

Submission
No 11

INQUIRY INTO NANOTECHNOLOGY IN NEW SOUTH WALES

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Re: Submission to the Inquiry into Nanotechnology in New South Wales

Dear Committee Members,

Thank you for the opportunity to make a submission to the NSW Legislative Council's Standing Committee on State Development's inquiry into Nanotechnology in New South Wales.

The University of Western Sydney (UWS) has a strong research presence in Nanotechnology and consequently is interested in ensuring that the results of our research and development can benefit not only the industries and community of NSW but also of the Nation.

The University of Western Sydney supports a research theme in Nanotechnology in the College of Health and Science. This theme spans a diverse range of disciplines. There are four main research foci:

- Characterisation
- Materials
- Natural Bio Molecules
- Medical

with each area covering a broad range of research activities.

Our comments below address the following items from the Terms of Reference of the inquiry:

- a. Current and future application of Nanotechnology for NSW industry and NSW community;
 - d. The adequacy of existing education and skills development opportunities related to Nanotechnology;
 - e. The adequacy of the National Nanotechnology Strategy in the NSW context;
 - f. The level of community understanding of nanotechnology and options to improve public awareness of nanotechnology issues.
1. UWS published a report in December 2007 titled *Nanotechnology in South-West Sydney: Pathways for Cluster Development* by C Martinez-Fernandez, T Weyman and K Leever. This report discusses the extent of

Nanotechnology uptake in South-West Sydney, the educational importance in this field and best practices of Nanotechnology clusters. A series of recommendations are made.

The Report is attached to the submission.

The report presents much material that is relevant to the terms of reference of this inquiry, not all of which is reproduced here. We recommend this report for further detail of the points made below.

2. Nanotechnology is now a very broad field indeed that is impacting on extremely diverse fields from electronics to pharmacology, biotechnology to aerospace, food science to optoelectronics etc. It is anticipated that explosive growth in the application of Nanotechnology techniques will occur in a variety of fields including medicine, energy, environment; robotics, manufacturing, commerce etc (see report for more details). It is clear that Nanotechnology research involves cross-disciplinary research with a diverse range of disciplines. With such a diverse range of applications, it will be very difficult to construct a regulatory regime which is applicable to all areas of Nanotechnology that does not disadvantage some. It is unlikely that blanket general coverage will be either possible or desirable.
3. Due to the massive growth in Nanotechnology applications, jobs requiring Nanotechnology training will grow requiring a significant increase in Nanotechnology education and training at the tertiary level. Some statistics relevant to this topic are presented in the report.
4. As a relatively new branch of science, the public is really only aware of what is presented in the mass media. This type of coverage is never adequate for informed debate. In particular there is currently significant discussion in the USA and Europe around the use of nanomaterials in food. It would be highly deleterious to the broad field of nanotechnology if one area is targeted in this way without differentiation from other nanotechnology areas. A concerted education campaign around the general topic will be required.
5. It is also clear that new technologies can be exploited too rapidly in some areas that may have deleterious impact on the community. As a consequence a regulatory regime for some areas will be required, but as such must not stifle areas where benefit can be (is being) derived from the technology. Regulation on health, safety and environmental issues must be specific.
6. The National Nanotechnology Strategy report makes some sound recommendations. We are not willing to comment on the adequacy of the strategy in the NSW context. However, we would strongly recommend that NSW (and indeed all states) should have input to the National Strategy to ensure that Australia does not end up with 7 different state based regulatory regimes which would inhibit national benefit from Nanotechnology research and development.
7. Finally, the areas covered by the term Nanotechnology are growing strongly and will without doubt be one of the central themes covered in the Review of the National Innovation System currently being carried out by DIISR. The results of this review will be presented in a green paper at the end of July 2008. The Standing Committee should be aware of this Green Paper as it may provide information relevant to their report.

I hope that these comments are constructive and useful. The University of Western Sydney will be happy to cooperate with your inquiry as we believe this to be an issue vital to the nation's industrial development.

Yours sincerely,

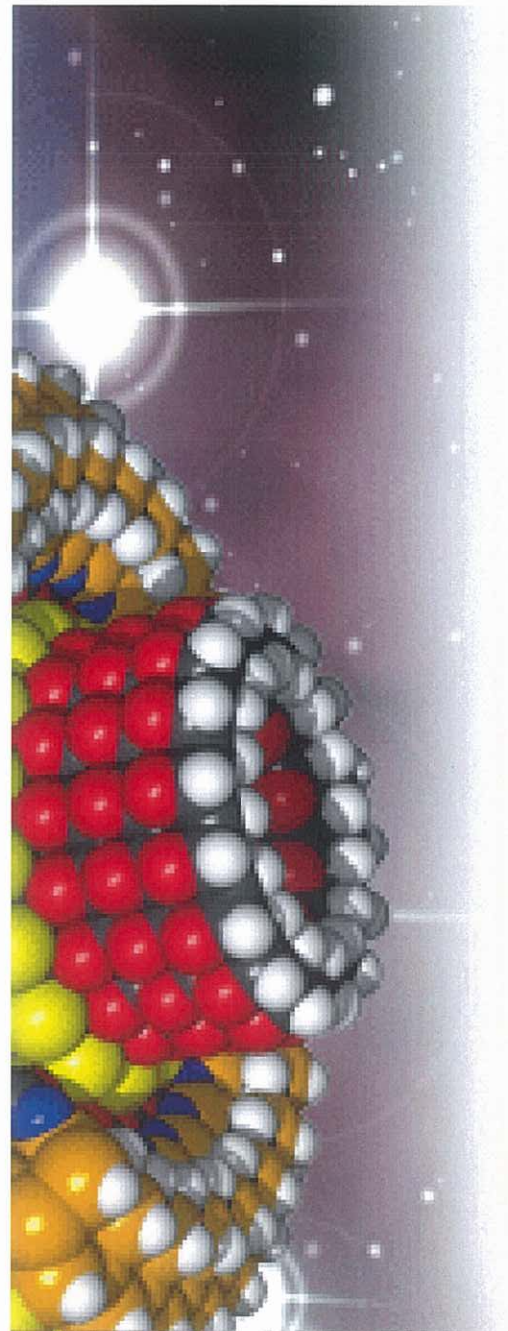
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Nanotechnology in South-West Sydney: pathways for cluster development

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December 2007



Acknowledgements

This report has been prepared by Dr Cristina Martinez-Fernandez. Tamara Weyman of the Urban Research Centre and Kim Leever of the Office of University Engagement participated in data collection, literature review, desktop research and analysis. Gabriela Rago and Marc Rerceretnam provided research services. Our gratitude to participating firms and institutions from South West Sydney and the city of Dresden.

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Executive Summary

This report discusses the extent of nanotechnology uptake in South-West Sydney, the education imperative in this field, and best practices of nanotechnology clusters. The following recommendations can be drawn.

First, *entrepreneurship needs to be encouraged* in the region. This can be in the form of supporting spin-outs from university researchers, financing areas of incubation of start-up companies and raising the number of formal collaboration projects between UWS and companies and between the core nanotechnology firms and SMEs. Public funding support and advice is necessary for the launch and growth of start-ups and in this regional and local institutions have an important role to play.

Second, *stimulating innovation and collaboration* will ultimately fuel the development of a nanotechnology cluster. This can be done through the continue focus on technology transfer already initiated by UWS but also fostering collaboration between different players in the network. Neutral agencies can best serve as brokers to facilitate this dialogue. Another mechanism that can be used is to eliminate administrative barriers that hinder people mobility from university to secondments into industry and vice-versa. Collaboration also needs to be encouraged between clusters at the national and international level in order to avoid knowledge local lock-ins. The UWS Nanotechnology Network has developed a 'knowledge interaction space' which is worthwhile and facilitates the process of dialogue between interested actors in the region.

Third, *coordination of public policies and regional initiatives* is necessary to create strong partnerships such as those discussed in the cases of Dresden and Grenoble clusters. Developing a joint strategy for the cluster is as important in the process as the financing or the scientific knowledge base.

Fourth, *ensuring quality human capital* will provide knowledge that is relevant for the region and prevent skills shortage especially if an education and skills strategy is planned by network companies with local knowledge providers. As the cluster develops, ensuring the availability of local talent will become an issue and the region needs to be ready to attract external talent early on so that slowdowns do not detract new players from settling in the region. For this to be achieved the area needs also to present a quality setting for people to move into and local authorities need to be part of these strategic developments at an early stage of planning.

Fifth, *facilitating access to financing* is critical for firms, and it has already been indicated by the small survey conducted in 2006. The three main strategies for this role are encouraging private investment by for example involving private investors in the activities of the cluster as it happens in the Grenoble cluster. Facilitating access to public funding for innovation in SMEs is also critical for the development of a cluster. Creating forums to seek financing and organising events around this topic will build the capacity of firms to finance their innovations.

Sixth, *industry clusters need a core of leading companies* that can drive the cluster and ultimately impact the economic development of the region. The UWS Nanotechnology Network is an excellent initiative of technology transfer in which emergent companies in South-West Sydney can build their leadership of the industry.

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1. Introduction to the Report

This report has been prepared for the UWS Nanotechnology Network hosted by the UWS Office of University Engagement (OUE). The report discusses a small survey conducted in 2006 by the OUE, nanotechnology careers and learning models of nanotechnology networks.

For this report, we define nanotechnology as the design, characterisation, production and application of structures, devices and systems that entails controlling the shape and size at the nanometre scale (Royal Society 2004). According to Roco and Bainbridge (2005) Nanotechnology offers rapid advances across many areas of science and engineering crucial to society. Education and human resources are the most fundamental, for without enough well-trained scientists and engineers, we will not be able to take advantage of the benefits of nanotechnology. Without a widespread, accurate awareness of the basic facts of nanoscience, the public and policy makers will not have the knowledge to make informed decisions about nanotechnology and its products. Box 1 shows some of these basic facts:

Box 1: Nanotechnology impact in society

- Productivity and equity – The effects of nanotechnology are expected to stimulate improvements in work efficiency in almost all sectors involving material work.
- Future economic scenarios – Breakthrough in nanoscale science and engineering can launch and sustain systemic economic progress. Nanotechnology will lower input costs in some industries, dramatically improve productivity in others, create entirely new industries, increase demand for some goods and lower demand for others. The net result will be significantly increased real wages and improved standard of living, with only a transitional increase in unemployment as labour and capital are shifted to new, more valuable uses from those that have been superseded or made less valuable.
- The quality of life – Nanotechnology will help ensure that we can produce enough food; water resources; energy technology; and preserve the environment.
- Future social scenarios – over the coming 10-20 years, civilisation will transition from the relatively crude technologies society demands upon today to more efficient and environmental friendly nano-enabled technologies.
- Converging technologies – Much of the impact of nanotechnology will occur through its convergence with other fields, especially biotechnology, information technology and new technology based on cognitive science.
- National security and space exploration – Nanotechnology provides advantages in the ability to gather, communicate, digest, and act upon information with advanced sensors, and to take requisite action with platforms that will have augmented capacity.
- Ethics, governance, risk and uncertainty – We need information systems that facilitate two-way conversation. Innovative technologies bring about unintended consequences.
- Public policy, legal and international aspects – Although there has been a significant increase in funding for nanoscale science and engineering, the perception is that we are still under-investing.
- Education and human development – The Nanotechnology Revolution will be social and cultural as well as scientific and technological, because it creates an opportunity to integrate education across science, technology, social sciences and even humanities. Nanotechnology will fulfil the mission of liberal education to make students into critical thinkers, capable of participating in intelligent debates about how societies ought to be transformed. The end result will be informed, educated publics emerging from our high schools and colleges, able to shape the direction of nanotechnology in beneficial ways.

Source: Roco and Bainbridge (2005)

Nanotechnology in SWS: Pathways for Cluster Development

Background research conducted in 2003 and 2005 highlights that UWS plays a significant role in providing knowledge and information on nanotechnology to the local industries in South West Sydney. The imperative for industries to take advantage of frontier technologies and the commensurate demand for highly skilled staff coupled with the shortage of people with these skills, places the university/industry/school nexus at a critical point for the development of the manufacturing industries in the region. This report intends to provide an understanding of the elements of successful nanotechnology networks and the future employment needs in this industry both for the firms in South-West Sydney and for the highly skilled graduates from the UWS B Sc. (Nanotechnology) course.

The 'UWS Nanotechnology Network' has been oriented to meet the following strategic priorities of the Campbelltown-Camden region:

- Improving regional employment opportunities for local people, especially young people;
- Develop and support local industry and attract new sustainable, environmentally friendly industry;
- Education and training at all levels; and
- Raising the profile of the region as a centre for science, innovation and emerging technologies such as nanotechnology and advanced manufacturing.

Ongoing benefits of the continuation of the Network are:

- Improved knowledge of emerging opportunities in nanotechnology for industry, especially the advanced manufacturing sector;
- Improved knowledge of skills requirements for industry to be able to realize the above benefits;
- Improved information for schools and students in choosing careers in industries in the local area thus retaining the benefits of the talented young people in the region; and
- Enhanced networks between UWS, secondary schools, TAFE and industry.

The report is divided in five sections. Section 2 after this introduction focuses on the level of industry participation in the UWS Nanotechnology Network as well as other innovation related information. Section 3 discusses nanotechnology careers for the future. Section 4 discusses two learning models of nanotechnology clusters in Dresden and Grenoble. Section 5 offers some conclusions and recommendations.

2. The UWS Nanotechnology Network

South West Sydney (SWS) is the strongest growing sub-region in Sydney, with 32 percent population growth since 1991 and expecting 200,000 new residents in the next 20 years. However, this growth in population does not correspond with the growth in employment which is lower than Sydney Metropolitan Area average. The largest employment sector in SWS is manufacturing with 18.10% of the labour force. The majority of firms are Small and Medium size Enterprises (SMEs) from the metals, glass, and building and construction industries and with an average turnover between AUD50,000 and AUD99,999.

One of the characteristics of SWS is the low levels of knowledge occupations which impacts the capacity of firms to innovate and to concentrate on the high value-end of the industry. For example, a recent business survey shows that most knowledge is accessed from within the local area and the Sydney metro area (Martinez-Fernandez et al, 2007). This strong embeddedness in the region has also the consequence of limited global connectivity and most manufacturing firms are unaware of the revolution of nanotechnology in global manufacturing. Regional embeddedness is therefore producing lock-in effects that threaten the sustainability of the industry in the short and medium term. This situation has brought significant concerns to industry bodies and policy makers in the region.

The complexity of the problem has been partially addressed through the project initiated by the local university (University of Western Sydney) in 2003 and funded by the Federal Department of Transport and Regional Services (DoTaRS) 'Sustainable Regions Programme' with AUD255,000. The objective of the project was to identify and build nanotechnology business potential in South West Sydney Region, specifically in the area of nano-materials. The University (UWS) aim was to work with existing organisations including local and regional peak industry associations to:

- Identify existing enterprises with potential for application of nano-materials technology;
- Facilitate and support development of networks and new enterprises applying nano-materials technology; and to
- Enable access to funding opportunities for industry and product development with concomitant research and training, including research and development granting schemes.

The project was designed to provide a space for conducting 'Knowledge Intensive Service Activities' (KISA) where the UWS Office of University Engagement would organise these activities providing specific knowledge, current research, specialised information and opportunities to discuss nanotechnology and possible applications to manufacturing processes. The UWS Nanotechnology Network is formed by academics, research students, industry, business people, government representatives and community groups that meet quarterly to discuss, attend lectures or seminars and showcase products. Activities are summarised as:

- Quarterly meeting of interested parties: presentations, showcase, discussions. Regular attendance of over 50 people with a stimulating agenda involving UWS Academics, Business, Industry, Government, Research Students and other presentations;
- Networking space: informal, friendly and relaxed atmosphere;
- Network newsletter (2C 10⁻⁹);

- Dedicated website www.uws.edu.au/nano
- Mailing list of over 500 people;
- TV program (community television);
- Schools engagement program engaging high schools and students (Sci-High);
- Linkage of multiple stakeholders in the region and multiple audiences; and
- Ongoing dialogue with policy makers.

The innovativeness of the project first refers to the focus of the initiative in engaging local business in a extremely complex scientific field; nanotechnology, which is still little understood by the community, including the scientific community.

The project focuses on supporting strategic development of manufacturing firms through the engagement with a local knowledge institution, the University of Western Sydney. The innovation component resides on placing the focus not at the science level but at facilitating a 'networking infrastructure and space' as a non-formal vehicle to stimulate dialogue between scientists and business people. This focus allows scientists to bring their internationally acquired knowledge to local firms which have limited international exposure. The knowledge transfer occurs outside the classroom, is more individually focused to particular enterprises and is tailored to local needs in the region.

The project has opened a dialogue between multiple stakeholders and multiple audiences in the region, especially in relation to one of the challenges facing SMEs in Australia and particularly by manufacturing firms in this region: the shortage of talent, especially regarding science and technology specialists. One of the activities (Sci-High) focuses on high school students and teachers exposing them to the meaning of nanotechnology and their practical applications to manufacturing products before students choose their career path.

To ensure the project positively contributed to the region there is a strong emphasis placed upon identifying and evaluating the opportunities that arise from the network activities and the soft infrastructure developed. The project has been evaluated via three small business surveys and case studies in 2003, 2005, and 2006 and three in-depth case studies in 2005. The industry break up in the 2003 survey of the network (279 members) shows that the majority of business are in manufacturing (32%), followed by business services (19%), government (17%), university and research and education organisations (29%) and other businesses in the area of biotechnology, ICT, health or packaging (3%). Of the 33 responses of the 2003 survey, only 27 percent of these firms knew about nanotechnology and only 6 percent were using nanotechnology. Six percent had plans to introduce nanotechnology, 24 percent were in partnership with a university conducting a particular project and 42 percent of the firms wanted to network with other members of the network.

The 2003 and 2005 surveys found that manufacturing firms applying nanotechnology were more reluctant to trust in-house sources of knowledge and information while in the case of software, tourism or mining technology services industries, internal sources of knowledge are more important for the firm (Martinez-Fernandez et al, 2005b,c,d; Martinez-Fernandez & Leever, 2004). This difference might relate to the early path creation of nanotechnology if compared with more established technologies. Consultancy firms (KIBS), industry associations and government departments have only a small role in the co-production of knowledge in both cases.

Results of these surveys indicate that the perceived barriers for the introduction of nanotechnology in the firm's product development have more to do with issues of 'relevance and

information' than with the market or the need for expertise. While funding is seen as a barrier to the introduction of nanotechnology by 29 percent of the respondents, issues of relevance for the firm and of information seem to be far more important for industry (72% of respondents). The contribution of network approaches such as the UWS Nanotechnology Network relates to the dissemination of nanotechnology information and the provision of a quality, well planned context where to discuss nanotechnology with other interesting parties, showcase current commercialisations and discuss new business prospects and discoveries by university researchers.

These surveys also suggest that scientific knowledge is driving nanotechnology agendas and that knowledge intensive service activities facilitated by local universities might have a high impact on firms' competitiveness as universities are partners in co-production of innovation. It also suggests that suburbs/regions with manufacturing business have the potential to apply nanotechnology in the medium term as nanotechnology greatly applies to many manufacturing processes such as materials, cosmetics, coatings, metals etc.

Overall this project shows that nanotechnology research and industry engagement is fragmented in South-West Sydney. The focus of research specialisation and KISA in certain sectors such as plastics, electronics, nanomaterials, nanomedicine, medical technologies offers good prospects for the future, especially with a new centre for nuclear magnetic resonance (NMR) opened at the UWS Campbelltown Campus in mid 2006. The case studies undertaken in 2005 show that partners in the innovation process of nanotechnology are from the local area, therefore policies and programs to develop networked nanotechnology innovation systems need to have a focus at the regional and local level. Local networking strategies and especially those linking industry and university research departments are needed to advance the field in the medium to long term in a way that is relevant for these firms.

2.1 Key results from the 2006 industry survey

In May 2006 a new survey was undertaken among 314 companies participating in the UWS Nanotechnology Network database and the Innovative Technology Network database of the UWS Office of University Engagement. 49 businesses returned the survey, a 15.6% response rate. 76 companies (24.2%) declined to fill out the survey as it was not relevant to their organisation operations. The survey was composed of 15 questions focusing on employment issues, expenditure, business strategy, research and development, partnerships for innovation and participation in the UWS nanotechnology network.

At the employment level, 47 people have been employed in a nanotechnology related jobs in the last 12 months although 31 out of the 47 were employed by just two companies. Existing employees in nanotechnology related occupations worked in product or service development and specifically in the fields of Materials Science; Electronics/Electrical Engineer; Strategy, sales & marketing; R&D and Engineering research of materials; and Policy submissions/settings.

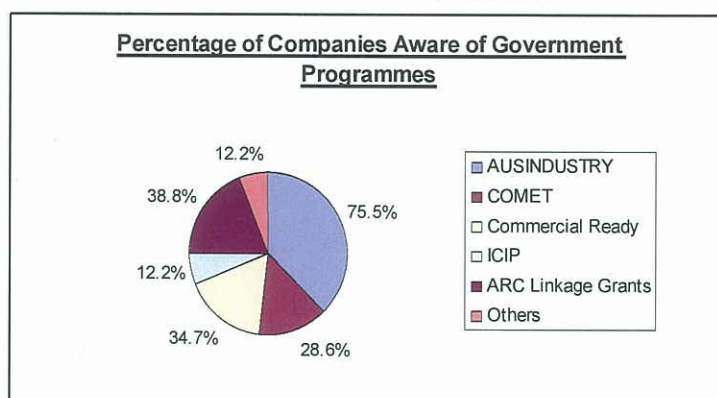
Similarly more than half of the anticipated 51 new employees in nanotechnology over the next 12 months will be hired by these two companies. The educational level required is tertiary education at the Bachelor level first, followed by PhD and Master Degree. The majority of required occupations are at the level of chemistry; biology and physics (see Table 1).

Table 1: New recruitment over the next 12 months

Nanotechnology Related Occupation	Bachelor	Master	PhD	TOTAL
Biologist	5	1	6	12
Physicist	3	0	6	9
Researcher	2	1	2	5
Psychologist	0	0	0	0
Chemist	17	0	8	25
Engineer	4	1	1	6
Pharmacists	0	0	0	0
Managers	4	0	0	4
Marketing	0	0	0	0
Lawyers	0	1	0	1
Social Scientist	0	0	0	0
TOTAL	35	4	23	

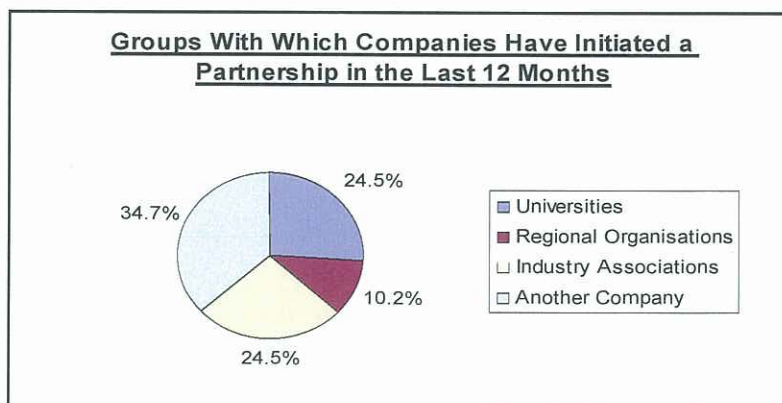
Expenditure in nanotechnology related research and development was small, the majority of companies expend under \$20,000. Most companies also did not have any specific strategy to increase the number of activities related to nanotechnology even if up to 71.4% of the companies were aware of research and development tax concessions and other programs (see Figure 1).

Figure 1: Companies aware of Government programs



Companies are engaged in partnerships for nanotechnology development, particularly with other companies and with universities (see Figure 2).

Figure 2: Partnerships for Nanotechnology



Firms were asked about their level of satisfaction with the services provided by the UWS Nanotechnology Network. Up to 26.5% of the companies were satisfied or very satisfied and the majority of companies (44.9%) indicated 'neither as their response' and only 4% indicated dissatisfaction. The 'neither' response was triggered by firms responding to the survey that have not been able to participate in many of the network events. There is certain interest in participating in short courses with up to 46.9% of firms indicating they would like to attend these types of training events (half a day been the most popular answer) specially related to the following themes:

- How to apply nanotechnology and benefit
- Carbon nano-tube reinforced plastics
- Funding, collaborations and equipment for study of nanotechnology
- Health and safety issues
- CVD diamond coating
- Australian resources, that is, publicity of scanning microscopy
- Application in paints & coatings
- How to best fit nanotechnology in with our business
- Paper security and credit card security
- Dispersion of nanoparticles
- Mechanical applications of nanotech
- An overview of nanotechnology - run for local businesses in Penrith

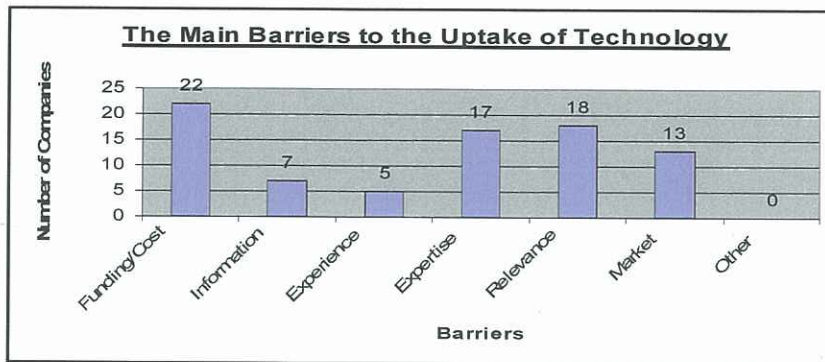
Firms were asked about their most important sources of knowledge regarding nanotechnology. Overall, 'customers' are the most important source of information followed by in-house sources, suppliers, universities and research institutes, conferences, journals and meetings, the Internet and business networks. Consultants, government departments, fairs, and industry associations have only small importance or are not relevant (see Table 2).

Table 2: Sources information for nanotechnology (highest frequency of responses only)

Sources of Knowledge	Not relevant	Small Importance	Medium Importance	High Importance
Within the firm				
Other firms within industry group				
Competitors				
Customers				
Consultancy firms				
Suppliers				
UWS				
Other Universities				
Research Institutes				
DSRD				
Conferences, journals, meetings				
Internet, databases				
Business networks				
Fairs / exhibitions				
Industry associations				

As in previous surveys, firms were asked about the main barriers to the uptake of nanotechnology. In 2003 and 2005 firms have indicated the main barrier was the lack of relevance of nanotechnology to their businesses. The 2006 survey indicates that ‘funding’ is the main barrier (see Figure 3).

Figure 3: Barriers to the uptake of nanotechnology



Overall results from the 2006 small survey indicates that nanotechnology is still fragmented in South-West Sydney although there are certain evidences of concentration and growth in the case of two particular companies that account for most of the employment growth, investment and development prospects in the region. At the occupational level material science is one of the hubs of development although employment has been created in other fields as well such as electronics and engineering. At the occupational level chemistry, biology and physics are the main disciplines from where university graduates and higher degree graduates are being recruited. Universities and research institutes still very important for innovation partnerships but other companies and in particular customers are the most significant source of nanotechnology information and knowledge. As knowledge of nanotechnology becomes more available firms are able to apply the new science to their businesses and ‘relevance’ is no longer the most important barrier to the uptake of nanotechnology but funding of the applications.

Results from the small surveys conducted during the life of this project have to be taken with caution because due to the small number of responses – still they provide an indication of the rapid change of the field in the region and the adaptation of manufacturing companies to what can be one of the most significant applications in the new millennium.

3. Nanotechnology Careers

Skills development in nanotechnology is still in its infancy and linked to university higher research degrees indicating its dependency on the critical research carried out all over the world (Bhat, 2005, Compano 2002). Perhaps one of the most prolific areas in relation to nanotechnology patents is the pharmaceutical field contributing to improve drug solubility/bioavailability and/or delivery to various sites of action in what is called 'nanomedicine' (Moghimi et al 2005). Nanotechnology is also being applied to the manufacturing of new therapeutical devices so the application is not only in the laboratory but also at the hardware level (Chapman 2005). Biotechnology and chemical industries are also among the most important users of nanotechnology worldwide, especially due to high public investment (DeFrancesco 2003). Nanomaterials are receiving increasing attention in the technical community and the public at large (Osman et al 2006).

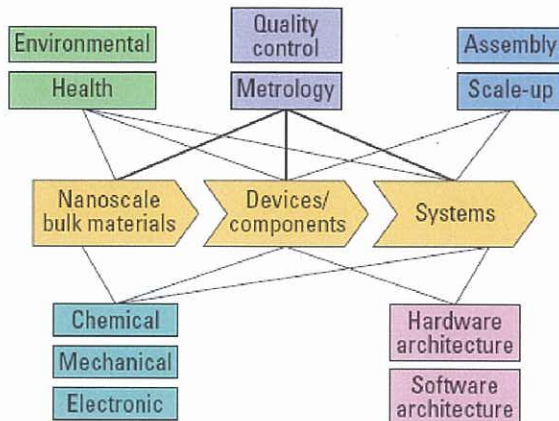
Still, if nanotechnology is going to produce the radical changes to industry that are predicted in terms of 'new style of knowledge revolutions' (Hough 2004), education and training systems need to be much more aware of the needs to create a strong nanotechnology and nanofabrication workforce. For example students need exposure to nanofabrication facilities which at the moment are very limited in most countries and non-existent in technical colleges. The education and training imperative is critical and it might constitute a challenge for our college and university degrees (Fonash 2001).

At the level of patents the single technology field "Chemistry: molecular biology and microbiology" and chemical industry remain in the lead worldwide (Huang 2004) and leading countries at the level of performance are France followed by Japan and Canada (Marinova 2003). Nanotechnology is emerging as one of the principal areas of investigation that is integrating chemistry and materials science, and in some cases integrating these with biology to create new and yet undiscovered properties that can be exploited to gain new market opportunities (Zhao et al 2003).

The annual market for products that carry nano-components, including all computer chips, half of pharmaceuticals and half of chemical catalysts, will reach \$1 trillion by 2015 affecting the way science and industry address medicine, food, electronics and the environment (Lim 2004). However, there are widely expressed concerns that commercialisation will be long and hard (Mazzola 2003). The estimations for employment worldwide is in exceed of 2 million nanotechnology workers by 2015 (Roco 2001, 2003, 2005).

Trade in special nanoparticulates and nanodevices have been hampered by concerns about quality and safety of the products. Globally, a new International Organisation for Standardisation (ISO) technical committee was recently established to develop international nanotechnology standards (ISO/TC 229-Nanotechnology). The need for standardisation with respect to quality control and metrology is listed explicitly for activities related to nanoscale bulk materials, devices and components, and final systems (See figure below).

FIGURE 1 Nanotech Career Opportunities For Quality Practitioners



Source: Nembhard, 2007

3.1 Education and Training needs

Education and skills development have been identified as the greatest challenge of nanotechnology applications to industry. The box below provides an analysis of this issue.

Box 2: Nanotechnology Education Challenge

One of the ‘grand challenges’ for nanotechnology is education, which is looming as a bottleneck for the development of the field, and particularly for its implementation. In 10 to 15 years, we may have the research results for the new technology without having the workers to take advantage of them. Since nanobiotechnology is being recognised as the most promising of all nanotechnology fields for venture funds, smaller companies and venture funding may be a harbinger of nanotechnology’s future. If that is the case, then the implications for education and training are clear. First, careers will be needed for specific biomedical technologies, such as tools to regenerate bone or skin, to reverse paralysis, and to detect illnesses earlier, or for developing and delivering targeted drugs that safely treat cancer. Second, jobs will be created in nanobiomaterials and nanobioprocessing for manufacturing. What is necessary is deep knowledge in at least one field of nanotechnology, coupled with the ability to communicate and collaborate with other related nanotechnology areas as well as with experts in other fields. The younger personnel seems to be more inclined to address nanobiotechnology topics, whereas the decision in larger organisations remains dominated by people who have only tangential knowledge of this new field.

A key challenge for nanotechnology development is the education and training of new generation skilled workers in the multidisciplinary perspective necessary for rapid progress of the new technology. The concepts at the nanoscale should penetrate the education system in the next decade in a manner similar to the way the microscopic approach made inroads in the last 50 years. Furthermore, interdisciplinary connections reflecting unity in nature need to be promoted. Such education and training must be introduced at all levels, from kindergarten to continuing education, from scientist too non-technical audiences that may decide the use of technology and its funding.

It is estimated that about 2 million nanotechnology workers will be needed worldwide by 2015. Extrapolating from previous experiences in information technology, where for each worker another 2.5 jobs are created in related areas, nanotechnology has the potential to create 5 million additional related jobs overall by 2015 in the global market.

University outreach activities should also stimulate nanotechnology innovation in industry and international interactions. The interest in each research topic can be estimated based on the trends in using typical nanotechnology instrumentation:

- Advanced materials 30% of all users
- Semiconductors and electronic about 25%
- Nanobiotechnology (including pharmaceuticals, biology and medicine) about 20%
- With the remaining 25% divided among tools, optics, electro-chemistry, aeronautics and energy.

Challenges for developing a nanotechnology workforce: Since the physical infrastructure for nanotechnology education is still in formation, the main challenge is the interdisciplinary and timely formation of nanotechnology technicians, engineers, medic and scientists. Another challenge is bridging and synchronising elementary, middle/high school, undergraduate, graduate and continuing education. A third challenge is to form a flexible workforce able to cross disciplines, areas of relevance and geographical lines. Increasing the international dimension of both nanotechnology R&D and industrial production would require suitable internationally oriented training for students. Finally, communication and generalisation of positive results, their integration in the general curriculum and institutionalisation of nanoscale science and engineering in K-12 and university education is needed. Engineering should play a key role in this process because of its integrative and interdisciplinary approach. School boards and school superintendents should be involved from the beginning in planning such activities. A systemic change can only be made with sustained funding, long-range planning and proper communication with the public and executive and legislative branches of government.

Nanotechnology's success will not be determined only by fruitful research in academic and industry laboratories or by individual education programs, but by the creativity of individual students in nanoscale science and engineering, connections between organisations, patent regulations, physical infrastructure, legal aspects, state and federal policies, and international cooperation. Although establishing the nanotechnology workforce may benefit from similarities with information technology and biotechnology, the time interval available for development appears to be shorter and the implications are at least as broad.

The availability of sufficient scientists and industrial experts is uncertain if we continue on the current path. One may consider changes in the way we structure the information on nanotechnology in order to improve learning and better disseminate the results. Engineering, and particularly manufacturing at the nanoscale, will increase in importance.

Source: Roco 2003

3.2 Nanocareers opportunities

The opportunities for careers in nanoscience and technology fields are expanding rapidly, however the major challenge for the field is the education and training of a new generation of skilled workers. According to the National Nanotechnology Infrastructure Network's (Allen 2005, Roco 2003) nanotechnology job projections are estimated to be nearly 2 million workers worldwide by 2015 within:

- USA – 0.8-0.9 million
- Japan – 0.5-0.6 million
- Europe – 0.3-0.4 million
- Asia Pacific (excluding Japan) – 0.2 million
- Other regions – 0.1 million
- In addition, nanotechnology will create another 5 million jobs worldwide in support fields and industries

Current application of nanoscale science and technology, and thus career opportunities, exist in areas such as (see Appendix for a list of occupations):

- Electronic/semiconductor industry
- Materials science including textiles, polymers, packages, etc
- Auto and aerospace industries
- Sports equipment
- Pharmaceuticals including drug delivery, cosmetics, etc
- Biotechnology
- Medical fields
- Optoelectronics
- Environmental monitoring and control
- Food science including quality control and packaging
- Forensics
- National security
- University and federal lab research
- National security
- Military

According to the National Nanotechnology Infrastructure Network's website (Allen, 2005), nanoscience and technology are fuelling a revolution in manufacturing and production, creating new materials and novel processes. Not only will the areas listed about continue to grow and benefit from nanotechnology, but the following fields are expected to undergo explosive developments:

- Medicine: diagnostics and therapeutics (e.g. drug delivery);
- Energy: capture, storage and use, fuel cells, batteries;
- Environmental remediation: in conjunction with MG microbes;
- Robotics;
- Manufacturing: self-assembly, 'bottom-up' fabrication of novel materials;
- Commerce: Radio frequency identification 'smart tags';
- Space exploration: space elevator;

Nanoscale phenomena underlay many of the properties and interactions of matter, and thus the sciences of physics, chemistry, and biology. Studying these field, and paying attention to the developments in nanoscience that advance them and the applications in nanotechnology that they support, can provide you with a solid foundation for any of a broad range of careers. Potential fields of study include:

- Biology
- Chemistry
- Physics
- Environmental science
- Agricultural science
- Engineering
- Medicine
- Forensic science
- Law
- Business
- Ethics

Not everyone working in the field will require a doctorate degree in one of the fields noted above. A skilled workforce trained at a variety of levels is needed to meet the projected workforce challenge of 7 million workers. According the National Nanotechnology Infrastructure Network's website (Allen, 2005) the Education levels include:

- Technical program
- Associates degree (2 years)
- Bachelors degree (4 years)
- Masters degree (6 years)
- Doctorate (8 years)

According to the Pennsylvania State University, Centre for Nanotechnology Education and Utilisation the expected salaries include:

- Two years associated - US\$30,000 - 50,000
- Four year bachelors - US\$35,000 - 65,000
- Six years Masters - US\$40,000 - 80,000
- Eight year doctorate - US\$75,000 – 100,000

3.2.1 Jobs in Nanotechnology

An analysis of the nanotechnology labour market during the months of May to November 2007 shows 157 jobs have been posted to the most popular nanotechnology websites:

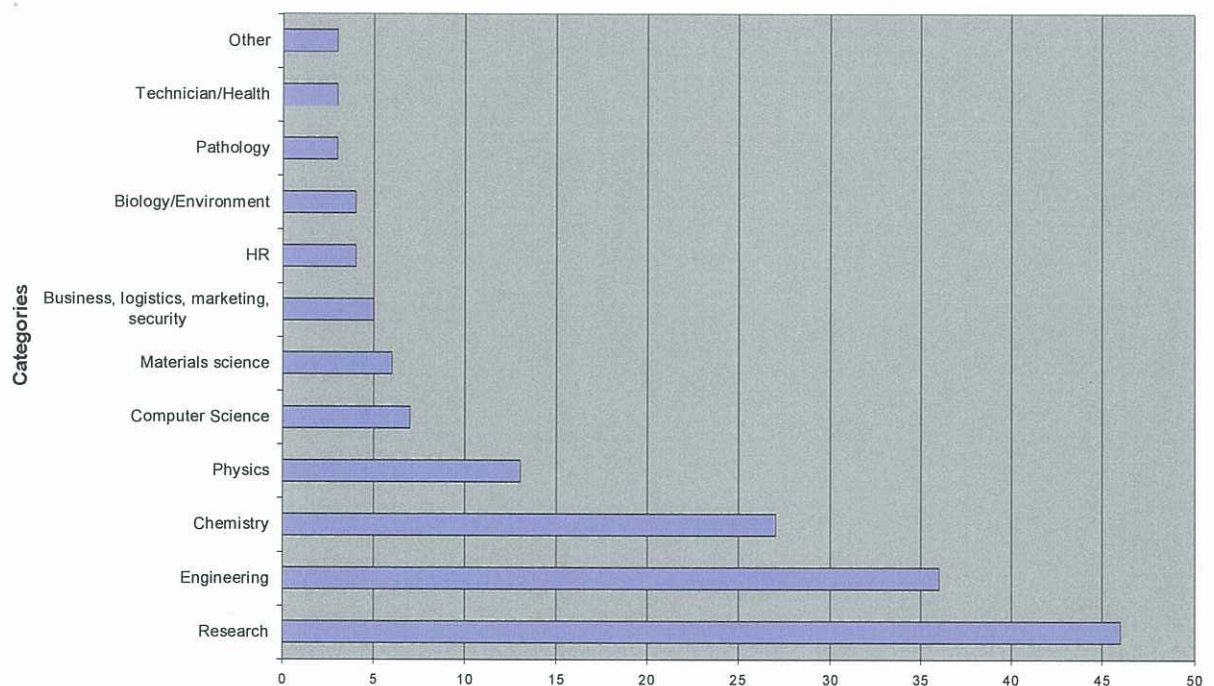
- Science Careers (<http://aaas.sciencecareers.org/js.php>)
- Nanotechweb.org (<http://nanotechweb.org/cws/jobs>)
- Seek (<http://www.seek.com.au/>)
- Working in nanotechnology (<http://www.workingin-nanotechnology.com/>)
- Nanosys Careers (<http://www.nanosysinc.com/careers/recr.html>)

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- Tinytechjobs (<http://www.tinytechjobs.com>)
- Careers in NanoTech (<http://cnse.albany.edu/JobBank/index.cfm?InstanceID=577>)
- Nanophotonic Job Opening (<http://www.ntc.upv.es/en/job.htm>)
- Veeco Careers (<http://www.veeco.com/company/careers.php>)
- My Career (<http://mycareer.com.au/>)

The majority of these websites are hosted and operated from the US and therefore the US is the leading labour market with 105 jobs, followed by India, Australia, Japan, Germany and other countries. By category the majority of jobs are found in research, followed by engineering, chemistry and physics. Emergent fields in the labour market are in business, logistics, marketing and security as well as in Human Resources (see Figure 4).

Figure 4: Nanotechnology jobs by Category (selected websites May-November 2007)



Source: Authors compilation from nanotechnology websites

3.3 Nanotechnology Careers in Australia

Nanotechnology is rapidly developing in Australia although public expenditure still small if compared with the US, EC or Canada. A number of specialised centres can be found across Australia (see Figure 5).

Figure 5: Nanotechnology specialised centers in Australia



Source: ANBF website <http://www.anbf.com.au/> (accessed 06 2007)

Nanotechnology employment is generated by the private sector, the public sector, universities and research institutes and industry associations and business networks. Some examples are provided below:

- Private sector companies
 - Advanced Powder Technologies (Nanopowders and functional products that incorporate nanopowders)– Perth
 - AGEN Biomedical (Medical and veterinary diagnostics)– Brisbane
 - Ambri (Diagnostic systems for the hospital critical care diagnostic market)– Sydney
 - AMIRA (Industry association for global minerals industry) – Melbourne
 - AorTech Biomaterials (Customer developed polymers for medical applications) – Victoria
 - Artimech (Design and supply of innovative equipment) – Victoria
 - Australian Venture Capital Association
 - Bandwidth Foundry (Photonics) – Sydney
 - Boeing (Aerospace and network enabled systems)
 - Bottle magic (Coatings for glass bottles) – Adelaide
 - Cap-XX (Supercapacitors: high energy storage devices, for the portable communications and information devices – Sydney

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- Canon Information Systems Research Australia (Digital imaging technologies) – Sydney
- Effel Technologies (Drug performance, delivery) – Melbourne
- Fujitsu (Communications, digital technology) – Sydney
- G James (Optically active glass) – Sydney
- Lehmann Pacific Solar (Sky cool – thermally efficient paints) – Sydney
- Lu Papi and Associates (Design, nanomaterials, polymers) – Sydney
- Micronisers (Manufacturing company specialising in fine milling) – Victoria
- Nanochem holdings (New materials for established industries)
- Nanotec Pty Ltd (Hydrophobic coatings)
- Nanoquest (Materials and processes in energy and environment) – Queensland
- Orica Australia (Paints and coatings) – Melbourne
- PanBio (Medical diagnostic kits) – Brisbane
- Pilkingtons (Self-cleaning glass) – Melbourne
- Psivida (Biomedical applications of porous silicon) – Perth
- Pacific Solar (Rooftop solar panels) – Sydney
- Poly Optics Australia (Lighting systems) – Queensland
- Pro-M Technology (Photolithography and masking products for semiconductor and photonics industry) – Sydney
- Quantum Precision Instruments (Nanometre precision positioning devices) – Melbourne
- Sirtex Medical (Treatments for liver cancer)
- SMR Scientific (Scientific equipment distributor) – Sydney
- Solutia (Energy efficient glazing system) – Melbourne
- Starpharma (Pharmaceutical applications of dendrimer nanotechnology) – Melbourne
- Sustainable Technologies International (Dry solar cells) – Canberra
- Very Small Particle Company (Metal oxide nanopowders) – Queensland

- Public Sector
 - CSIRO (From biomedical nanotechnologies to molecular electronics)
 - ANSTO (From protective coatings to biomedical technologies)
 - DSTO (Advanced materials and devices in defence applications)
 - Nanovic (Helping develop Victoria and Australia based nanotechnology companies)

- Universities based Research Institutes and Centres
 - UTS: Institute for Nanoscale Technology (Energy efficiency applications and biomedical engineering) – Sydney
 - UNSW Centre for Quantum Computer Technology (Research into developing a quantum computer)
 - UQ Nanomaterials Centre (Research and development in nanomaterials and applications)
 - Curtin Nanochemistry Research Institute (Strategic research centre)
 - U. or S.A., Ian Wark Research Institute (Research and development linked to improving existing processes in industry and developing new technologies)
 - U. Syd. Nanostructural Analysis Network (Research facility supporting Australian nanotechnology)

- Industry Associations / Business Services

- Nanovic
- Australia Nanobusiness Forum (ANBF)

In summary the physical infrastructure for nanotechnology education is still in formation, the main challenge is the interdisciplinary and timely formation of nanotechnology technicians, engineers, medic and scientists. Nanoscale phenomena underlay many of the properties and interactions of matter, and thus the sciences of physics, chemistry, and biology so these are the fields where education strategies from high school to universities should be focused. Another challenge is bridging and synchronising elementary, middle/high school, undergraduate, graduate and continuing education. A third challenge is to form a flexible workforce able to cross disciplines, areas of relevance and geographical lines. Rapid demand is expected in the fields of medicine (especially regarding drug delivery), energy capture and use, environmental remediation, robotics, manufacturing (especially nanofabrication), commerce (smart tags) and space exploration. Today, the majority of jobs are found in research, followed by engineering, chemistry and physics. Emergent fields in the labour market are in business, logistics, marketing and security as well as in human resources

4. Nanotechnology clusters: strategies and learning models

This section draws on international studies of clusters and their success factors and, specifically, on the nanotechnology clusters in Dresden (Germany) and Grenoble (France) which are briefly discussed as learning models.

OECD analysis over the last five years has recognised the advantage of clusters as entrepreneurial environments as a major source of economic growth and jobs and as an environment conducive of productivity gains (OECD 2007). Studies conducted by Martinez-Fernandez in South West Sydney brought attention to the advantages of supporting clusters at the regional and local level if competition is to be maintained in South West Sydney, an important manufacturing region in Australia (Martinez-Fernandez et al 2007). Among the key factors in cluster success identified by these studies are:

1. *Innovation and supply chain collaborations.* Interlinkages and collaborations among SMEs and big firms are often at the heart of successful clusters but it is the intensity of the collaboration along the supply chain what might be more important; from small value-chain linkages to complex interactions in innovation projects 'collaboration' is one of the keys of success.
2. *Leading enterprises.* A strong core of enterprises leading the cluster is found in most of the successful cases and many times responsible for enterprise expansion and employment growth in the cluster.
3. *Strong universities and research centres.* An essential element for the success of clusters is the presence of universities and research centres specialised in the main area of work of the cluster so that knowledge is produced and circulated in the cluster and there is a provision of human capital for the cluster companies to employ.
4. *Investment by the public sector.* Support by the public sector has often played a critical role for the emergence and development of clusters. In particular public sector investment works better if there are strong mechanisms to coordinate partnerships

between State, regional authorities, business support agencies and local firms and research organisations. This support needs to be sustained over time if the effect is going to be noticed.

5. *Quality of life.* The development of urbanisation and the mobility of scientists and knowledge workers highlight the importance of having a stimulating environment with quality services to people and where people have enough options for leisure and long-life learning. These factors are indeed found at the heart of regions that have been successful in capturing and retaining human capital in their clusters.
6. *Social capital.* Clusters are strongly based on a social fabric where social networks are developed to exchange information, knowledge and ideas. Trust is developed over time and the presences of strong social networks ultimately stimulate collaboration in innovation projects and joint ventures, both at the core of cluster development.

A number of obstacles to the development of clusters have also been identified:

1. *Inadequate incentives to the commercialisation of public research.* Especially in the case of nanotechnology university and research institutes discoveries are of enormous importance for industry to become competitive in the global market. Unfortunately there are many barriers related to the use of Intellectual Property by the researchers that worked in any breakthrough discovery and barriers exist to the participation of researchers in industry workloads. Incentives have been developed over the years for consultancy projects participation and they are somehow easier to undertake by researchers than industry applications of their work. More sophisticated mechanisms of university-industry partnerships need to be developed to promote a culture of entrepreneurship and co-innovation between cluster companies and public sector researchers.
2. *Maintaining a critical mass of qualified labour.* Clusters face important obstacles if they cannot find qualified labour when new projects are to be undertaken; and this is not only related to managers and scientists but also regards to technician and laboratory and fabrication specialised human resources. A training strategy needs to oversee the development of the clusters so that skills shortages can be anticipated and planning can be undertaken in conjunction with training institutions and state and local development organisations.
3. *Lack of seed capital.* This is a serious barrier for firms, specially those working on the frontier of new technologies that need seed capital for a continuous period of time in order to overcome market penetration difficulties and especially in the start-up phase and until production is underway.
4. *Lack of a coordinated policy strategy for the cluster.* This is an area of much needed coordination for development of clusters. Coordination of the different range of institutions and actors at the regional level is important but also coordination with national agencies and funding regimes so that actions are convergent for major clusters to develop. Successful clusters will not only benefit their geographical area of operations but also national economies.
5. *Congestion.* Rapid growth of a cluster can result in congestion and may impede further growth particularly when there is little opportunity to expand the

agglomeration because of planning or physical constraints. Strong growth in constrained agglomerations is associated with rising land and property prices, increasing commuting times, transport problems, rising wage costs and an impact on the decline of attractiveness of the area for keeping firms and labour force.

6. *Risk of 'social divisions'*. Growing and expanding clusters can originate social divisions among knowledge workers and other support workers sometimes due to the rising cost of living in the areas fuelled by the rapid growth. An increase of social divisions can negatively impact social networks, knowledge transfer and support by public authorities.
7. *Ethical objections*. Especially in the case of nanotechnology a growing cluster can encounter objections by the public and sometimes political parties to the commercialisation of research discoveries on ethical grounds. This can hinder further development of the cluster.

4.1 The case of Dresden (Germany)

Dresden is a city of 505,000 inhabitants and 1 million in the region in the state of Saxony, in the eastern part of Germany. Not long ago Dresden was a shrinking city suffering the effects of population and business migration to the western parts of Germany but in recent times it has made a remarkable transformation. In 2006 Dresden was labelled as the most dynamic city in Germany, and one of the most dynamic industrial locations in Europe¹. The tourism industry have had an important role in the recovery of Dresden as the city centre reconstruction is taking place with a total of 12 million visitors in 2006, a 150% increase if compared with 2005.²

Figure 6: Dresden, view across the river Elbe to the Church of our Lady



Industry development in two high-technology sectors, microelectronics and nanotechnology, is playing a critical role in the transformation of Dresden as a 'knowledge intensive city'. Dresden ranks 13 as business place among the 433 German cities and regions and

¹ Study of Initiative Neue Soziale Marktwirtschaft and Wirtschaftswoche Magazine (comparison of German cities under economic aspects)

² City of Dresden, Economic Development Department, case study meeting, August 2007.

20 among all European cities.³ Dresden has three particular fields of expertise: New Materials/Nanotechnology; Microelectronics/ Information and Communication Technology, and Life Sciences/Biotechnology. In particular, Dresden is one of the largest European regions in the field of semiconductors technology, with more than 760 companies and more than 25,000 employees. On-site competencies cover the whole value creation chain and investment is rising to more than 12 billion Euros by 2008.⁴

A series of factors have contributed to the emergence of Dresden as a micro and nano technology cluster. The decline of Dresden was evident by the mid 90's when the city continued to have many highly skilled but unemployed people. From 1994 important investments started to happen with a new production plan built by Siemens (now Infineon/Qimonda) and other important projects and companies such as AMD followed as well as start-ups and spin-offs that contributed to the growth of the cluster. A decisive factor in this growth has been the concentration of highly skilled and available workforce with 55% employees in Dresden working in high technology sectors (see employment growth in Dresden in Table 3) and the high density of research institutes working in partnership with companies:

- Technical University of Dresden (TU Dresden)
- Hochschule für Technik und Wirtschaft Dresden (University of Applied Science)
- TU Bergakademie Freiberg
- 3 institutes of the Max Planck Society
- 5 Institutes of the Leibniz Association
- 11 Institutes of the Fraunhofer Society
- Various other private research institutes

Table 3: No Employees in the High Technology Industry (%)

	1994	2005	Change
Germany	21.2	22.2	+1.0
Saxony	16	18.8	+2.8
Dresden	37.8	55.2	+17.4

Source: FERI Institute 2005

Two industry networks facilitate knowledge flows in the cluster: Silicon Saxony and the Fraunhofer Nano-technology Alliance.

Silicon Saxony connects manufacturers, suppliers, service providers, colleges, institutes and decision-makers on-site and in the region. It has more than 235 member companies that employ over 17,000 people and account for 3 billion Euros net turnover per year. The network governance develops around six working groups with the main companies in Dresden leading the network: education and training, research and development, equipment, financing for start-ups, photonics, logistics and automation, micro-system technologies and software.⁵ In 1990 there were 10,000 people working in the microelectronic sector in the Saxony region. In 2007 there are in excess of 35,000. The network started in the year 2000 with some of the most important companies such as DAS, GWT, Infineon and Qimonda at the head and several of the Dresden research institutes and universities. Core competencies are in services (suppliers – 45%) and manufacturing (19%). The fields of work are presented in Table 4.

³ Future map Germany“ by Prognos, 2007; Manager Magazin 12/2005

⁴ Ibis 2.

⁵ Silicon Saxony case study interview, August 2007

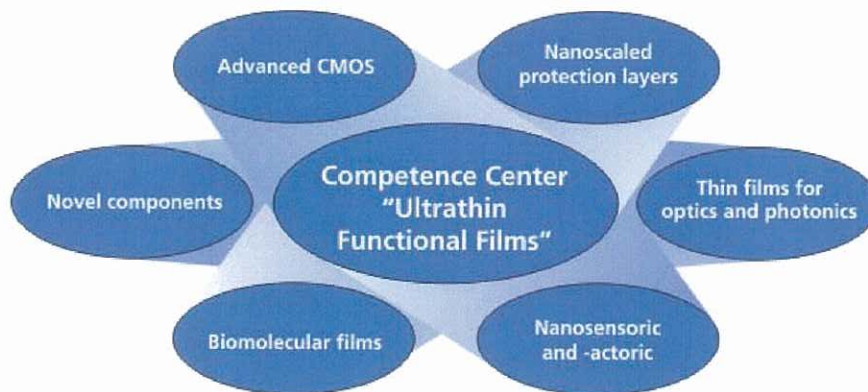
Table 4: Silicon Saxony members business fields (%)

Fields	Percentage of business
Semiconductors	44
Equipment	22
Electronics	21
Automotive suppliers	19
Medical technology	17
Environmental technology	13
Communication	10
Aerospace	10
Computers	8

Source: Silicon Saxony case study interview, August 2007

The *Fraunhofer Nano-technology Alliance* and Nano-Technology Center of Competence "Ultrathin Functional Films", is a network of 88 companies, research facilities and organizations in thin film technology (see Figure 7).

Figure 7: Sectors of activity of Nanotechnology Competence Center.

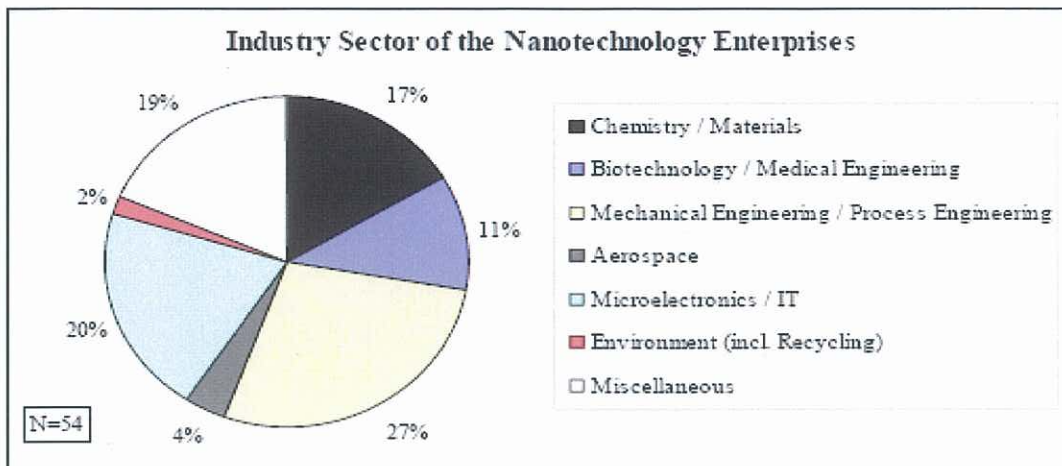


Source: Fraunhofer Institute – case study interview, August 2007

The network includes 51 enterprises, 10 university institutes, 22 research institutes, and 5 corporations. Funding is provided by the Government and activities concentrate on knowledge transfer by organising conferences, workshops, and fairs that provide an exchange of experiences and scientific discussions.

The main industry sectors of nanotechnology firms in Dresden are shown in Figure 8 below: mechanical engineering/process engineering (27%), microelectronics/IT (20%), chemistry/materials (17%) as well as biotechnology/medical engineering (11%). SME's dominate and business start-ups take place continuously.

Figure 8: Industry focus of nanotechnology firms in Dresden region



Source: VDI Technologiezentrum 2006

A study conducted by VDI Technologiezentrum (2006) found that close proximity of firms in the cluster was an advantage especially for the spin-offs of the R&D organizations. 80% of the spin-offs (out of 14) established themselves near their mother company. This is an interesting finding that shows the importance of spin-offs as a way to strengthen the economy of a region.

Finding nanotechnology workers is a challenge for the cluster companies as one of the core companies noted; and extensive specialised training is a necessary step for the companies:

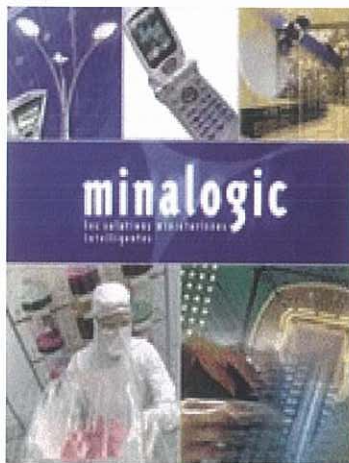
‘There is hardly any nanotechnology worker around; we attract physicists, chemists, engineers from universities and then we have to train them for one and a half years to bring them up to speed. That is why we have founded a new training centre together with the university so we send them there and they get a diploma in the end. This is attractive for new employees, our company gives them a chance to learn and make their Masters Degrees at the same time than earning a salary’. (case study interview, August 2007)

...

We have a lot of physicists, we have a lot of electronic engineers, we have chemists, and then we try to form the organization around the people. You have to form organization around the capability and know-how of the people. So when people grow and experiences also growing in know-how you can do different things, you can start more projects for example because there is a project structure behind this. Having people is not enough, they need to have a basic understanding of how these microelectronic and circuits are behaving and there is a need for lots of soft skills. How to form teams, how to run teams, how to report, they have to understand difference between invest and cost. For the physicists it’s hard for them to understand, because it’s all about money. How many invests do you need and how many costs do you produce, so they have to understand this. This is training on the job; we have also lots of courses for project management’. (case study interview, August 2007)

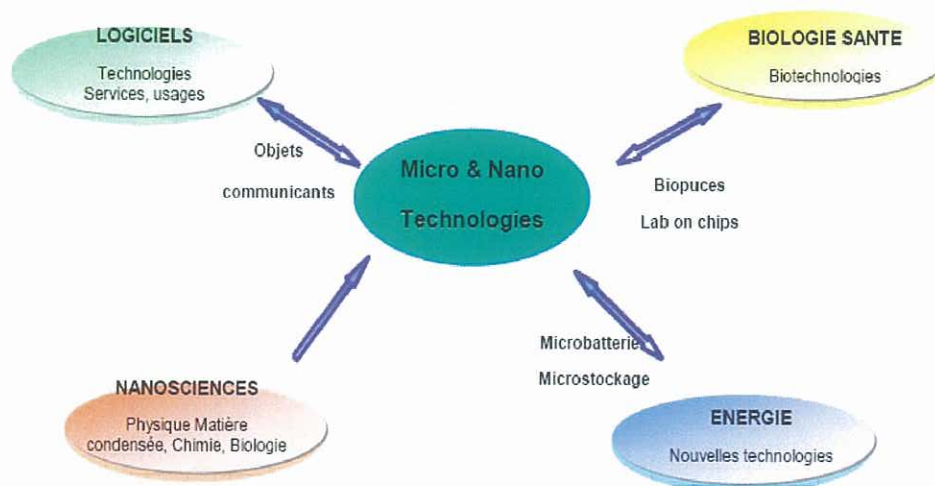
4.2 The case of Grenoble (France)

Grenoble is a city in the South of France with 600,000 inhabitants and the host region of one of the fastest growing high-technology clusters at the front of nanotechnology in France: Minalogic “Pôle de Compétitivité”. The main industry sector is micro-electronics with 280 enterprises (94% are SMEs) employing 40,000 people of which 34,000 people are employed in firms and 5,000 people are employed in public research institutes. The city has four universities with 60,000 students. There are 15,000 researchers working in Grenoble, 75% in public research institutes and 25% in private laboratories.



Minalogic was labelled “Pôle de Compétitivité” in 2005 by the ‘Direction Interministérielle pour l’Aménagement et la Compétitivité du Territoire’ and is the oldest of this type in France. Minalogic was created from two other projects funded by government: Minatec and Alliance Crolles. The core businesses of Minalogic are companies working in micro and nano technologies and within four different sectors: logistics (technologies and services), biotechnologies, nanosciences and energy (see Figure 9).

Figure 9: Areas of specialization in Grenoble cluster



Source : AEPI 2006

Nanotechnology in SWS: Pathways for Cluster Development

According to a recent OECD study (2007) the key factors contributing to the success of Minalogic are:

- Support of national government and local institutions;
- Governance of the cluster in partnership;
- An active facilitator of the cluster that brought together public and private actors;
- A critical mass of human capital;
- Presence of networks and social capital;
- SMEs engaged in innovative activities through competition;
- Application of research to the industry production; and
- Active inward attraction by the local and regional economic agencies.

There are also factors or barriers to further development of the cluster:

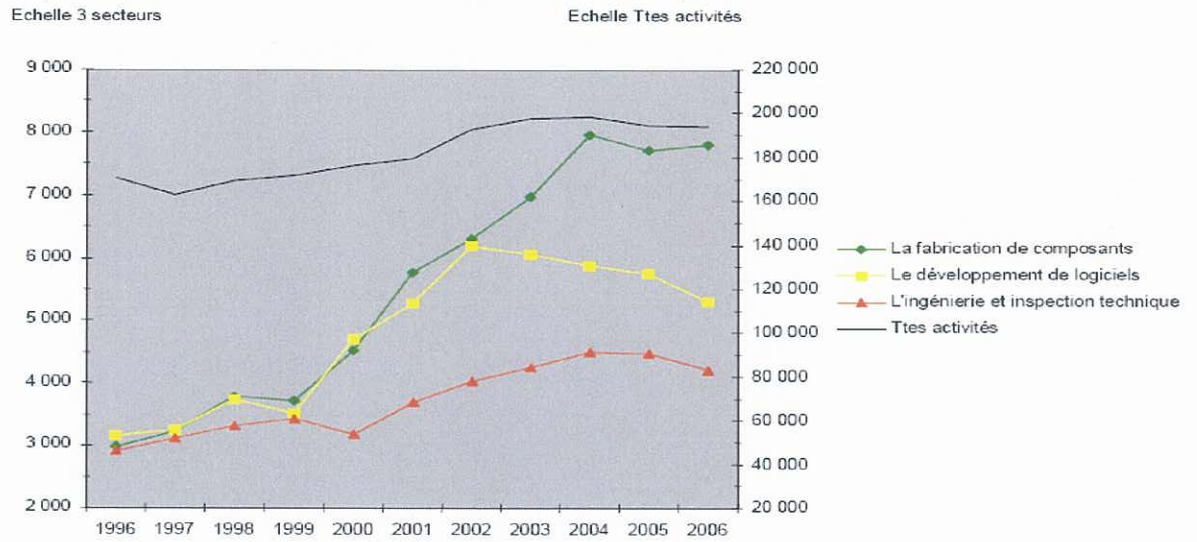
- Insufficient infrastructures;
- Difficulties in finding private financing for high technology firms;
- Lack of flexibility in the local universities;
- Poor adaptation of the labour force to the needs of the cluster;
- Failure to develop an entrepreneurial culture in the local universities;
- Poor coordination of the different levels of government, especially in relation to budget issues; and
- Risk of emergent social divisions.

Among the activities organised by the cluster to facilitate access to financing are encouraging private investors and venture capitalists to become members of the Minalogic cluster, creating forums to seek financing by bringing together investors and entrepreneurs and informing SMEs about the activities of the cluster.

Minalogic counts with 79 partners of which 50 are companies, 33 are SMEs, 10 are research and university institutes, 15 are local government agencies and 6 are economic development organisations. Minalogic strong core is supported by 25,000 jobs in the field of micro and nano technologies and 18,000 jobs in the software business with successful attraction of US and Japanese investors. In 2007 Minalogic invested €80 million in eight new collaborative projects focused on micro and nanotechnologies for next generation semiconductors and new manufacturing processes. Companies are moving their European headquarters from London to Grenoble in order to be closer to their electronic sector clients and to take advantage of the skilled talent of the region.

The growth of salaries in Grenoble gives an indication of the success of the cluster. Since 1996 salaries in the fabrication of components have grown up to 163%, software development has grown 68%, and the development of engineering and technical inspection has grown 44%. During the same period, all activities in Grenoble have grown 13% (see Figure 10).

Figure 10: Salary evolution in Grenoble (key industry sectors and all sectors)



Source : Sirène champ Ics

In summary, the learning cluster models of Dresden and Grenoble both indicate the need for a core of growing companies where nanotechnology is central to their production process and their strategic development in the market. The presence of a complete value-chain developing around the core nanotechnology companies has assured a rapid and strong growth of the two case study clusters. In addition public support, a coordinated funding strategy from different levels of government, and the presence of a highly specialised labour force have nurture the clusters to a position where networks that facilitate knowledge flows are being created and lead by the core companies in collaboration with research institutes where new developments can be tested to fuelled the innovativeness of the cluster.

5. Conclusions and recommendations

This report discussed the extent of nanotechnology uptake in firms of South-West Sydney; then it explored the education imperative that needs to be considered for further development of nanotechnology in the region. Learning models of nanotechnology clusters were discussed as best practices where the UWS Nanotechnology Network can reflect for its future. Some recommendations are offered in this section.

Results from the 2006 small survey of South-West Sydney firms indicates that nanotechnology still fragmented in the region although there are certain evidences of concentration and growth in the case of two particular companies that account for most of the employment growth, investment and development prospects in the region. At the occupational level material science could be a hub of development although employment has been created in other fields as well such as electronics and engineering. At the occupational level chemistry, biology and physics are the main disciplines from where university graduates and higher degree graduates are being recruited in the region. Universities and research institutes still very important for innovation partnerships but other companies and in particular customers are noted now as the most significant source of nanotechnology information and knowledge. As knowledge of nanotechnology becomes more available firms are able to apply the new science to their businesses and 'relevance' is no longer the most important barrier to the uptake of nanotechnology but funding of the applications.

The physical infrastructure for nanotechnology education is still in formation, the main challenge is the interdisciplinary and timely formation of nanotechnology technicians, engineers, medic and scientists. Nanoscale phenomena underlay many of the properties and interactions of matter, and thus the sciences of physics, chemistry, and biology so these are the fields where education strategies from high school to universities should be focused. Another challenge is bridging and synchronising elementary, middle/high school, undergraduate, graduate and continuing education. A third challenge is to form a flexible workforce able to cross disciplines, areas of relevance and geographical lines. Rapid demand is expected in the fields of medicine (especially regarding drug delivery), energy capture and use, environmental remediation, robotics, manufacturing (especially nanofabrication), commerce (smart tags) and space exploration. Today, the majority of jobs are found in research, followed by engineering, chemistry and physics. Emergent fields in the labour market are in business, logistics, marketing and security as well as in human resources

The learning cluster models of Dresden and Grenoble both indicate the need for a core of growing companies where nanotechnology is central to their production process and their strategic development in the market. The presence of a complete value-chain developing around the core nanotechnology companies has assured a rapid and strong growth of the two case study clusters. In addition public support, a coordinated funding strategy from different levels of government, and the presence of a highly specialised labour force have nurture the clusters to a position where networks that facilitate knowledge flows are being created and lead by the core companies in collaboration with research institutes where new developments can be tested to fuelled the innovativeness of the cluster.

5.1 Recommendations for the development of a nanotechnology cluster in SWS

The analysis conducted during the life of the UWS Nanotechnology Project and the discussion presented in this report suggest the following recommendations which are not exhaustive but they might offer some inspiration to strength the UWS Nanotechnology Network.

First, *entrepreneurship needs to be encouraged* in the region. This can be in the form of supporting spin-outs from university researchers, financing areas of incubation of start-up companies and raising the number of formal collaboration projects between UWS and companies and between the core nanotechnology firms and SMEs. Public funding support and advice is necessary for the launch and growth of start-ups and in this regional and local institutions have an important role to play.

Second, *stimulating innovation and collaboration* will ultimately fuel the development of a nanotechnology cluster. This can be done through the continue focus on technology transfer already initiated by UWS but also fostering collaboration between different players in the network. Neutral agencies can best serve as brokers to facilitate this dialogue. Another mechanism that can be used is to eliminate administrative barriers that hinder people mobility from university to secondments into industry and vice-versa. Collaboration also needs to be encouraged between clusters at the national and international level in order to avoid knowledge local lock-ins. The UWS Nanotechnology Network has developed a 'knowledge interaction space' which is worthwhile and facilitates the process of dialogue between interesting actors in the region.

Third, *coordination of public policies and regional initiatives* is necessary to create strong partnerships such as those discussed in the cases of Dresden and Grenoble clusters. Developing a joint strategy for the cluster is as important in the process as the financing or the scientific knowledge base.

Fourth, *ensuring quality human capital* will provide knowledge that is relevant for the region and prevent skills shortage especially if an education and skills strategy is planned by network companies with local knowledge providers. As the cluster develops, ensuring the availability of local talent will become an issue and the region needs to be ready to attract external talent early on so that slowdowns do not detract new players for settling in the region. To achieve this the area needs also present a quality setting for people to move in and local authorities needs to be part of these strategic developments at an early stage of planning.

Fifth, *facilitating access to financing* is critical for firms, and it has already been indicated by the small survey conducted in 2006. The three main strategies for this role are encouraging private investment by for example involving private investors in the activities of the cluster as it happens in the Grenoble cluster. Facilitating access to public funding for innovation in SMEs is also critical for the development of a cluster. Creating forums to seek financing and organising events around this topic will built the capacity of firms to finance their innovations.

Sixth, *industry clusters need a core of leading companies* that can drive the cluster and ultimately impact the economic development of the region. The UWS Nanotechnology Network is an excellent initiative of technology transfer in which emergent companies in South-West Sydney can build their leadership of the industry.

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Appendix: Nanotechnology related occupations

UNIVERSITY

Bachelors

Bachelor of Science holder specialising in nanotechnology will usually be working as laboratory technicians at "clean" facilities, where micro and nanostructures are etched into silicon, or in a biological laboratory where new ways of utilising medicine are developed.

Graduates

A Master of Science degree holder in nanotechnology will participate in research and development. For example, the development of catalysts for non-polluting automobiles or of new materials whose nanostructure makes them stronger and lighter than what is available today.

Ph.D.

A Doctorate holder will be a researcher, holding independent responsibility for part of research within a project. One example might be the development of an entire laboratory on a plastic chip capable of investigating many diseases in no time at all. You might also be assigned the task of developing self-assembling electronic circuits.

Biologists:

- Biologist
- Microscopist
- Biophysicist
- Biochemist
- BioOptics
- Biotechnologist

Marketing:

- Public Relations
- Advertising Media/Business Advertising
- Sales and Marketing

Lawyers:

- Legal experts
- Patent agents
- Policy analyst

Physicists:

- Microscopist
- Material scientist
- Material chemist
- Biophysicist
- Surface chemist

Researchers:

- Academic researchers
- University lecturers
- Masters or PhD research candidates
- Research Assistants

Managers:

- Administrators

Psychologists:

- Nanobiologist – nanoparticle use for MRI scanning
- Neuropsychology – combined with neuropsychopharmacology, stereotactic neurosurgery, transcranial electromagnetic stimulation, and neurofeedback

Chemists:

- Microscopist

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- Biochemist
- Nano chemical engineers
- Surface chemist
- Inorganic scientist

Engineers:

- Computer engineers - integrated microsystems
- Microscopist
- Biomedical nanosystems scientist
- BioOptics – molecular devices and nanoscale hybrid electronics

Pharmacists:

- Microscopist
- Biomedical scientist
- Biophysicist

Nanotechnology in SWS: Pathways for Cluster Development

Nanotechnology

Biotechnology

Social aspects

Cognitive Science

Biomedical

Electronics

Chemical

Materials

Pharmaceutical

Education

Ethics

Law Governance

- Nanobiologist – MRI scanning
- Neurophysiologist

- Microscopist
- Biotechnologist
- Nanosystems scientist
- Biophysicist
- Sales/marketing
- Patent agent

- Microscopist
- Biomedical nanosystems scientist
- System architecture
- Sales/marketing
- Patent agent

- Microscopist
- Biochemist
- Nano chemical engineers
- Surface chemist
- Inorganic scientist
- Sales/marketing
- Patent agent

- Microscopist
- Material scientist
- Material chemist
- Biophysicist
- Surface chemist
- Data analyst
- Sales/marketing
- Patent agent

- Microscopist
- Biomedical scientist
- Biophysicist
- Sales/marketing
- Patent agent

- Lawyers
- Research

- Administration
- Policy analyst
- Equity
- Researchers

- Lecturers
- researchers
- teachers