12. *Investigation into Accurate Mass Capability of Matrix-Assisted Laser Desorption/Ionization Time-of-Flight Mass Spectrometry, with respect to Radical Ion Species,* M.F. Wyatt, B.K. Stein and A.G. Brenton, **Journal of the American Society for Mass Spectrometry,** 2006, 17, 672-675.

13. *Application of Liquid Chromatography-Mass Spectrometry to the Investigation of Poisoning by Oenanthe crocata,* G.C. Kite, C.A. Stoneham, N.C. Veitch, B.K. Stein and K.E. Whitwell, **Journal of Chromatography B,** 2006, 838, 63-70.

14. *Characterization of Various Analytes using MALDI Time-of-Flight Mass Spectrometry and 2-[(2E)-3-(4-tert-Butylphenyl)-2-methylprop-2-enylidene]malononitrile Matrix,* M.F. Wyatt, B.K. Stein and A.G. Brenton, **Analytical Chemistry,** 2006, 78, 199-206.

15. *First general Solvent-Free Synthesis of Symmetrical Triindolymethanes using Acid-Washed Montmorillonite Clay,* M. Chakrabarty, S. Sarkar, A. Linden and B.K Stein, **Synthetic Communications**, 2004, 34, 1801-1810.

16. *Water repellency of sandy soils from the Netherlands and the UK: the role of high molecular mass polar organic compounds,* K.A. Mainwaring, C.P. Morley, S.H. Doerr, P. Douglas, C.T. Llewellyn, G. Llewellyn, I. Matthews and B.K. Stein, **Environmental Chemistry Letters**, 2004, 2, 35-39.

17. *The role of heavy polar organic compounds for water repellency of sandy soils,* K.A. Mainwaring, C.P. Morley, S.H. Doerr, P. Douglas, C.T. Llewellyn, G. Llewellyn, I. Matthews and B. K. Stein, **Environmental Chemistry Letters**, 2004, 2, 35-39.

18. *Oxidation of Guanine Nucleosides to 4-Amidinocarbamoyl-5-hydroxyimidazoles by Dimethyldioxirane,* R.J.H. Davies, C. Stevenson, S. Kumar, J. Lyle, L. Cosby, J.F. Malone, D.R. Boyd, N.D. Sharma, A.P. Hunter and B K. Stein; **Nucleosides, Nucleotides, and Nucleic Acids**, 2003, 22, 1355-57.

19. *Novel oxidation products from guanine nucleosides reacted with dimethyldioxirane,* R.J.H. Davies, C. Stevenson, S. Kumar, J. Lyle, L. Cosby, J.F. Malone, D.R. Boyd, N.D. Sharma, A.P. Hunter and B. K. Stein, **Chemical Communications**, 2002, 13, 1378-9.

Conference Presentations

20. *Further Developments in the Application of Solvent-free Preparation Methods for MALDI-TOFMS*, B.K. Stein, A.G. Brenton, and M.F. Wyatt; Poster presented at the **29th Annual Meeting of the British Mass Spectrometry Society**, held in Edinburgh, 9 - 12 September 2007.

21. *Further Applications of NALDI-TOFMS*, M.F. Wyatt, S. Ding, B.K. Stein, A.G. Brenton, R.H. Daniels, and C.M. Williams; Poster presented at the **29th Annual Meeting of the British Mass Spectrometry Society**, held in Edinburgh, 9 - 12 September 2007.

22. *Porphyrin Calibration Standards for Accurate Mass Measurement of Radical Ions by MALDI-TOFMS*, M.F. Wyatt, S.D. Kean, B.K. Stein and A.G. Brenton; Poster presented at the **17th International Mass Spectrometry Conference**, held in Prague, Czech Republic, August 27 - September 1, 2006.

23. *Application of Solvent-free Sample Preparation Methods for MALDI-TOFMS to Organometallic and Coordination Compounds*, L. Hughes, M.F. Wyatt, B.K. Stein and A.G. Brenton; Poster presented at the **17th International Mass Spectrometry Conference**, held in Prague, Czech Republic, August 27 - September 1, 2006.

24. *Investigation of Surface-Assisted (SA) LDI-TOFMS for the Characterization of Organometallic and Coordination Compounds*, D. Thomas, M.F. Wyatt, B.K. Stein and A.G. Brenton; Poster presented at the **54th Conference of the American Society of Mass Spectrometry**, held in Seattle, Washington, May 28 - June 1, 2006.

25. *Application of Solvent-free Sample Preparation Methods for MALDI-TOFMS to Organometallic and Coordination Compounds*, L. Hughes, M.F. Wyatt, B.K. Stein and A.G. Brenton; Poster presented at the **54th Conference of the American Society of Mass Spectrometry**, held in Seattle, Washington, May 28 - June 1, 2006.

26. *Investigation of Solventless Sample Preparation Methods for MALDI-TOF-MS*, L. Hughes, M.F. Wyatt, B.K. Stein and A.G. Brenton; Poster presented at the **28th Annual Meeting of the British Mass Spectrometry Society**, held in York, 4 - 7 September 2005.

27. *Analysis of metal acetylacetonate complexes by MALDI-TOF-MS*, M.F. Wyatt, S. Havard, B.K. Stein and A.G. Brenton; Poster presented at the **52nd Conference of the American Society of Mass Spectrometry,** held in Nashville, Tennessee, May 23-27, 2004.

28. *Investigation into accurate mass capability of MALDI-TOF-MS with respect to organometallic and highly conjugated compounds*, B.K. Stein, M.F. Wyatt and A.G. Brenton; Poster presented at the **52nd Conference of the American Society of Mass Spectrometry**, held in Nashville, Tennessee, May 23-27, 2004.

29. *Developments in the analysis of metal complexes by MALDI-TOF-MS*, M.F. Wyatt and B.K. Stein; Poster presented at **16th International Conference on Mass Spectrometry,** held in Edinburgh, Scotland, August 31 – September 5, 2003.