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AN EPSRC VIEW OF THE NANOTECHNOLOGY HORIZON

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Abstract

This paper gives a perspective on Nanotechnology research policy from the UK Engineering & Physical Sciences Research Council (EPSRC) having a mission to support the highest quality research and related postgraduate training for the benefit of the UK. The paper reviews the UK approach to the support of Nanotechnology and the importance of user engagement in shaping the long-term research agenda. The paper comments on future prospects for the UK.

1. Background

Nanotechnology is suddenly extremely fashionable. Its importance is expounded in government reports, ministerial pronouncements, funding agency policy documents, and the popular scientific press. This must be the first time that a size scale has generated such interest; certainly science did not proclaim "milli" or "micro" eras -other than in specific areas of application (e.g. microelectronics). In part the excitement is generated by the mind-boggling challenges of the precise manipulation of matter at such tiny length scales (equivalent to 1/80,000th the diameter of a human hair). However, it is the potential for important applications of nanotechnology, in manufacturing, medicine, information technology, processing technologies, and elsewhere that has forced it from the realms of science fiction to industrial reality.

It needs to be stressed that nanotechnology is not a field of science as such. Rather the term has come to cover an amalgam of tools, techniques and processes for the precision manipulation of matter at the nanometre scale. The microelectronics industry pioneered many of the technologies, in pursuit of the goal of maximising the packing of components on an electronic chip; to minimise size, power consumption, and cost -and to maximise speed and profits. The lithographic techniques that revolutionised the microelectronics industry then found wider application to other micro- devices. At the same time advanced tooling was producing miniature devices with hitherto unimaginable precision. However,

moving from the micro to the nano meant that the research challenges change, as the properties of the macro-world give way to the quantum phenomena of the atomic and molecular world. And now a choice is available - to construct nano-devices "bottom up", molecule by molecule -or pursue the "top down" precision machining to finer and finer scales. The multi-disciplinary nature of nanotechnology calls on physicists, chemist, materials scientists, biological scientists, mathematicians and engineers. They need to work in multidisciplinary teams - a form of behaviour that requires special forms of encouragement.

Early attempts in the late 1980s-early 1990s to promote the importance of nanotechnology in the UK met with mixed success. The then Science and Engineering Research Council, SERC (the predecessor to EPSRC), had an initiative in nanotechnology, and used a specialist co-ordinator to identify new opportunities and provide catalyst funding. Some interesting projects resulted -most notably in the early demonstrations of the potential application of nanotechnology for medical devices. But a decade ago many research leaders appeared not to be ready to respond to a centrally - generated attempt to catalyse new research activity in nanotechnology. The perceived low level of investment in nanotechnology in the mid-1990s drew criticism from the UK Parliamentary Office of Science and Technology. That situation has changed spectacularly in the past few years, to the point where central co-ordination to stimulate research seems unnecessary - and indeed may be counter- productive since once a field of research catches the imagination of leading research teams then they demonstrate an effective ability to work within existing funding regimes. Although dependent on definitions (which in the realms of nanotechnology are not always clear) current EPSRC investment in nanotechnology research, in all its guises, is ca £25M pa, (mainly through the responsive mode grants mechanism.) However there have been some recent centrally led initiatives in nanotechnology - the most noteworthy being the establishment of two Interdisciplinary Research Collaborations (IRCs). There are sponsored by EPSRC, MRC, BBSRC, and MoD. One is centred at Oxford University, and has a distinct biological sciences focus. The second is centred on Cambridge University, with a stronger physical sciences focus. Each is funded for six years - with a

government investment of over £9M per centre. In a further attempt to address the multidisciplinary nature of nanotechnology, and to forge partnerships between researchers and users, several Networks have been formed. And specialist training courses are now been offered to address the shortage of key skills.

An evaluation of the nanotechnology research portfolio supported by EPSRC, carried out by a peer panel including prominent industrialists and overseas researchers; presented a broadly optimistic assessment of UK research in nanotechnology. But many challenges remain -not least in the training of a future generation of researchers skilled in the methodologies of nanotechnology and comfortable working in such a highly multidisciplinary field.

2. User Pull

Whilst policy makers may not now have a central role in catalysing research opportunities, an urgent task for policy makers is to relate research requirements to potential user need. With a very few exceptions (the most noteworthy being pharmaceuticals and aerospace), UK industry has found it difficult to address a long-term research agenda and define research challenges for academia comparable in intellectual content to when the researchers set their own research challenges. The national Foresight programme has been successful in networking senior individuals from industry, academia and government. However, it is a moot point whether Foresight has had a significant impact on the national research agenda. The first round of Foresight from 1993 to 1996 over-looked the potential of nanotechnology - although in the 1997 to 2000 round the Materials Foresight panel did promote the importance of the field.

If left to itself it is unlikely that even the visionary parts of UK industry would take the lead on nanotechnology. The field is still at a stage where it is not unreasonable for industry and government to share the investment risk. Yet there are many obvious areas of application. It has been estimated by the

Venture Capitalists "Evolution Capital" that the global market generated by breakthroughs in nanotechnology could be in excess of £700 billion pa. In pharmaceuticals it is estimated that within a decade half of all drug production will be based on nanotechnology. Nanotechnology will presage the next wave of advances in the communications and electronics/photonics sectors. Miniature devices for selective drug delivery and minimally-invasive diagnostic and surgical techniques will revolutionise medicine. In the chemical sector such areas as nanostructured catalysts, novel coatings and advanced ceramics will all benefit from research in nanotechnology.

A UK government Advisory Group has recently identified six key application areas deserving of focused attention. These are -

- Informatics -including structure electronic devices, displays, photonic crystal structures, and quantum information processing;
- Drug delivery systems -including polymer-drug conjugates, nano-particles, liposome and polymer micelles and dentrimeters;
- Tissue engineering, medical implants and devices -including external tissue implants, in-vivo testing devices, and medical instrumentation;
- Applications from novel materials -including nanostructured materials, smart composites, and biosensors;
- Instrumentation, tooling and metrology -tools for top-down manufacture, e.g. high resolution and soft lithography, and nanometrology;
- Sensors and actuators -including medical diagnostics and implants.

The advances projected for nanotechnology are extremely attractive from a sustainability perspective - with miniaturisation of components (designed to maximise recycling) making a reduced demand on non-renewable resources, and lower power consumption from miniaturised devices saving on energy.

With many top researchers now fully engaged, and industrial opportunities clearly apparent, the issue now to be addressed is the realisation of competitive opportunities and the engagement of industrialists and venture capitalists.

3. Will the UK be able to respond?

The inability of major UK companies to respond to new technological opportunities is not an encouraging precursor to a booming UK nanotechnology industry. As so often has been the case in the past for pioneering technologies, many major UK companies are adopting a "wait and see" approach to nanotechnology. One should not feel too despondent with such an attitude. Once new technologies are firmly established then major UK companies have demonstrated an adroitness to acquire the knowledge and skills they need to absorb the new technologies through acquisition. If there is a strong UK research base in an area, then this can act as a magnet for inward investment. Finally the dramatic increase in science-based start-up companies in recent years could drive the UK nanotechnology revolution (providing the feedstock for the major companies to pick the technologies they need later though acquisition). The UK photonics industry demonstrates the combination of these effects. Although the communications industry is presently in the trough of a dramatic market down-turn, the demand for increased bandwidth augers well for the future of the photonics companies once the network providers start re-investing (which they most certainly must do if they are to meet consumer demands for increased speed of internet access). The UK photonics industry was nurtured by the strength of the academic research base following sustained SERC and EPSRC investment in research, by inward investment, and by start-up companies coming out of academia. What photonics has and is achieving provides a blue-print for the emergence of a nanotechnology industry for the UK -but with a spectacularly greater potential

breadth of application than photonics. If this established pattern is to be followed, then start-up nanotechnology companies addressing niche markets will emerge. There is already evidence that this is happening.

In these circumstances, then the best path for the UK government to follow will be to continue to nurture the fiscal environment for high-technology start-up companies, to catalyse the investment of private venture funds in such endeavours, and to continue to offer flexible support for long-term research and the provision of a skills base needed to underpin new nanotechnology-based industries. In addition the UK government Advisory Group has proposed the setting up of a national centre or network of virtual centres offering product development, prototyping and incubator facilities for the nascent start-up companies in nanotechnology.

The future for nanotechnology in the UK looks reasonably bright. The excellence of the research base and the ingenuity of UK researchers, are not in question. Entrepreneurial skills are improving. Opportunities for start-ups emerging from research advances in academia are burgeoning. Skills shortages remain a problem to be addressed, but a start has been made to address the problems. And with time more academic researchers will come to recognise the benefits that arise when researchers from cognate disciplines come together to address the multidisciplinary challenges of nanotechnology.

The prospectus for "Nanotec-UK" presents a most persuasive case for investment.