**Institution:** Imperial College London

**Unit of Assessment:** 8 Chemistry

**Title of case study:** C4 - Bio Nano Consulting: a successful bio and nanotechnology consultancy business

**1. Summary of the impact** (indicative maximum 100 words)

Bio Nano Consulting (http://www.bio-nano-consulting.com) was established as an operating business in 2007 through a joint venture between Imperial College London and UCL, whose formation was underpinned by research produced by Professor Tony Cass's group at Imperial. The company is the first consultancy in Europe to focus on the increasingly important intersection between bio- and nanotechnology, and it facilitates the development and commercialisation of new biomedical and nanotechnology-based techniques. Since its start-up, the company has attracted numerous clients across the aerospace and diagnostics sectors, including Lockheed-Martin and [text removed for publication]. The company's activities have generated £6M worth of revenue and it has a growing portfolio. The company, which is based in London, currently has 8 full time employees.

**2. Underpinning research** (indicative maximum 500 words)

The establishment of Bio Nano Consulting (BNC) was a direct consequence of a DTI grant [G1] under the Micro and Nanotechnology Manufacturing Initiative Capital Facilities programme in the specific area of bionanotechnology (awarded in 2005). Its remit was to help UK industry in de-risking new micro- and nanotechnology enabled biomedical devices, especially in the diagnostics sector.

In a series of papers, the Cass group at Imperial College demonstrated that the use of protein design and engineering, often in combination with nanostructured surfaces, could lead to novel sensor designs. The use of engineered extensions ('tags') to enzymes was shown to enhance their immobilisation on sensor surfaces. This work was in collaboration with the Universities of Warwick, Southampton and Texas (Austin) [e.g. 1]. A related collaboration with Prof E. Kobatake's group at the Tokyo Institute of Technology, funded by JSPS and BBSRC, was also focussed along the same lines [2]. Most of the research prior to this used very non-specific and poorly controlled chemistry to attach enzymes to surfaces, often resulting in significant and variable loss of function. Our work on engineered tags showed how they could be used to develop a more rational approach. In addition, the attachment of enzymes to nanostructured metal oxide surfaces was being investigated, through collaboration with Prof James Durrant and funded by the BBSRC [G2], and it was shown that a functional coupling between the hard and soft materials could be achieved [3-5]. The unique properties of the metal oxides meant that both optical and electrochemical signal transduction schemes could be used, so yielding a flexible design strategy. This resulted in the grant of a patent [6] with Cass, Durrant and Gilardi as inventors. These papers and the patent established the advantages of using engineered proteins with nanomaterials in producing novel diagnostic devices, as well as demonstrating the expertise of the Cass group in this area. It was this proven, internationally recognized expertise that led directly to the establishment of BNC and the early contracts that it won with diagnostics companies.

The personnel contributing to this research programme at Imperial were Academic staff members Prof A.E. Cass (1983-present), Prof James Durrant (1993-present), Prof Gianfranco Gilardi (Reader 1993-2011 then Visiting Professor 2011-present), and research associate Catherine Halliwell (1998-2002). The primary collaborators were the group of Prof E Kobatake (Tokyo), Prof P.N. Bartlett (University of Southampton). In the collaboration with Southampton, the contribution of the Cass group was to carry out all the protein engineering work and to characterise the engineered proteins in terms of their biochemical properties. Incorporating these engineered proteins into electrically conducting polymers and demonstrating the sensing aspects was done both at Imperial and in Southampton. Collaborating with the Tokyo group, we had already cloned,

engineered and fluorescently labelled the glutamine binding protein and this knowledge and materials (plasmids) were sent to Tokyo, where the new tag was attached and the behaviour of the immobilised protein characterised.

**3. References to the research** (* References that best indicate quality of underpinning research)


[1] Halliwell, C. M., Simon, E., Toh, C. S., Bartlett, P. N., & Cass, A. E., "*Immobilisation of lactate dehydrogenase on poly (aniline)–poly (acrylate) and poly (aniline)–poly (vinyl sulphonate) films for use in a lactate biosensor*". Analytica Chimica Acta, *453* (2), 191-200 (2002). DOI. **Times cited: 37 (as at 6/3/13)**

[2] *Wada, A., Mie, M., Aizawa, M., Lahoud, P., Cass, A. E., & Kobatake, E., "*Design and construction of glutamine binding proteins with a self-adhering capability to unmodified hydrophobic surfaces as reagentless fluorescence sensing devices",* J. Am. Chem. Soc., *125* (52), 16228-16234 (2003). DOI. **Times cited: 26 (as at 6/3/13)**

[3] *Topoglidis, E., Cass, A. E., Gilardi, G., Sadeghi, S., Beaumont, N., & Durrant, J. R., "*Protein adsorption on nanocrystalline TiO2 films: an immobilization strategy for bioanalytical devices*", Anal. Chem., *70* (23), 5111-5113 (1998). DOI. **Times cited: 140 (as at 6/3/13)**

[4] Topoglidis, E., Cass, A. E., O'Regan, B., & Durrant, J. R., "*Immobilisation and bioelectrochemistry of proteins on nanoporous $TiO_2$ and ZnO films*", J. Electroanalytical Chem., 5*17*(1), 20-27 (2001). DOI. **Times cited: 155 (as at 6/3/13)**

[5] *Topoglidis, E., Campbell, C. J., Cass, A. E., & Durrant, J. R., "*Factors that affect protein adsorption on nanostructured titania films. A novel spectroelectrochemical application to sensing",* Langmuir, *17* (25), 7899-7906 (2001). DOI. **Times cited: 112 (as at 6/3/13)**

[6] Patent, PCT Int. Appl., EP 1071945 B1, "*Biochemical devices and their methods of manufacture*", Inventors: Cass, A. E., Durrant, J. R., Gilardi, G., Applicant: Imperial College


**Grants**:


[G1] DTI, "A Bionanotechnology Centre", £3.74m (Imperial College element £1.5m), 2005-2010, PI: Tony Cass

[G2] BBSRC, E11939, "A novel strategy for bioanalytical and biocatalytic devices : biomolecule immobilisation on nanoporous TiO2 electrodes", 10/04/2000 - 10/04/2003, £191,904, PI: Prof J. Durrant, Co-Is: Prof A Cass, Prof G Gilardi


**4. Details of the impact** (indicative maximum 750 words)

The formation of Bio Nano Consulting arose from the realisation that combining the expertise at Imperial College (A Cass in nanobiotechnology and diagnostics, Tim Jones in nanomaterials) with that at UCL (G Aeppli in nanofabrication and M Horton in nanomedicine), and drawing on the National Physical Laboratory's metrology resources, would present a unique offering in Bionanotechnology to provide services to the UK's biomedical sector. Imperial College and UCL had already jointly established the London Centre for Nanotechnology (LCN) in 2003 and discussions had started on how to build on the academic excellence of the LCN to enhance its interactions with industry. A call for proposals in Micro and Nanotechnology Manufacturing Facilities by the Department of Trade and Industry in 2004 led to a successful bid by the consortium of the 3 organisations (late 2005) [grant G1]. The company was incorporated in October 2007, appointing the experienced Dr David Sarphie as CEO, who had "*over a decade's worth of senior management expertise in drug delivery, diagnostics and medical-device companies*" [A]. Following a total investment in infrastructure, instrumentation and working capital of £5m from the Technology Strategy Board (TSB) and London Development Agency (LDA), it was officially launched in April 2008 [A, B] as a "*specialist product development consultancy applying nanotechnology tools to address real-world problems from the biomedical industry*" [B].

In 2010, following steady growth in the business, Lord Alec Broers accepted the role of Chairman. By late 2010, BNC announced the completion of its publically funded phase of corporate development. To "*mark the company's transition to a self-supporting and revenue-funded organisation, BNC…acquired new expanded offices in central London to meet the increasing demand for its services and specialist expertise*" [C]. At that time BNC had "*completed 22 projects*

*for 16 life science and high-technology sector companies*" and, as an indication of its continued success, "*already [had] a further 10 projects actively in progress*" [C].

As a not-for-profit company, wholly owned by Imperial College London and University College London, the business has focussed on applying expertise in bio- and nanotechnology in the two universities to provide technical consulting services to UK and overseas companies and institutions. It offers four main services: consultancy services, project management services, contract research and development, and open access to instrumentation [D]. The BNC business model is to be a 'lableless' company, employing scientist and engineers, as well as project managers, who will deliver the project objectives and who carry out the research in collaborating academic institutions (Imperial and UCL). In doing so, it pays bench fees and equipment access charges to the Universities. Over the assessment period, the company has diversified both its client base and the type of projects that it has taken on. It currently employs 8 people (7 PhD scientists/engineers with backgrounds in chemistry, materials science and the life sciences) and has employed a yearly average of 13 people over the 2009-2012 period [Item 3, E, F, G]. It has generated £6M worth of revenues from both UK and overseas clients since 2008. During the 2009-2012 period, total revenues exceeded £4.6M of which 78% was attributable to overseas clients [Item 2, E, F, G].

BNC's business model of working closely with academic groups has resulted in £2.8M of the revenues being returned to the Universities through bench fees and equipment access payments, as described above [Item 5/'Research and development expenditure', E, F, G]. The company has filed 8 patent applications and is actively negotiating exploitation agreements for several of these. In total, the company has had approximately 14 domestic and international clients including: Oxford Immunotec Ltd., Applied Nano Detectors Ltd, Lockheed-Martin Inc., Vestergaard Frandsen, Targanta Therapeutics Inc., Linde A.G., King Abdulaziz University, [text removed for publication] [H]. The nature of the consultancy has been quite varied as is demonstrated in the examples below.

**Oxford Immunotech Ltd:** In the work with Oxford Immunitech Ltd, an international medical diagnostics company, that commenced in 2008, BNC applied "*its expertise in nano-characterisation to assist Oxford Immunotec in a project related to its novel Enzyme-Linked ImmunoSPOT (ELISPOT) system…Oxford Immunotec [were] commercialising a diagnostic test to detect tuberculosis (TB) based on its patented T-SPOT technology, effectively providing a new way to diagnose and monitor this deadly disease*" [I]. By collaborating with Oxford Immunotec, BNC facilitated the development of precise, accurate techniques to diagnose and monitor infection and disease. It developed and successfully transferred a method that allowed the client to implement an improved QC process for one of its bought-in assay components.

**King Abdulaziz University (KAU), Saudi Arabia:** In 2009 BNC was chosen to "*lead the UK arm of a collaboration with [KAU] in a multi-million pound environmental nanotechnology endeavour. The agreement, worth in excess of £2 million over two years for BNC and its London partners,… [utilised] the expertise of the London Centre for Nanotechnology (LCN…on two important projects looking at the applications of nanotechnology to environmental issues: 'nano-catalysts for wastewater treatment' and 'nano-catalysts for the synthesis of fine chemicals'*" [J]. In 2012, a further contract was signed with KAU "*for two collaborative research projects in the field of environmental nanotechnology… worth £1 million over two years for BNC and its London partners…The aim of each project will be to develop new classes of multifunctional nanomaterials that can pave the way for more sustainable and energy-efficient processes*" [K]. The work with KAU has resulted in 6 patents being filed and 10 publications (as of June 2013). The patents and publications were a direct result of BNC enabling an on-going, collaboration with Prof Milo Shaffer's group at Imperial.

**Targanta Therapeutics Inc (Now part of the Medicines Company):** Targanta Therapeutics Inc. approached BNC in 2008 for help in elucidating the mechanism of action of one its antibiotics (oritavancin), where the lack of a defined mechanism was seen as a barrier to obtaining FDA approval [L, M]. This project built on the BNC's experience with other antibiotics. BNC researchers

*"spearheaded the development of the label-free detection of antibiotic-mucopeptide interactions using cantilever arrays, achieving 100 pM sensitivity...This technique is now being made available on a commercial basis for the assessment of drug-target interaction for a broad range of other antibiotics and drugs under development*" [N]. This "*novel technique exploiting nanotechnology used in the micro-electronics industry presents the opportunity to speed up the discovery process for antibiotics and other pharmaceutical products, as well as many other diagnostic and therapeutic processes*" [L]. Commenting on the project Dr David Sarphie, CEO of the BNC said, "*We are thrilled to be working with a company of the quality of Targanta Therapeutics and to assist them in advancing their understanding of the mechanism of action of this new antibiotic drug candidate. This further establishes the BNC as a leader in applying cantilever-array technology to the assessment of drug-target interaction. In addition, it further demonstrates the important role that the BNC plays in the rapidly expanding bio-nanotechnology sector*" [M].

**Linde A.G.:** Working with Linde A.G., the company developed a method for separating carbon nanotubes that was very successful. The head of nanotechnology at Linde testifies: "*Bio Nano Consulting facilitated a program of collaborative work to advance a UCL/Imperial technology for the separation of carbon nanotubes from academic research to the point of commercialization. The team at BNC managed the overall project, organised regular meetings and ensured that all milestones and report deadlines were met in accordance with the agreed schedule…the responsiveness was vastly superior compared to similar projects at other institutions…Overall the project was a great success and resulted in not only the commercialisation of the technology, but the establishment of a new business entity in our company*" [O]. Linde subsequently spun out a company to develop this work further.

**5. Sources to corroborate the impact** (indicative maximum of 10 references)


[A] http://medicalphysicsweb.org/cws/article/research/33933 (Archived at https://www.imperial.ac.uk/ref/webarchive/fmf on 10/6/13)
[B] http://www.bio-nano-consulting.com/NewsAndEvents/Archive%20-%202008/LaunchofBioNanoConsulting.aspx (Archived at https://www.imperial.ac.uk/ref/webarchive/cmf on 10/6/13)
[C] http://www.mtbeurope.info/news/2010/1011038.htm (Archived at https://www.imperial.ac.uk/ref/webarchive/gmf on 10/6/13)
[D] http://www.bio-nano-consulting.com/ServicesAndExperts/OurServices.aspx (archived at https://www.imperial.ac.uk/ref/webarchive/gmf on 11/6/13)
[E] Bio Nano Annual Report, year ending 31 July 2010 (available here)
[F] Bio Nano Annual Report, year ending 31 July 2011 (available here)
[G] Bio Nano Annual Report, year ending 31 July 2012 (available here)
[H] CEO, Bio Nano Consulting
[I] http://www.azonano.com/news.aspx?newsID=7023 (Archived at https://www.imperial.ac.uk/ref/webarchive/hmf on 10/6/13)
[J] http://www.bio-nano-consulting.com/NewsAndEvents/Archive%202009/Saudi%20Contract.aspx (Archived at https://www.imperial.ac.uk/ref/webarchive/kmf on 11/6/13)
[K] http://www.bio-nano-consulting.com/NewsAndEvents/News/New%20KAU%20contract.aspx (Archived at https://www.imperial.ac.uk/ref/webarchive/lmf on 11/6/13)
[L] http://www.mtbeurope.info/content/ft1106001.htm (Archived at https://www.imperial.ac.uk/ref/webarchive/pmf on 11/6/13)
[M] Bio Nano Press release, 'Bio Nano Consulting commences first pharmaceutical project' 17/1/08, (available here)
[N] http://www.bio-nano-consulting.com/SuccessStories/SuccessStories/TargantaTherapeutics.aspx (Archived at https://www.imperial.ac.uk/ref/webarchive/nmf on 11/6/13)
[O] http://www.bio-nano-consulting.com/Testimonials/Testimonials/Linde%20AG.aspx (Archived at https://www.imperial.ac.uk/ref/webarchive/mmf on 11/6/13)