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UK innovation nanotechnology patent landscape analysis

April 2009

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IPO Patent Informatics Project Report:
UK innovation nanotechnology patent landscape analysis

Customer:
Nanotechnology Knowledge Transfer Network

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Executive Summary

Patent data reflecting UK innovation in the field of nanotechnology was analysed and several subsets considered separately:

UK innovation commercial organisations
University applicants
Global patent activity in nanotoxicity

These yield the following observations in respect of UK innovation:

- UK strong overall in bionanotechnology
- Commercial organisations prolific in medical and cosmetic applications
- Universities strong in science-base research in nanostructures, physics and electrical applications including scanning probes, light guides, semiconductors and magnets
- Most prolific commercial patents closely related to densely patented (established) technology sectors
- University patents spread very broadly across all sectors and tend to populate underrepresented sectors supporting research bias

It was noted that whilst recent declines in nanotechnology patenting may be attributable to patent publication delays, evidence in university patenting, and the GB patent bias in the dataset suggested that the decline may be actual. If so, nanotechnology patent activity would seem to have peaked in 2002.

Under technology breakdown, medical preparation including targeted drug delivery and antibody directed enzyme therapy is seen to decline since prolific activity in the early 1990s. On the other hand, cyclodextrins and medicinal preparations involving nanoparticles and/or nanocapsules is recently resurgent. Activity in nanostructures and physics/electrical fields is ongoing and may be attributable to recent university research pursuing these technologies.

The UK is underrepresented in nanotoxicity, but this appears to be a growth area, peaking recently in 2005.

Patent portfolio (holdings) analysis suggests, despite the bias of patents in established areas assigned to commercial organisations, that new entrants and exploratory research still form a significant part of the UK nanotechnology landscape; 49% of patents are held within portfolios of less than 20 nanotechnology patents.

Collaborative activity between applicants is noted although inventor collaborations are more prolific. Universities are seen to collaborate widely suggesting a high degree of technology transfer and/or spin out.

Patents held by non-commercial organisations make up 33% of the dataset. This suggests a significant research and development activity-base with continuing commercialisation and applications development.

Oxford and Cambridge universities are seen to top the league of university applicants, but the University of Glasgow is noted for its specialism in semiconductors, lasers and light guides; the University of Bristol for its strength in nanometrology and the University of Liverpool for its strength in nanofiltration and separation.

Key patents are identified on the basis of citation analysis and evidence specific UK strengths in nanowires, nanotubes, nanoparticle compositions and nanoprobes.

A similar analysis of nanotoxicity patents yields prevalent US and WO patents, some with UK designation or equivalents.

A high level comparison with European patent data reveals overlap with the UK patent landscape, but highlights UK strengths in pharmaceutical compositions and delivery. European patents on the other hand occur in fields underrepresented by the UK, such as composite carbon polymers and nanostructure films.

Recommendations

- Investigation of the portfolios of applicants who are currently active.
- Investigation of a date-limited dataset covering e.g. the last ten years.
- Analysis of specific organisations' (or universities') patent portfolios including the status of those patents, their relevance to specific fields or interests and a more refined assessment of their technological value (for example by referring to the search reports, patent family size etc.).
- Further narrowing of specific requirements to discover key patents within relevant technological areas, which may be obscured in the current dataset.
- Refinement of the technology groupings, combined with temporal limitation could highlight recent UK strengths in this area and potentially highlight areas of emergent UK-based activity.
- Interactive interrogation of the patent landscape could also provide further information on UK nanotechnology activity. In particular, the examination of relevant patents associated with identified key patents may provide a more detailed overview.
- Time-slicing of certain data representations can also indicate the nature of changing technical characteristics over time, which in turn can facilitate the identification of future technology growth or decline.
- Specific example patents (e.g. from the nanotoxicity dataset) could be rigorously analysed to further understand their potential, transferability or demise.
- It is essential that the examination of UK nanotechnology is viewed in a global context, as it will then become more evident where UK expertise and research is being directed through contrast with global activity.

Table of Contents

1 Introduction

1.1 Basis for report

Reference to ‘patents’ relates to both patent applications and granted patents unless otherwise indicated.

For this project the European Patent Office (EPO) database EPODOC was interrogated, which encompasses published patent documents derived from the majority of leading industrialised countries and patent organisations, for example the World Intellectual Property Organisation (WIPO), EPO and the African Regional Industry Property Organisation (ARIPO). It should be noted that since by convention patents are usually classified and published within eighteen months after filing, the patent record set covering June 2007 – present may not be complete. Further, varying, delays in patent systems around the world may also add to this effect. This should be borne in mind when considering recent patent trends (within the last eighteen months at least).

As specified, the data reported herein relates specifically to nanotechnology related patent activity in the UK, unless otherwise stated.

1.2 Priority year, application year and publication year

There are generally three dates which can be associated with a patent application as follows:

Application date: The date on which a physical application was made for a patent. This enables an accurate temporal reflection of the technical content of a patent application.

Priority date: A patent can claim priority from an earlier application. This usually happens for two reasons: a) when an application is filed in one country, international convention dictates that the applicant then has 12 months to file a corresponding application abroad. Thus the patent application would then have a priority date, which indicates the earliest date attributed to the invention; b) an earlier application may contain part of a subsequent invention so a subsequent application, made within 12 months of filing, may claim priority from the earlier application. However, in the new application, this date is only valid for that part of the invention which appears in the earlier application. Care should therefore be taken when analysing the priority date of an invention.

Publication date: The date when the patent application was published. This is normally 18 months after the priority date or the application date, whichever is earlier.

The analysis presented in this report is primarily based on priority year to give the earliest indication of innovative activity.

1.3 WO and EP filings

As well as filing in separate national countries, patents can also be filed as International patents (WO) and European patents (EP). WO patents may designate in which national states protection is sought; these patents are then published and processed in the respective national states and will then be included in the other figures for FR, GB, DE etc. WO patents may themselves designate EP, and these patents will go on to become European patents which may have validity in one or more European states. European patents can also be obtained in their own right. The country of validity cannot be easily determined except on a patent-by-patent basis. Figures for patent with WO and EP priorities have been included for completeness, although no single attributable country is immediately apparent.

1.4 Limitations

In general, patent data is factual and reliable, although circumspect interpretation of analysis results should be applied in view of the following:

- Publication / processing delay discussed above.
- Some patent databases contain over 70, 000, 000 records and inevitably inconsistencies or omissions arise.
- Classification terms may be automatically or manually applied and are thus occasionally prone to inaccuracy. Multiple classification terms can be applied to a single patent record which may dilute a specific technical observation.
- Whilst applicant (assignee) fields are cleaned, this is a manual process and resources necessarily limit the available degree of supportive research to establish company associations, take-overs, mergers etc.
- Inventor fields are not cleaned as it is not resource efficient. Consequently inventor rankings and relations are approximate.
- Multiple search streams in conjunction with variable patent publication number formats, patent family (mis)association and different database sources can lead to occasional, isolated patent records being duplicated within a dataset. Empirical analysis suggests this is likely to account for less than 2% of records, and the effect on macro-trends is negligible. Where small datasets or sub-groupings are considered, targeted de-duplication is undertaken.

Although care is taken to resolve and mitigate the above limitations, inevitably a margin of error is accepted. For this reason specific figures (e.g. of total patent records) should be regarded as indicative rather than absolute. Characteristics in patent data, trends, relationships and observations provided herein are identified and formed on the basis of patent data and so are subject to the above limitations. Where the likelihood of limitations affecting results is prevalent comments are provided accordingly. In general, the larger or broader[1] the patent volume analysed, the less susceptible the analysis to the above limitations.

[1] E.g. across multiple assignees, years or classification terms

1.5 Patent documents analysed

The document dataset identified during search was targeted through the use of European Classification (ECLA) codes and International Patent Classification (IPC) codes in conjunction with patent examiner technology-specific expertise.

Where dates are attributed to patent documents, this is the priority date of that patent. Priority dates are the earliest available indication of inventive activity. In certain cases a patent comprises more than one priority date. This should be borne in mind when interpreting the data.

The search for patent documents targeted those arising from 'UK innovation' on the basis that patents having:

GB priority or
GB applicant or
GB inventor

may be deemed to arise from UK-sourced innovation. Clearly this assumes that a patent filed in GB first, or naming a GB nationality inventor or assignee arises from UK innovation[2]. Whilst patents from foreign companies with a policy of filing in GB (perhaps to enjoy a quick statutory search) would thus be included, so will non GB patents filed by UK inventors and assignees. On balance, although favouring inclusion, this approach provides a good reflection of UK innovation.

A separate search was made for patents relating specifically to nanotoxicity. Given the complex nature of identifying nanotoxicity aspects in a general nanotechnology dataset, this approach ensured comprehensive coverage. This dataset was not limited to a GB inventor, applicant or priority. However, the data was regarded through a 'UK lens'. Further detail and analysis of this dataset is presented in section 2.3.2.

It is also important to note that prior to analysis, the applicant field data was 'cleaned' to de-duplicate database entries, which relate to the same applicant, but where a different form of applicant name is used, for example arising from spelling error, international variation (e.g. Ltd, Pty, GmbH etc.) or equivalence (e.g. Ltd., Limited). This avoids erroneous apparition of apparent multiple applicants which are in fact one and the same, however this can also mean that some subsidiary companies are obscured by larger parent companies.

[2] "GB" patents, and in this context applicants and inventors, in fact reflect "UK" nationality.

1.6 Objectives

This report addresses the aims stated within the proposal document, and makes further observations where appropriate, by considering aspects of the following:

Analysis of the UK nanotechnology patent landscape, including:

- Identification of key applicants and inventors
- Identification of key technology sub areas
- Identification of key patents
- Nanotechnology lifecycle, maturity and development
- Landscape map of the technology space
- Identification of technology cross-over potential
- Emergent technologies
- Academic/research strengths and opportunities
- High-level comparison with European patent data

Initial analysis of the technology area will comprise:

- Technology lifecycle, including present stage of maturity
- Key applicants, including their geographical[3], technical and collaborative profile
- Key areas of technology growth, including geographical[3] variations
- Technology sub areas:
    - Bionanotechnology
    - Nanomaterials / nanostructures
    - Nanometrology
    - Applications of nanotechnology
    - Nanotoxicity

[3] GB 'originated' inventions may have effect in other jurisdictions

2 General overview

2.1 Patent trends

Summary data representing the UK nanotechnology dataset is shown in Table 1 below.

Total Number of Records:	6,362		
Years Range From:	1935 - 2008		
Peak Year	2002		
Top Country:	GB		
Top Company Name:	TIOXIDE GROUP PLC		
Field Choices	**Field Name**	**Number of entries**	**Field Coverage**
People	Inventors	5,126	91%
Companies	Patent Assignees	2,333	89%
Countries	Priority Countries	26	100%
Years	Priority Year	59	100%
Technology	EPO Classifications	2782	100%

Table 1 Summary of nanotechnology dataset

Figure 1 shows the number of patents published per priority year for the UK nanotechnology dataset.

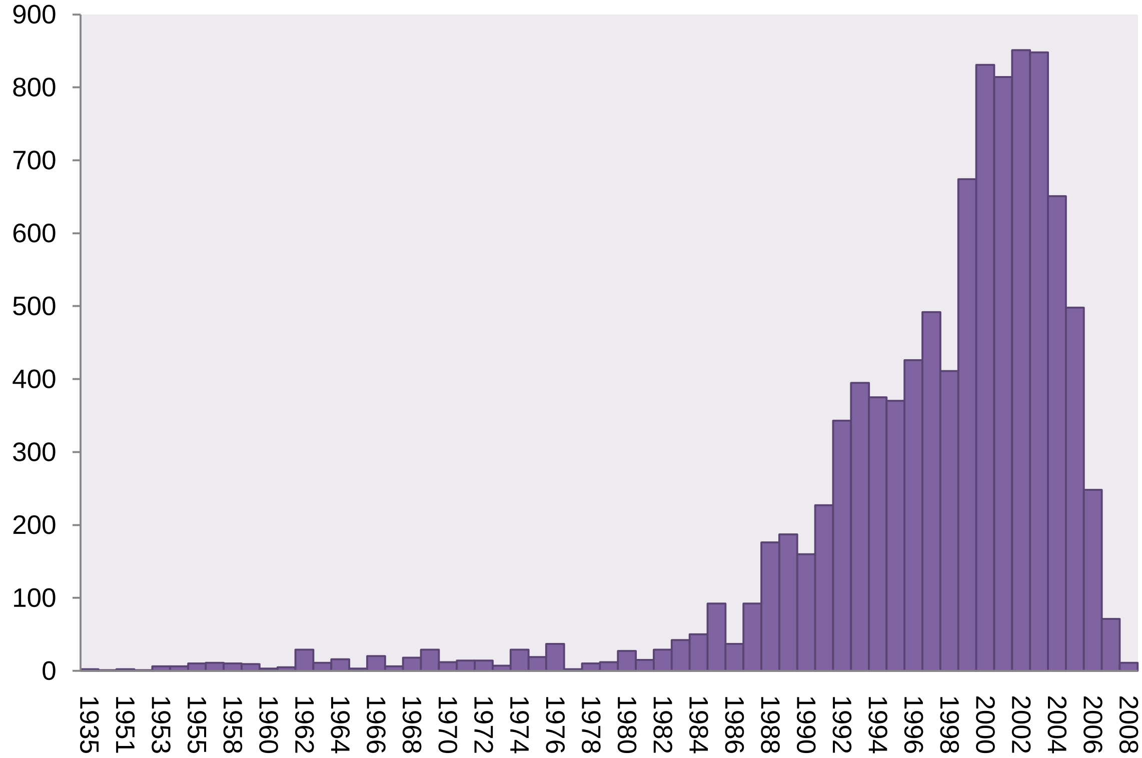

Figure 1 Published patents for the UK nanotechnology dataset

The distribution shows some activity back as far as 1935, albeit at a low level. Although at the time such activity may not have been deemed (or termed) “nanotechnology”, automated retrospective application of nanotechnology classification terms has caused their inclusion. 1962 appears to be the start of a period of significantly more activity until 1976. From 1978, after a break, there is a general climb to the peak period of activity which extends from 2000 to 2003. The sharp decline from 2004 to the present is to some extent due to publication and processing, so this is not necessarily evidence for a genuine decline in activity. However the bias of predominantly GB priority documents in the dataset (GB: 5289; WO 2467; US 887[4]) ought to reduce the influence of this effect beyond 18 months as compared with a truly ‘global’ dataset. The decline may therefore be actual, although some falsity will be attributable to non-GB patent publication delays. UK nanotechnology is certainly undergoing rapid change and developing research but it is not clear whether it is still emerging or just at the peak of activity. Further analysis of the patent data may provide a clearer picture.

2.2 Key technology areas

The key technology areas, as determined by the top ECLA classification terms applied, are shown in Figure 2. The top classification term for this dataset is A61K

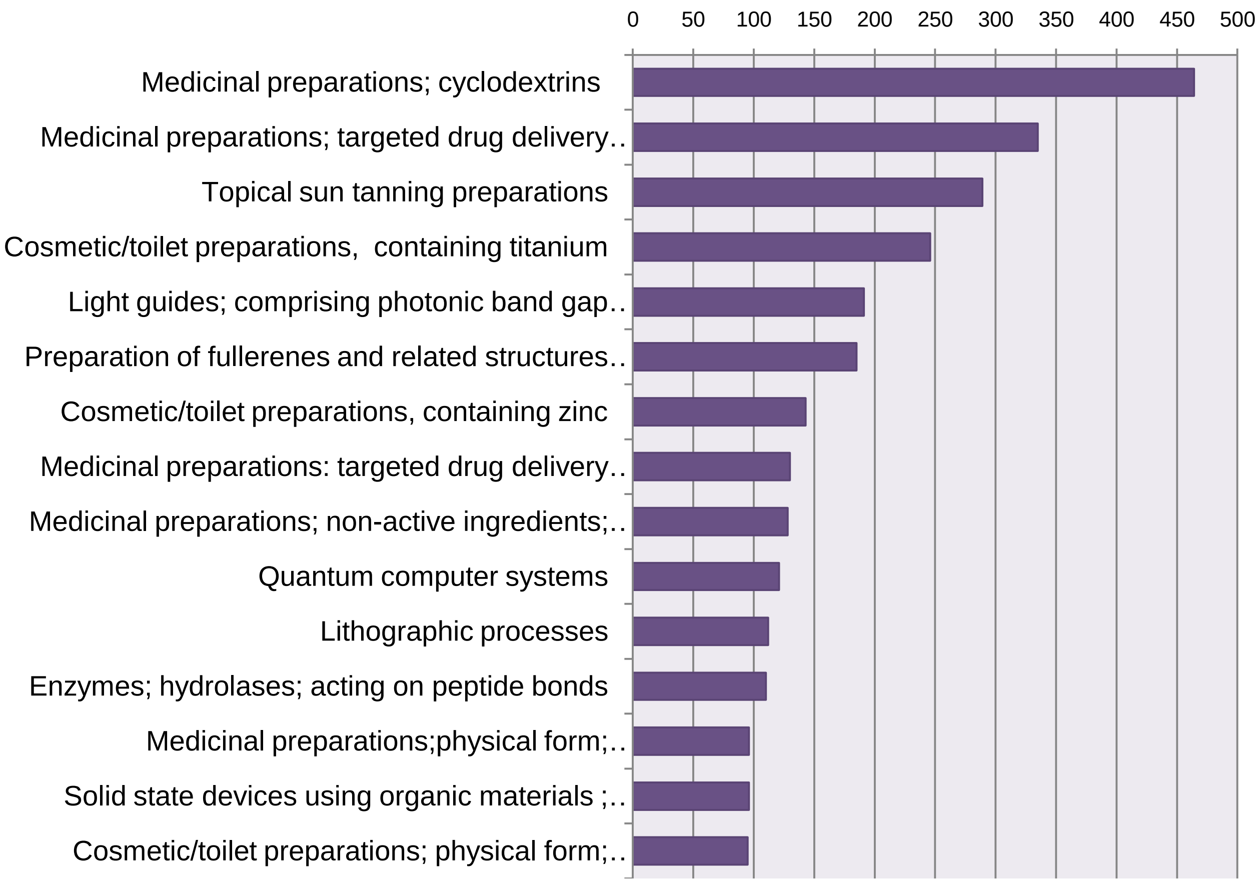

Figure 2 Top classification terms for the UK nanotechnology dataset

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[4] There may be multiple priority documents per record, so the total priority documents exceed the number of patent records in the dataset. Figures shown for GB, WO and US only; others not stated.

47/48W18B, which relates to medicinal preparations, and in particular the use of an active ingredient, specifically cyclodextrins. The higher level classification A61K, relating to medicinal preparations, features heavily in this dataset, with three occurrences within the top four classifications, indicating that the UK has a sizable area of research in this field.

The codes are not shown in Figure 2 above; for clarity an English language description has been substituted. On reviewing these codes it is quickly evident that they correlate well with the key areas of interest. A more extensive definition of these technology areas can therefore be found in Table 2.

N° of patents	Classification code	Technology area
464	A61K47/48W18B	Medicinal preparations characterised by the non-active ingredients used: cyclodextrins
335	A61K47/48T8P	Medicinal preparations characterised by the non-active ingredients used, targeted drug delivery systems; antibody directed enzyme therapy
289	A61Q17/04	Topical preparations for affording protection against sunlight or other radiation; topical sun tanning preparations
246	A61K8/29	Cosmetic or similar toilet preparations, containing titanium; compounds thereof
191	G02B6/122P	Light guides; basic optical elements; comprising photonic band gap structures or photonic lattices
185	C01B31/02B	Carbon; compounds of; preparation of fullerenes and related structures i.e. carbon nanotubes
143	A61K8/27	Cosmetic or similar toilet preparations, containing zinc; compounds thereof
130	A61K47/48R6F	Medicinal preparations characterised by the non-active ingredients used: targeted drug delivery systems; enzyme producing therapy
128	A61K47/48W14B	Medicinal preparations characterised by the non-active ingredients used: nanocapsules; nanoparticles
121	G06N1/00K	Quantum computer systems
112	G03F7/00A	Lithographic processes using patterning methods other than exposure to radiation
110	C12N9/48	Enzymes; hydrolases; acting on peptide bonds
96	A61K9/51	Medicinal preparations characterised by special physical form; nanocapsules; nanosols; nanoparticles
96	H01L51/05B2B6	Solid state devices using organic materials as the active part; lateral single gate single channel transistors
95	A61K8/11F	Cosmetic/toilet preparations; physical form; nanocapsules

Table 2 Top classification codes in more detail for the UK nanotechnology dataset

Figure 3 shows a plot of records in each of the top ten patent classification terms per priority year. It evidences the simultaneous increase in activity in related areas. For example the increase in activity in the area of cosmetic/toilet preparations containing titanium and the concurrent activity in suntan protection preparations, as these two technology areas are very obviously linked.

Amongst medicinal preparations, cyclodextrins, enzyme producing therapy, and non-active ingredients show continued development, contrasting with antibody directed enzyme therapy, which is in a greater state of decline than any other classification in the plot, from the highest peak.

Non-medicinal and non-cosmetic applications of nanotechnology, specifically light guides, preparation of fullerenes, and especially quantum computer systems, are later entries in this plot. Light guides are particularly interesting, as there is a small increase towards the end of the plot, which may be the start of a period of growth and therefore indicate a candidate emerging technology. Glasgow University has a number of patents in this area as noted in section 3.3.4.

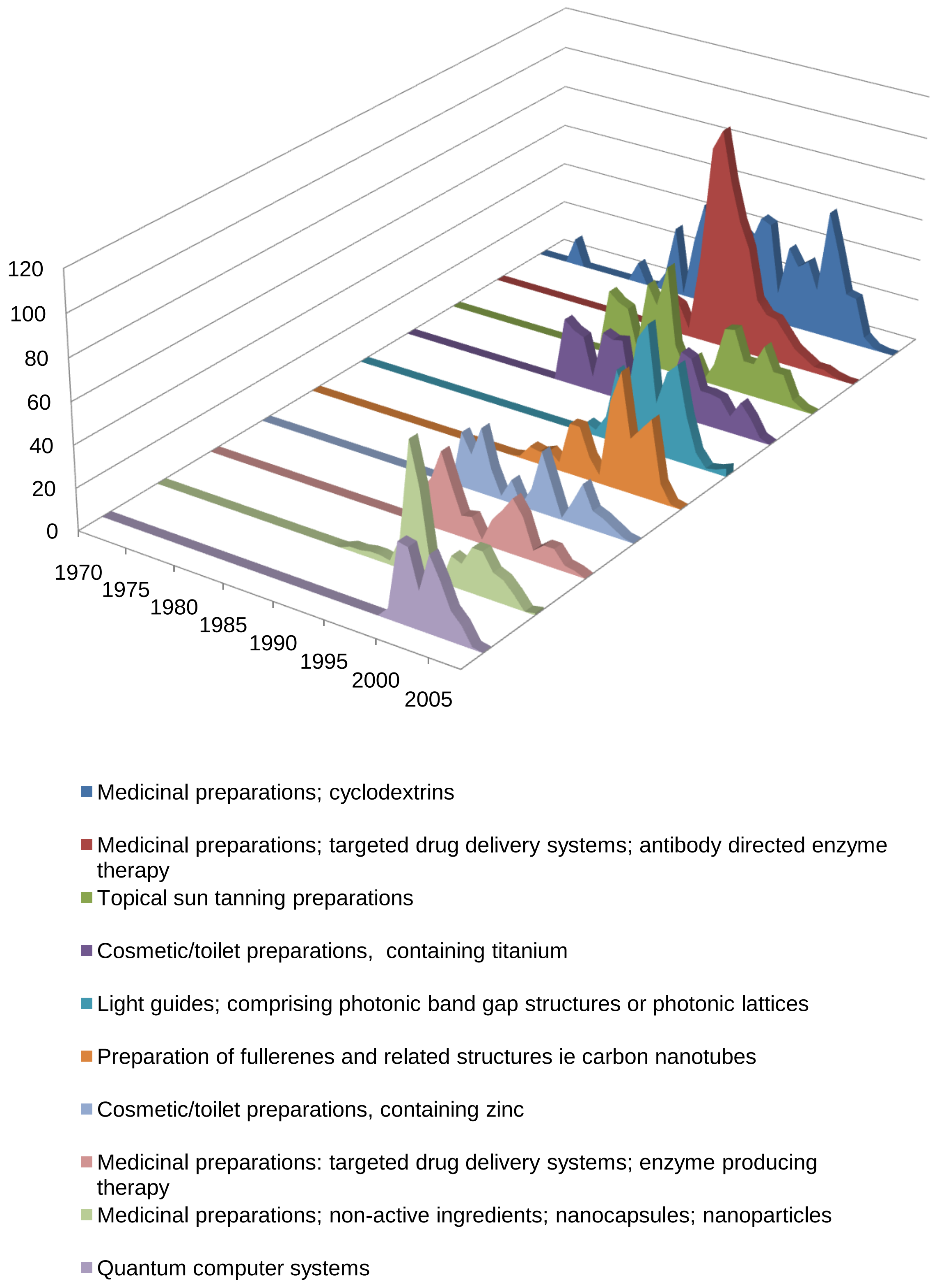

Figure 3 Plot of top 10 technology areas via classification against time and number of records for the UK nanotechnology dataset

2.3 Technology Groupings

2.3.1 Whole UK dataset

Only the top ten classification terms are shown in Figure 3. Since there are 2782 different ECLA classifications applied to records in the dataset, overall patterns in the whole dataset may be missed. Therefore, each classification code was assigned to a group according to areas of interest expressed in the proposal. When analysing the dataset in detail, it became clear that the analysis would benefit from having two additional categories not included in the proposal: electronics and nanofiltration / nanoseparation. In terms of high-level classification term assignment, nanofiltration / nanoseparation is the best approximation to a general ‘nanotoxicity’ / ‘nanopollution’ definition. Nanotoxicity is specifically studied separately in section 2.3.2. It should be noted that an ECLA code may be assigned to more than one of the six groups if it has spread relevance. Some records therefore are assigned to more than one group, hence the totals of the records in each group exceeds the number of distinct records in the dataset.

The overall distribution is given in Figure 4.

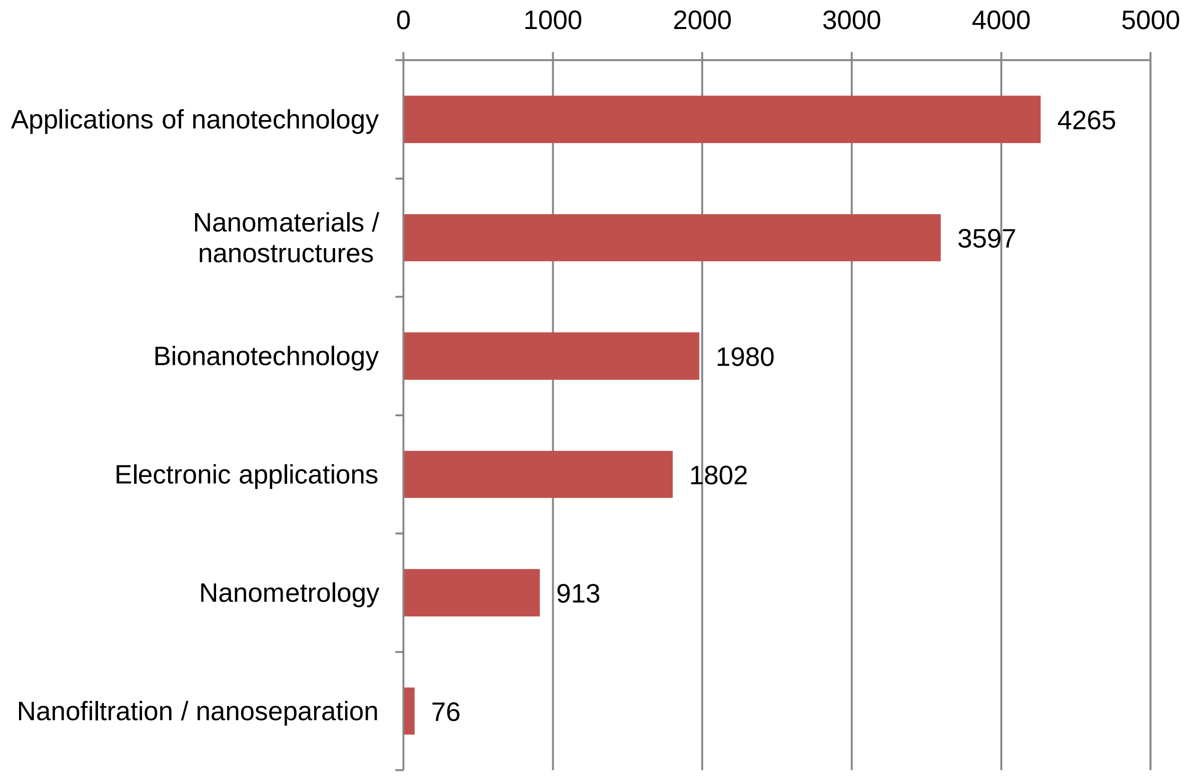

Figure 4 Distribution of records across technology groups

The time distribution for these groups is given in Figure 5. Note that there is some correlation between different categories in certain periods, such as applications of nanotechnology with nanomaterials / nanostructures and electronic applications. However, at other times the different categories show different trends. Nanomaterials / nanostructures, bionanotechnology, and nanometrology decline from about 2002, whilst applications of nanotechnology and electronic applications peak later before declining. In all cases, the apparent decline since 2007 (and maybe earlier) may be attributable to processing and publication delay, and should not necessarily be taken as evidence of true decline.

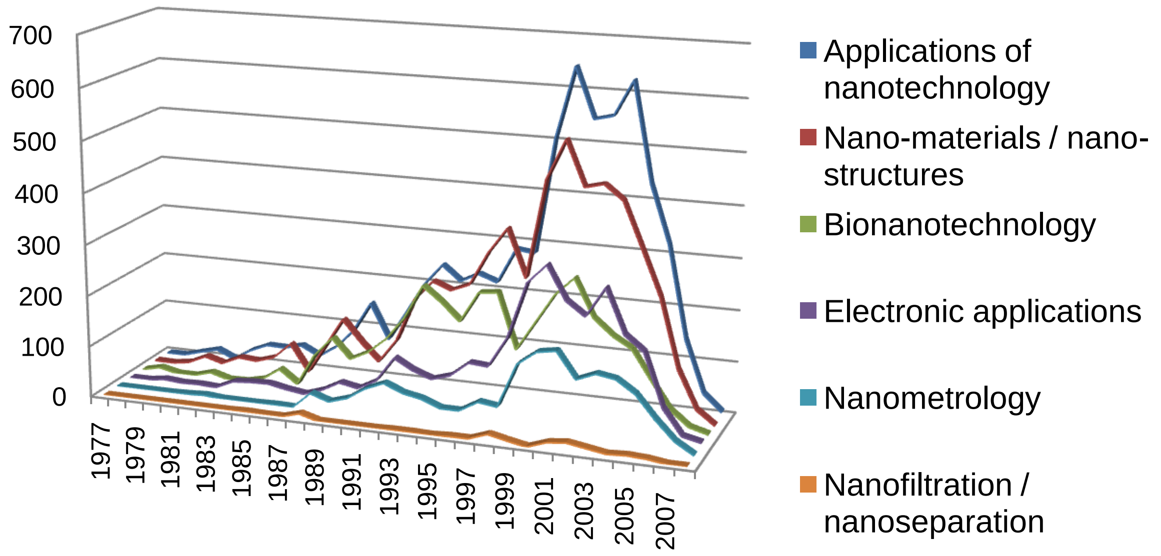

Figure 5 Distribution of records across technology groups through time

The most frequently occurring inventors and applicant organisations in each of these technology groups is given in Table 3.

Technology Term	Top People	Top Organisation Names
Applications of nanotechnology	Sirringhaus Henning Friend Richard Henry Birks Timothy Adam	Tioxide Group Plc [204]; QinetiQ Ltd [133]; Philips NV [130]
Nanomaterials / nanostructures	Springer Caroline Joy Illum Lisbeth Birks Timothy Adam	Tioxide Group Plc [233]; Cancer Res Campaign Tech [129]; Pfizer [129]
Bionanotechnology	Springer Caroline Joy Illum Lisbeth Marais Richard	Cancer Res Campaign Tech [172]; Pfizer [134]; AstraZeneca AB [119]
Electronic applications	Sirringhaus Henning Friend Richard Henry Cowburn Russell	Cambridge University Technical[5] [101]; Hitachi Ltd [91]; Philips NV [78]
Nanometrology	Reading Michael Welland Mark Cowburn Russell	Cambridge University Technical[5] [46]; Renishaw Plc [28]; T A Instr Inc [24]; Univ Bristol [24]
Nanofiltration / nanoseparation	Tessler Nir Friend Richard Henry Ho Peter	Cambridge Display Technology [10]; Glaverbel [10]; Procter & Gamble [10]

Table 3 Top inventors and organisations in each technology grouping

[5] Not including Cambridge Enterprise

2.3.2 Global nanotoxicity dataset

A basic search for patent data relating to nanotoxicity data was completed. No restriction on UK origin or inventor was made, as the data volume was initially very small. The dataset was expanded by locating all the patents cited by examiners during the patent application process, on the initial search results, to ensure capture of relevant patents. The dataset was reviewed manually through examination of the abstracts for relevance to nanotoxicity. The resulting dataset consists of 253 documents, which allows a simple analysis to be carried out; unfortunately it is not possible to create a detailed patent landscape for a dataset of this size. Other techniques, however, such as citation analysis were possible, the results of which are presented in Section 4.2.

It is essential to remember that this is a relatively small dataset, which means that accurate conclusions are limited, due to the potential restricted statistical significance of the results. Table 4 shows the summary data for this dataset.

Total Number of Records:	253		
Years Range From:	1983 - 2008		
Peak Year	2005		
Top Country:	US		
Top Company Name:	Trustees of the University of Illinois		
Field Choices	**Field Name**	**Number of entries**	**Field Coverage**
People	Inventors	230	92%
Companies	Patent Assignees	140	88%
Countries	Priority Countries	9	100%
Years	Priority Year	16	100%
Technology	EPO Classifications	116	92%

Table 4 Summary of nanotoxicity dataset

Analysis of the dataset yields Figure 6, which looks at volumes of patent priority filings over time. Overall filings in this area are low, but an interesting peak appears in 2005. Certainly, fears were raised about nanotoxicity in the press in 2004[6], so that this could be a result of the issue gaining prominence and incentivising research.

[6] "*Scientists attack Prince's little grey cells*", Sam Coates, The Times, published July 12 2004, available from: http://www.timesonline.co.uk/tol/news/uk/article456317.ece

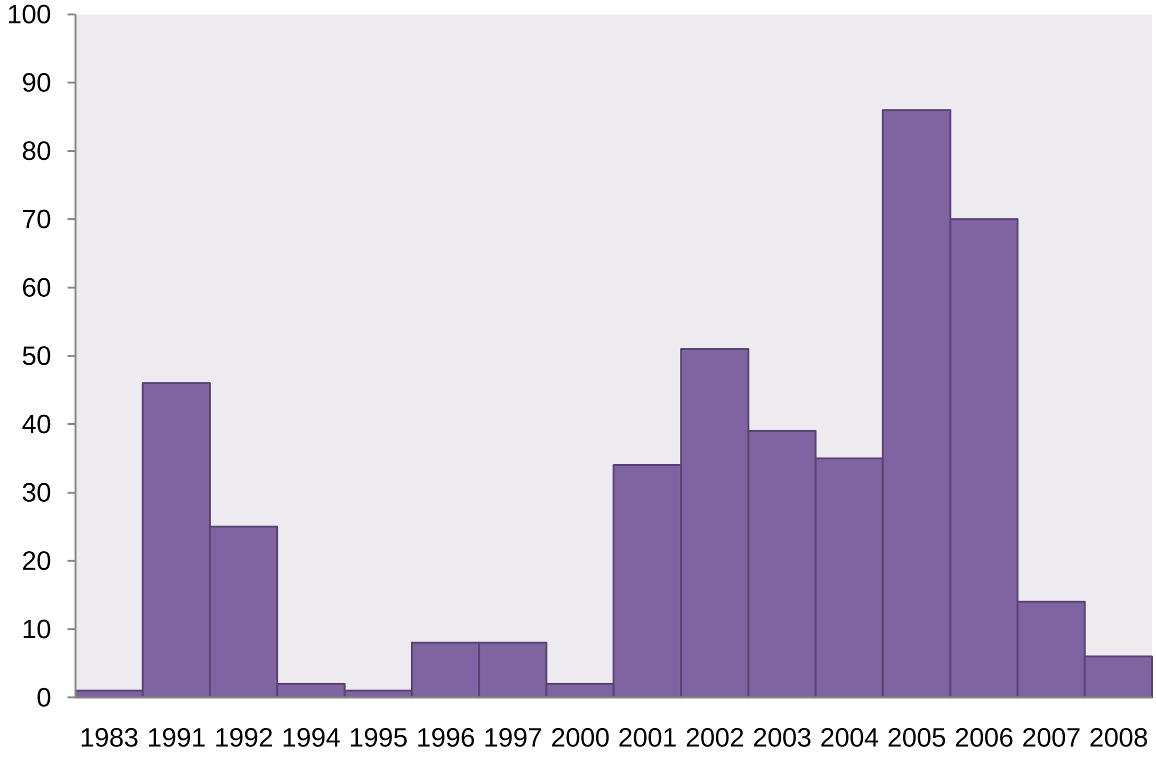

Figure 6 Published patents for the nanotoxicity dataset

A priority country analysis shows that the US is the most prominent county of origin, followed by WO and then France. The UK does not appear in Figure 7. Patents having a UK base/inventor may, however, be present within the WO and EP priority patents; section 1.3 provides an explanation for this.

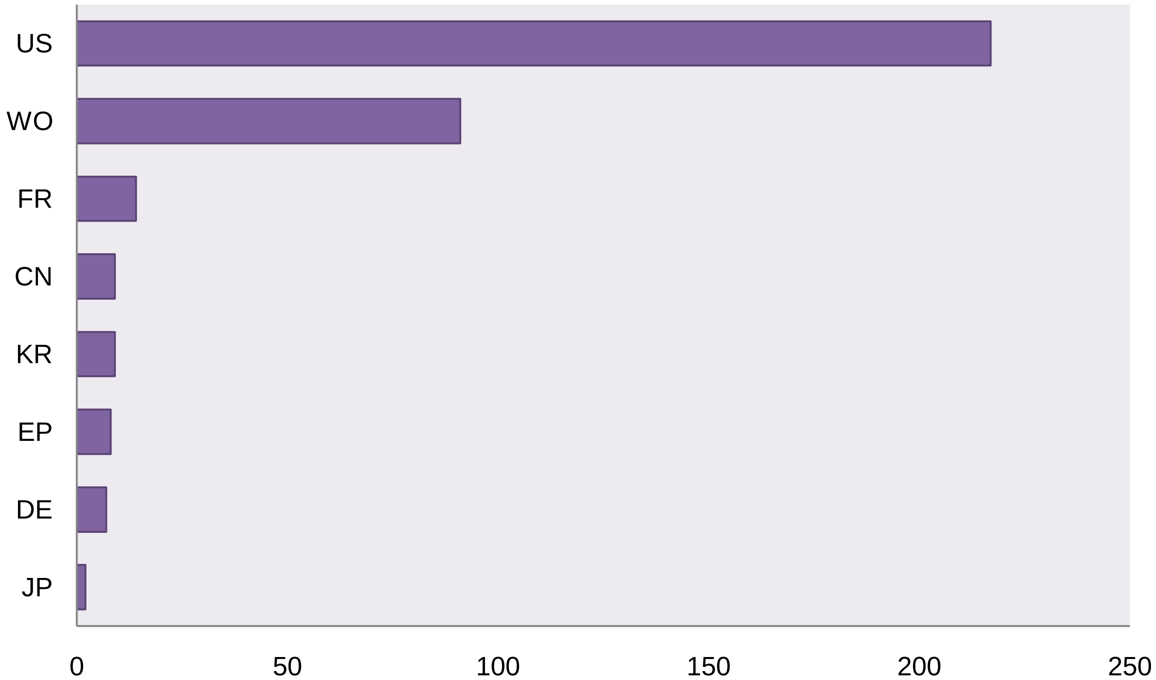

Figure 7 Published patent volumes according to priority country

The top 15 classifications are shown in Figure 8. Medicinal preparations feature heavily in these top classifications, particularly in terms of drug delivery systems. This is due to the necessity of consideration of toxicity data for such systems, in association with the drug itself. In compiling the current dataset a distinction was made between patents that simply referred to toxicity in the context of the drug delivered, and those that directly considered the toxicity of the nano-scale delivery system. This was a challenging distinction to make but one that was considered necessary to ensure the dataset could be appropriately analysed.

In examining the classifications it is important to comprehend that more than one classification may be attached to a single patent, and this would certainly appear to be the case here, given the 'groupings' of classifications of inter-related patents. The diversity of classifications within this dataset reflects the spread of interest in the toxicity aspect of nanotechnology. A table giving further detail on classification definitions is also provided in Table 5.

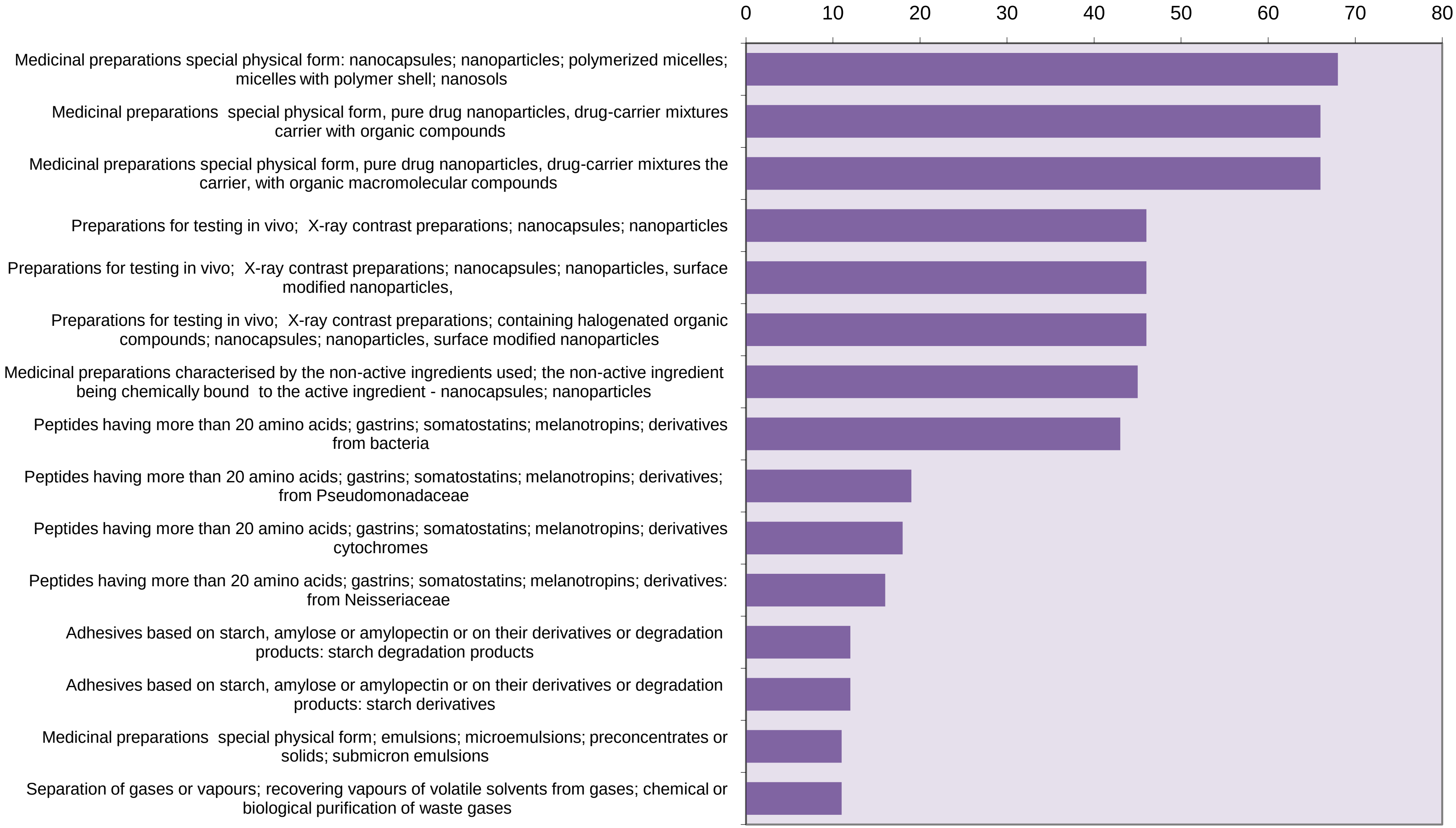

Figure 8 Top classification terms for the nanotoxicity dataset

Classification code	Technology area
A61K9/51	Medicinal preparations characterised by special physical form: nanocapsules; nanoparticles; nanosols
A61K9/14H4	Medicinal preparations characterised by special physical form, pure drug nanoparticles, intimate drug-carrier mixtures characterised by the carrier with organic compounds
A61K9/14H6	Medicinal preparations characterised by special physical form, pure drug nanoparticles, intimate drug-carrier mixtures characterised by the carrier, with organic macromolecular compounds
A61K49/04F8N	Preparations for testing in vivo; X-ray contrast preparations; nanocapsules; nanoparticles
A61K49/04F8N 2	Preparations for testing in vivo; X-ray contrast preparations; nanocapsules; nanoparticles, surface modified nanoparticles,
A61K49/04H8P 4S	Preparations for testing in vivo; X-ray contrast preparations; containing halogenated organic compounds; nanocapsules; nanoparticles, surface modified nanoparticles,
A61K47/48W14 B	Medicinal preparations characterised by the non-active ingredients used; the non-active ingredient being chemically bound to the active ingredient - nanocapsules; nanoparticles
C07K14/195	Peptides having more than 20 amino acids; gastrins; somatostatins; melanotropins; derivatives from bacteria
C07K14/21	Peptides having more than 20 amino acids; gastrins; somatostatins; melanotropins; derivatives; from Pseudomonadaceae
C07K14/80	Peptides having more than 20 amino acids; gastrins; somatostatins; melanotropins; derivatives cytochromes
C07K14/22	Peptides having more than 20 amino acids; gastrins; somatostatins; melanotropins; derivatives: from Neisseriaceae
C09J103/02	Adhesives based on starch, amylose or amylopectin or on their derivatives or degradation products: starch degradation products
C09J103/04	Adhesives based on starch, amylose or amylopectin or on their derivatives or degradation products: starch derivatives
A61K9/107D	Medicinal preparations characterised by special physical form; emulsions; microemulsions; preconcentrates or solids thereof; submicron emulsions
B01D53/94H	Separation of gases or vapours; recovering vapours of volatile solvents from gases; chemical or biological purification of waste gases

Table 5 Top classification codes in more detail for the nanotoxicity dataset

The top five most frequently named assignees are listed in Figure 9. Interestingly, the most prolific applicant is a US university.

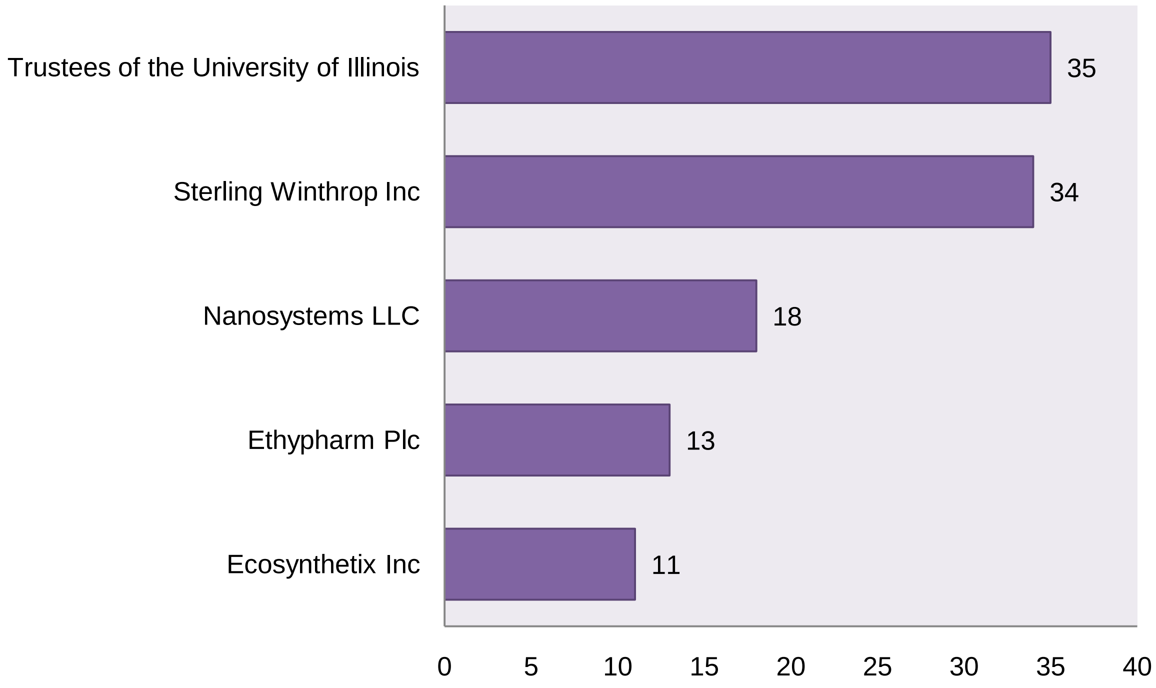

Figure 9 Top five patent assignees in the nanotoxicity dataset

2.4 UK nanotechnology patent landscape map

The patent landscape mapping software works best on patent records having a consistent core language. Importing the patent applications identified in the UK dataset, the resulting patent landscape map, as shown in Figure 10, is based on around 1500 deduplicated patent families and provides a good overview of the technology space.

Patents are represented on the map by dots (not all patents are visible at the zoom level shown) and the more intense the concentration of patents (i.e. the more closely related they are) the higher the topography as shown by contour lines.

Patents are grouped according to the occurrence of keywords in the title and abstract. The top three keywords within localised regions appear on the map.

The map is self-explanatory in respect of patent density in different technology sectors represented by the keywords shown. Notably the map is consistent with the observations elsewhere in this report evidencing UK strengths in sectors corresponding to 'beam electron pattern'; 'structures quantum electron'; 'nanoparticles material preparing'; 'carbon nanotubes surface' and 'pharmaceutical cyclodextrin derivatives'.

Significant areas of lower topography and estuaries / inland water-ways may represent areas of immaturity or early emergence. Although a rigorous analysis of the map has not been undertaken, further work could pursue this aspect, although observations in section 3.3.5 are consistent with these areas harbouring academic research.

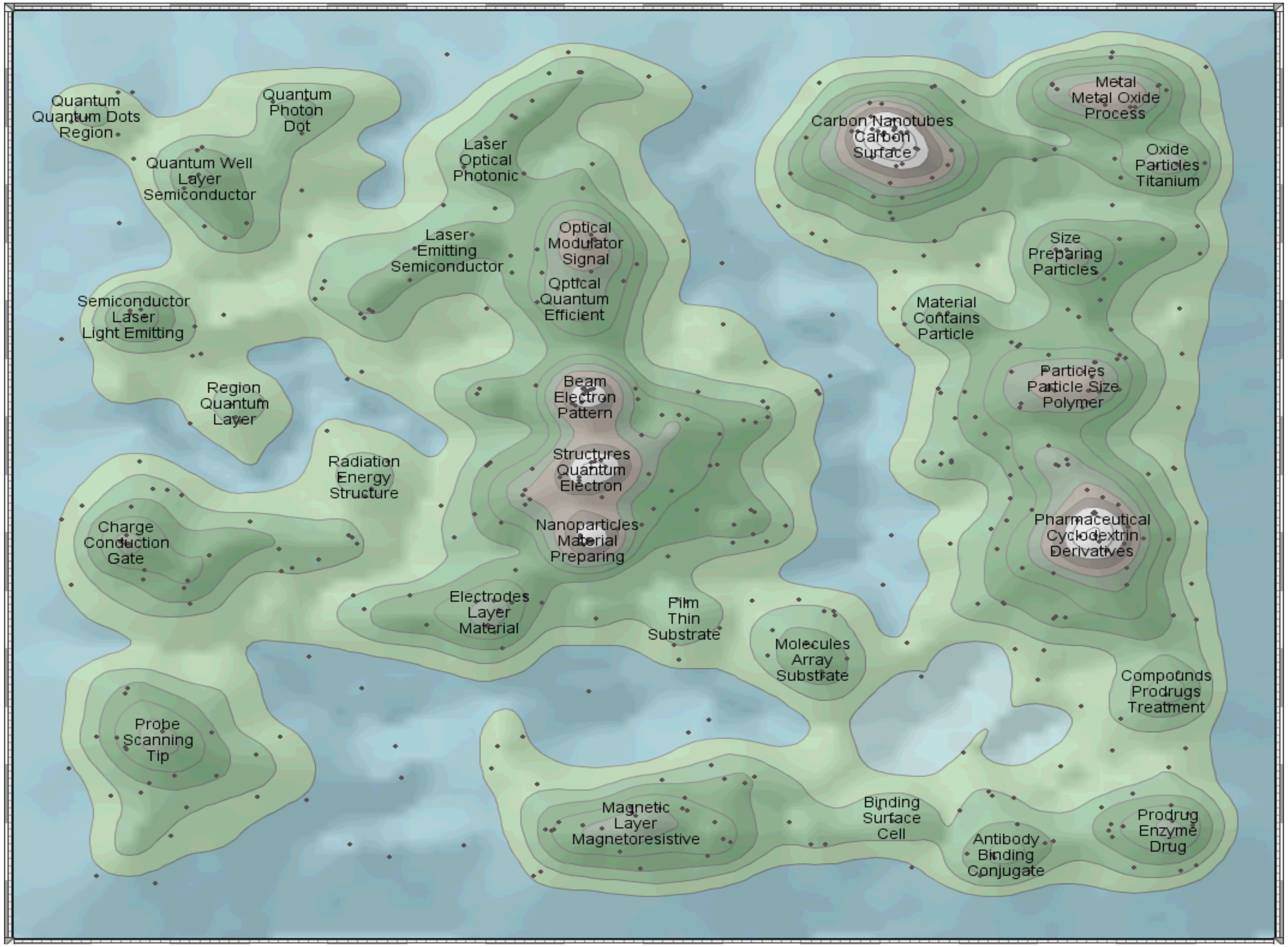

Figure 10 Patent map of the UK nanotechnology dataset ©Thomson Reuters

2.5 Patent holdings

Figure 11 shows the number of patents per assignee (‘portfolio size’) for the patents in the dataset. The size of each segment shows the number of patents in portfolios of a particular size, not the number of assignees having portfolios of that size. Patents in the largest portfolio size category (101+) are held by assignees holding a high number of records in their portfolio; those in the lowest category hold only one record.

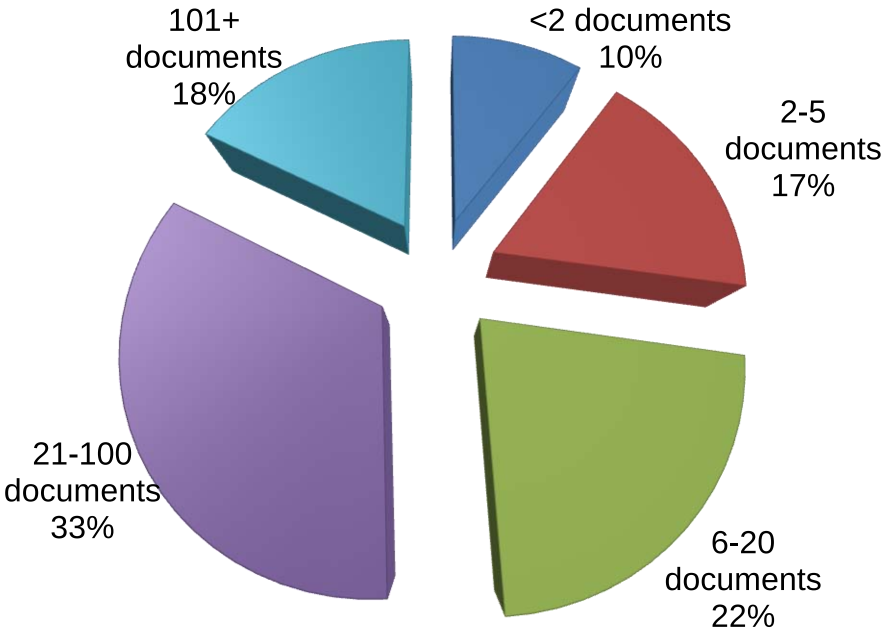

Figure 11 Patent holdings chart for the UK nanotechnology dataset

The chart shown in Figure 11 is indicative of a technology involving ongoing research and development. There are a number of established applicants in the technology area (holding >101 documents in their portfolio), but there are still significant numbers of small patent portfolios. Further refinement of the search areas could pinpoint areas of rapid development, which might identify emergent technologies.

Further work could investigate the portfolios of applicants who are still active, or concentrate on a similar analysis limited to e.g. the last ten years. Many smaller groups appear to be active in this technology space in the UK. However it would be essential that this assessment be put in context via analysis of the UK based activity, in comparison to activity in the global patent space for nanotechnology.

2.6 Collaborations

A collaboration map of the top twenty applicants was generated and is shown in Figure 12. This map shows the degree to which pairs of applicants tend to appear in same records and is an indicator of technology transfer. The strength of the lines indicates the frequency with which that pair both appear in a record together. This is an explicit indicator of collaboration.

A further collaboration map of the top twenty applicants was generated and is shown in Figure 13. In this case the map is showing the degree to which inventors are shared between the respective pairs of applicants. The strength of the lines indicates the frequency with which an inventor appears in both applicants' records. This may also be interpreted as an indicator of collaboration.

These maps only display collaborations between any of the top twenty applicants with any other of the top twenty applicants. Therefore, although many of these applicants show collaborative activity with other applicants, these cannot all be displayed at once. Figure 14 shows a map for the top three commercial applicants and the top three university applicants that are examined in detail in section 3 below, together with all of their significant collaborators. The more tenuous collaborations are not included so as to avoid crowding the map.

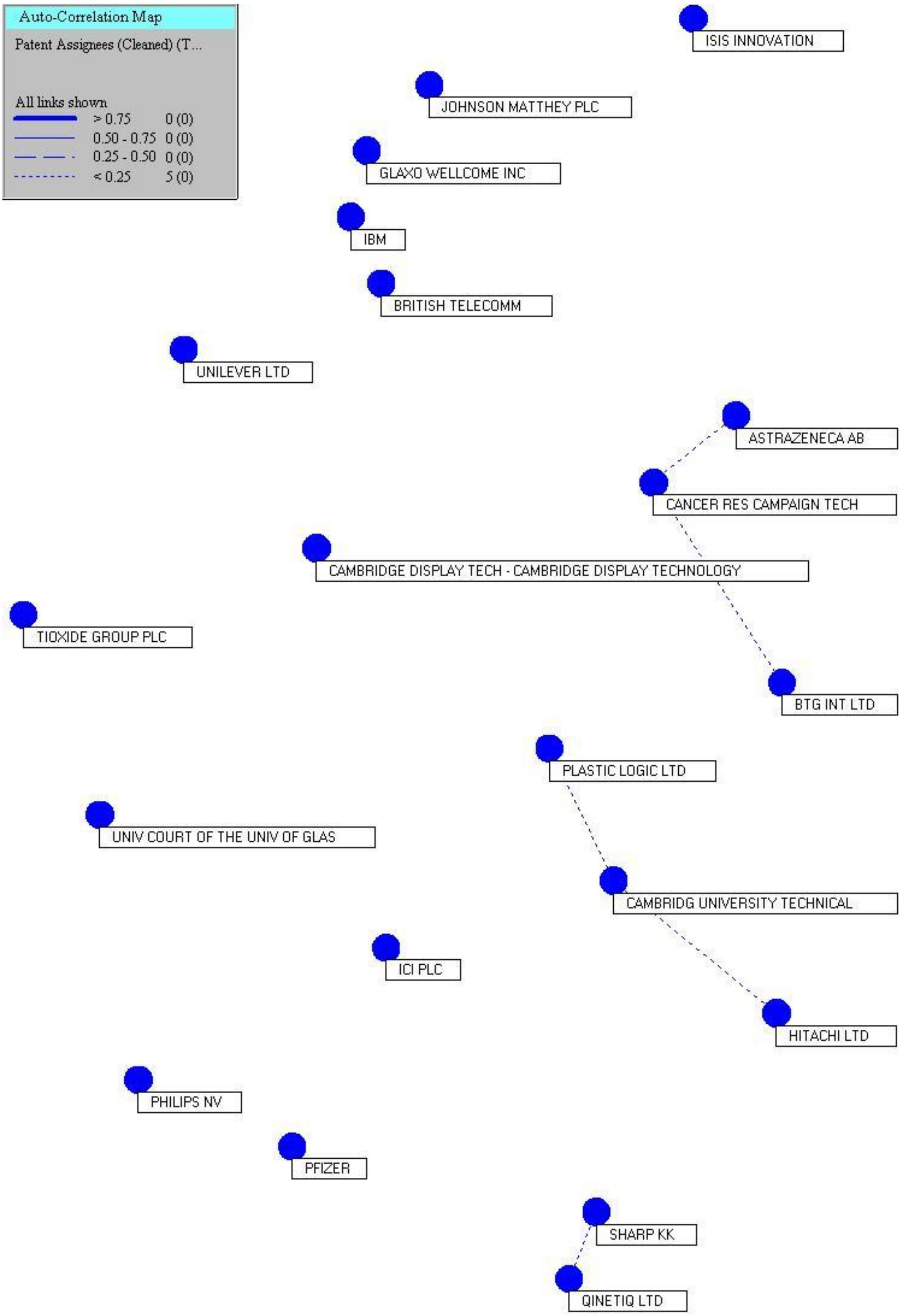

Figure 12 Collaboration map showing collaboration by applicant

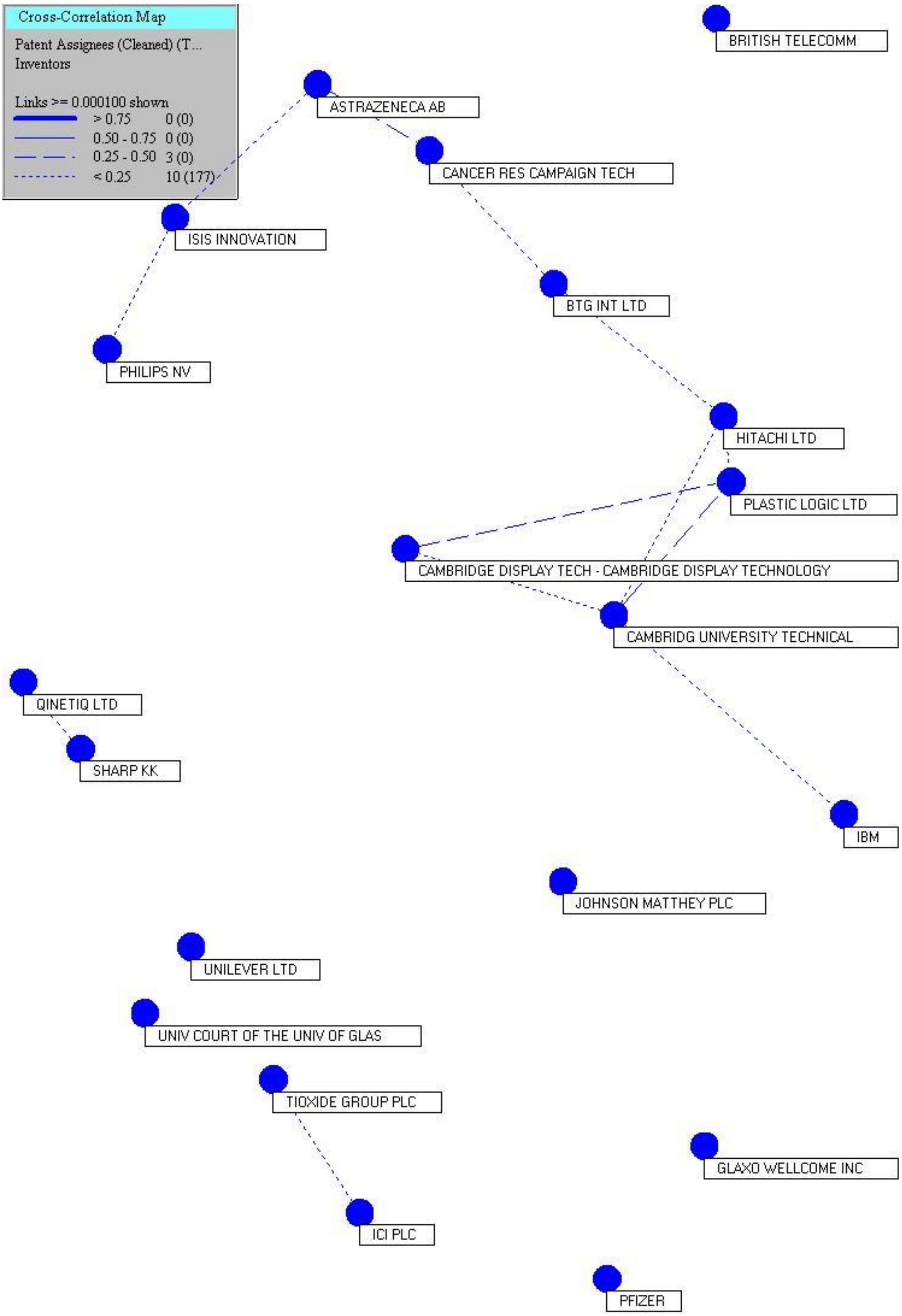

Figure 13 Collaboration map showing collaboration by inventor

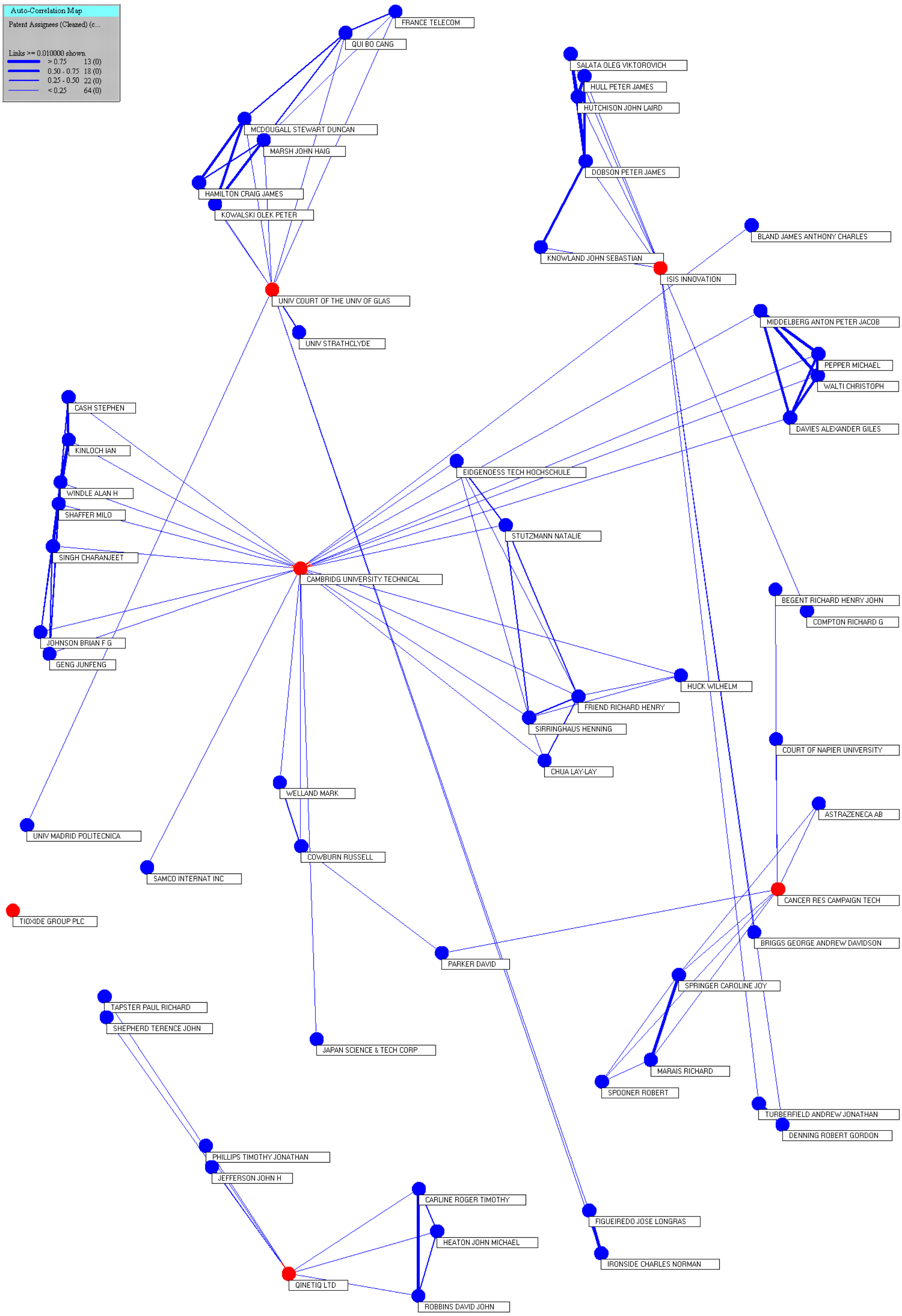

Figure 14 Collaboration map of top three commercial and university applicants (highlighted)

3 Detailed Applicant Analysis

3.1 UK applicant overview

Figure 15 gives the numbers of the top 10 applicants' patents for the UK nanotechnology dataset. Note that Tioxide was a spin out company from ICI plc and is now part of Huntsman Plc.

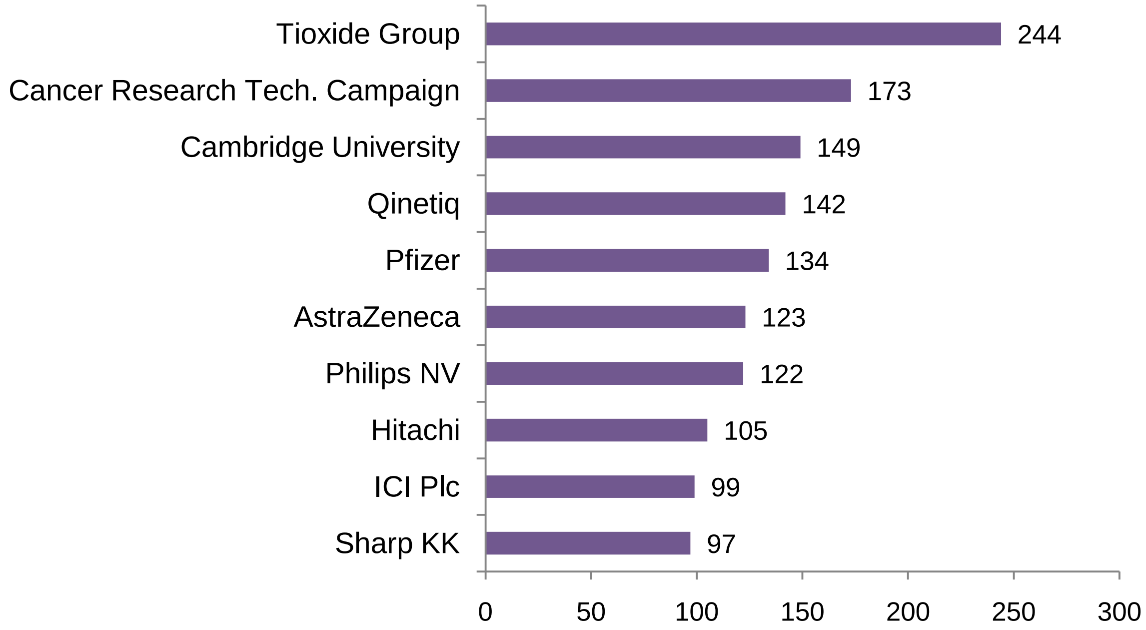

Figure 15 Top 10 patent applicants in UK nanotechnology dataset

The main assignees are Tioxide, Cancer Research and large multinational companies such as Pfizer, Philips and AstraZeneca. Interestingly, in this dataset Cambridge University is ranked in the top ten applicants. This may be linked to the amount of work completed on OLED systems by Friend et al. before forming the spin out company Cambridge Display Technology.

There are a number of different types of applicant within the current dataset, and different applicant types tend to exhibit different characteristics which merit specific consideration. The dataset has therefore been divided by applicant type to further study the UK contribution to the subject area.

The split of the dataset is shown in Figure 16, below.

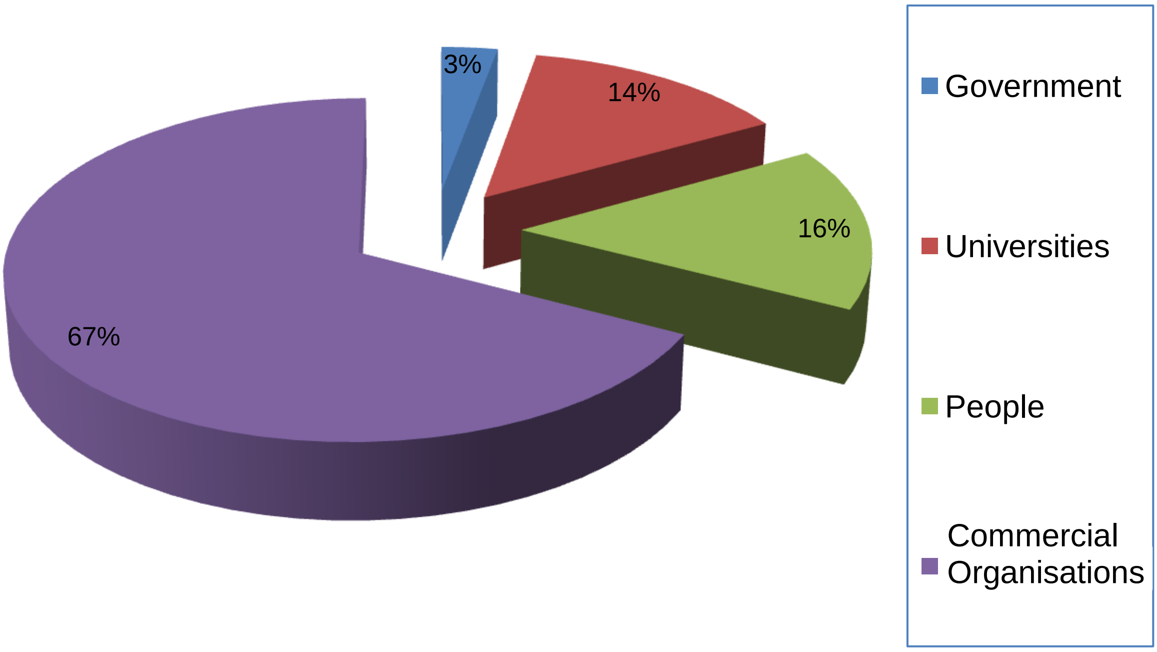

Figure 16 Plot showing the split of applicant type in the UK nanotechnology dataset

The distribution of UK nanotechnology based activity shows that, despite considerable activity from the commercial organisation sector, much of the work in this area originates from universities. This indicates that there is further scope for ongoing fundamental research, and that this is a developing technology rather than a mature one.

In Figure 17, this grouping is reviewed on a temporal basis. It is noticeable that university assignees have proliferated particularly since 1999, which further supports the conclusion that research in this field is ongoing. The relative balance of activity in each subset by applicant type may also be analysed, and is given in Figure 18.

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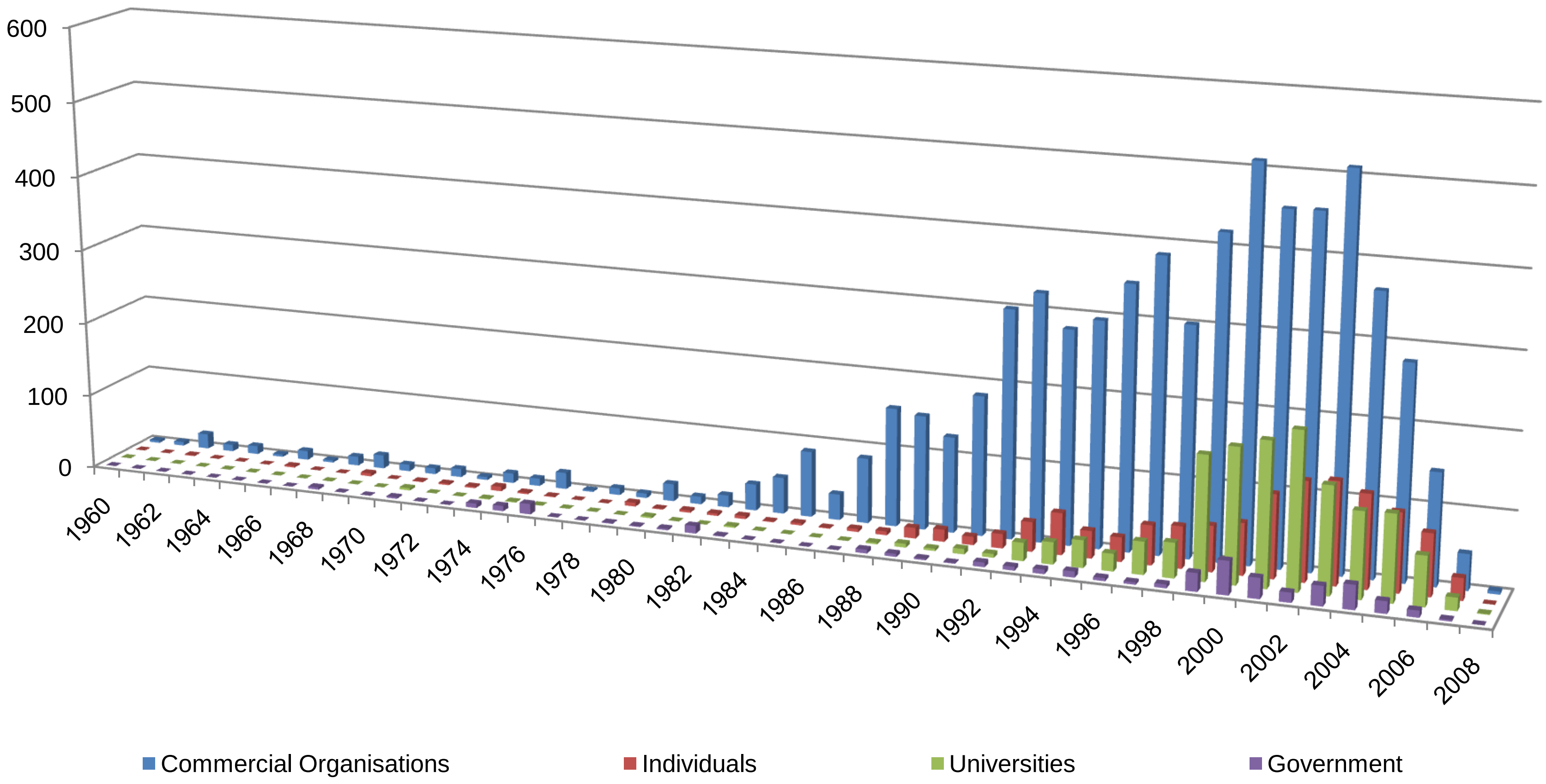

Figure 17 Applicant type by year

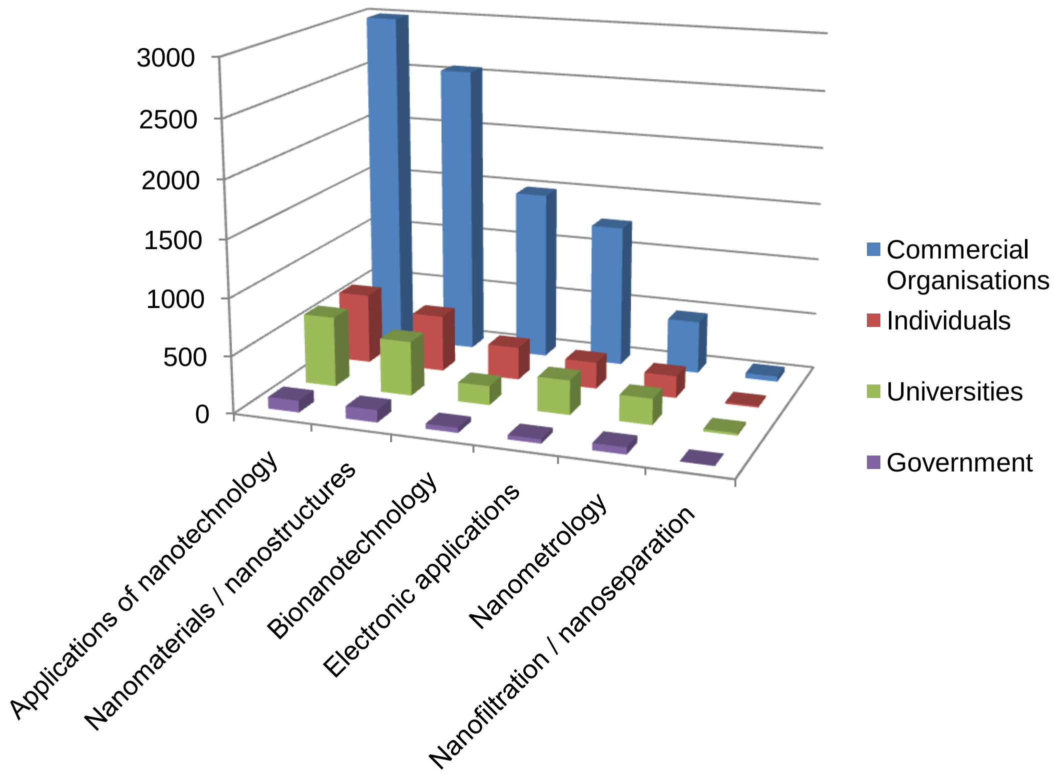

Figure 18 Distribution by applicant type

The different distribution of interests between universities and commercial organisations, for example, is evident from this plot. Bionanotechnology in particular appears to be underrepresented amongst universities, whereas nanomaterials / nanostructures is the most prolific sector amongst government applicants.

Furthermore, the relative interests amongst the applicants within one applicant type may be plotted; for example the top 20 universities are plotted in Figure 19.

The specialism of each university can be seen here, as can the main contributors to each of the categories. It is notable that the most prolific academic applicant in nanofiltration / nanoseparation is the University of Liverpool.

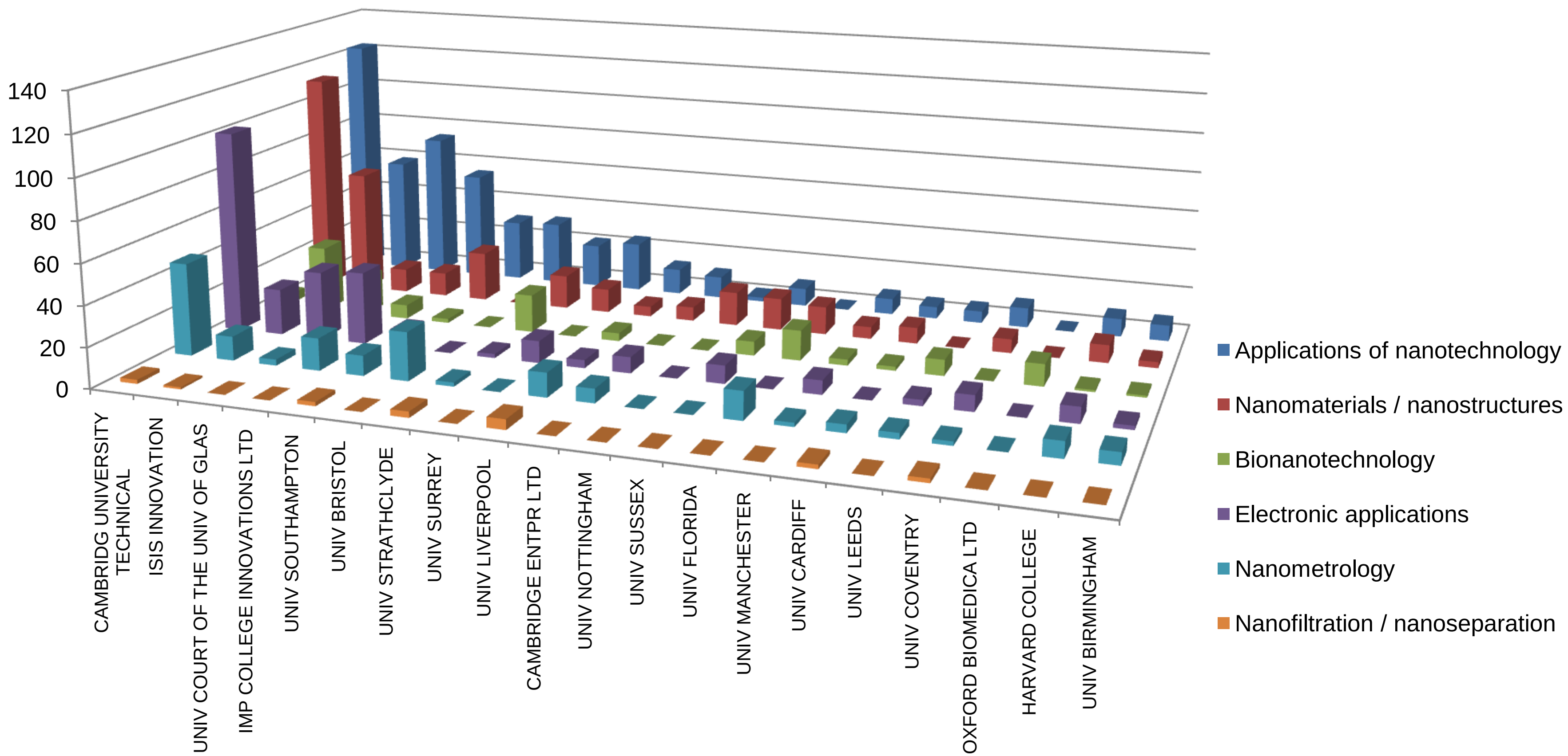

Figure 19 Distribution of records by technology grouping for the top 20 universities

3.2 Commercial organisations

3.2.1 Overview

A data subset of the commercial organisations was derived from the UK nanotechnology dataset. The summary information is shown below in Table 6.

Total Number of Records:	4,426		
Years Range From:	1935 - 2008		
Peak Years:	2000; 2003		
Top Country:	GB		
Top Company Name:	TIOXIDE GROUP PLC		
Field Choices	**Field Name**	**Number of entries**	**Field Coverage**
People	Inventors	3,784	97%
Companies	Patent Assignees	1,569	100%
Countries	Priority Countries	24	100%
Years	Priority Year	59	100%
Technology	EPO Classifications	2247	100%

Table 6 Summary of UK nanotechnology organisation data subset

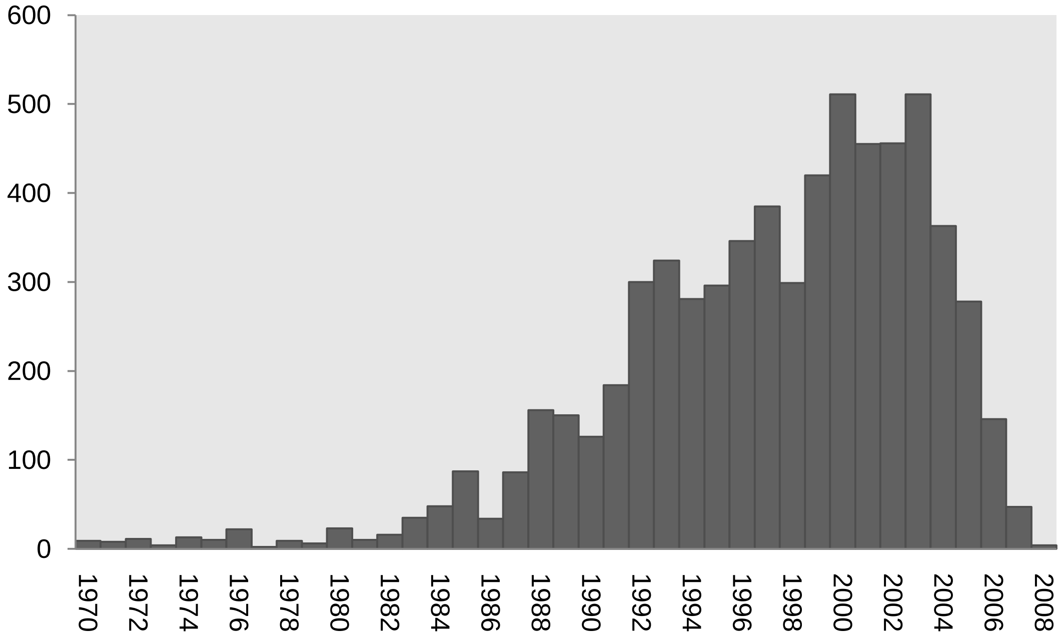

Figure 20 Plot of annual patent filings for the UK nanotechnology organisation subset

The peak for patent filings spans 2000 and 2003 as is illustrated in Figure 20.
The US Patent Office started publishing ungranted patent applications in 2000[7] and therefore may exaggerate this characteristic in the data.

[7] The USPTO started publishing patent applications from the 29 November 2000, stemming from a statutory mandate contained in the American Inventors Protection Act of 1999 (AIPA).

This graph shows that there is continuing activity in this area in the UK. The tail off since 2004 is sharp and is consistent with previous observations of this phenomenon. The plot shown in Figure 20 has been limited to the years 1970-2008 as there is negligible activity outside of this range.

The data can also be examined by applicant as in Figure 21 .

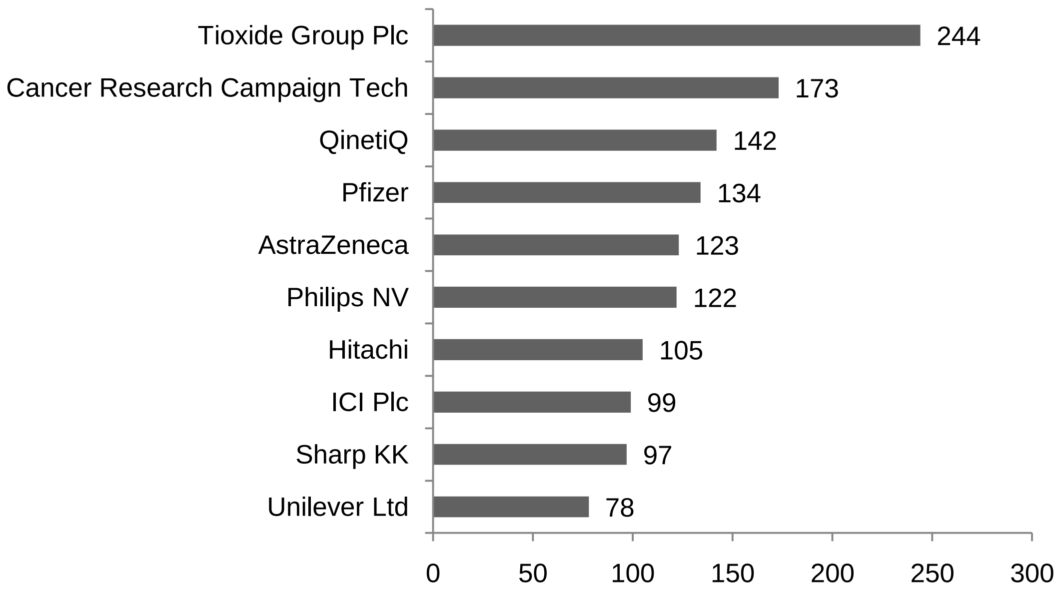

Figure 21 Top 10 applicants in UK nanotechnology organisation data subset

If the commercial organisation data in Figure 21 is compared to the overall data in Figure 15, it can be seen that the top two most prolific applicants remain the same. However, by removing the university-related activity, QinetiQ are now in third place. It should remembered that this plot is representative of total patenting activity over the time period from 1935-2008. Therefore, some of these applicants may not have been active for some time; the former ICI's activities, for example, are now divided amongst other organisations and no further activity would be expected.

A comparison of technology areas for the commercial organisations data subset has also been undertaken. Since the overall dataset is dominated by Tioxide and Cancer Research, there is little difference in technology areas observed by comparing Figure 2 and Figure 22. However, quantum computing systems are more prominent, as are the use of enzymes, whereas solid state devices are absent from the top commercial technology areas.

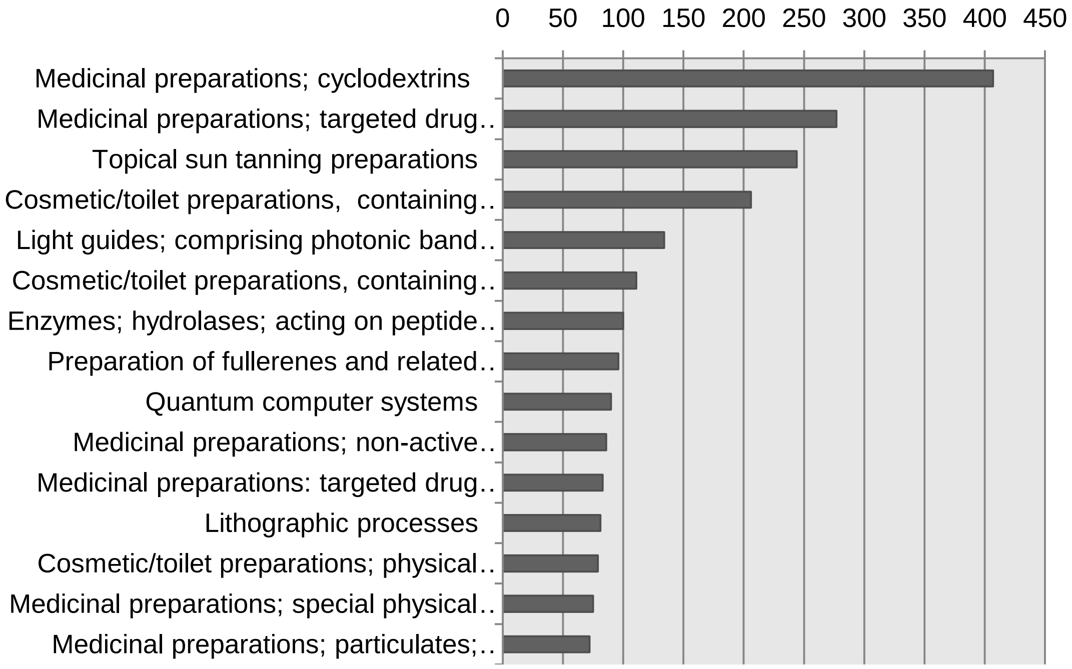

Figure 22 Plot of top technology areas for the UK nanotechnology organisation data subset

The top three assignees, Tioxide, Cancer Research and QinetiQ, have been analysed further to explore their primary technology areas and interests. It is important to note that the data subsets which have been analysed are relatively small.

3.2.2 Tioxide

The summary information for this data subset is shown in Table 7 below.

Company Name	TIOXIDE GROUP PLC		
Number of Records	244		
Range of Years	1972 - 1997		
Peak Year	1995		
Average People / Record	2.4		
Field Choices	**Field Name**	**Number of entries**	**Field Coverage**
People	Inventors	111	95%
Organization	Patent Assignees	1	100%
Country	Priority Countries	4	100%
Years	Priority Year	59	100%
Technology	EPO Classifications	64	100%

Table 7 Summary of the Tioxide dataset

It should be noted the number of records in Table 7 do not equal the sum of the records in Figure 23 because each patent application can have more than one priority document.

The peak year for Tioxide filings in this dataset was 1995 with 69 patents filed. This is shown in Figure 23. No significant collaborations were noted in this dataset.

Key inventors for Tioxide were all based in the UK and were: Leslie Simpson, Keith Robson and Herbert Dahms. Tioxide shows no activity since 1997. The company was taken over by Huntsman in 1999, so subsequent patents may have been filed with a non-UK based priority, or non-UK based inventors, and therefore not appear in the UK dataset.

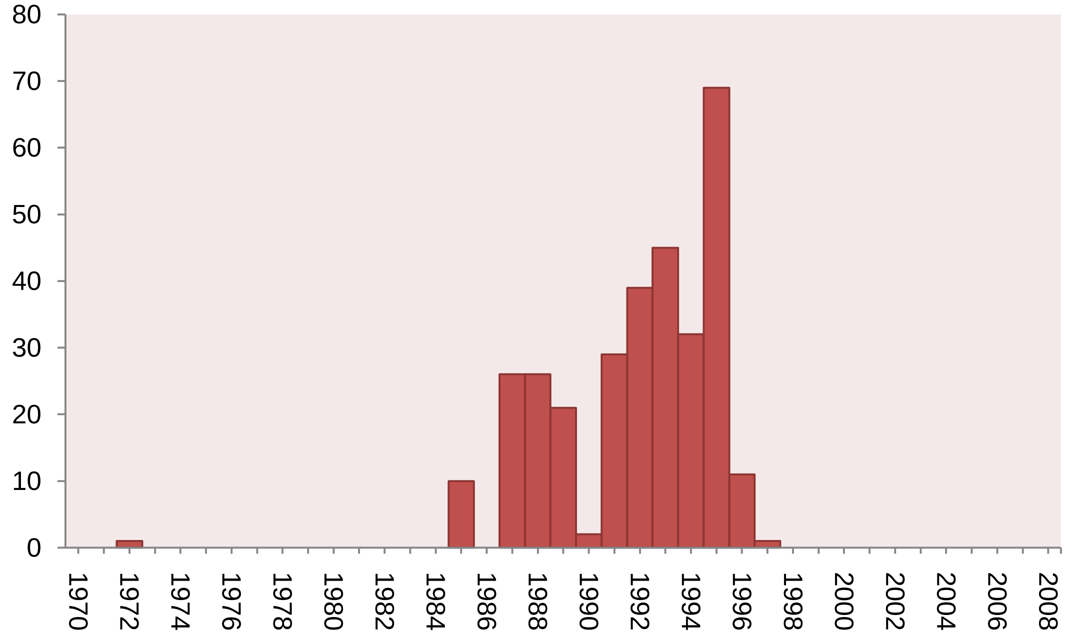

Figure 23 Patent filing activity over time for the Tioxide dataset

The data plotted in Figure 23 has been temporally limited from 1970 to present.

Classification code	Technology area	Peak Year	Peak Value
A61Q17/04	Topical preparations for affording protection against sunlight or other radiation; topical sun tanning preparations	1987	26
A61K8/29	Cosmetic or similar toilet preparations, containing titanium; compounds thereof	1987	26
C09C1/00H2	Treatment of specific inorganic material other than fibrous fillers; composite particulate pigments or fillers; containing titanium dioxide	1995	36
A61K8/27	Cosmetic or similar toilet preparations, containing zinc; compounds thereof	1991	19
C09C1/00H	Treatment of specific inorganic material other than fibrous fillers; composite particulate pigments or fillers	1992/1992	22
C08K9/02	Use of pretreated ingredients; treated with inorganic substances	1987	25
A61K8/11F	Cosmetic/toilet preparations; physical form; nanocapsules	1987	25
C09C1/36D6B	Treatment of specific inorganic material other than fibrous fillers; titanium dioxide; coating	1994/1995	15
C09D7/12D2B	Other additives; inorganic; modified by treatment with other compounds	1987	26
A61K8/06	Cosmetic or similar toilet preparations, characterised by physical form; emulsions	1987	26

Table 8 Top 10 classifications with peak year and values (i.e. number of times applied) for the Tioxide dataset

3.2.3 Cancer Research Campaign Group

The summary information for this dataset is shown in Table 9 below.

Company Name	CANCER RES CAMPAIGN TECH		
Number of Records	174		
Range of Years	1987 - 2005		
Peak Year	1993		
Average People / Record	2.9		
Field Choices	**Field Name**	**Number of entries**	**Field Coverage**
People	Inventors	87	100%
Organization	Patent Assignees	30	100%
Country	Priority Countries	4	100%
Years	Priority Year	59	100%
Technology	EPO Classifications	59	100%

Table 9 Summary of the Cancer Research Campaign Group dataset

It should be noted the number of records in Table 9 do not equal the sum of the published applications in Figure 24 because each patent application can have more than one priority document.

The peak year in terms of patent filings for the Cancer Research Campaign (CRC) was 1993, with 73 filings. This is highlighted in Figure 24. CRC have collaborated with AstraZeneca (1997-1999) and BTG International (2001-2002). Another collaborator is Edinburgh Napier University (2001-2002).

The key inventors were all based in the UK and appear to work together as part of a research group. The most prolific named inventor is Caroline Springer, who was last named on an application in 2003. Richard Marais, Robert Dowell and Philip Burke are the next most frequently named respectively. However, none of these inventors has published anything appearing in the UK dataset in the last three years in the name of CRC.

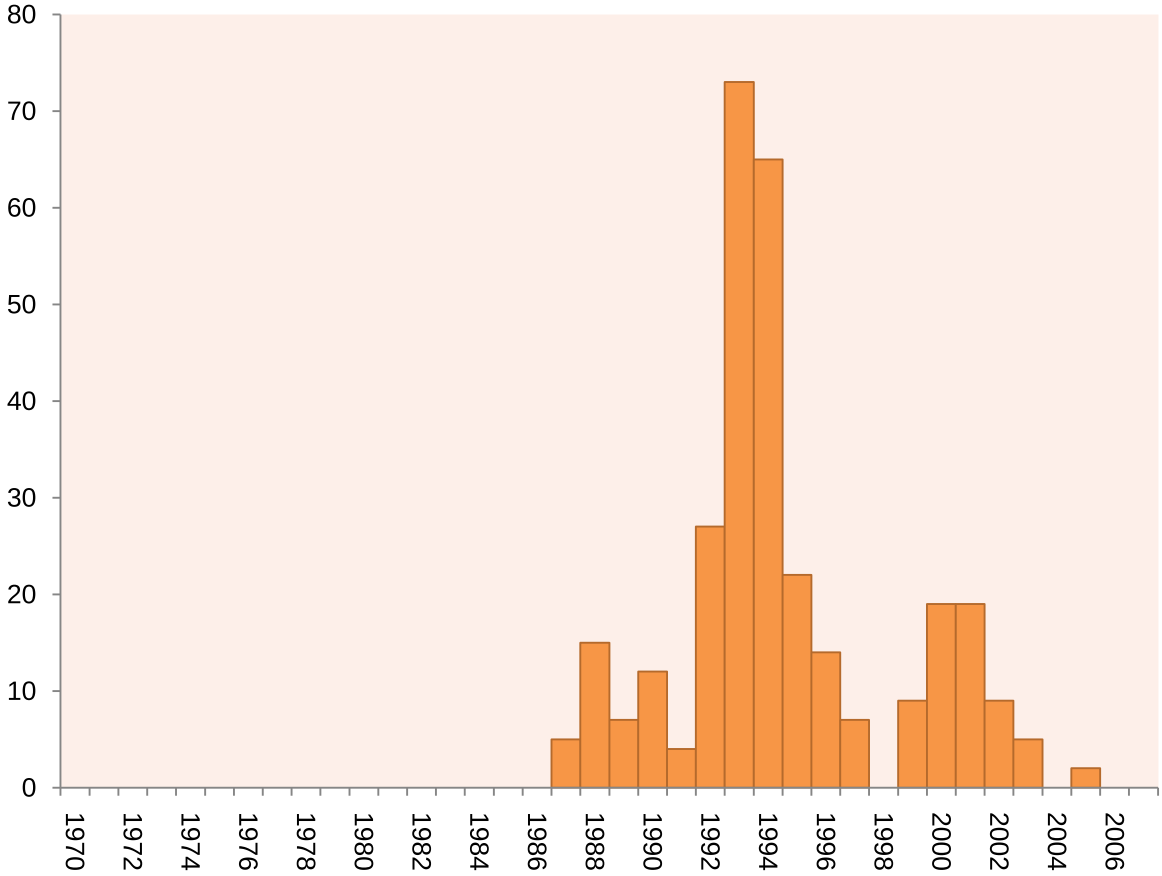

Figure 24 Patent filing activity over time for the CRC dataset

The data plotted in Figure 24 has been temporally limited from 1970 to present.

Classification code	Technology area	Peak Year	Peak Value
A61K47/48T8P	Medicinal preparations characterised by the non-active ingredients used, targeted drug delivery systems; antibody directed enzyme therapy	1993	60
A61K47/48R6F	Medicinal preparations characterised by the non-active ingredients used: targeted drug delivery systems; enzyme producing therapy	1994	26
A61K47/48R6D	Medicinal preparations characterised by the non-active ingredients used: targeted drug delivery systems; pretargeting systems	1994	33
C12N9/48	Enzymes; hydrolases; acting on peptide bonds	1994	25
A61K47/48R	Medicinal preparations characterised by the non-active ingredients used: proteins, peptides	1994	26
C07C275/40	Derivatives of urea; having nitrogen atoms of urea bound to carbon atoms of 6-membered aromatic rings of a carbon skeleton; further substituted by N atoms	1993	25
A61K38/48H	Medicinal preparations containing peptides; enzymes; hydrolases; exopeptidases	1994	25
C07K14/71	Peptides having more than 20 amino acids; from animals/humans; receptors; for growth factors; for growth regulators	1994	25
C07K16/30A	Immunoglobins; against material from animals or humans; from tumour cells; carcino-embryonic antigens	1993	13
C12N9/12	Enzymes; hydrolases	1994	25

Table 10 Top 10 classifications with peak year and values (i.e. number of times applied) for the CRC dataset

3.2.4 QinetiQ

The summary information for this dataset is shown in Table 11 below.

Company Name	QINETIQ LTD		
Number of Records	142		
Range of Years	1984 - 2007		
Peak Year	1999		
Average People / Record	3.1		
Field Choices	**Field Name**	**Number of entries**	**Field Coverage**
People	Inventors	129	100%
Organization	Patent Assignees	47	100%
Country	Priority Countries	4	100%
Years	Priority Year	59	100%
Technology	EPO Classifications	80	100%

Table 11 Summary information for the QinetiQ data subset

The peak year in terms of patent filings for QinetiQ was 1999, with 32 filings. This is highlighted in Figure 25, below.

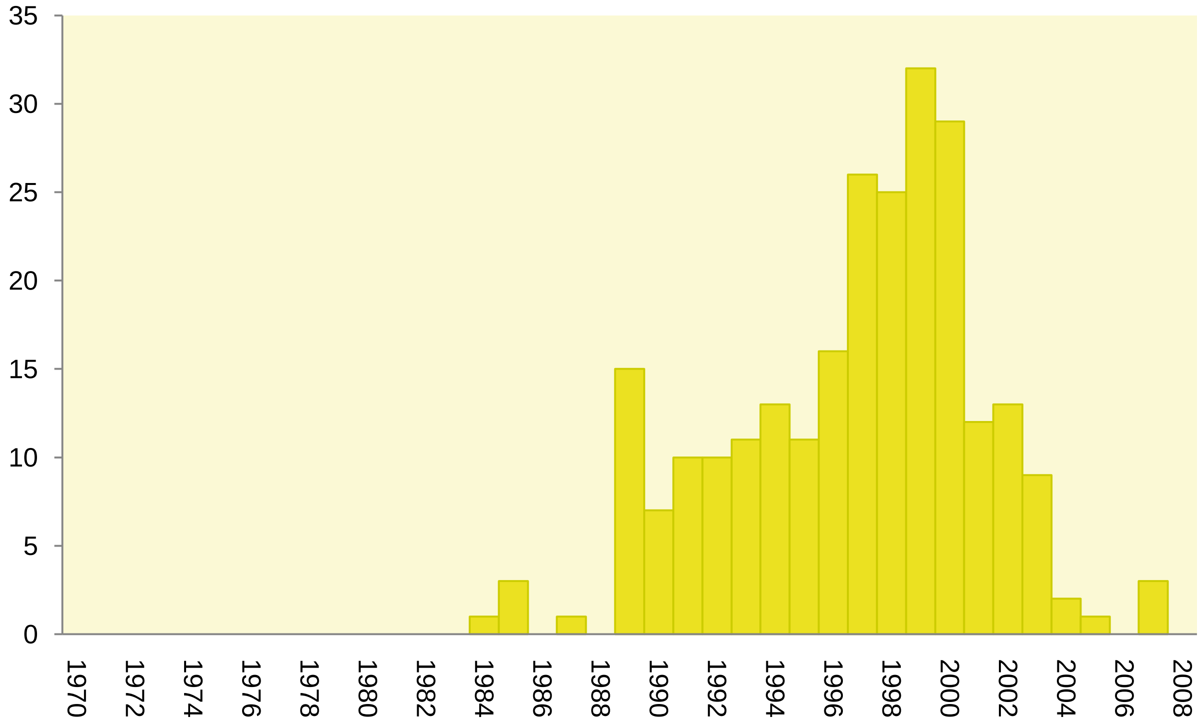

Figure 25 Plot of annual patent filings for QinetiQ

The pattern in this graph must be approached with caution because QinetiQ was formed when the Defence Evaluation and Research Agency was split into DSTL and QinetiQ in 2001. Therefore the apparent drastic fall in activity between 2000 and 2001 would seem likely to be due to the way in which patents were reassigned during the split. It has been assumed that most DERA patents were subsumed into

QinetiQ. The only collaboration in this dataset is that with Sharp, which occurred in 1998.

A number of key inventors are highlighted by the analysis; Weng Leong, Paul Tapster and Trevor Canham. All of these inventors were UK based and working in the time period 1989-2001. These inventors do not currently appear to be active within QinetiQ in the UK.

Classification code	Technology area	Peak Year	Peak Value
G02B6/122P	Light guides; comprising photonic band-gap structures or photonic lattices	1997	15
H01L33/00C4B4	Semiconductor devices; at least one potential-jump barrier or surface barrier; light emission	1993	11
H01L21/306	Processes or apparatus; semiconductor/solid state devices; chemical or electrical treatment	1989	13
G02B6/02P6K2	Optical fibre with cladding; complex periodic lattices or multiple interpenetrating periodic lattices	1999	9
C03B37/012B	Manufacture or treatment of flakes, fibres, or filaments from	1999	9
H01L31/0352B3	Semiconductor devices; superlattices; multiple quantum well structures; elements of the fourth group	2000	8
H01L33/00B3	Semiconductor devices; details; encapsulation	1991	10
H01L33/00C3	Semiconductor devices; details; shape or structure of the epitaxial layers	1991	10
H01L33/00D	Semiconductor devices; devices characterised by their operation	1991	10
H01L33/00G2	Semiconductor devices; processes; for devices with an active region; group IV elements	1991	10

Table 12 Top 10 classifications with max. peak year and values (i.e. number of times applied) for the QinetiQ dataset

3.2.5 Patent landscape for the top three UK commercial organisations

The patent map shown in Figure 10 earlier has been searched for the locations of the three applicant's activities. The applicants are highlighted in Figure 26. The key is given below in Table 13.

Organisation	**Marker colour**
Tioxide	Red
Cancer Research	Green
QinetiQ	Yellow

Table 13 Key to company marker colour for Figure 26

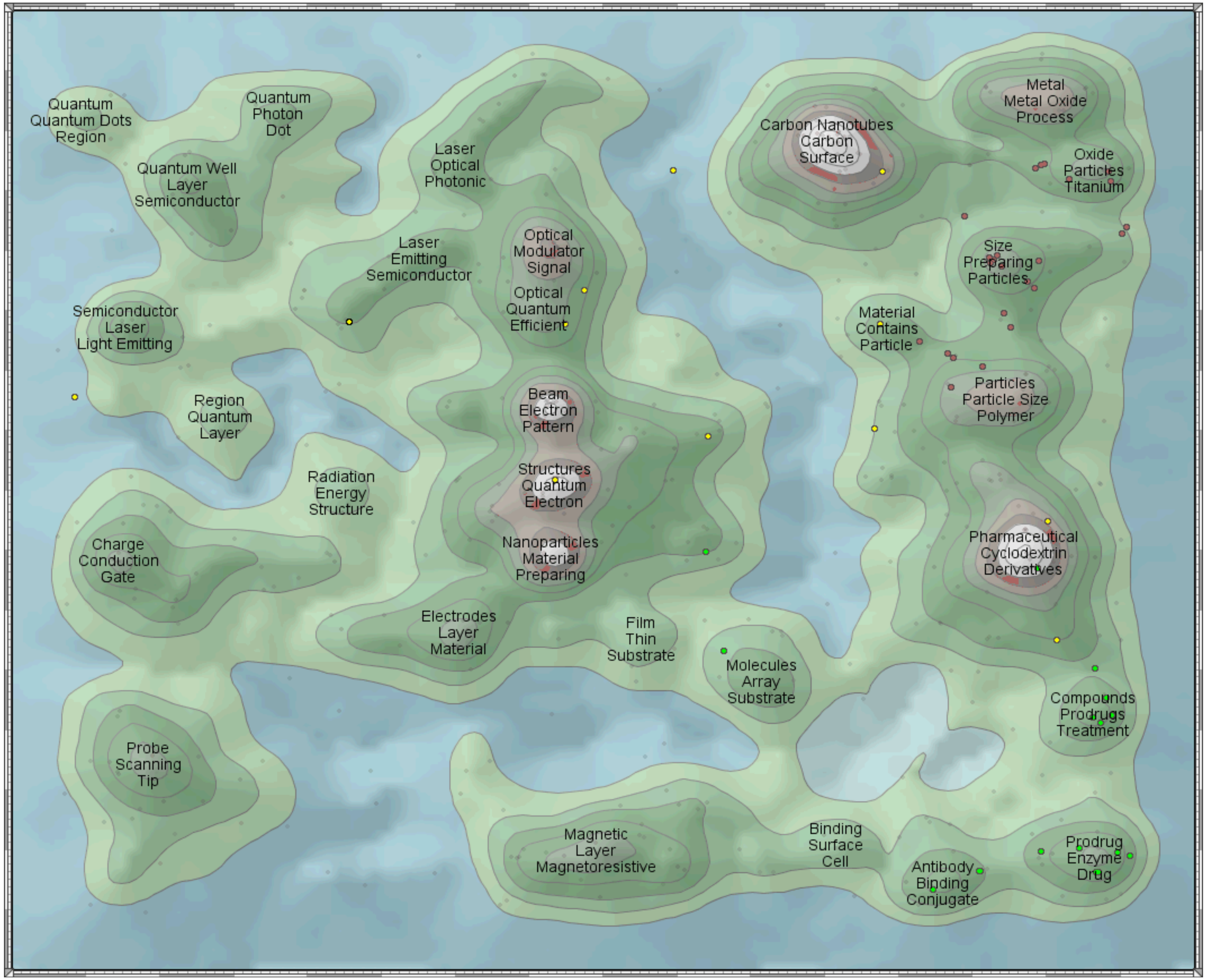

Figure 26 Patent map for UK nanotechnology showing location of patents for the top three prolific applicants ©Thomson Reuters

3.3 University analysis

3.3.1 Overview

A general analysis of the universities data subset, derived from the UK nanotechnology dataset was also completed. The summary information is shown below in Table 14.

Total Number of Records:	855		
Years Range From:	1935 - 2008		
Peak Year	2002		
Top Country:	GB		
Top Company Name:	CAMBRIDGE UNIVERSITY		
Field Choices	**Field Name**	**Number of entries**	**Field Coverage**
People	Inventors	1,067	100%
Companies	Patent Assignees	740	100%
Countries	Priority Countries	15	100%
Years	Priority Year	59	100%
Technology	EPO Classifications	698	99%

Table 14 Summary information for the UK nanotechnology universities data subset

The year of peak filings for the universities data subset was 2002, as noted in Table 14. Given GB patent predominance in the dataset it is likely this represents a genuine decline in academic activity and may pre-empt a real decline in activity overall as speculated above. It is also evident from this figure that there is hardly any academic nanotechnology related activity before the late 1980s; this contrasts with the early data for commercial organisations represented in Figure 20.

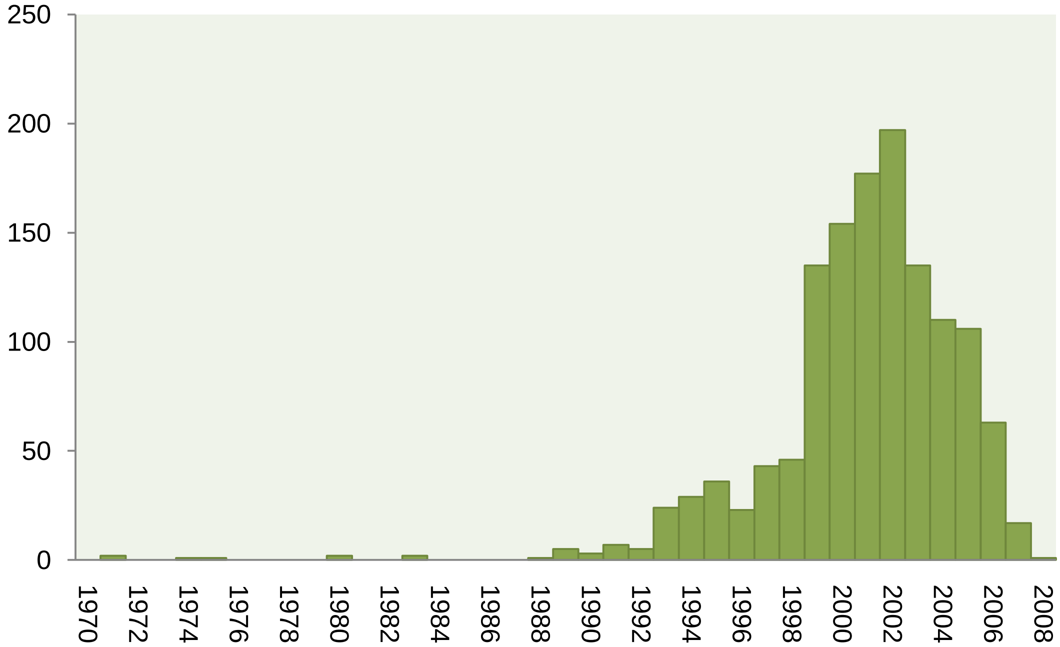

Figure 27 Plot of annual patent filing activity for the UK nanotechnology universities dataset

The plot shown in Figure 27 has been date limited to 1970-2008. The data can also be examined by assignee as in Figure 28.

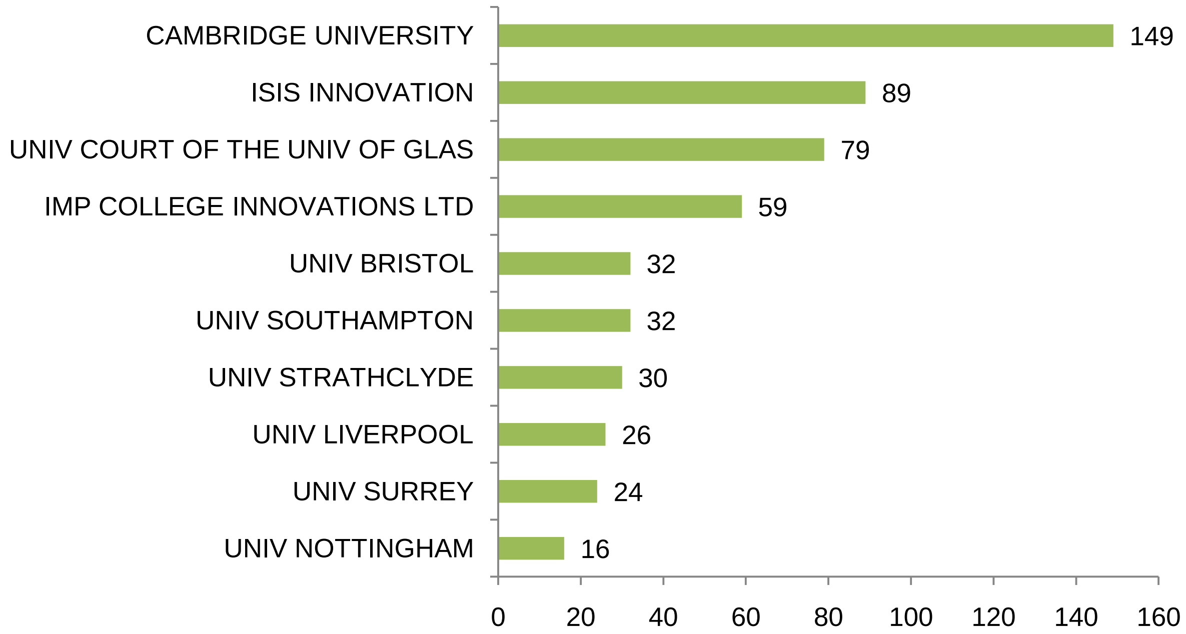

Figure 28 Patents per university for the UK nanotechnology universities dataset

Removing the company/organisation data has allowed the academic interest in this area to be highlighted. From Figure 28 it is evident that Cambridge University lead the table by a significant margin. Again, there is another jump in terms of activity between Oxford (Isis Innovation), Glasgow and Imperial universities when compared to Southampton, Bristol and other less prolific UK university applicants. This would suggest that there is a tiered hierarchy of nanotechnology research activity within the UK University system.

Figure 29 shows the principal areas of interest to the UK academic community.

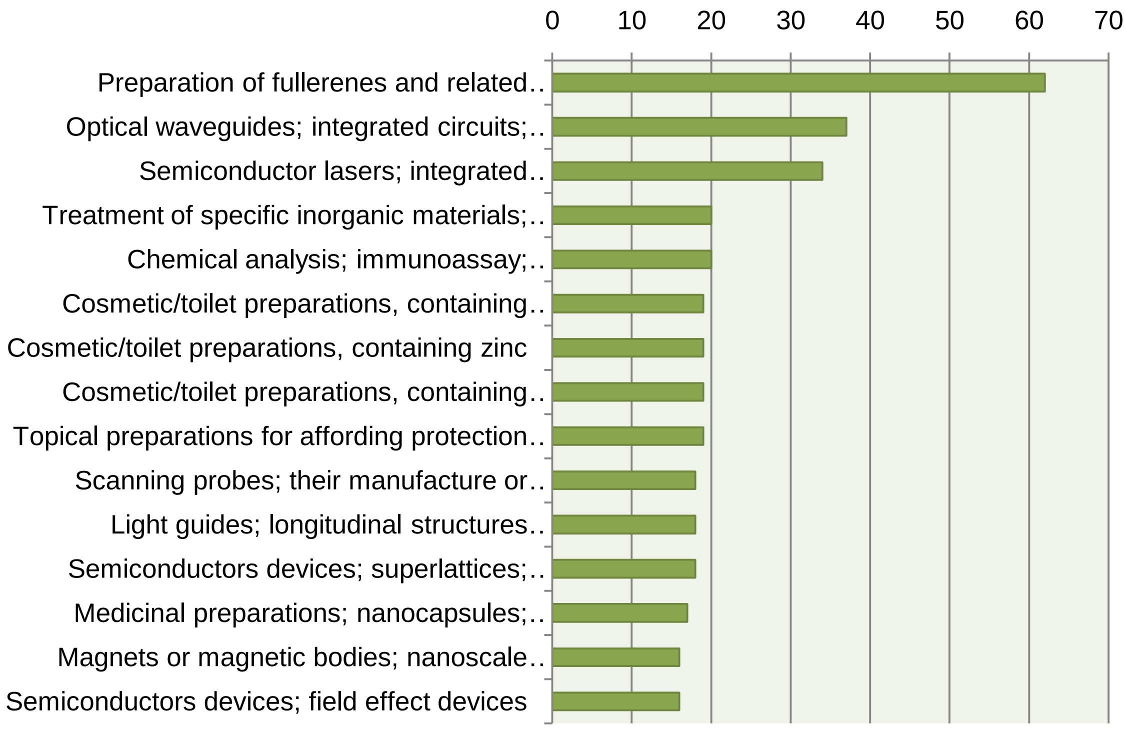

Figure 29 Plot of top technology areas in the UK nanotechnology universities data subset

3.3.2 Cambridge University

Detailed analyses of the activities of the top three universities in the UK nanotechnology dataset were also performed, and are presented below. The most prolific is Cambridge University.

The summary information for this data subset is shown in Table 15 below.

Company Name	CAMBRIDGE UNIVERSITY		
Number of Records	149		
Range of Years	1997 - 2006		
Peak Year	2000		
Field Choices	**Field Name**	**Number of entries**	**Field Coverage**
People	Inventors	165	100%
Organization	Patent Assignees	113	100%
Country	Priority Countries	5	100%
Years	Priority Year	59	100%
Technology	EPO Classifications	105	95%

Table 15 Summary information for the Cambridge University data subset

The peak year in terms of patent filings for the Cambridge University was 2000. This is highlighted in Figure 30. Cambridge University have collaborated with Seiko Epson (2000-2004), Plastic Logic Ltd (2001-2002) and Eidgenoess Tech Hochschule (2000-2001). Other collaborators include: Samco International Inc (2003-2004), Cardiff University (2001-2002) and Southampton University (2005-2006).

Again, the key inventors were all based in the UK, and appear to work together in small research groups. Russell Cowburn and Mark Welland work together with Henning Sirringhaus, Richard Friend and Nathalie Stuzmann and Lay-lay Chua. It is the final group who have been working most recently, with applications last published in 2006.

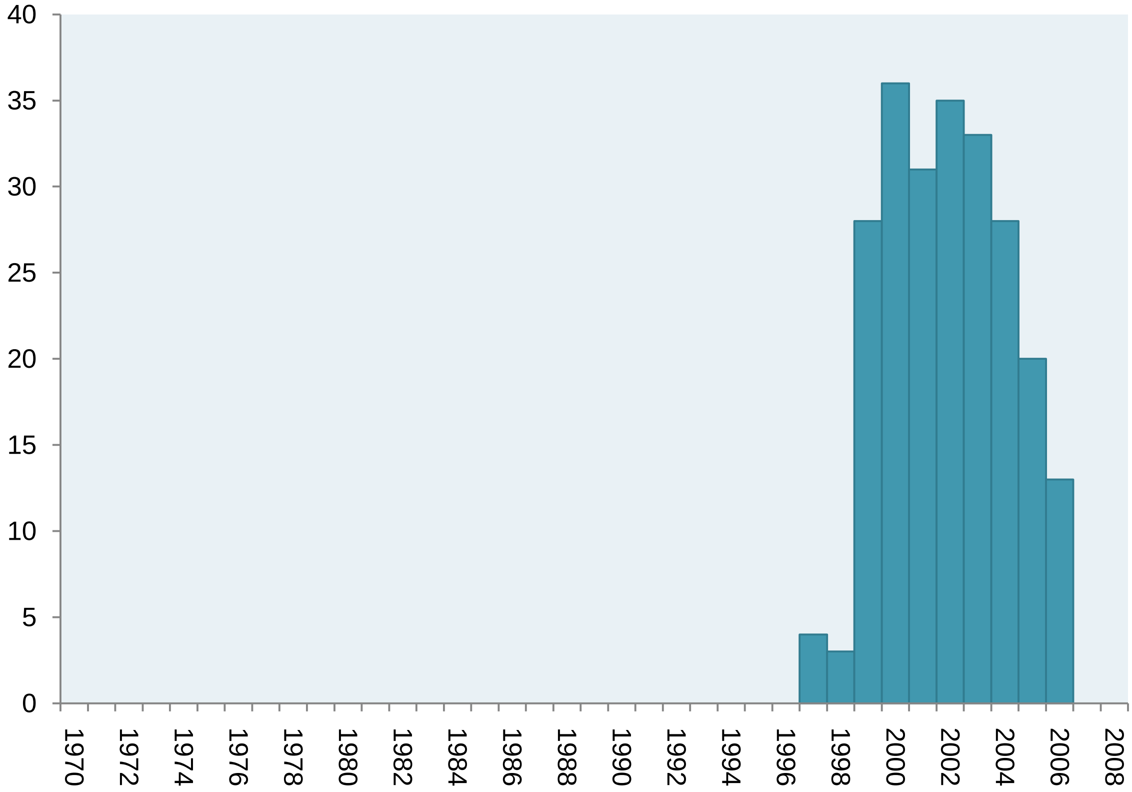

Figure 30 Patent filing activity over time for the CU dataset

The data plotted in Figure 30 has been temporally limited to 1970.

The most prolific activity from Cambridge University is in chemical and physical-electrical fields, including applications, as shown in Table 16.

Classification code	Technology area	Peak Year	Peak Value
H01F1/00E12	Magnets or magnetic bodies characterised by the magnetic materials; bidimensional, e.g. nanoscale period nanomagnet arrays	1999	16
G01R33/02	Arrangements or instruments for measuring magnetic variables; measuring direction or magnitude of magnetic fields or magnetic flux	1999	14
C01B31/02B	Carbon; compounds of; preparation of fullerenes and related structures i.e. carbon nanotubes	2002	17
H03K19/168	Logic circuits; Inverting circuits, using thin film devices	1999	12
G11C19/08C	Digital stores in which the information is moved stepwise, e.g. shift register; magnetic elements, thin films, using magnetic domain preparation	1999	11
H03K19/195	Logic circuits; Inverting circuits, using superconductive devices	1999	11
H01L51/05B2	Solid state devices using organic materials as the active part; specially adapted for resistors; insulated gate field effect transistors	2004	10
H01L51/05B2B2	Solid state devices using organic materials as the active part; specially adapted for resistors; insulated gate field effect transistors characterised by the gate dielectric	2004	10
H01L51/05B2B6	Solid state devices using organic materials as the active part; specially adapted for resistors; Lateral single gate single channel transistors with inverted structure,	2004	11
H01L51/52	Solid state devices using organic materials as the active part; specially adapted for light emission (ie OLEDs,PLEDs) details of devices	2004	10

Table 16 Top ten classifications with peak year and values (i.e. number of times applied) for the CU dataset

3.3.3 Isis Innovation (Oxford University)

The summary information for this dataset is shown in Table 17 below.

Company Name	ISIS INNOVATION		
Number of Records	89		
Range of Years	1989 - 2007		
Peak Year	1999		
Average People / Record	2.5		
Field Choices	**Field Name**	**Number of entries**	**Field Coverage**
People	Inventors	76	100%
Organization	Patent Assignees	38	100%
Country	Priority Countries	4	100%
Years	Priority Year	59	100%
Technology	EPO Classifications	66	100%

Table 17 Summary information for the Oxford University dataset

The peak year in terms of patents for Oxford University (OU) was 1999, with 26 records. This is highlighted in Figure 31. No significant collaborations were noted in this dataset. The data plotted in Figure 31 has been temporally limited to 1970.

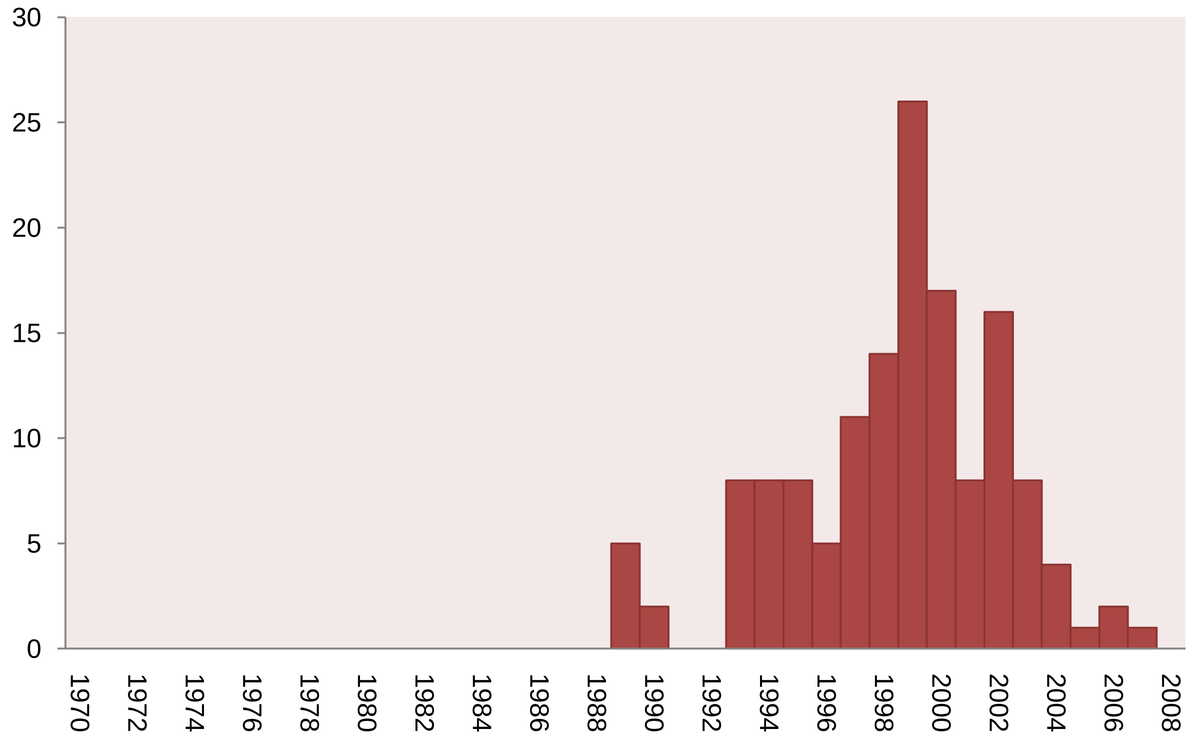

Figure 31 Plot of annual patent filings for Oxford University

In contrast to Cambridge University, Oxford University tends to specialise in medical and cosmetic applications of nanotechnology as shown in Table 18.

Classification code	Technology area	Max peak Year	Max peak Value
A61Q17/04	Topical preparations for affording protection against sunlight or other radiation; topical sun tanning preparations	1999	17
A61K8/19	Cosmetic or similar toilet preparations, containing inorganic ingredients	1999	17
A61K8/27	Cosmetic or similar toilet preparations, containing zinc; compounds thereof	1999	17
A61K8/29	Cosmetic or similar toilet preparations, containing titanium; compounds thereof	1999	17
C09C1/36D6	Treatment of specific inorganic material other than fibrous fillers; titanium dioxide	1999	16
C23C16/04	Chemical coating by decomposition of gaseous compounds, Coating on selected surface areas	1993	8
C23C16/448H	Chemical coating by decomposition of gaseous compounds; method of coating; by producing an aerosol	1993	8
C09C1/04	Treatment of specific inorganic materials; compounds of zinc	1999	11
A61K8/25	Cosmetic or similar toilet preparations; silicon; compounds thereof	1999	11
G02B6/122P	Light guides; comprising photonic band-gap structures or photonic lattices	1997	5

Table 18 Top ten classifications with peak year and values for the Oxford University data subset

3.3.4 University of Glasgow

The summary information for this dataset is shown in Table 19 below.

Company Name	UNIV OF GLASGOW		
Number of Records	79		
Range of Years	1999 - 2005		
Peak Year	2001		
Average People / Record	3.8		
Field Choices	**Field Name**	**Number of entries**	**Field Coverage**
People	Inventors	91	100%
Organization	Patent Assignees	43	100%
Country	Priority Countries	4	100%
Years	Priority Year	59	100%
Technology	EPO Classifications	27	100%

Table 19 Summary information for the Glasgow University dataset

The peak year in terms of patents for Glasgow University was 2001, with 51 records. This is highlighted in Figure 32. The data plotted in Figure 32 has been limited to the years 1970-2008.

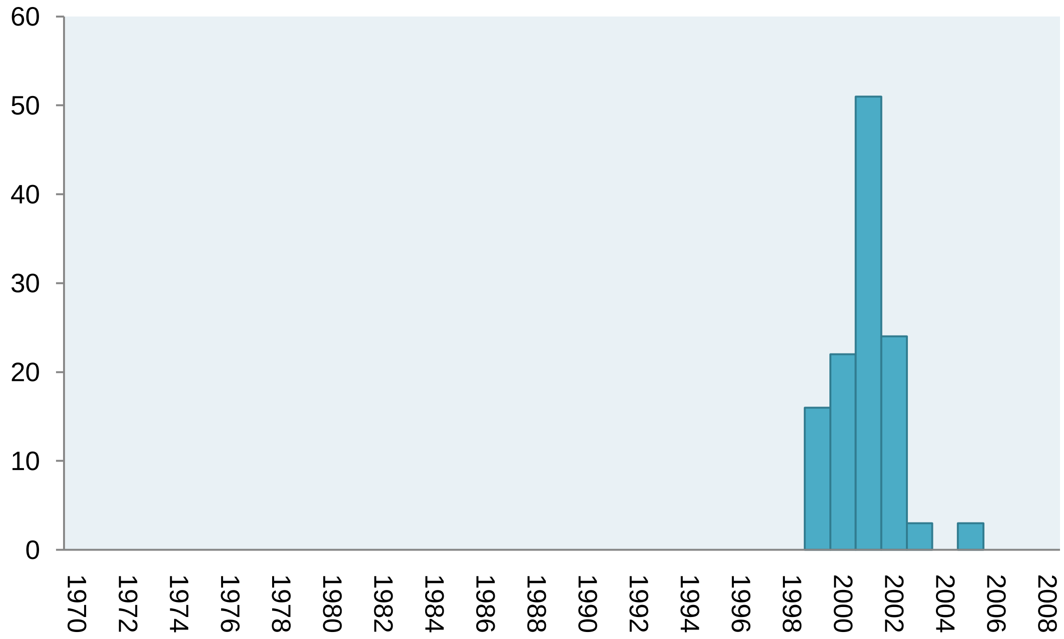

Figure 32 Plot of annual patent filings for Glasgow University

Interestingly, Glasgow University has collaborated with the University of Strathclyde (1999-2002), the Centre for Natural Research Scientifique (2001-2002) and the University of Madrid (2005). There has also been some work in conjunction with France Telecom and Intense Ltd.

The key inventors at Glasgow University are: John Marsh, Craig Hamilton and Stewart McDougall, who all work in a research group (2000-2002), and tend to publish jointly. Another research group appears to be Marie Parker, Joann Partridge and Barry Moore (1999-2000).

Classification code	Technology area	Max peak Year	Max peak Value
H01S5/026	Semiconductor lasers; monolithically integrated components	2001	30
C30B7/00+29/58	Single-crystal growth from solutions using solvents	1999	12
C07K1/32	General methods for the preparation of peptides; extraction; separation; purification; by precipitation as complexes	1999	12
G02B6/12D	Light guides of the optical waveguide type of the integrated circuit kind Combinations of two or more optical elements	2000	7
G02B6/42	Light guides Coupling light guides with opto-electronic elements	2000	7
G02F1/025	Devices/arrangements; intensity, colour, phase, polarisation or direction of light arriving based on semiconductor source in an optical waveguide structure	1999	4
H01S5/12	Semiconductor lasers; optical resonator; resonator having a periodic structure	2001	6
H01L21/18A	Semiconductor devices or devices having semiconductor bodies comprising elements of the fourth group; Intermixing or interdiffusion or disordering of III-V heterostructures	2001	6
A61K47/48T8	Medicinal preparations; antibodies; immunoglobulins; targeted drug delivery systems	2001	5
A61K47/48T4K2	Medicinal preparations; antibodies; immunoglobulins; polymer drug antibody conjugates; starburst conjugates, dendrimers or cascade conjugates	2001	5

Table 20 Top ten classifications with max. peak year and values (i.e. number of times applied)for the Glasgow University dataset

3.3.5 General patent landscape of university activity

Figure 33 shows records of universities highlighted within the patent map. It is immediately evident that a wider spread of records can be seen in this figure than in the equivalent map for commercial organisations. Many records appear in less densely populated areas of the map, in contrast to the commercial records shown in Figure 26, underlining the nature of universities to pursue early science research and explore underrepresented technology sectors, as opposed the general commercial model of prolific exploitation and intense patenting to defend markets and products.

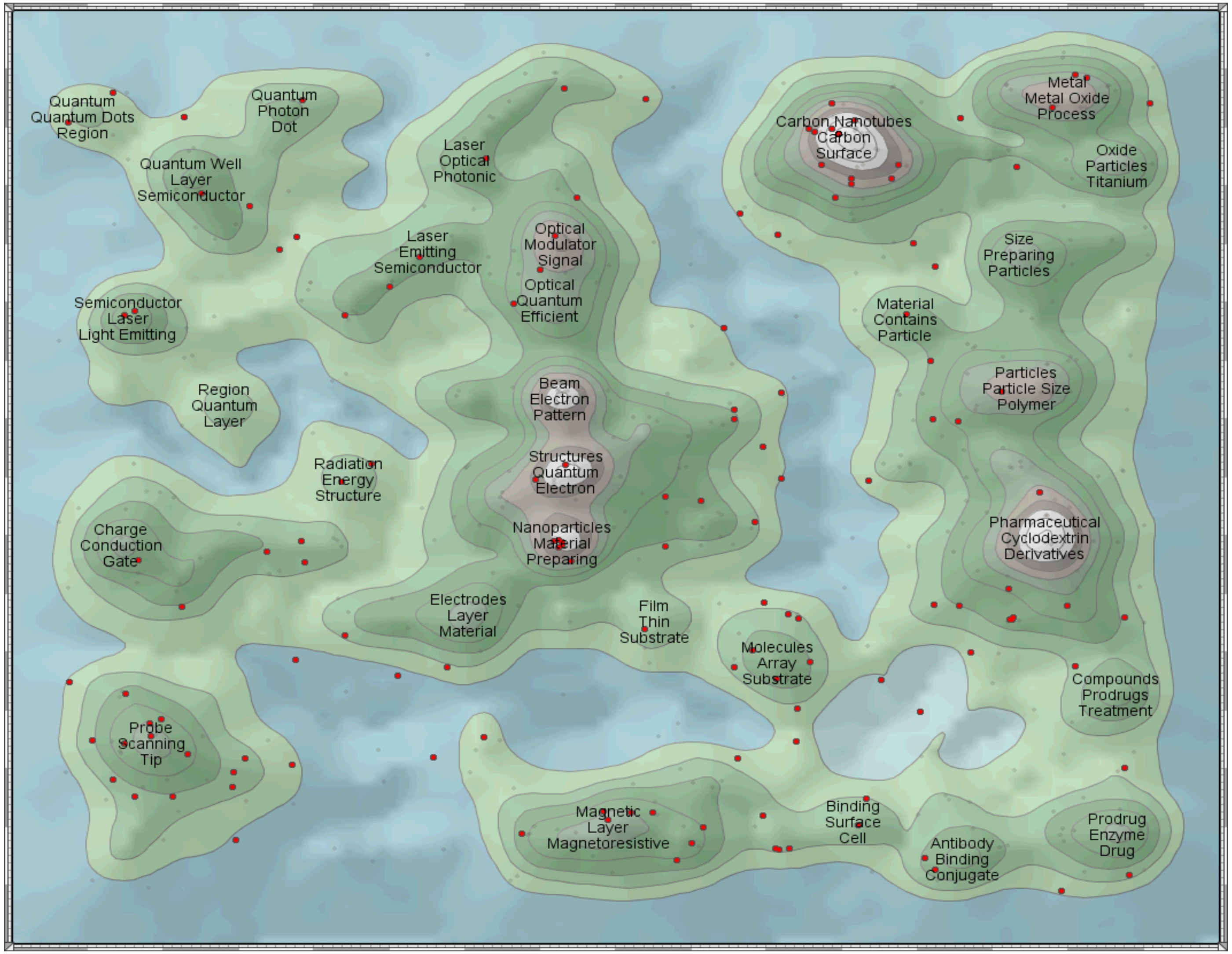

Figure 33 Patent map for UK nanotechnology showing location of University patents ©Thomson Reuters

3.3.6 Patent landscape for the top three universities

The patent map shown in Figure 10 earlier has been searched for the locations of the three applicants' activities, to orientate the map. The applicants are shown highlighted in Figure 34. The key is given below in Table 21.

Organisation	**Marker colour**
Cambridge	Yellow
Oxford	Green
Glasgow	Red

Table 21 Key to Company Marker Colour for prolific university applicants

It is evident from the patent landscape map that the top three universities' interests are diverse, although specialisms apply as noted above. Such diversity may be explained by initial technology being licensed out, or a spin out company formed, which then took on the substance of the patent (patenting subsequent developments under a different name).

There appears to be lower patent intensity for a single university than would be expected for a commercial entity. Perhaps this is an effect of the technology area, when there are so many potential areas of research; it tends to be less crowded in terms of R&D space. Then again, with an often transitory research staff, researchers may move to other universities or companies transferring knowledge with them. A number of scenarios can be considered, but the overall effect is nonetheless interesting and appears to be characteristic of successful academic research.

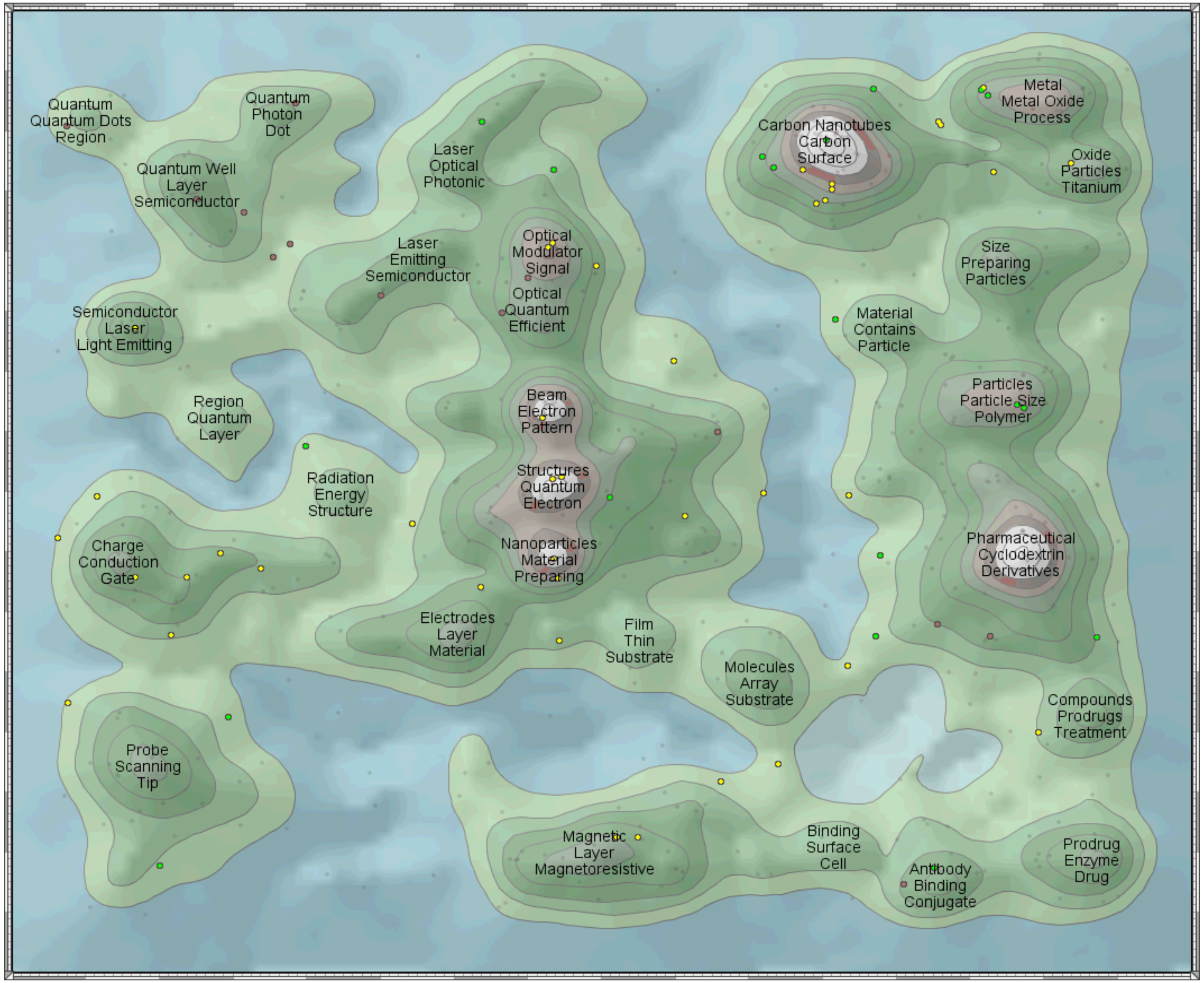

Figure 34 Patent map for UK nanotechnology showing location of patents for the top three prolific universities ©Thomson Reuters

4 Key patent analysis

4.1 UK dataset

A potential indicator of the quality of a patent application lies in the number of times it was subsequently cited ('forward citations') on other patent applications, by the patent examiner as part of the patent application process; the more fundamental, or important, a patent is, the more it will be referred to in examination proceedings. It is essential to remember that more modern patents will not have a large number of forward citations as they will have only been published relatively recently. Consequently, this form of analysis should not be considered the sole indicator of the importance of patent.

Checking for the most cited documents in the UK nanotechnology dataset reveals that US 2003/0089899 has 103 forward citations, relating to *"Nanoscale wires and related devices"*. In detail, the patent discusses sub-microelectronic circuitry, and more particularly, nanometer-scale articles. These articles can include nanoscale wires which can be selectively doped at various locations and at various levels. In some cases, the articles may be single crystals. The nanoscale wires can be doped, for example, differentially along their length, or radially, and either in terms of identity of dopant, concentration of dopant, or both. This may be used to provide both n-type and p-type conductivity in a single item, or in different items in close proximity to each other, such as in a crossbar array. The fabrication and growth of such articles is described, and the arrangement of such articles to fabricate electronic, optoelectronic, or spintronic devices and components. For example, semiconductor materials can be doped to form n-type and p-type semiconductor regions for making a variety of devices such as field effect transistors, bipolar transistors, complementary inverters, tunnel diodes, light emitting diodes, sensors, and the like.

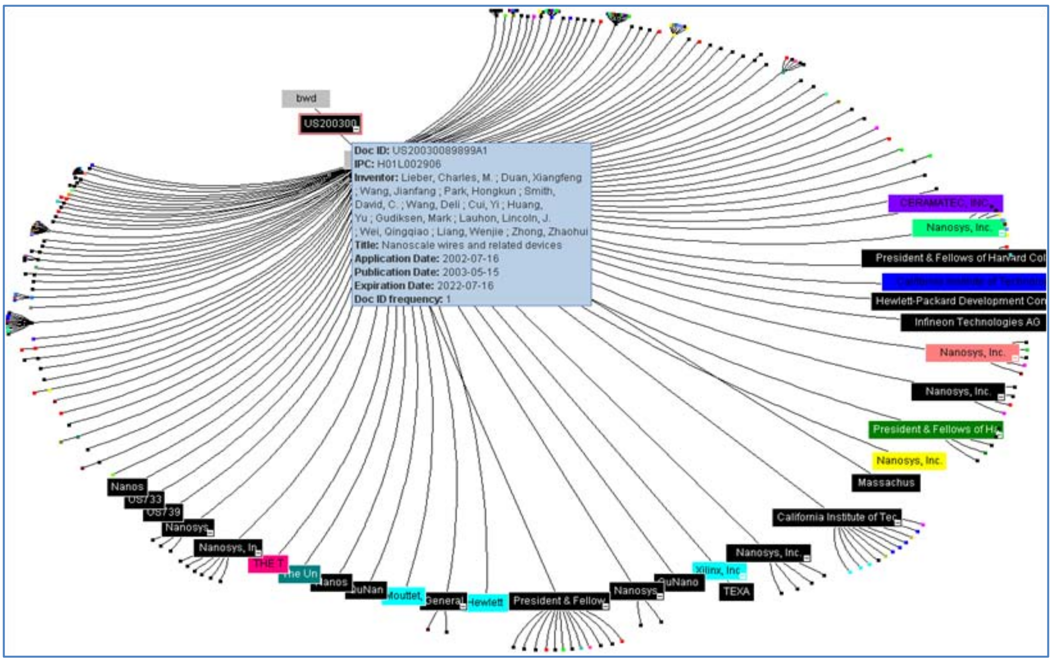

Figure 35 Citation tree for two 'generations' forward and backward for US 2003/0089899

This patent was developed in conjunction with Harvard and Southampton University[8]. A David C Smith, GB based inventor, is noted on the patent. A citation tree for this patent is shown in Figure 35. Differently coloured patents highlighted in the tree carry different patent classifications, illustrating the breadth of developmental subject matter spawned from the initial patent.

It is also interesting that this patent had no documents cited by the examiner against the novelty or inventiveness of the document. It therefore would appear to be a key patent in this technology area. It also has a large family of patents associated with it, notably: WO 02/17362, WO 02/48701, WO 03/005450, EP 1314189, EP 1342075, WO 2004/038767, EP 1436841, EP 1736760 to list but some of the members. The large patent family is caused by this initial patent being used as a priority document for further patents, on related/similar subject matter. This would explain why there are such a large number of forward citations associated with a single patent. However, despite this, it can still be considered an important patent, as it was deemed valuable enough to extend protection into a number of separate patents and jurisdictions (another indicator of patent value). Some of these patents have not yet been granted; however, EP 1342075 and the associated international patent, WO 02/48701, have both been granted, and specify UK as a designated state.

[8] http://www.nano.ecs.soton.ac.uk/

The next most cited patent is US 5346683, assigned to the Gas Research Institute, but with two British inventors: Malcolm Green and Shik Tsang, who live in Oxford and work at Oxford University[9,10]. This patent relates to: *Uncapped and thinned carbon nanotubes and process*. It describes the production of uncapped and thinned carbon nanotubes, produced by reaction with a flowing reactant gas capable of reaction selectively with carbon atoms in the capped region of nanotubes. The uncapped and thinned nanotubes provide open compartments for insertion of chemicals and exhibit enhanced surface area with modified physical and chemical properties. The patent citation tree is shown in

Figure 36. Interestingly, this patent does not have any GB, WO or European family members.

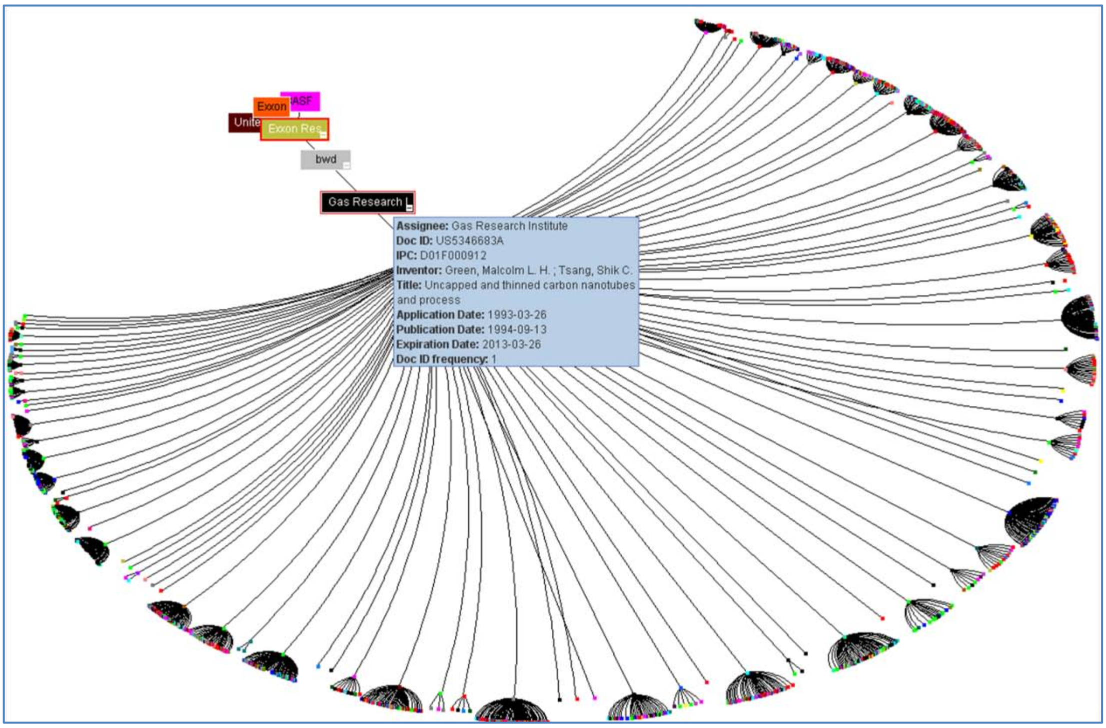

Figure 36 Citation tree for two 'generations' forward and backward for US 5346683

Nanosystems Inc are the assignees of the next most frequently cited patent; US 5569448. The citation 'tree' for this patent is shown in Figure 37. This relates to "*Sulfated nonionic block copolymer surfactants as stabilizer coatings for nanoparticle compositions*". This patent describes a composition comprised of nanoparticles containing a therapeutic or diagnostic agent. A block copolymer is linked to at least one anionic group, such as a surface modifier, adsorbed on the surface. A method of making such nanoparticles is also defined. The compositions exhibit improved autoclave stability, reduced macrophage uptake, improved toxicological profiles and facilitate particle size reduction, so that milling time can be reduced and/or sterile filtration of the nanoparticles can be accomplished. This patent has an associated

[9] http://www.chem.ox.ac.uk/icl/nanotubegroup/people.htm
[10] http://www.chem.ox.ac.uk/researchguide/mlhgreen.html

international patent, WO 96/22766. This patent did specify protection in the UK but was withdrawn before grant and, as such, is not in force.

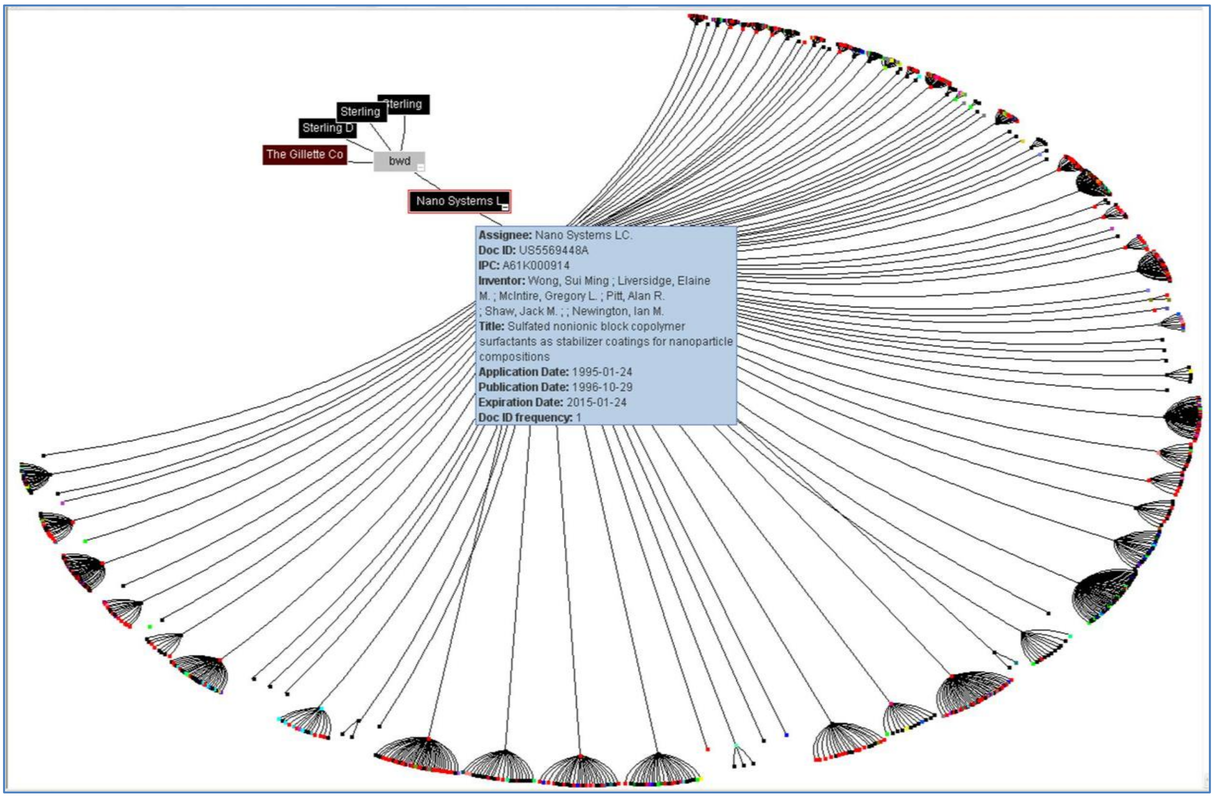

Figure 37 Citation tree for one 'generation' forward and backward for US 5569448

Finally, Amersham (now GE Healthcare) are the assignees of the fourth most cited patent, US 5047633. This relates to the high resolution imaging of micromolecules and is entitled: *Imaging apparatus and method* . The patent details apparatus for the high resolution imaging of macromolecules and interactions involving macromolecules. The apparatus comprises a surface on which the macromolecule under test is placed and a plurality of fine probes. Means such as a scanning tunnelling and/or atomic force detector are used to monitor the movement of the individual probes in a direction transverse to the surface and display means are used to display the transverse movement of the probes, being illustrative of the topography of the surface. The citation tree for this patent is shown in Figure 38. This patent has a European family member, EP 0397416 which designated UK as an area for protection. However, the patent was withdrawn before grant, and as such, is no longer in force.

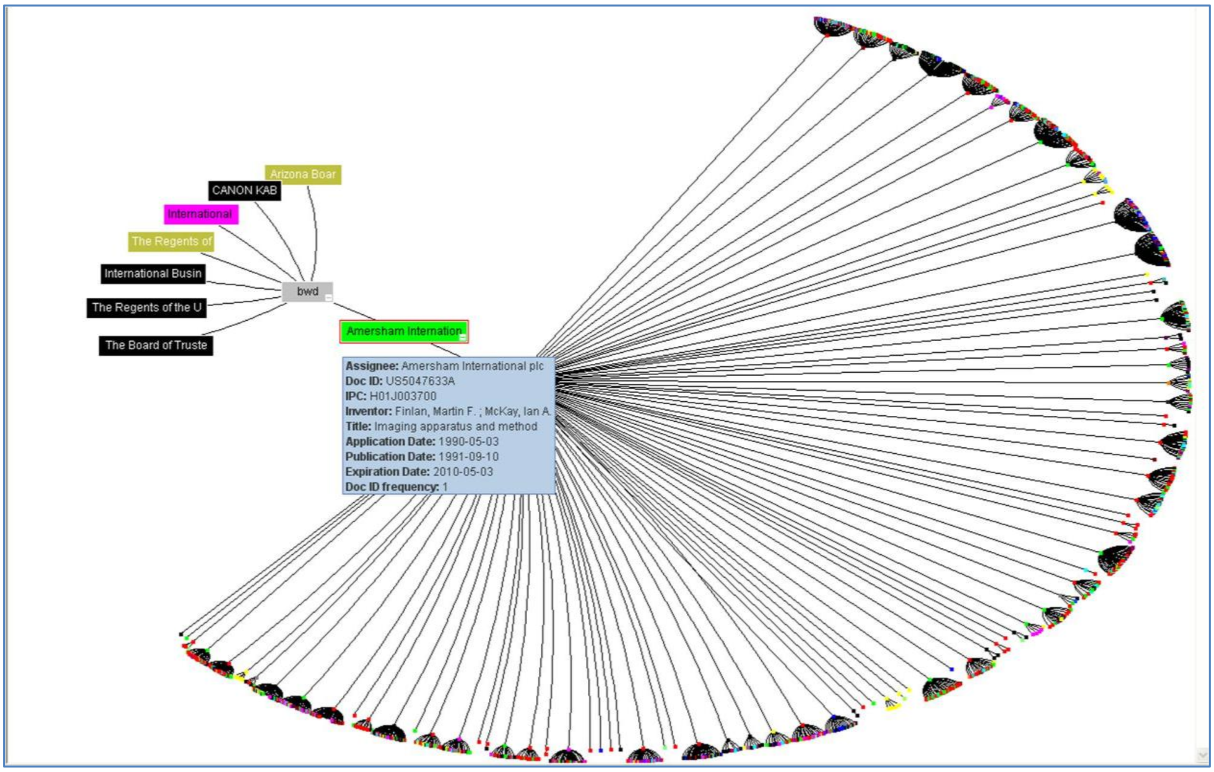

Figure 38 Citation tree for one 'generation' forward and backward for US 5047633

These patents have been highlighted on the same patent map shown in the earlier figures, in Figure 39. The patents are noticeable by their degrees of separation from one another, and further serve to indicate the diversity of technologies located under the term "nanotechnology".

A key to locating the patents on the map is provided in Table 22, below.

Patent No.	**Marker colour**
US 2003/0089899	Blue
US 5346683	Yellow
US 5569448	Green
US 5047633	Red

Table 22 Key to Patent Marker Colour for most forward cited patents

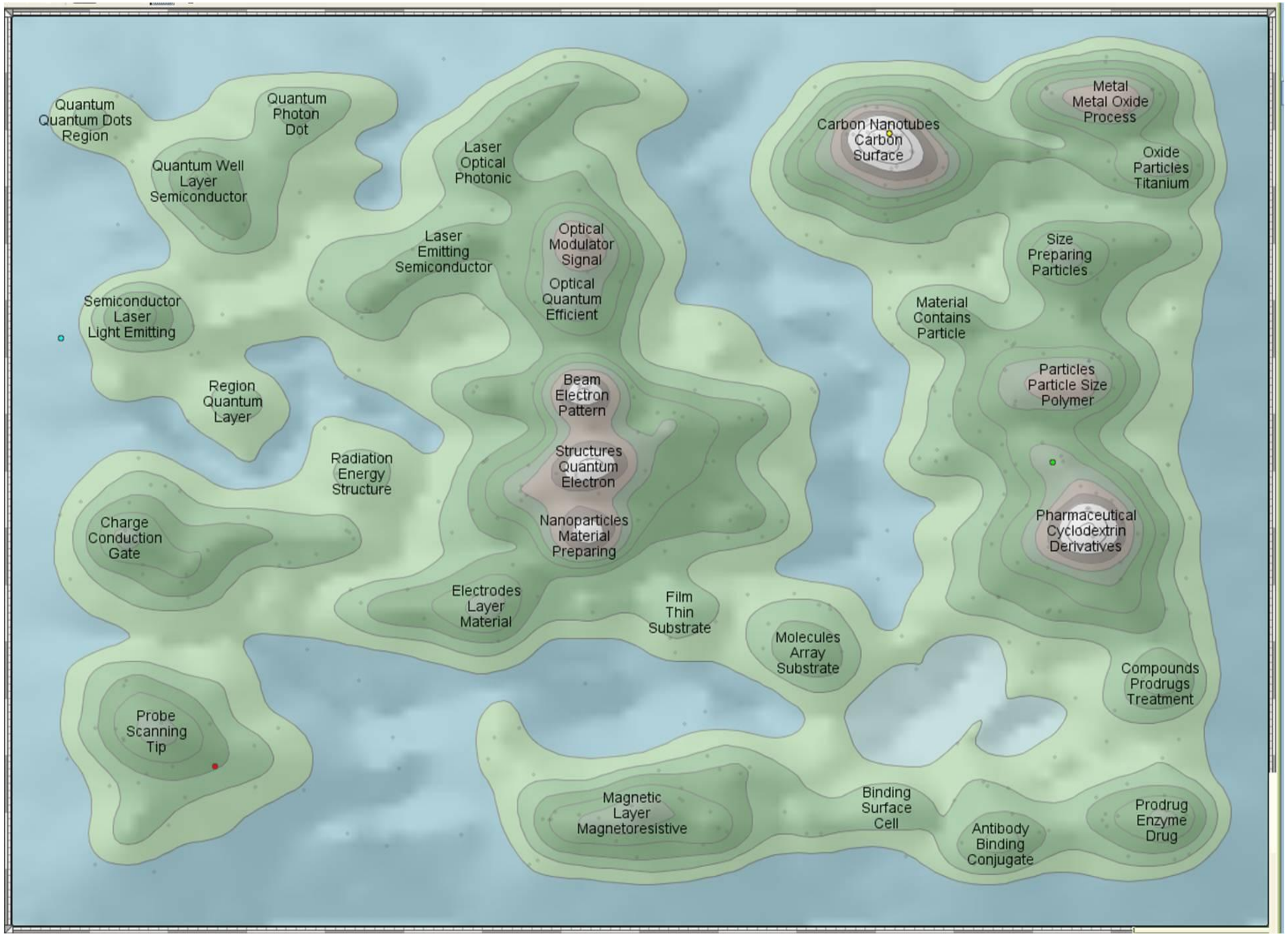

Figure 39 Patent map for UK nanotechnology showing location of patents for the top most cited patents ©Thomson Reuters

4.2 Nanotoxicity patent analysis

In terms of patent analysis, one of the most forward cited patents is US 5990373, which relates to: *Nanometer sized metal oxide particles for ambient temperature adsorption of toxic chemicals*, and is assigned to Kansas State University; the named inventor is: Kenneth J. Klabunde. This patent describes a method for the absorption of targeted toxic compounds (i.e. HCN, ClCN) via contact with nanoscale oxide adsorbents, such as MgO and CaO, at a temperature in the range of 70 to 90° C. and at atmospheric pressure. This patent also has an international patent (WO 98/07493) and European patent equivalent (EP 0944419), with a UK designation. These patents are still undergoing the examination process, and have not yet been granted. A patent citation tree is shown in Figure 40.

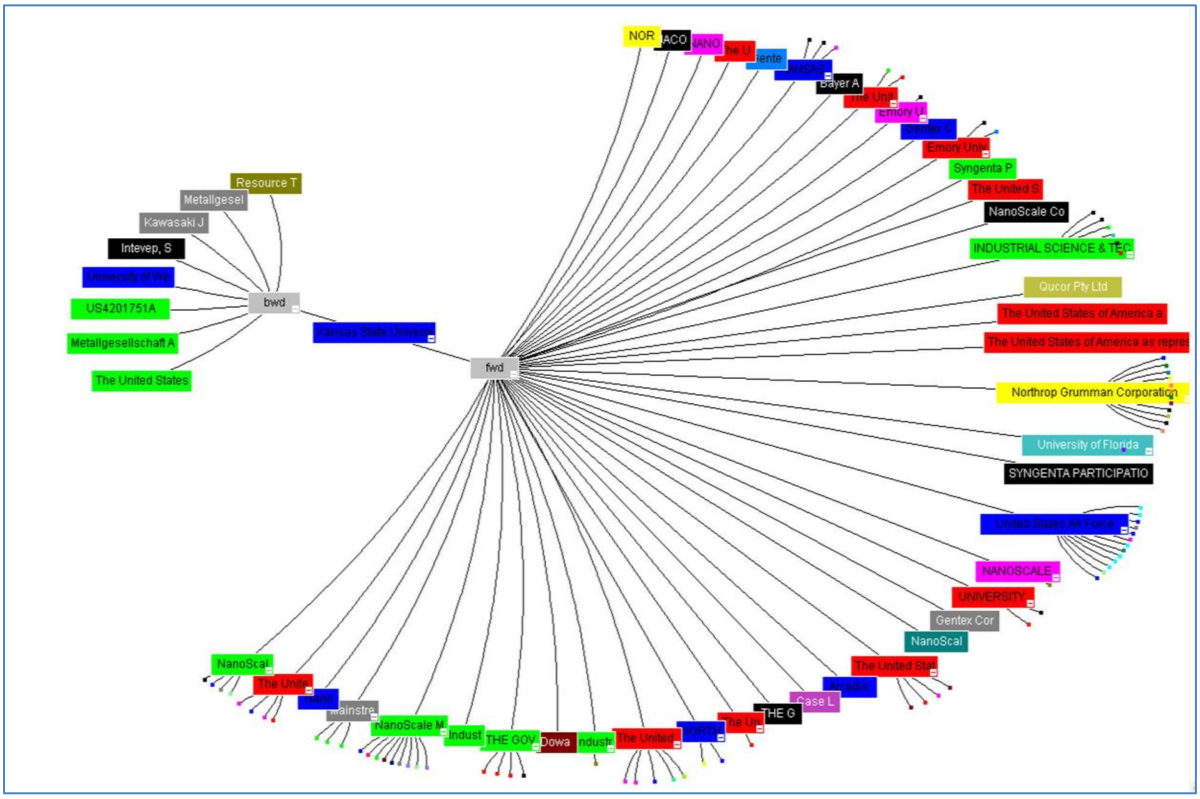

Figure 40 Citation tree for two 'generations' forward and one backward for US 5990373

The citation tree shown in Figure 40 is interesting for a number of reasons; firstly, the different colours that the citing patents are highlighted with represent different IPC classifications; this shows that US 5990373 is relevant to many different technology areas. There are a large number of forward citations here, with eight backward citations. The fact that there are a large number of backward citations suggest that this patent was not a 'breakthrough' patent but builds on existing technology, however, it is an important patent in this area given the number of times it has been cited subsequently.

Another patent that also has a high number of forward cites is US 2005/0208083. This patent relates to: *Compositions for inactivating pathogenic microorganisms,* *methods of making the compositions, and methods of use thereof*, it is assigned to Nanobio Corp, and the named inventor is Theodore Annis. This patent details nanoemulsion compositions with low toxicity that demonstrates broad spectrum inactivation of microorganisms or prevention of diseases. The nanoemulsions contain an aqueous phase, an oil phase comprising oil and an organic solvent, and one or more surfactants. Methods of making nanoemulsions and inactivating pathogenic microorganisms are also provided. The nanoemulsion comprises nanoemulsion particles having an average diameter of ≤250 nm. This patent also has an international patent (WO 2005/02787) and European patent equivalent (EP 1633322), with a UK designation. These patents are still undergoing the examination process, and have not yet been granted.

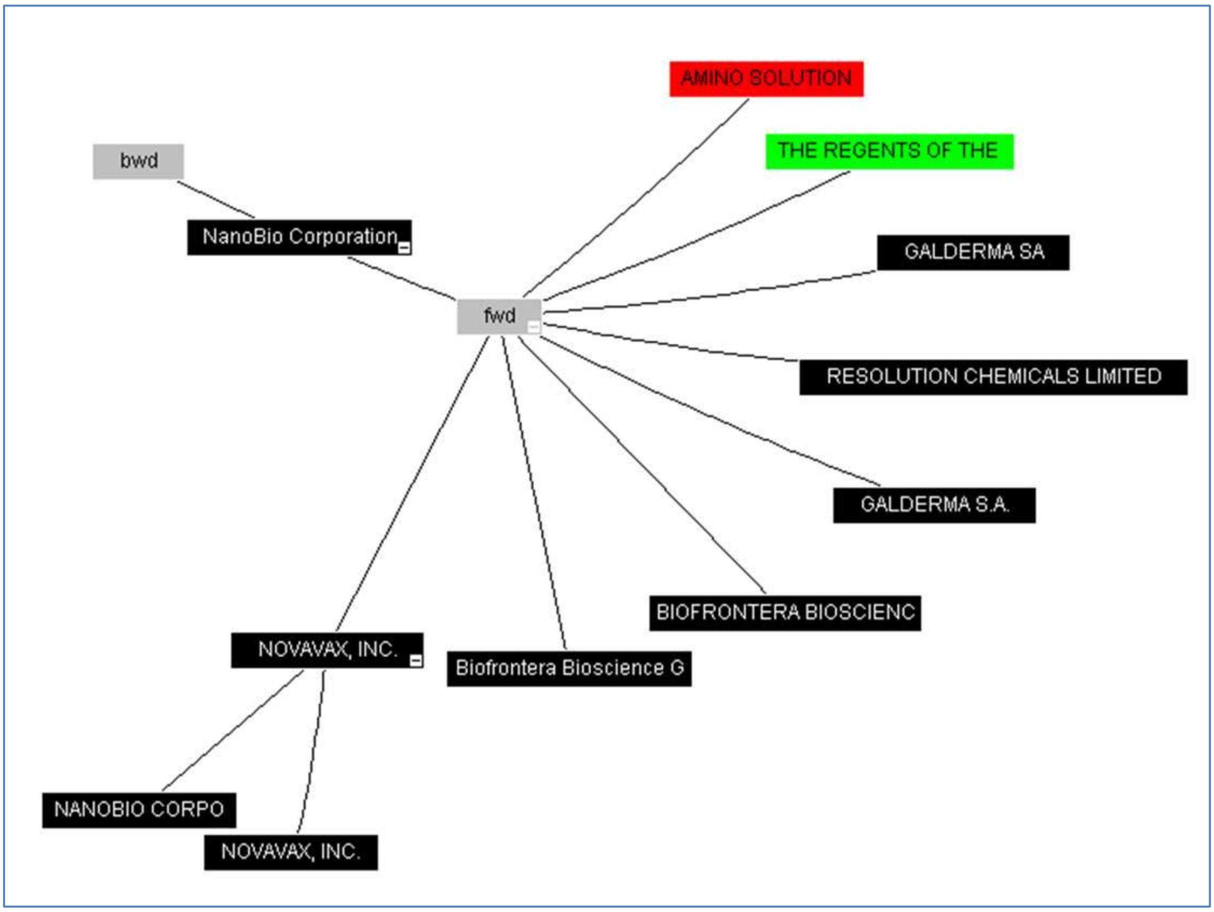

Figure 41 Citation tree for two 'generations' forward and one backward for US 2005/0208083

The citation tree for US 2005/0208083 (Figure 41, above) presents a marked contrast to that shown in Figure 40. This patent does not have any backward citations and has eight forward citations, suggesting high innovation pre-empting follow-on innovation from other applicants. Most of the citing patents carry the same IPC classification suggesting subsequent innovation is in a closely related field.

US 2005/0178111 may also be of interest as it defines a process for reduction in nanoparticle counts via an exhaust scrubber and is titled: *Exhaust after-treatment system for the reduction of pollutants from diesel engine exhaust and related method*. It is assigned to Converter Technology Inc and the inventor is: Refaat Kamel. In more detail, it describes an exhaust after-treatment system for the reduction of particulate, NOx, HC, CO, VOCs, nanoparticle count and sulfur dioxide from diesel exhaust. The system uses: a diesel oxidation catalyst, exhaust cooling system, particulate converter, soot collection chamber, soot processing drum, EGR and water scrubber. This patent also has a World patent (WO 2004/011783) and European patent equivalent (EP 1546515), with a UK designation. These patents have been granted and are therefore in force. A citation tree for this patent is shown in Figure 42.

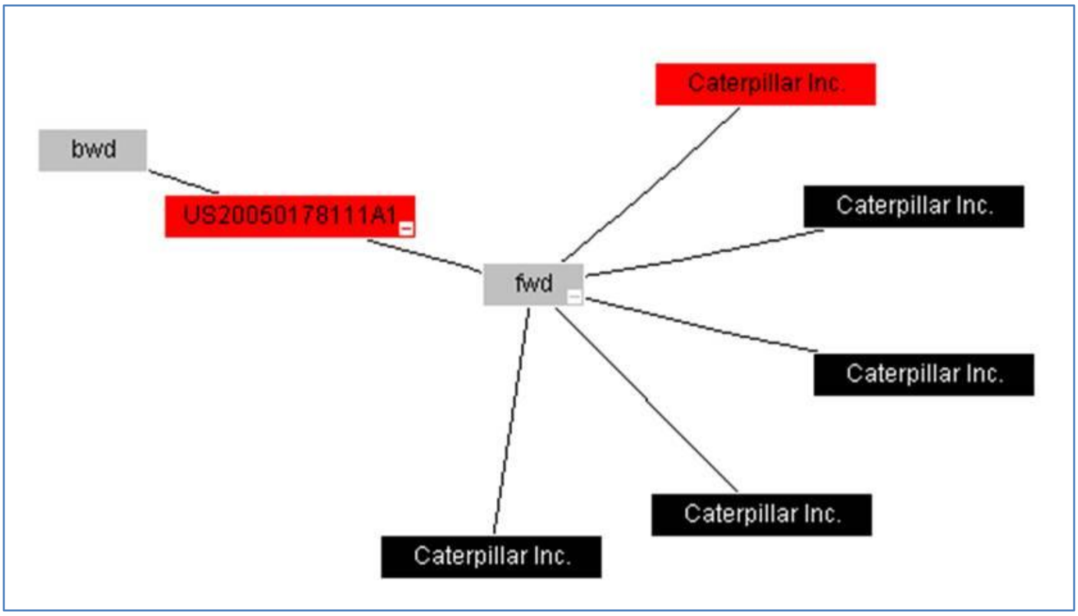

Figure 42 Citation tree for two 'generations' forward and one backward for US20050178111

The citation tree *(Figure 42)* for US 2005/0178111 shows that no patents were cited against this patent during the examination process, and that five patent have had this patent cited whilst undergoing examination. Interestingly they are all from the same applicant which perhaps indicates that the inventor or technology of US 2005/0178111 has been transferred to Caterpillar Inc. Caterpillar Inc. may indeed self-cite US 2005/0178111 and certainly appear to be building on this technology in their patent filings.

WO 02/051376 is another patent that features on the list of top most cited patents. The assignee is Henkel, with Christian Kropf the principle inventor. The patent title is: *Nanoparticle-containing Peeling Compositions*. The patent describes aqueous compositions for the abrasive treatment of the skin of the human body, especially of the face and/or the neck. Said compositions contain, in a cosmetically and/or dermatologically acceptable excipient, a toxicologically safe nanoparticulate compound of an element of the second to fourth main group, or the second, fourth or eighth subgroup of the periodic system of elements that is poorly soluble in water. Said particles have an average particle size in the range of from 10 to 1000 nm. This patent did designate UK for patent protection but has been withdrawn before examination (in 2004). It does have a German equivalent, DE 10064489, but no data was found relating to the legal status of this patent.

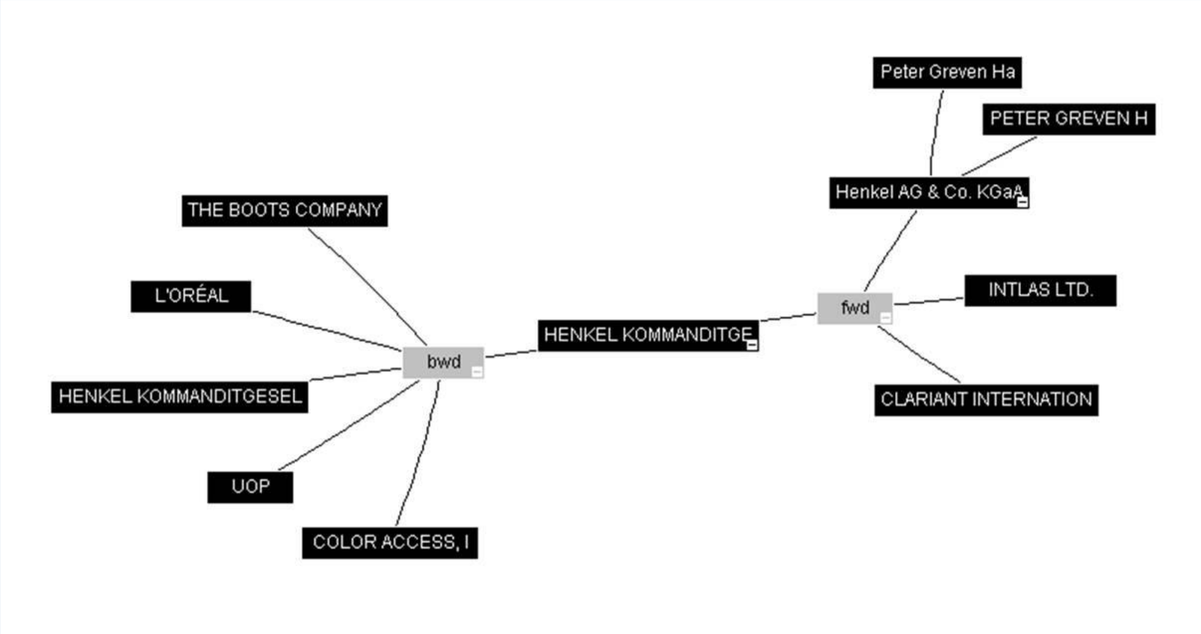

Figure 43 Citation tree for two 'generations' forward and one backward for WO02/051376

The citation tree in Figure 43, above, illustrates the refinement process that many patented inventions undergo; they build on R&D work within an organisation, as it is easy to see that a Henkel patent is cited against WO 02/051376 and then, in turn, WO 02/051376 is cited against a further Henkel patent. It may be the case that a discovery was made which was not covered by WO 02/051376 and this led to this patent being abandoned in favour of a further patent. Naturally, the contents of WO 02/051376 would be relevant to this subsequent patent. However, it could simply be that the applicant was not fully aware of the prior art (i.e. other published patents) which would be relevant to WO 02/051376, and, after discovering these then decided abandon WO 02/051376. This area appears to be of interest to a number of companies given that all of the patents have common classifications/technology area, and could relate to an applied research area of nanotechnology.

Finally, another patent in the top most cited list from this dataset is US 2003/0134409 which is titled: *Delivery vehicles for environmental remediants*, and has Thomas E Mallouk named as the principle inventor. The patent is assigned to Pars Environmental Ltd. The patent details environmental remediants and methods for remediating contaminated soils, earth, ground, or groundwater, particularly subsurface sites. The remediants comprise a chemically or biologically active material, in the form of a particle which is less than about one micron, and a carrier which is interactive with an environmentally acceptable solvent. The carrier is capable of maintaining the particles in a persistent suspension which can permeate soil pores due to its small size, thereby delivering the remediant to the subsurface contamination. Significant advantages over prior art methods, particularly for metallic nanoparticles, are avoiding agglomeration, ease of application, and delivery to subsurface sites. This patent also has an international patent (WO 03/013252) and European patent equivalent (EP 1432317), with a UK designation. This patent did designate UK for patent protection but has been withdrawn before examination (in 2008). Therefore these patents are not in force.

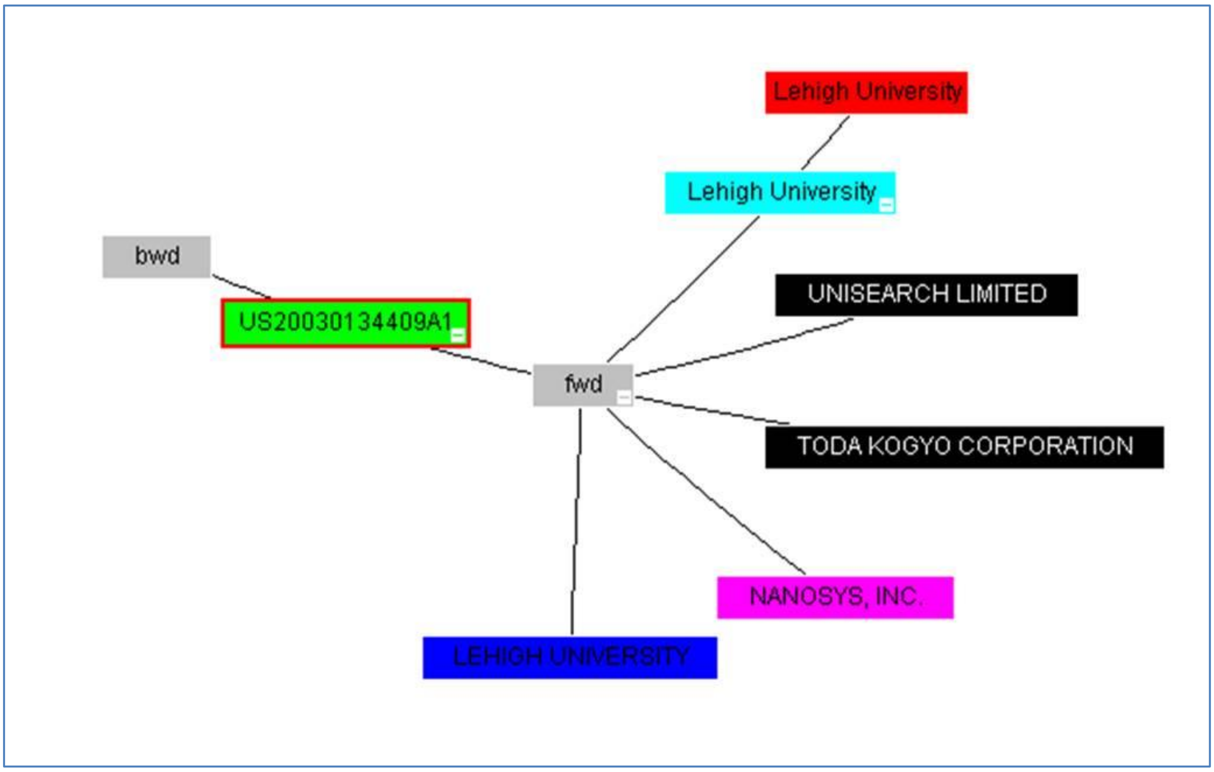

Figure 44 Citation tree for two 'generations' forward and one backward for US 2003/0134409

The citation tree for US 2003/0134409 is shown in Figure 44. No patents were cited against US 2003/0134409 during the examination process, which may indicate that this is a relatively new application of nanotechnology; subsequent patents span a number of classifications which perhaps show that the underlying technology is relevant to a number of other different fields. This does not explain, however, why the patent has not proceeded to grant. It may be a case of the applicant running out of money or that later work, for a different assignee, has rendered the patent less useful.

4.3 High-level comparison with European patent data

A patent map was generated from a dataset of EP records obtained using the same search strategy as the main dataset. A number of comparisons may be drawn between this landscape and that of Figure 10. The EP map shows more activity in areas that do not appear significant in the UK map. Specifically, 'composite carbon polymer', 'film nanostructures substrate', and 'pattern substrate steps' have no equivalent in the UK map. Conversely, the region of the UK map towards the bottom left contains many topics having a pharmaceutical theme, such as pharmaceutical, drugs, enzyme, antibody, representations of which are lacking on the EP map. There is a different overall balance of activity between the two datasets. Also notable is that barely any records (only three) having any of the top three commercial or university applicants from the UK dataset appear on the EP map. It therefore seems that patenting directly in the UK, rather than through the European Patent Office, is the favoured route for these applicants.

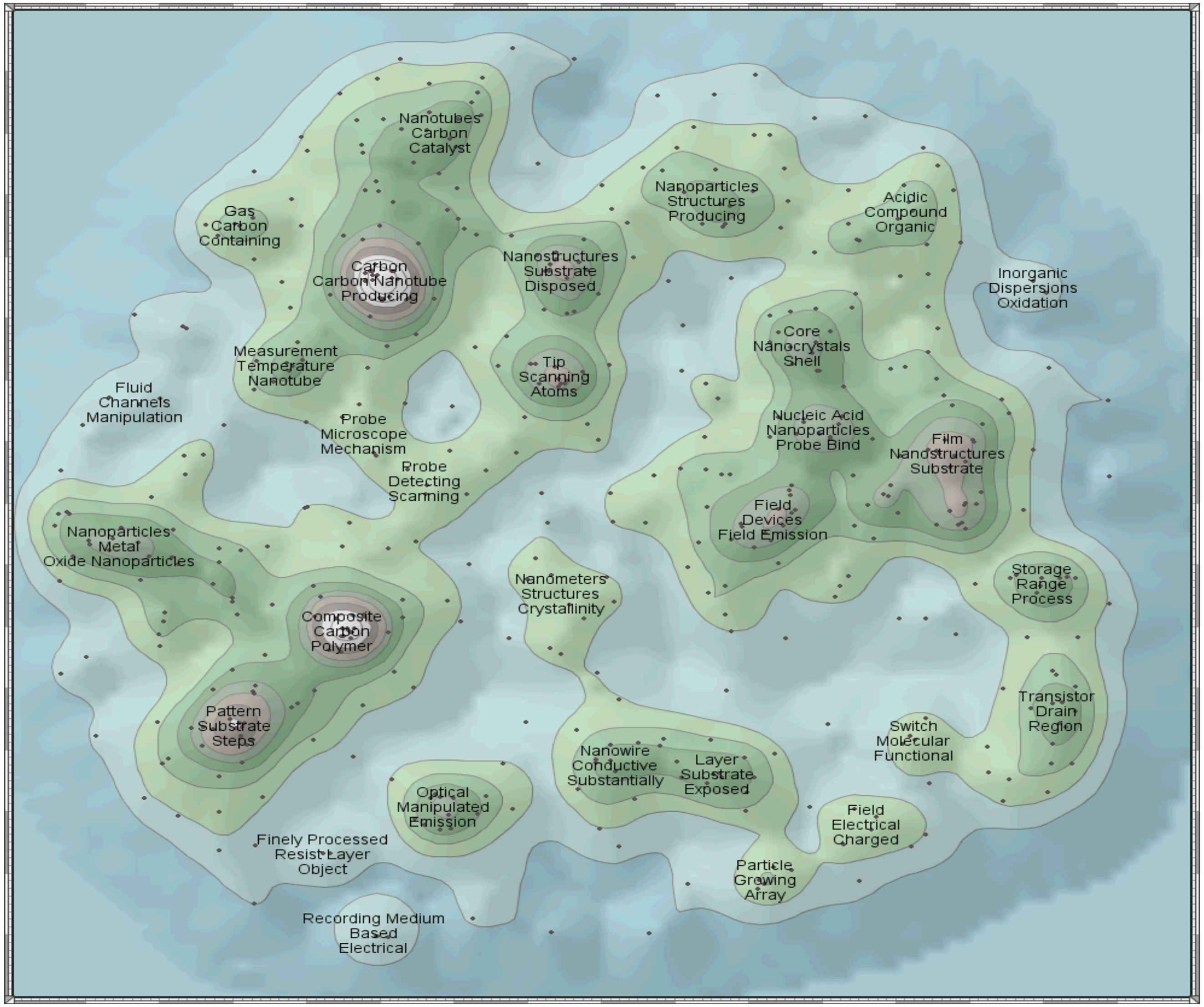

Figure 45 Landscape map of EP dataset © Thomson Reuters

5 Conclusions

The peak of activity of UK-based nanotechnology patent activity has been in recent years, from 2000-2003 and may exhibit a genuine decline since then. The most prolific classification relates to medicinal preparations and cyclodextrins, whilst other classifications relating to medicinal, topical or cosmetic preparations occupy seven of the top ten places.

Looking at sheer patent volumes, the main industrial filers are Tioxide, Pfizer, AstraZeneca and Philips. Cancer Research Campaign and QinetiQ are in the top five. Cambridge University is also ranked in the top five applicants but 67% of activity is from the commercial sector. However, the fact that 14% of activity is from universities is a significant point to note. Furthermore, much of this activity is very recent (post-1999) indicating that research is still ongoing. Cambridge, Oxford, and Glasgow were the top three universities.

Commercial activity overall continues up until 2003 with a subsequent sharp tail off which is likely due at least in part to publication delay. The top commercial applicant, Tioxide, has a peak year in 1995 but activity is zero beyond 1997. The second commercial applicant, Cancer Research Campaign, had a peak year in 1993 and appear to be active up to the present day. QinetiQ had a peak year in 1999 and their activity also appears to continue up to the present. A narrowing down of the temporal range could identify more recent UK based activity and provide further evidence for current specialisms.

In terms of the general categories used, “applications of nanotechnology” is the most prolific. This grouping was frequently applied in conjunction with others (e.g. an application of bionanotechnology would invite double grouping). The transition of science-base to technical application is often regarded as an indication of emergence and gaining maturity. The smallest technology grouping was that of nanofiltration/separation, but many such techniques may exist in the working up of the nanosystems prepared. Nanotoxicity, even on a global scale, provides a small dataset, but further work on precisely defining this category could provide more insights. Nanomaterials / nanostructures, bionanotechnology, and nanometrology have decreased more readily in recent years than applications of nanotechnology, electronic applications. Government applicants are overrepresented in the field of nanomaterials / nanostructures. Cambridge University is a top applicant in the areas of nanomaterials, electronic applications and nanometrology.

The patent holdings profile for nanotechnology shows that the field still appears to have significant amounts of research ongoing, with a relatively small number of established applicants having large portfolios. Given that the dataset covers the whole of nanotechnology, time spent further studying separate research areas could provide evidence for emergent technologies, as the large volumes of patents seems to obscure indicators of such areas. In comparison with EP data, the UK data shows more activity in pharmaceutical fields, whereas thin films and related fields appear more significant in the EP data.

Overall there appear to be aspects of UK nanotechnology activity which are fertile sources of patentable technology, however, in the current dataset they appear to be somewhat obscured by areas of previous activity, such that they cannot necessarily be identified as emerging or emergent areas. Further work in this area could address this.

6 Recommendations

Future work could cover the following:

- Investigation of the portfolios of applicants who are currently active.
- Investigation of a date-limited dataset covering e.g. the last ten years.
- Analysis of specific organisations' (or universities') patent portfolios including the status of those patents, their relevance to specific fields or interests and a more refined assessment of their technological value (for example by referring to the search reports, patent family size etc.).
- Further narrowing of specific requirements to discover key patents within relevant technological areas, which may be obscured in the current dataset.
- Refinement of the technology groupings, combined with temporal limitation could highlight recent UK strengths in this area and potentially highlight areas of emergent UK-based activity.
- Interactive interrogation of the patent landscape could also provide further information on UK nanotechnology activity. In particular, the examination of relevant patents associated with identified key patents may provide a more detailed overview.
- Time-slicing of certain data representations can also indicate the nature of changing technical characteristics over time, which in turn can facilitate the identification of future technology growth or decline.
- Specific example patents (e.g. from the nanotoxicity dataset) could be rigorously analysed to further understand their potential, transferability or demise.
- It is essential that the examination of UK nanotechnology is viewed in a global context, as it will then become more evident where UK expertise and research is being directed through contrast with global activity.

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