THE STRUCTURE AND INFRASTRUCTURE OF THE GLOBAL NANOTECHNOLOGY LITERATURE**

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ABSTRACT

Text mining is the extraction of useful information from large volumes of text. A text mining analysis of the global open nanotechnology literature was performed. Records from the Science Citation Index/ Social Science Citation Index (SCI) were analyzed to provide the infrastructure of the global nanotechnology literature (prolific authors/ journals/ institutions/ countries, most cited authors/ papers/ journals) and the thematic structure (taxonomy) of the global nanotechnology literature, from a science perspective. Records from the Engineering Compendex (EC) were analyzed to provide a taxonomy from a technology perspective.

- The Far Eastern countries have expanded nanotechnology publication output dramatically in the past decade.
- The Peoples Republic of China ranks second to the USA (2004 results) in nanotechnology papers published in the Science Citation Index, and has increased its nanotechnology publication output by a factor of 21 in a decade.
- Of the six most prolific (publications) countries in nanotechnology, the three from the Western group (USA, Germany, France) have about eight percent more publications (for 2004) than the three from the Far Eastern group (China, Japan, South Korea).
- While most of the high nanotechnology publication-producing countries are also high nanotechnology patent producers in the US Patent Office (as of 2003), China is a major exception. China ranks 20th as a nanotechnology patent-producing country in the US Patent Office.

1. INTRODUCTION

Nanotechnology is the development and use of techniques to study physical phenomena and construct structures in the physical size range of 1-100 nanometers (nm), as well as the incorporation of these structures into applications. Experiments and computer simulation have been targeted at very small scales for decades. However, the advent of high speed and high storage capacity computers, as well as accurate instruments for measuring and manipulating at the nanoscale, have accelerated the development of nanoscale structures and devices into reality.

Public and private support for further nanotechnology development has increased dramatically. In the National Nanotechnology Initiative, established in 2001, the U. S. Federal government will contribute billions of dollars to further development by the end of the decade. World-wide, other governments have infused substantial funding to nanotechnology programs. The private sector is heavily investing in this technology, anticipating the large size of the potential market.

Along with the growth in the tools and products of nano-science and technology (and its financial support) has come the growth in the related technical literature. For example, in the fundamental nanotechnology research literature as represented by the Science Citation Index (SCI), publications grew from 4552 articles in 1991 to 33060 articles in 2004.

Given this voluminous literature, as well as the other voluminous literatures of Patents, Technical Reports, other large databases, and the Web, how can one gain an integrated perspective of the overall state of nanotechnology? Text mining offers one potential approach. This report applies text mining to the SCI and EC nanotechnology literatures. The query to retrieve these literatures is defined operationally as follows (* denotes the wild-card character used in most search engines).

NANOPARTICLE* OR NANOTUB* OR NANOSTRUCTURE* OR NANOCOMPOSITE* OR NANOWIRE* OR NANOCRYSTAL* OR NANOFIBER* OR NANOFIBRE* OR NANOSPHERE* OR NANOROD* OR NANOTECHNOLOG* OR NANOCLUSTER* OR NANOCAPSULE* OR NANOMATERIAL* OR NANOFABRICAT* OR NANOPOR* OR NANOPARTICULATE* OR NANOPHASE OR NANOPOWDER* OR NANOLITHOGRAPHY OR NANO-PARTICLE* OR NANODEVICE* OR NANODOT* OR NANOINDENT* OR NANOLAYER* OR

NANOSCIENCE OR NANOSIZE* OR NANOSCALE* OR ((NM OR NANOMETER* OR NANOMETRE*) AND (SURFACE* OR FILM* OR GRAIN* OR POWDER* OR SILICON OR DEPOSITION OR LAYER* OR DEVICE* OR CLUSTER* OR CRYSTAL* OR MATERIAL* OR ATOMIC FORCE MICROSCOP* OR TRANSMISSION ELECTRON MICROSCOP* OR SCANNING TUNNELING MICROSCOP*)) OR QUANTUM DOT* OR QUANTUM WIRE* OR ((SELF-ASSEMBL* OR SELF-ORGANIZ*) AND (MONOLAYER* OR FILM* OR NANO* OR QUANTUM* OR LAYER* OR MULTILAYER* OR ARRAY*)) OR NANOELECTROSPRAY* OR COULOMB BLOCKADE* OR MOLECULAR WIRE*

This query, generated using an iterative relevance feedback technique [Kostoff et al, 1997], is used to retrieve relevant documents from selected source databases. Then, the retrieved database is analyzed to produce the following characteristics and key features of the nanotechnology field: recent prolific nanotechnology authors; journals that contain numerous nanotechnology papers; institutions that produce numerous nanotechnology papers; keywords most frequently specified by the nanotechnology authors; authors, papers and journals cited most frequently; pervasive technical themes of the nanotechnology literature; and relationships among the pervasive themes and sub-themes.

2. BACKGROUND

2.1. Text Mining

A typical text mining study of the published literature develops a query for comprehensive information retrieval, processes the retrieved database using computational linguistics and bibliometrics, and integrates the processed information. In this section, the computational linguistics and bibliometrics are overviewed.

Science and technology (S&T) computational linguistics [Kostoff, 2003a; Hearst, 1999; Zhu and Porter, 2002; Losiewicz et al, 2000] identifies pervasive technical themes in large databases from technical phrases that occur frequently. It also identifies relationships among these themes by grouping (clustering) these phrases (or their parent documents) on the basis of similarity. Computational linguistics can be used for:

- Enhancing information retrieval and increasing awareness of the global technical literature [Kostoff et al, 1997; Greengrass, 1997; TREC, 2004]

- Potential discovery and innovation based on merging common linkages among very disparate literatures [Kostoff, 2003b, 2005a; Swanson, 1986; Swanson and Smalheiser, 1997; Gordon and Dumais, 1998]
- Uncovering unexpected asymmetries from the technical literature [Kostoff, 2003c; Goldman et al, 1999]. For example, Kostoff [2003c] predicted asymmetries in recorded bilateral organ (lungs, kidneys, testes, ovaries) cancer incidence rates from the asymmetric occurrence of lateral word frequencies (left, right) in Medline case study articles.
- Estimating global levels of effort in S&T sub-disciplines [Kostoff et al, 2000, 2004a; Viator and Pastorius, 2001]
- Helping authors potentially increase their citation statistics by improving access to their published papers, and thereby potentially helping journals to increase their Impact Factors [Kostoff et al, 2004a, 2004b]
- Tracking myriad research impacts across time and applications areas [Kostoff et al, 2001; Davidse and VanRaan, 1997].

Evaluative bibliometrics [Narin, 1976; Garfield, 1985; Schubert et al, 1987] uses counts of publications, patents, citations and other potentially informative items to develop science and technology performance indicators. Its validity is based on the premises that 1) counts of patents and papers provide valid indicators of R&D activity in the subject areas of those patents or papers, 2) the number of times those patents or papers are cited in subsequent patents or papers provides valid indicators of the impact or importance of the cited patents and papers, and 3) the citations from papers to papers, from patents to patents and from patents to papers provide indicators of intellectual linkages between the organizations that are producing the patents and papers, and knowledge linkage between their subject areas [Narin et al, 1994]. Evaluative bibliometrics can be used to:

- Identify the infrastructure (authors, journals, institutions) of a technical domain,
- Identify experts for innovation-enhancing technical workshops and review panels,
- Develop site visitation strategies for assessment of prolific organizations globally,
- Identify impacts (literature citations) of individuals, research units, organizations, and countries

2.2. Nanotechnology

2.2.1. Literature Review Overview

A comprehensive background of the seminal works in nanotechnology is contained in a companion document [Kostoff et al, 2005c], and will not be repeated here. There are numerous books (e.g., Bhushan's Handbook of Nanotechnology [Bhushan, 2004]; Goddard's Handbook on Nanoscience, Engineering, and Technology [Goddard, 2002]; Freitas' multi-volume set on nanomedicine [Freitas, 1999, 2003]; see Appendix 1 for more complete listing of reference books), review articles (e.g., Kricka's multi-lingual survey of nanotechnology books and patents [Kricka and Fortina, 2002]; Simon's review of the science and potential applications of nanotechnology [Simon, 2005]), and reports (e.g., The Royal Society's comprehensive review on nanoscience and nanotechnologies [Dowling et al, 2004]; Colton's in-depth review of nanoscale measurements and manipulation [Colton, 2004]) that cover various sub-sets of nanotechnology. For the research literature, none of these published reviews have the spatial and temporal breadth of coverage of the present report, none use a query of the extent and complexity of the present report, and none do full text mining of the results to obtain structure and infrastructure of the nanotechnology literature. Every published research review on nanotechnology typically covers a focused technology sub-set, not the total field as was done in the present report. For the Patent literature, [Huang et al, 2004] provides a comprehensive text mining analysis of international nanotechnology development that serves to complement the present study.

2.2.2. Technical Background Overview

Nanoscience and its underlying science involve materials where some critical property is attributable to a structure with at least one dimension limited to the nanometer size scale, 1 – 100 nanometers. Below that size scale, the disciplines of Chemistry and Atomic/ Molecular Physics have already provided detailed scientific understanding. Above that size scale, Condensed Matter Physics and Materials Science have provided detailed scientific understanding of microstructures in the last 50 years. So, the nanoscale is the last "size" frontier for materials science.

If one expected to simply extrapolate the properties of nanostructures from the size scales above or below, then there would be little reason for the current interest in nanoscience / nanotechnology. However, there are three reasons for nanostructured materials to behave very differently at nanoscale levels: large surface/interface to volume ratios; size effects (where cooperative phenomena like ferromagnetism are compromised by the limited number of atoms/molecules); and quantum effects. Many of the models for materials properties at the micron and larger sizes have characteristic length scales of nanometers. When the size of the structure is in the nanometer region, the parameters used in the microscopic models will no longer be adequate to model/predict the property. One can expect "surprises" – new materials properties that may be technologically exploitable.

While the scientific understanding of nanostructures is deficient, their use in technology is at least two thousand years old. The Lycurgis cup, a Roman artifact pictured in the lower left of Figure 1, utilizes nanosized gold (Au) clusters to provide different colors depending on front or back lighting. The Roman artisans knew how to achieve the effect; they didn't know its nanocluster basis. In the last century, nanostructures have contributed to <u>many</u> significant technologies - examples include the addition of nanosized carbon particles to rubber for improved mechanical properties (tires), the use of nanosized particles for catalysis in the petrochemical industries, and the nucleation of nanosized silver (Ag) clusters during photographic film exposure. These technologies were all developed empirically. As depicted in Figure 1, one might assign these examples to an empiric epoch in the continuing evolution of nanotechnology.

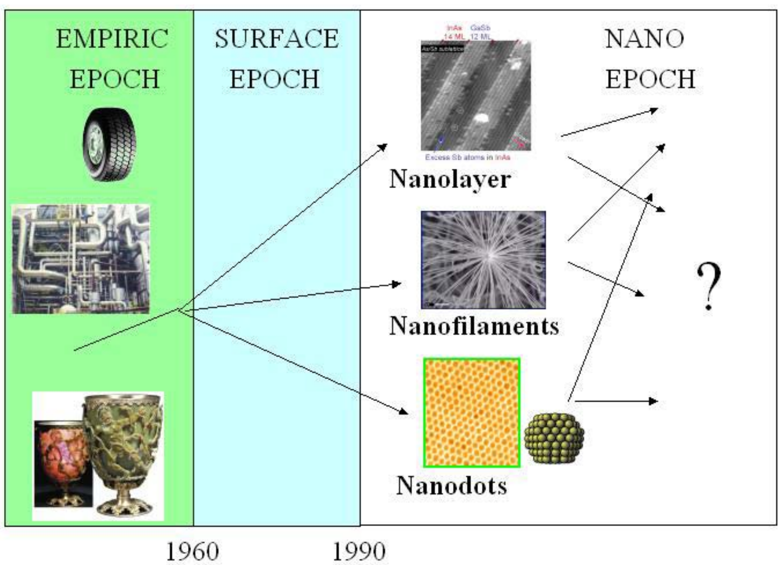


Figure 1: Paleontology of Nanostructures

Empirically based technology, without greater scientific understanding, is usually difficult to extend or control. The scientific foundation of nanostructures received a boost in the 1960s when surface science enjoyed a renaissance. Surface science deals with the study of material surfaces, and generally was constrained to the nanometer size scale in one dimension. Events catalyzing that renaissance were the development of new surface-sensitive analytical tools, the ready availability of ultra-high vacuum (a by-product of the space age), and the maturity of solid-state physics (surfaces representing a controlled lattice defect – termination of repeating unit cells). The principal economic driving force was the electronics industry, but surfaces were also recognized to play an essential role in many "reliabilities" – adhesives, corrosion protection, friction, wear, fracture, etc. From 1960 to the present, surface science has progressed from "clean, flat and cold" into the technologies of thin films (two or more nanoscale interfaces) and film processing. The scientific contributions toward nanotechnology until the late 1980s are examined below under the heading Early Nanoscience Development – pre 1985.

What might be labeled as modern nanotechnology development began in the late 1980s, when the science literature involving nanostructures showed the beginnings of a classic S-curve. The emergence of nanoscience/ nanotechnology in the 1990s has close parallels to the 1960 surface science renaissance. First, beginning in 1980, the discovery and development of proximal probes – scanning tunneling microscopy/spectroscopy, atomic force microscopy/spectroscopy, near-field microscopy/spectroscopy – have provided tools for measurement and manipulation of individual nanosized structures. Those tools needed 10-15 years for reliable commercial instruments to come onto the markets. The properties of the individual nanostructures can now be observed, rather than the ensemble averaged values. In turn, those properties can be understood in terms of composition / structure. With that understanding came the possibility for control, and with control came the possibility for accelerated progress toward new technology.

Second, in addition to the new experimental measurement capabilities, computer hardware is now sufficiently advanced (speed and memory capacity) such that accurate predictions, based on ab initio first principles, are enabled for the number of atoms incorporated in a nanostructure. Modeling and simulation will play a leading role in the race toward nanotechnology. Third, the disciplines of biology, chemistry, materials, and physics have all reached a point where nanostructures are of interest – chemistry building up from simpler molecules, physics/materials working down from microstructures, and biology sorting out from very complex systems into simpler subsystems. Finally, there are several economic engines driving the interest in information technology (electronics and photonics), biotechnology (pharmaceuticals and healthcare), and high performance materials. Estimates of potential economic impact cite a worldwide commercial market on the order of $1 trillion per year well before 2020 for systems whose function is enabled by the properties of nanostructures – "Nano-Inside."

With the substantial scientific and economic opportunities, it is not surprising to find strong global interest in fostering nanoscience, with the intent of accelerating scientific discovery into innovative commercial product. The increasing nanotechnology patent literature gives evidence for that acceleration. From estimates of global FY04 budgets, over $3 billion was invested worldwide in nanotechnology S&T in 2004, with the U.S. contribution around $950 million. This strong commitment of science and technology (S&T) funds will ensure the rapid growth in nanoscience and nanotechnology continues.

3. DATABASE GENERATION

The first step in database generation is query development. The iterative relevance feedback technique of Simulated Nucleation [Kostoff, 1997] is used to develop the query as follows. A test query is generated (e.g., "nanotechnology"); records are retrieved from the SCI using this query; the retrieved records are divided into relevant and non-relevant categories; the phrase patterns of each category are analyzed using the TextDicer software; and the query is modified by inclusion of selected phrase patterns. The process is repeated until convergence occurs. During the iterative query development process, clustering of the retrieval is performed at least one time, to identify the main technical categories and insure that the query includes adequate technical terms that represent each of the main technical thrusts [Kostoff, 2005d]

For the final retrieval, the query shown in the Introduction was inserted into the Science Citation Index [SCI, 2005] search engine to retrieve relevant records from the source SCI database published in 2003 only. Due to SCI downloading limitations at the time the data were taken, records had to be downloaded separately from the top 350 journals containing the most nanotechnology papers. These 21474 downloaded papers were used for the computational linguistics and most of the bibliometrics. The institution and country bibliometrics were obtained from direct query of the SCI. These downloaded records were current at the time of the study, and the numbers of records retrieved provided an adequate sampling of the literature. The SCI-retrieved database consists of selected journal records (including authors, titles, journals, author addresses, author keywords, abstract narratives, and references cited for each paper) obtained by searching the Web version of the SCI for nanotechnology articles. The prolific institution and country bibliometrics were updated to 2004, especially to highlight the rapid advance made by a number of countries in recent years. The query was also inserted into the Engineering Compendex to retrieve relevant records.

4. RESULTS

The results from the publications bibliometric analyses are presented in section 4.1, followed by the results from the citations bibliometrics analysis in section 4.2. Results from the computational linguistics analyses are shown in section 4.3. The SCI bibliometric fields incorporated into the database included, for each paper, the author, journal, institution, and keywords. In addition, the SCI included references for each paper.

4.1 Publication Statistics on Authors, Journals, Organizations, Countries

The output and productivity metrics of paper counts are presented initially.

4.1.1 Author Frequency Results

There were 50969 authors listed in the 21474 downloaded records. Table 1 contains the names of the twenty most prolific of these authors. All the names of the twenty most prolific authors appear to be of Asian origin, and the number of their publications listed for 2003 appeared quite high. While some of the names applied to multiple authors, in some cases, an author listed as most prolific was indeed one person. YT Qian, for example, published 106 research articles in SCI-accessed journals in 2003 (based on direct query of the SCI), and 346 articles in SCI-accessed journals over a four-year period.

TABLE 1 – MOST PROLIFIC AUTHORS – 2003

AUTHOR	#PAPERS

ZHANG--Y	84
LI--J	63
QIAN--YT	62
WANG--J	62
WANG--Y	62
LEE--JH	59
LIU--Y	58
ZHANG--LD	58
CHEN--Y	56
BANDO--Y	52
CHEN--J	52
WANG--X	52
ZHANG--J	51
GAO--L	50
WANG--H	47
KIM--JH	46
LI--Y	45
KIM--J	44
ZHANG--H	44
WANG--L	41

As the first author's previous text mining studies have shown, one characteristic of prolific authors is that they tend not to be first authors on many of their articles. For example, the twenty most prolific authors from 2000-2003 in the two nanotechnology-focused journals Nano Letters and Nanotechnology authored/ co-authored 193 papers in the two journals since the journals' inception. They were first authors on just fourteen of the 193 papers, or about seven percent. Eleven of the authors had zero first authorships, five of the authors had one first authorship, three of the authors had two first authorships, and one author had three first authorships. Interestingly, three of the four authors who had more than one first authorship work at national laboratories. The practical implications of prolific authors tending not to be first authors, in terms of Bibliometrics impact, will be addressed in the Most Cited Authors section.

4.1.2. Journals Containing Most Nanotechnology Papers

The twenty journals containing the most nanotechnology papers (Table 2) from the 21474 downloaded records tend to be in the technical disciplines of Physics, Chemistry, and Materials, with an emphasis on surface science. The top tier in volume of nanotech-related articles had three physics journals (Applied Physics Letters, Physical Review, and Journal of Applied Physics).

TABLE 2 – JOURNALS CONTAINING MOST NANOTECHNOLOGY RESEARCH ARTICLES – 2003

JOURNAL	#PAPERS
APPLIED PHYSICS LETTERS	1240
PHYSICAL REVIEW B	899
JOURNAL OF APPLIED PHYSICS	875
LANGMUIR	690
JOURNAL OF PHYSICAL CHEMISTRY B	558
JAPANESE JOURNAL OF APPLIED PHYSICS PART 1-REGULAR PAPERS SHORT NOTES & REVIEW PAPERS	435
JOURNAL OF THE AMERICAN CHEMICAL SOCIETY	408
CHEMICAL PHYSICS LETTERS	390
PHYSICAL REVIEW LETTERS	353
NANO LETTERS	346
CHEMISTRY OF MATERIALS	319
APPLIED SURFACE SCIENCE	291
PHYSICA E-LOW-DIMENSIONAL SYSTEMS & NANOSTRUCTURES	278
THIN SOLID FILMS	260
INORGANIC CHEMISTRY	254
JOURNAL OF MAGNETISM AND MAGNETIC MATERIALS	247
JOURNAL OF MATERIALS CHEMISTRY	243
MACROMOLECULES	243
ADVANCED MATERIALS	239
JOURNAL OF VACUUM SCIENCE & TECHNOLOGY B	229

4.1.3. Institutions Producing Most Nanotechnology Papers/ Patents

Table 3A contains the most prolific paper-publishing institutions in 2003, based on direct query of the SCI. Also in this table are the most prolific patent-publishing instutions (for nanotechnology patents granted by the US Patent Office) in 2003, according to [Huang et al, 2004]. Seven of the prolific paper-publishing institutions are research centers, and the rest are universities. No industry institutions are listed. Nineteen of the prolific patent-producing institutions are industry, and the other two are universities. The two universities listed (MIT, Univ of Cal) are common to both lists.

The relatively high fraction of paper-publishing research centers (1/3) compared to the first author's previous technology text mining studies suggests a more applied focus to the research. The near-orthogonality of the two lists suggests that the organizations/ people who publish are not the same as those who patent. It might be useful for management researchers to study the MIT example, to ascertain how MIT maintains a publishing-patenting balance, and what (if any) advantages accrue from maintaining such a balance.

TABLE 3A - MOST PROLIFIC INSTITUTIONS – SCI; USPTO PATENTS - 2003

INSTITUTION - SCI	#PAP	INSTITUTION - PATENTS	#PAT
CHINESE ACAD SCI	1303	IBM	198
CNRS	1198	MICRON TECHNOLOGY	129
RUSSIAN ACAD SCI	687	ADVANCED MICRO DEVICES	128
TSING HUA UNIV	454	INTEL	90
UNIV TOKYO	429	REGENTS, UNIV OF CALIFORNIA	89
TOHOKU UNIV	352	MMM	79
OSAKA UNIV	345	MOTOROLA	72
NATL INST ADV IND SCI & TECHNOL	341	HITACHI	68
UNIV SCI & TECHNOL CHINA	297	XEROX	68
NANJING UNIV	288	CANON KABUSHIKI KAISHA	64
NATL INST MAT SCI	287	EASTMAN KODAK	64
TOKYO INST TECHNOL	283	NEC	57
CNR	275	CORNING	50
CSIC	268	APPLIED MATERIALS	47
UNIV ILLINOIS	245	FUJI PHOTO FILM	42
PEKING UNIV	245	MATSUSHITA ELECTRIC	41
SEOUL NATL UNIV	244	LUCENT TECHNOLOGIES	37
UNIV TEXAS	230	TEXAS INSTRUMENTS	37
UNIV CAMBRIDGE	229	GENENTECH	36
MIT	226	KABUSHIKI KAISHA TOSHIBA	36
UNIV CALIF BERKELEY	210	MIT	36

Table 3B contains the most prolific institutions, updated for 2004. Of the twenty most prolific institutions, thirteen are universities, and the remaining seven are government laboratories. Thirteen are from the Far East, three are from the USA, three are from Western Europe, and one is from Eastern Europe. There are no major changes at the top of the list between 2003-2004.

TABLE 3B – PROLIFIC INSTITUTIONS – SCI PAPERS - 2004

INSTITUTION	COUNTRY	#PAPERS
CHINESE ACAD SCI	CHINA	1533
CNRS	FRANCE	1241
RUSSIAN ACAD SCI	RUSSIA	641
TSING HUA UNIV	CHINA	504
UNIV TOKYO	JAPAN	444
OSAKA UNIV	JAPAN	373
TOHOKU UNIV	JAPAN	363
CSIC	SPAIN	345
UNIV SCI & TECHNOL CHINA	CHINA	342
NANJING UNIV	CHINA	333

NATL INST ADV IND SCI & TECHNOL	JAPAN	311
CNR	ITALY	311
TOKYO INST TECHNOL	JAPAN	308
SEOUL NATL UNIV	S. KOREA	296
MIT	USA	284
UNIV ILLINOIS	USA	283
NATL UNIV SINGAPORE	SINGAPORE	277
UNIV TEXAS	USA	273
NATL INST MAT SCI	JAPAN	272
PEKING UNIV	CHINA	262

4.1.4. Countries Producing Most Nanotechnology Papers/ Patents

Table 4A contains the most prolific paper-producing countries for 2003, based on direct query of the SCI. Also in this table are the most prolific countries for nanotechnology patents granted by the US Patent Office in 2003, according to [Huang et al, 2004]. The most striking difference is that of China, which is tied for second on the paper-producing list and tied for 20th on the patent-producing list. Canada, Netherlands, and Israel have a paper performance that outproduces the patent performance by a substantial margin.

TABLE 4A – MOST PROLIFIC COUNTRIES – SCI; USPTO PATENTS - 2003

COUNTRY - SCI	#PAP	COUNTRY - PATENTS	#PAT
USA	7512	USA	5228
JAPAN	4431	JAPAN	926
PEOPLES R CHINA	4417	GERMANY	684
GERMANY	3099	CANADA	244
FRANCE	1900	FRANCE	183
SOUTH KOREA	1592	SOUTH KOREA	84
UNITED KINGDOM	1520	NETHERLANDS	81
RUSSIA	1293	UNITED KINGDOM	78
ITALY	1015	TAIWAN	77
INDIA	830	ISRAEL	68
SPAIN	727	SWITZERLAND	56
TAIWAN	706	AUSTRALIA	53
CANADA	690	SWEDEN	39
POLAND	515	ITALY	31
SWITZERLAND	498	BELGIUM	28
NETHERLANDS	492	DENMARK	23
BRAZIL	455	SINGAPORE	20
SWEDEN	435	FINLAND	17

AUSTRALIA	434	IRELAND	10
SINGAPORE	372	AUSTRIA	8
ISRAEL	347	PEOPLES R CHINA	8

Table 4B shows the most prolific paper-producing countries, updated for 2004. At the top, there is little difference in the rankings compared to 2003, with the exception that China has clearly moved into second place. There were 101 countries listed. In 2004, three countries dominate: USA, China, and Japan; Germany is a strong contributor as well. In the top six countries, the three from the Western group (USA, Germany, France) have about eight percent more publications than the three from the Far Eastern group (China, Japan, South Korea). However, studies have shown an English language bias for the SCI [Winkmann et al, 2002], and these Far Eastern publication numbers based solely on the SCI should be viewed as an under-estimate.

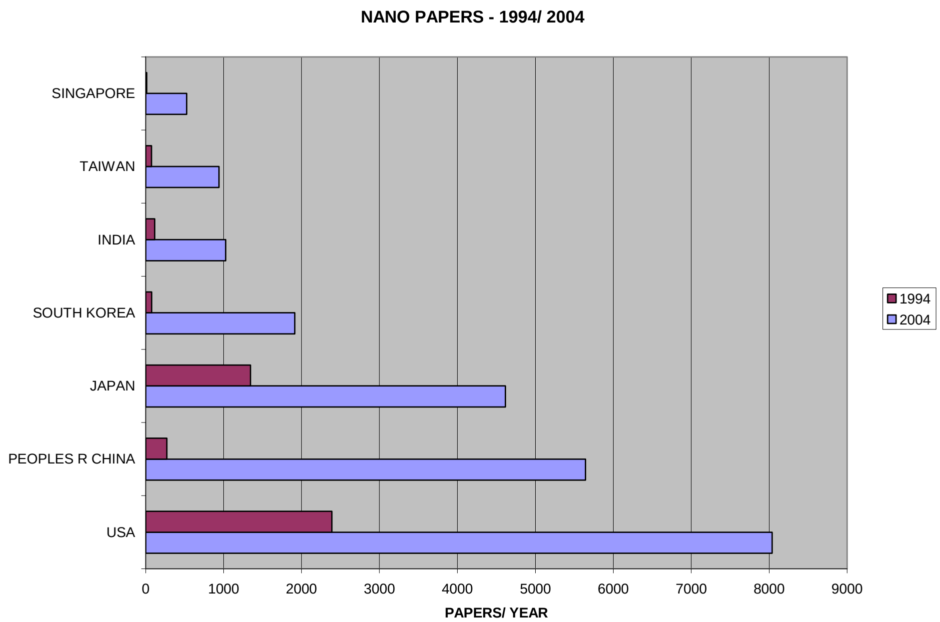
TABLE 4B – PROLIFIC COUNTRIES – 2004

COUNTRY	2004 NANO PAP	2004 TOT PAP	RATIO 2004 NANPAP/ TOTPAP	1994 NANO PAP	1994 TOT PAP	RATIO 1994 NANPAP/ TOTPAP	RATIO 2004/1994 NANPAP	RATIO 2004/1994 TOTPAP
USA	8037	294762	0.027266	2388	283530	0.008422	3.365578	1.039615
CHINA	5644	54024	0.104472	271	8976	0.030192	20.82657	6.018717
JAPAN	4617	71411	0.064654	1346	49524	0.027179	3.430163	1.441947
GERMANY	3120	65358	0.047737	928	45686	0.020313	3.362069	1.430591
FRANCE	1954	46647	0.041889	519	35346	0.014683	3.764933	1.319725
SOUTH KOREA	1912	22284	0.085801	77	3450	0.022319	24.83117	6.45913
ENGLAND	1465	57134	0.025641	467	43254	0.010797	3.137045	1.320895
RUSSIA	1300	23992	0.054185	249	24737	0.010066	5.220884	0.969883
ITALY	1115	35561	0.031355	204	21054	0.009689	5.465686	1.689038
INDIA	1025	21117	0.048539	115	12129	0.009481	8.913043	1.741034
TAIWAN	941	13456	0.069932	73	5244	0.013921	12.89041	2.56598
SPAIN	829	26302	0.031519	114	12548	0.009085	7.27193	2.096111
CANADA	785	35630	0.022032	246	29200	0.008425	3.191057	1.220205
SWITZERLAND	598	14552	0.041094	175	9882	0.017709	3.417143	1.472576
NETHERLANDS	584	20176	0.028945	207	14376	0.014399	2.821256	1.40345
POLAND	582	12968	0.04488	67	5878	0.011398	8.686567	2.206193
SINGAPORE	527	5348	0.098542	14	1378	0.01016	37.64286	3.880987
SWEDEN	471	15021	0.031356	128	11167	0.011462	3.679688	1.345124
BRAZIL	462	14631	0.031577	47	4368	0.01076	9.829787	3.349588
AUSTRALIA	462	22789	0.020273	101	14392	0.007018	4.574257	1.583449

In addition, trends are very important. In Table 4B, the first column on the left (COUNTRY) represents the country, the next column (2004 NANO PAP) contains the nanotechnology papers published by each country in 2004, the next column (2004 TOT PAP) contains the total papers published by each country in 2004, the next column is the ratio of the 2004 nano papers to total papers, the next three columns are the same type of data for 1994, and the final two columns are the ratios of 2004/ 1994 nanotechnology papers and total papers, respectively. Three important observations follow.

First, the 2004/ 1994 ratio of nanotechnology papers is in double digits for the Far Eastern countries only (Peoples R China, South Korea, Taiwan, and Singapore). Figure 1 shows this trend more dramatically, where the short bar for the countries depicted represents the 1994 nanotechnology papers, and the long bar represents the 2004 nanotechnology papers. Second, the 2004/ 1994 ratio of total SCI papers is above ~4 for Far Eastern countries only (Peoples R China, South Korea, Singapore). Third, the fractions of nanotechnology papers to total papers for 2004 above eight percent are for Far Eastern countries only (Peoples R China, South Korea, Singapore). Thus, in the past decade, these Far Eastern countries have shown substantial growth in total SCI papers, in nanotechnology papers, and in the ratio of nanotechnology papers to total papers.

FIGURE 1 – 2004 AND 1994 PAPERS PUBLISHED FOR SELECT COUNTRIES



4.2 Citation Statistics on Authors, Papers, and Journals

The second group of metrics presented is counts of citations to papers published by different entities. The citations in all the retrieved SCI papers were aggregated; the authors, specific papers, years, journals, and countries cited most frequently were identified, and were listed in order of decreasing frequency. While citations are ordinarily used as impact or quality metrics [Garfield, 1985], much caution needs to be exercised in their frequency count interpretation, since there are numerous reasons why authors cite or do not cite particular papers [Kostoff, 1998; MacRoberts and MacRoberts, 1996].

4.2.1 Most Cited Authors

The most cited first authors were examined initially, since only the first authors are shown on the references downloaded en masse from the SCI. There were 134906 cited first authors listed. About half of the most cited first authors are from the Far East, with most of the remainder being from the USA.

TABLE 5 – MOST CITED FIRST AUTHORS

AUTHOR	INSTITUTION	COUNTRY	#CITES

IIJIMA S	NEC CORP LTD	JAPAN	1048
DRESSELHAUS MS	MIT	USA	529
WANG J	NANJING UNIV TECHNOLOGY	CHINA	465
ULMAN A	POLYTECHNICAL UNIVERSITY	USA	456
SAITO R	TOHOKU UNIV	JAPAN	455
ALIVISATOS AP	UNIV CAL BERKELEY	USA	449
CHEN J	NANKAI UNIV	CHINA	395
MURRAY CB	IBM CORP	USA	392
CARUSO F	UNIV MELBOURNE	AUSTRALIA	380
VAIA RA	AFRL	USA	367
AJAYAN PM	RENSSELAER POLY	USA	357
DECHER G	UNIV STRASBOURG	FRANCE	318
KONG J	ACAD SINICA	CHINA	314
TANS SJ	FOM INST ATOM & MOL PHYS	NETHERLANDS	310
HUANG MH	UNIV CAL BERKELEY	USA	309
INOUE A	TOHOKU UNIV	JAPAN	307
NAKAMURA S	TEIKYOU UNIV	JAPAN	303
PERDEW JP	TULANE UNIV	USA	302
CHEN Y	HEFEI UNIV TECHNOLOGY	CHINA	297
ZHANG Y	PEKING UNIV	CHINA	295

The citation data for authors and journals represent citations generated only by the 21474 specific records extracted from the SCI database for this study. They do not represent ***all*** the citations received by the references in those records; these references in the database records could have been cited additionally by papers in other technical disciplines, as will be shown in the Most Cited Documents section.

The numbers of citations for first authors under-represent the actual (total) citations for those authors for the following reasons. When references in a document are downloaded as a group from the SCI, they list the first author only. Thus, any reference on which any of its authors was not first author will not count as a citation for the author. As was shown by the prolific author example for the two nanojournals, the most prolific authors tend not to be first authors. Therefore, they will not receive citation credit for most of their papers. The more accurate citation numbers could be obtained, but only for references that are themselves in the SCI, and then only with a laborious manual filtering process where each reference is downloaded individually (example shown later in this section). In essentially all the text mining studies performed by the first author, it was found that the lists of most prolific authors and most cited first authors were almost disjoint. While there are a number of reasons for this phenomenon, the lack of first authorship by most prolific authors is clearly an important reason.

In the results for most cited first authors, some of the researchers acknowledged to be major contributors to the development of nanotechnology (e.g., Smalley, Lieber) did not appear. One potential reason, under-representation due to limited first authorship, has been described above. To test this hypothesis, the following experiment was performed. The 232 most cited papers in the retrieved database were downloaded individually from the SCI. This allowed all the authors to be represented on the download. Then, the most prolific authors in this database of 232 highly cited references were identified, and listed in frequency order. The top twenty authors on this list are shown in Table 6. Smalley, Lieber, and others who did not appear in the most cited first authors list now are listed in Table 6. This confirms the limited first authorship hypothesis, and shows that these acknowledged leaders participated in many highly cited papers, although not as first authors.

<u>TABLE 6 – AUTHORS OF MOST HIGHLY CITED PAPERS</u>

AUTHOR	**#PAPERS**	**AUTHOR**	**#PAPERS**
SMALLEY, RE	17	VAIA, RA	6
LIEBER, CM	16	DRESSELHAUS, MS	5
GIANNELIS, EP	10	EKLUND, PC	5
RINZLER, AG	9	MIRKIN, CA	5
ALIVISATOS, AP	8	DUAN, XF	4
COLBERT, DT	8	BAWENDI, MG	4
THESS, A	7	MURRAY, CB	4
DAI, HJ	7	OKADA, A	4
DEKKER, C	7	PENG, XG	4
NIKOLAEV, P	6	GRATZEL, M	4

Not all the prolific authors of the 232 most cited papers were independent. Some of these authors functioned as groups, for multiple papers. A clustering analysis of the authors' relationships was performed. For example, Smalley, Rinzler, Colbert, and Nikolaev form a moderately close knit unit, as evidenced by their clustering. More detailed examination of their publication data shows significant co-publication, with Smalley being the central figure on many of the publications.

Of these 232 most cited papers, 66 were published in Science, 44 in Nature, 15 in Physical Review Letters, 10 in Applied Physics Letters, 10 in Chemical Reviews, and 9 in Physical Review B.

4.2.2. Most Cited Documents

There were 308961 references listed in the retrieved papers. Essentially all the top tier most cited documents were published within the last decade, showing the dynamic nature of this discipline. These are the most recent references of any discipline examined in the first author's previous text mining studies. Additionally, only one of the authors in this tier, SS Fan (24^{th} in the ranking), was listed at a Chinese institution. Thus, while the prolific author, institution, country lists, and most cited first author list show a substantial Chinese (country) representation, the most cited document list shows a minor Chinese (country) representation. While there are a number of reasons for this difference, one possible reason is that the citations received by Chinese authors are spread over many documents. A re-examination of the most cited documents in three or four years should show whether the large number of Chinese documents published presently are accompanied by adequate quality.

Table 7 lists the ten highest frequency references in the 21474 retrieved papers. The fields for each record, starting from left, are: AUTHOR (first author); YEAR (year of publication); SOURCE (name of journal or book); VOL (volume number); PAGE (page number); #CITES-2003-REF (frequency of reference in the 2003 retrieved database); #CITES – SCI-TOT (number of total citations listed in the Times Cited field of the SCI record). The narrative line (in bold italics) following the field listings for each record contains the record title (in parenthesis).

TABLE 7 – MOST CITED REFERENCES

FIRST AUTHOR	COUNTRY	YEAR	SOURCE	VOL	PAGE	#CITES 2003-REF	#CITES SCI-TOT
IIJIMA S	JAPAN	1991	NATURE	V354	P56	730	4079
(HELICAL MICROTUBULES OF GRAPHITIC CARBON)							
ALIVISATOS AP	USA	1996	SCIENCE	V271	P933	249	1538
(SEMICONDUCTOR CLUSTERS, NANOCRYSTALS, AND QUANTUM DOTS)							
KRESGE CT	USA	1992	NATURE	V359	P710	213	3801
(ORDERED MESOPOROUS MOLECULAR-SIEVES SYNTHESIZED BY A LIQUID-CRYSTAL TEMPLATE MECHANISM)							
THESS A	USA	1996	SCIENCE	V273	P483	196	1601
(CRYSTALLINE ROPES OF METALLIC CARBON NANOTUBES)							
MURRAY CB	USA	1993	JACS	V115	P8706	194	1317
(SYNTHESIS AND CHARACTERIZATION OF NEARLY MONODISPERSE CDE (E = S, SE, TE) SEMICONDUCTOR NANOCRYSTALLITES)							
ULMAN A	USA	1996	CHEM REV	V96	P1533	191	1534
(FORMATION AND STRUCTURE OF SELF-ASSEMBLED MONOLAYERS)							
MORALES AM	USA	1998	SCIENCE	V279	P208	177	772
(A LASER ABLATION METHOD FOR THE SYNTHESIS OF CRYSTALLINE SEMICONDUCTOR NANOWIRES)							

TANS SJ	NETHER	1998	NATURE	V393	P49	174	968
(ROOM-TEMPERATURE TRANSISTOR BASED ON A SINGLE CARBON NANOTUBE)							
OREGAN B	SWITZ	1991	NATURE	V353	P737	173	1878
(A LOW-COST, HIGH-EFFICIENCY SOLAR-CELL BASED ON DYE-SENSITIZED COLLOIDAL TIO2 FILMS)							
HUANG MH	USA	2001	SCIENCE	V292	P1897	170	529
(ROOM-TEMPERATURE ULTRAVIOLET NANOWIRE NANOLASERS)							

Seven of the ten references had first authors from the USA. Science and Nature journals accounted for eight of the first ten. Three articles focused on nanotubes, two on nanowires, two on nanocrystallites/ quantum dots, and the remainder on surface-dominated applications (molecular sieves, self-assembled monolayers, and solar cells). The articles as a unit focused on demonstration of growth, fabrication, synthesis, and some small-scale device integration. Two authors were from industry, and the remainder from universities.

4.2.3. Most Cited Journals

There were 31321 journals cited in the 21474 retrieved papers. Table 8 contains a list of most cited journals. At the very top were Phys Rev B and Appl Phys Letters. On average, the most cited journals appear more fundamental than the most prolific journals, a trend that has been observed in other text mining studies as well. The distribution of journal disciplines is about the same in both the most prolific and most cited journals, focusing on Physics, Chemistry, and Materials, in that order. Eleven of the journals are in common between the two lists. There are no Chinese journals on either list, implying that many Chinese authors are publishing in the more recognized international journals, where they are more likely to receive higher citations.

<u>TABLE 8 – MOST CITED JOURNALS</u>

JOURNAL	#CITES
PHYS REV B	27936
APPL PHYS LETT	27281
PHYS REV LETT	20000
J AM CHEM SOC	17127
SCIENCE	16154
J APPL PHYS	13620
NATURE	13429
LANGMUIR	13280
J PHYS CHEM B	10038
CHEM MATER	8415
J CHEM PHYS	7956
MACROMOLECULES	7683

ADV MATER	7623
J PHYS CHEM-US	6188
CHEM PHYS LETT	6133
THIN SOLID FILMS	4804
ANGEW CHEM INT EDIT	4537
J ELECTROCHEM SOC	4501
SURF SCI	4024
ANAL CHEM	3608

4.3 Taxonomy Results

The first author's past text mining studies have used a variety of approaches to identify the main technical themes in the database. These include extracting key phrases and manually assigning them to categories; extracting key phrases and assigning them with statistical computer algorithm, using factor analyses and multi-link clustering; and grouping documents based on text similarity.

Both factor analysis and document clustering were used for the present study. Appendix 2 contains the factor analysis results. In document clustering, documents are combined into groups based on their text similarity. Document clustering yields numbers of documents in each cluster directly, a proxy metric for level of emphasis in each taxonomy category. For both the total SCI and EC databases, document clustering was performed using the Abstracts text only.

The clustering approach presented in this section is based on a partitional clustering algorithm [Karypis, 2005; Zhao and Karypis, 2004] contained within a software package named CLUTO. Most of CLUTO's clustering algorithms treat the clustering problem as an optimization process that seeks to maximize or minimize a particular clustering criterion function defined either globally or locally over the entire clustering solution space. CLUTO uses a randomized incremental optimization algorithm that is greedy in nature, and has low computational requirements.

CLUTO requires specification of the number of clusters desired. Cluster runs (using the retrieved 21474 SCI records) ranging from 64 to 1024 clusters were generated, providing thematic details at different levels of specificity (resolution). CLUTO also agglommerated the 64 cluster results into a hierarchical tree (taxonomy) structure. This taxonomy is presented in some detail in the next sections. Appendix 3 contains the details of each cluster's contents. A 256 cluster run of the EC database was made, and a schematic of the EC taxonomy is shown in Figure 2, following the SCI taxonomy description in the next section.

Nanotechnology Taxonomy

<u>SCI</u>

Based on the CLUTO output, a multi-level hierarchical taxonomy was generated of the 21474 SCI retrieved records for 2003. Because a number of the component technologies of nanotechnology are quite different from each other, the hierarchical structure was converted to the following flat taxonomy (all categories at the same level) by modifying the fourth level of the hierarchical taxonomy slightly (combining some categories, splitting others to fifth level).

Each category is defined by its component themes, in bullets. The number preceding each category heading is the number of records in that category. The bullets listed under each category are the major themes within the category, and represent the themes of the elemental clusters within the category.

(2127) **<u>Polymers/ Nanocomposites</u>**

- clays, emphasizing production of polymer-layered silicate nanocomposites from organoclays and montmorillonite-derived clays using melt intercalation.
- nanocomposites, mainly polymer, including fiber composites as well as nanoparticles embedded in matrices.
- addition of block copolymers, or polymeric micelles, to promote self-assembly and improve material properties and structures
- polymers, especially on the molecular chain structures, and the structures and molecular weights of polymer aggregates in solution, especially water-based.
- bonds and ligands among groups in complexes and compounds, with some emphasis on hydrogen bonds
- structure of crystals, emphasizing space group parameters.

(1713) **<u>Particles/ Nanoparticles</u>**

- nanoparticles, with primary emphasis divided between gold/ noble metal nanoparticle mixtures and magnetic nanoparticles in magnetic fluids, and secondary emphasis on ZnO nanoparticles. Also addresses production of nanoparticles or nanobubbles by core-shell separation
- silver, especially nanoparticles (especially with core-shell nanostructures), colloids, particles, and determination of their structural, chemical, and electrical properties.
- particles in fluids, especially colloids, typically a particle core with surfactant shell, and use of emulsions and microemulsions polymerization to generate these particles
- particles, especially nanoparticles, their size distribution, and properties of particle aggregates, especially magnetic

(2641) **Nanowires, Powders, and Catalysts**

- TiO_2 (including titania colloids), especially for its photocatalytic activity, and examines electronic and metallurgical properties resulting from different fabrication techniques, including conversion of the anatase phase into rutile phase as a function of annealing temperature.
- catalysts using very small particles, especially their deposition on carbon supports, and the nature of reactions at these small particle sizes
- porous materials, especially mesoporous silica structures generated with nanomaterial templates, and emphasizes pore size distribution of activated meso-carbon-microbeads.
- nanowires, especially the fabrication and synthesis of nanowire arrays, and on evaluation of the geometric, structural, and electronic properties of these nanowires as a function of fabrication technique and parameters
- growth and fabrication of ZnO nanomaterials and nanostructures, especially nanobelts and nanorods, emphasizing structural determination with transmission electron microscopy
- nanorod and nanocrystal production through chemical reaction synthesis routes, and determination of the structural properties by transmission electron microscopy and x-ray diffraction
- powders, emphasizing sol-gel synthesis processes with different precursors for optimal growth, and parameterizing the effect of temperature on growth during the calcination process
- nanomaterial structures with emphasis on implants, emphasizing phases of crystals and amorphous materials, and especially their variation with thermal factors, such as annealing, growth, implantation, and synthesis temperatures.

(1171) **Materials**

- alloys, especially relation of phase composition to magnetic properties of nanocrystalline alloys and amorphous alloys, and the tailoring of these properties by annealing.
- high-energy ball milling to produce alloy powders, including effects on particle structure and phase of mill time, material composition, and annealing temperature.
- grains, especially their size and boundaries, and how bulk crystalline properties depend on grain size, especially at nanometer levels
- coatings, and the effect of sintering on their properties, especially for Al_2O_3 and SiC powders and other structures, and Al_2O_3-SiC composites
- indentation, especially nanoindentation, and plastic deformation to measure mechanical properties of nanostructures, including stress-strain relationships, tensile strength, shear, ductility, and fracture

The following three segments deal with Surfaces, Films and Layers:

(2200) **Thin Films**

- films, both thick and thin, and the variation of properties with film thickness, especially magnetic and dielectric properties.
- thin films, emphasizing PZT films for application to high-density ferroelectric random access memory, and TiO_2 films for application to high efficiency solar cells, and further emphasizing films created by the sol-gel process.
- films, especially thin films and their deposition on substrates, and parameters that affect their properties such as annealing

(1194) **Self-Assembled Monolayers and Gold Electrodes**

- self-assembly, emphasizing thiols because of their capability to form self assembled monolayers (SAM) on noble and semi-noble metals, and examining the adsorption properties of thiols with various terminal groups
- monolayers, especially self-assembled surface monolayers, with some emphasis on alkyl monolayers, gold monolayers or gold substrates, and molecular chains in ordered and disordered monolayers.
- surface adsorption, emphasizing proteins, monolayers, and molecules, and the use of scanning tunneling microscopy to characterize the adsorption process
- gold electrodes in electrochemical systems, typically coated with self-assembled monolayers for enhanced electrochemical performance, as well as deposition of gold nanoparticle films on surfaces for detection/ sensing purposes.

(1794) **Surface Layer Modification**

- layers, especially multi-layer oxides/ SiO2 on silicon-based substrates, emphasizing thick layers/ coatings, factors affecting their deposition, and characterization of their interface properties
- ion bombardment, irradiation, and implantation of surfaces, examines the effects as a function of energy levels, dose, depth of penetration, fluence, and annealing.
- growth of surface layers on substrates, including GaN layers, emphasizing epitaxial deposition, and the formation of islands and their parameter-dependent clustering
- etching of surface patterns, especially silicon-based films or crystals/ wafers, and the relationship, and control, of surface roughness to increase etching resolution. Also focuses on AFM for both measuring surface roughness and wear, as well as performing the etching process.
- proximal probe tip properties and dynamics, including cantilever dynamics and fabrication complexities, and the use of electron beam lithography for mask fabrication.

(2352) **Optics/Spectroscopy**

- optics, especially nonlinear optical materials, and material refractive indices, especially for photonic crystals
- optical waveguides, including their gratings and optical fibers
- laser power and output, especially second harmonic generation from diode and optically pumped lasers
- pulsed lasers, emphasizing beam properties, and their use in characterizing optical properties of materials, nanofabrication of materials, and on materials for solid-state lasers
- luminescent and fluorescent emissions from excited energy states, emphasizing intensity, emission and absorption spectra, emission peaks, and photoluminescence.
- molecular dynamics, emphasizing calculations of excited state energies, dissociation spectra, molecular energy transfer, electron vibrational energy and transitions, photon energy absorption, and molecular bonds.
- radiation interaction with nanomaterials, emphasizing spectral bands, absorption bands, band gaps, especially at Raman and optical frequencies.

(1255) **Quantum Dots**

- exciton (electron-hole pair) states, especially in quantum dots.
- quantum dots, emphasizing electronic states and energy levels, and growth mechanisms
- quantum dots, especially InAs, GaAs, CdSe QDs, emphasizing growth techniques, self-assembled layers, and photoluminescent properties.
- InAs and GaAs, especially InAs quantum dots grown by molecular beam epitaxy.on GaAs substrates

(1079) **Magnetics**

- tunneling, in tunneling junctions, especially magnetic tunnel junctions in magnetoresistance devices, with emphasis on Kondo states and Coulomb blockades
- spin, including spin-dependent electron scattering, spin-orbit interactions, spin channels, quantum dot spin states, quantum dot spin polarization, and electron spin resonance
- behavior of magnetic nanostructures in magnetic fields, including effect on spin, domain structures, and optical, magnetic, and mechanical anisotropies
- magnetic properties of nanomaterials and nanostructures, and the variation of these properties with growth and treatment parameters, such as annealing.

(1518) **Solid State Electronic Structure/Properties**

- GaN for light emitting diodes, and also includes AlGaN, InGaN, and AlN.
- electroluminescent emitters and fabrication of light-emitting devices/ diodes, with strong emphasis on determining and increasing efficiency
- gates for transistors and other electronic devices.
- electrical properties and characteristics of nanomaterial structures, including voltage-current plots, electric fields, field emission, electrical conductivity, and electronic devices
- quantum wires, emphasizing energy states, and electrical conductivity and transport in one dimensional systems.

(1624) **Nanotubes**

- single wall nanotubes, especially carbon, including growth of bundles and ropes, and determination of composition using Raman Scattering, as well as adsorption properties
- nanotubes, especially single-wall carbon nanotubes, and addresses properties of bundles, emphasizing zigzag and armchair nanotubes
- nanotubes, mainly carbon but including carbon nanotube composites and other nanotube materials as well. Emphasizes multi-wall nanotubes, their alignment, and their use as field emission devices
- multi-wall nanotubes, especially carbon, especially vertically-aligned catalyzed chemical vapor deposition grown films, including use as glassy-coated film electrode
- carbon nanotubes, especially vertically aligned catalytically activated plasma-assisted chemical vapor deposited grown CNT, and examines their applications to field emission devices and field-effect transistors.

(806) **Nano-Bio-technology**

- detection of proteins and inhibitors, emphasizing their active binding sites.
- artificial and biological membranes, including their structure determination, and formation of the artificial membranes as well. Some emphasis was placed on nanoscopic structures using hydrated single lipids and lipid mixtures, where.the nanostructures formed by these extruded vesicles/ liposomes ranged from isolated unilamellar vesicles to flat sheet membranes.
- animal and solar cells, emphasizing the use of indicator dyes to enhance the photosensitivity of these cells, and both increase the efficiency of solar cells and use the luminescence as detectors for animal cells
- DNA, emphasizing oligonucleotides used in hybridization studies in order to detect and study specific nucleic acid fragments, such as single or double-strand DNA

EC

For the purpose of comparing the EC technical nanotechnology structure with that of the SCI, a hierarchical taxonomy of the EC nanotechnology literature was generated. The first four levels of the taxonomy are shown on Figure 2.

<u>FIGURE 2 – FOUR LEVEL HIERARCHICAL TAXONOMY - EC</u>

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Carbon Nanotubes (CNTs) 1225	Structural Properties of CNTs (1044)	General Single-Wall CNT Theory/Measurements (159)	
		CNT Wall Properties - Chiral/Zigzag/Armchair (885)	Single-Wall CNT Wall Properties (679)
			Multi-Wall CNT Wall Properties (206)
	Growth & Alignment of CNTs (181)	CNT Alignment (by Plasma-Induced Fields) (72)	
		Growth of CNTs on Patterned Catalysts (109)	
Other Nanostructures (11411)	Nano-Photonics, Thin Film Deposition (6417)	Nano-Photonics/Nano-Optics (4573)	Quantum Dots (2541)
			ZnO Laser Optics (2032)
		Thin Film Deposition (1844)	Non-Carbon Thin Film Deposition (1293)
			Carbon Layer Film Deposition (551)
	Nanostructures for Informational, Biological, and Material Reinforcement Applications (4994)	Nanostructures with Electronic/Magnetic Application (IT) (2370)	Magnetic Properties of Nanostructures (708)
			Nanowire Properties/Fabrication (1662)
		Nanoparticles with Material Reinforcement or Biological Application (2624)	Colloidal Au/Ag Nanoparticles (Biological Application) (988)
			Polymer Nanocomposites (1636)

The first level of the EC taxonomy bears similarity to the second level of the SCI taxonomy. In both cases, Carbon Nanotubes form a separate major category, and are about ten percent of the other nanostructure records (EC, 10.7%; SCI, 8.2%). At the fourth taxonomy level, the categories are quite similar. The EC has moderately more emphasis on fabrication, while the SCI has more emphasis of the fundamental areas such as excited emissions, band absorption, energy states, self-assembly, and DNA proteins.

Taxonomy Observations

SCI

Relative to the other categories, Nano-Bio-Technology appears to be under-represented. This may be a real effect, or it may result from use of a query terminology different from that used by the biology research authors. This observation is supported by the absence of any biology journals in the top twenty most cited journals or top twenty journals containing most nanotechnology papers.

Also, the focal point of the total database is research and development to develop products using technology at the nanometer scale. This is essentially a technology production database, focused on the nanotechnology front end. There is almost no research on health effects (animal or human), environmental/ climate impacts, security issues, vulnerability, synergistic effects from coupling with other new technologies, etc. Of the 64 elemental document clusters examined, none had themes or even critical phrases that addressed these important issues.

EC

The comments on the SCI taxonomy from the previous section apply here as well, especially as pertaining to the focus of the database. In both cases, more research on the back-end of nanotechnology production would add balance to the overall science and technology effort.

Potential Applications

A taxonomy of potential applications was also generated manually. The keywords and phrases from the SCI Abstracts were inspected visually, and those relating to potential applications were extracted. They were categorized by visual inspection. Figure 3 contains the applications categories, and examples of applications phrases within each category, for those categories that include phrases other than the category name. The technique of Citation Mining [Kostoff et al, 2001] would provide supplementary information on potential applications by examining papers that cite nanotechnology papers, and would complement the present approach.

FIGURE 3 – POTENTIAL APPLICATIONS

- CATALYSTS (PHOTO, ELECTRO, AUTO, METHANE-REFORMING, HETEROGENEOUS/ IMMOBILIZED ENZYME, DIRECT BIO-ELECTRO, BIMETALLIC);
- ELECTRODES (GOLD, SILVER, PLATINUM);
- SEMICONDUCTORS (METAL-OXIDE, CUPRATE, AMORPHOUS, POLYMER, SINGLE NANOCRYSTAL, DILUTED MAGNETIC);
- LITHOGRAPHY (SOFT, ETCHING, DRY ETCHING, PLASMA ETCHING, ELECTROCHEMICAL ETCHING, SELECTIVE ETCHING, ELECTRON BEAM, OPTICAL, DIP-PEN NANO, X-RAY);
- STORAGE (HYDROGEN, OXYGEN, OPTICAL);
- FIELD EMISSION (THERMIONICS);
- DRUGS (DELIVERY, RELEASE);
- SWITCHING;
- SOLAR (CELLS, PHOTOVOLTAICS);
- SUPERCONDUCTING (NANOWIRES, TAPES, THIN FILMS, HIGH TEMPERATURE, MICROBRIDGES/ ULTRAFAST SWITCHES, COULOMB-BLOCKADE ELECTROMETERS, QUANTUM LOGIC GATES);
- RECORDING (MAGNETIC MEDIA, HEADS);
- WAVEGUIDE (OPTICAL);
- TRANSISTOR (FIELD-EFFECT, MOSFET, SINGLE ELECTRON, THIN FILM, ORGANIC, QUANTUM DOT);
- CAPACITORS (MOS, SUPER, DOUBLE-LAYER);
- DETECTORS;
- PRINTING;
- PIEZOELECTRIC;
- GENE DELIVERY;
- ELECTROLYTE;
- WIRES (QUANTUM, NANOWIRE ARRAYS);
- DISPLAYS (NEMATIC LIQUID CRYSTAL, FLAT PANEL);
- FILTERS (ADD-DROP, CHROMATIC DISPERSION REDUCTION, WAVELENGTH DIVISION MULTIPLEXING, OPTICAL, RESONANT GRATING, HOLOGRAPHIC INTERFERENCE, THERMAL WAVELENGTH TUNING, MOLECULAR SIEVES);
- INSULATORS (GATE, LOW K);
- BLOOD (VESSEL ENGINEERING, SERUM TESTING, FLOWMETER, CATECHOLAMINE MONITORING);
- HOLOGRAPH (DIFFRACTION GRATINGS, RECORDING, DATA STORAGE);

- TRIBOLOGY (LUBRICATION, SOLID LUBRICANTS, WEAR RATE/ RESISTANCE, FRICTION COEFFICIENT, DURABILITY);
- METHANOL;
- FERROELECTRIC;
- LASERS;
- CERAMICS;
- DIODES (LIGHT-EMITTING);
- RESISTS (PHOTO);
- SENSING (ANTIBODY, BIO);
- CIRCUITS;
- CORROSION (RESISTANCE);
- ENZYMES (DNA DAMAGE DETECTION,GLUCOSE SENSING);
- BATTERIES (RECHARGEABLE LITHIUM);
- GATE (OXIDES, LOGIC, MOSFET);
- FUEL CELLS;
- MEMBRANES;
- ELECTROLYTES (POLYMER);
- SHAPE MEMORY;
- QUANTUM COMPUTER;
- MEMORY (RANDOM ACCESS);
- MOLECULAR DEVICES (DIODES, WIRES, MEMORY, SWITCHES, DATA STORAGE)
- OPTICAL FIBERS;
- MAGNETS (PERMANENT, FERRO);
- BONE (TISSUE ENGINEERING, IMPLANTS, FRACTURE REPAIR);
- ENVIRONMENTAL PROTECTION (WASTE WATER TREATMENT, AIR PURIFICATION)

5. FUTURE STUDIES RECOMMENDED

While the present study was probably the most comprehensive of its genre, nevertheless, many areas for further research were uncovered during the course of the study. Research, resource, and scope limitations precluded further analyses, but it is strongly recommended that future nanotechnology text mining studies address the following issues.

5.1. Databases

The present study examined two databases, the Science Citation Index and the Engineering Compendex, with emphasis on the former. However, there exist many more databases that offer the possibilities of additional perspectives on global nanotechnology research. Medline would identify additional nanotechnology efforts in biology and medicine. The DTIC/ NTIS Technical Reports would identify reports sponsored by the US government addressing nanotechnology. Many of the findings from these DTIC/ NTIS studies might not end up in the SCI/ EC databases, but may nevertheless be very important. The RADIUS database would identify ongoing Federal programs in nanotechnology. The unclassified RDT&E Budget Item Justification Sheet, Exhibit R-2 database would identify ongoing and planned DoD programs in nanotechnology. The Federal agency awards databases (e.g., NSF, NIH, DOE) would identify existing projects sponsored by different Federal agencies being conducted in nanotechnology. Databases of foreign journals not accessed by the SCI or EC would provide a more comprehensive picture of global nanotechnology research.

Identifying the journals other than those accessed directly by the SCI is a major task, but needs to be done. One approach would be to examine all the references from the SCI nanotechnology articles retrieved, and identify the journals in which they were published. Some of the journals would be those accessed by the SCI, and the remainder would not be accessed. Then, either those non-SCI-accessed journals would be retrieved and searched in full (at least those with reasonable frequencies), or the specific documents referenced would be retrieved and analyzed. ***It is strongly recommended that a comprehensive text mining study of the nanotechnology literature that incorporates these diverse databases, for the same time frame coverage, be conducted.***

5.2. Queries

The present study focused on a keyword-based query, developed through an iterative feedback technique. While this query contained approximately 100 terms, and is quite comprehensive, more terms could have been added. Another iteration of the query by another group of researchers, starting from the existing query, might offer a moderately different perspective on what could be included under nanotechnology.

Additionally, a query need not be limited to phrases or keywords. For example, for the years 2004-2005, there are sixteen journals listed in the SCI that contain NANO in their title. If, after sampling, it is concluded that all the articles in these journals, or some sub-set, are relevant to nanotechnology, whether or not they contain the terms in the phrase query, then all these articles could be retrieved. This form of query expansion would be in the spirit of the MESH retrieval approach in Medline. There are a number of other fields that could be used for query expansion, and these are described in detail in Kostoff, 2005a.

The focus of the query in the present report is on articles directly related to nanotechnology. All the expansions above lead to further refinement of the query for capturing what could be described as the core nanotechnology articles. However, as shown in Kostoff, 2005a, if one objective of a nanotechnology text mining study is to identify enabling technologies in disciplines more indirectly related to nanotechnology, then a required precursor step is to expand and generalize the query used to retrieve the core nanotechnology articles. This expansion and generalization process is described in more detail in Kostoff, 2005a. ***It is strongly recommended that such a query expansion be generated, as part of the expanded database text mining study recommended in Section 5.1.***

5.3. Discovery

If radical discovery and innovation (crossing intellectual boundaries to use insights and principles from other disciplines to solve problems of interest in nanotechnology) is a target of interest in nanotechnology development, then the expanded and generalized query mentioned above can serve as the basis for such discovery and innovation. The articles retrieved with use of the expanded and generalized query, and the authors of these articles, can be used to help generate the literature-based (article-driven) and literature-assisted (author-driven) radical discovery and innovation. Myriad literature-based and literature-assisted techniques for generating such discovery and innovation are described in detail in Kostoff, 2005a.

5.4 Time Frame

Of necessity, the present study examined the nanotechnology publication records in 1994 and 2003, with some 2004 updates, in detail. As shown in the comparison of nanotechnology publications in the most prolific countries (Table 4B), there has been significant increase in the number of nanotechnology papers from 1994 to 2004. The Far Eastern group (China, Japan, South Korea, Taiwan, and Singapore) in particular showed substantial increase beyond the proportionate increase in total publications. Many more years, and in more databases, should be examined (and correlated with other events occurring in these countries and on the world stage) to obtain a more complete analysis of trends.

5.5. Resolution

The bibliometrics were performed at the aggregate total retrieval level, and the taxonomy analysis was performed at the elemental cluster level. For some purposes, such as organizing site visits for specific focused nanotechnology areas, much finer resolution on results and analysis might be required. Additionally, comparing country outputs at the aggregate nanotechnology level might be insufficient for some applications.

For example, in the present study, it was shown that China was a close second to the USA on SCI-based research paper output, for the aggregate nanotechnology output. However, there may very well be sub-areas of nanotechnology where China is ahead of the USA on research output, as well as other sub-areas where China ranks lower than second. It might be useful for strategic analysis if such sub-areas could be identified. For example, much of the nanotechnology effort in South Korea is thought to be focused on nanoscale electronics for information technology. If that is the case, one can anticipate the paper count would be proportionately higher in that sub-area of nanotechnology research. To access these more detailed sub-technology levels, larger numbers of clusters with more focused themes would have to be generated.

It is recommended that large numbers of clusters (>500) be used in future taxonomy generations of nanotechnology, and automated methods be developed to generate bibliometric information for every node in the taxonomy hierarchical tree. Thus, for a 500 elemental cluster run, bibliometrics would be available for all the approximately 1000 nodes in the full hierarchical tree (generated with cluster bifurcation from one level to the next lowest level).

5.6. Citation Mining

Citation mining was developed at the turn of the 21st century [Kostoff et al, 2001]. Its objective is to understand the dissemination and impact of science and technology. It accomplishes this objective by studying the characteristics of those documents that cite the outputs of the research of interest.

Citation mining has three major components: 1) Identification and selection of the documents whose citing documents will be analyzed; 2) Assignment and population of metrics to attributes of the citing documents; and 3) Performance of temporal and spatial analyses of the attributes of the citing documents.

In the initial paper on citation mining [Kostoff et al, 2001], attributes in addition to those assigned by the SCI for each record were generated. These additional attributes (categories) tended to be qualitative (e.g., developed vs developing vs under-developed countries), and offered insights tailored to the problem of interest. The bibliometrics employed in the present study, and in most, if not all, other text mining studies, were essentially quantitative. However, simple counts of documents or citations, and the standard categories available from the SCI, offer limited insights into the intrinsic characteristics of nanotechnology. It is highly recommended that bibliometrics studies be conducted using additional attributes important to nanotechnology.

It is strongly recommended that future nanotechnology text mining studies include citation mining. Such analyses would provide some indication of the level and breadth of the impact of nanotechnology research on myriad research disciplines and downstream applications. In addition, as was shown in the initial citation mining paper [Kostoff et al, 2001], the diffusion rate of nanotechnology research into other basic research, applied research, and technology development could be estimated.

5.7. Interpretations and Context Analysis

For nanotechnology in particular, further analyses are required to interpret the meaning of the country and document citation results. In the country output results, the USA was listed as first, and China was listed as second. However, this analysis is based solely on the SCI results. Some analysts believe that there is an English language bias in the SCI [Winkmann et al, 2002]. An examination of Chinese language journals not in the SCI would have to be conducted for nanotechnology content, compared to similar US journals not in the SCI, and the results combined with the SCI results to get a more comprehensive picture of the relative country outputs.

In the paper citation results, only a very few of the most cited papers have Chinese authors (~two percent). What is more important than the actual numbers is the interpretation of the numbers.

Is the low representation of highly cited papers by Chinese authors due to poor quality? Is the low representation of highly cited papers due to unawareness of the rest of the nanotechnology community of Chinese-authored research? Is the low representation of highly cited papers due to the content being more applied? Previous studies by the first author on this topic have shown that the more fundamental papers, and the more fundamental journals, tend to receive higher citations.

If the latter (more applied content) is a significant factor in reduced citations, what are its implications? Perhaps the dynamic is that developed countries like the USA, Japan, and Germany are producing the fundamental research advances in nanotechnology, and China is exploiting these advances to produce products of defense and commercial importance.

The research sponsoring community has long assumed a classical model for the respective roles of industry and government in the research enterprise. Government would fund the high-risk potentially high-payoff research that industry would be unwilling to fund, and industry would fund the more developed technology when some of the front-end risk had been removed. However, what if China has decided, at least in its present stage of development, to operate in the industrial mode? Its front end very fundamental research would be provided by the (presently) advanced countries, and China would be free to use its scarce research funds to focus more closely on applications.

To answer these questions concerning relatively low citation rates of Chinese-authored articles, more citation mining types of bibliometrics analyses are required. The nature of the Chinese-authored papers in both the SCI and non-SCI journals needs to be explored. Some types of qualitative analyses are required to understand the quality and category of development of published papers.

First, the Chinese-authored papers would need to be identified in the SCI-accessed journals, in the non-SCI English-language journals, and in the non-SCI non-English language journals (mainly, but not exclusively, Chinese). Then, a sampling would have to be read, and qualitative metrics assigned to each article. Such metrics are discussed in more detail in Kostoff, 2005b. ***It is strongly recommended that future text mining studies on nanotechnology include these qualitative analyses, especially for papers in the non-English literature.***

6. SUMMARY AND CONCLUSIONS

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A text mining analysis of the nanotechnology literature was performed, consisting of a bibliometrics component for obtaining the infrastructure, and a computational linguistics component for obtaining the technical themes and their taxonomy structure. Abstracts as they appear in Science Citation Index were used to represent the basic research literature, and Engineering Compendex Abstracts were used to represent the technology/ engineering literature.

Bibliometrics

There appear to be a large number of prolific authors with Asian names, far larger than in any of the first author's previous text mining studies, reflecting the large contributions from the Far East Asian countries (e.g., Japan, China, South Korea). The twenty journals containing the most nanotechnology papers tend to be in the technical disciplines of Physics, Chemistry, and Materials, with an emphasis on surface science. The top tier in volume of nanotech-related articles had three physics journals (Applied Physics Letters, Physical Review, and Journal of Applied Physics). Conspicuously absent are the biology journals.

Of the twenty most prolific institutions, thirteen are universities, and the remaining seven are government laboratories. Thirteen are from the Far East (corresponding to the large number of prolific authors from that region), three are from the USA, three are from Western Europe, and one is from Eastern Europe.

In 2004, three countries dominate in production of research papers: USA, China, and Japan; Germany is a strong contributor as well. In the top six countries, the three from the Western group (USA, Germany, France) have about eight percent more publications than the three from the Far Eastern group (China, Japan, South Korea). However, studies have shown an English language bias for the SCI, and these Far Eastern publication numbers should be viewed as an under-estimate.

Overall trends between 1994 and 2004 were tabulated. The 2004/ 1994 ratio of nanotechnology papers is in double digits for the Far Eastern countries only (Peoples R China, South Korea, Taiwan, and Singapore). The 2004/ 1994 ratio of total SCI papers is above ~4 for Far Eastern Asian countries only (Peoples R China, South Korea, Singapore), showing tremendous research interest and growth in nanotechnology in Far East Asia. The fractions of nanotechnology papers to total papers for 2004 above eight percent are for Far Eastern countries only (Peoples R China, South Korea, Singapore). Thus, in the past decade, these Far Eastern countries have shown substantial growth in total SCI papers, in nanotechnology papers, and in the ratio of nanotechnology papers to total papers.

About half of the most cited first authors are from Far East, with most of the remainder being from the USA. Of the 232 most cited papers, 66 were published in Science, 44 in Nature, 15 in Physical Review Letters, 10 in Applied Physics Letters, 10 in Chemical Reviews, and 9 in Physical Review B.

Essentially all the top tier most cited documents were published within the last decade, showing the dynamic nature of this discipline. These are the most recent references of any discipline examined in the first author's previous text mining studies. Additionally, only one of the authors in this tier, SS Fan (24^{th} in the ranking), was listed at a Chinese institution. Thus, while the prolific author, institution, and country lists show a substantial Chinese (country) representation, the top tier cited document list shows a minor Chinese (country) representation.

Seven of the ten most cited references had first authors from the USA. Science and Nature journals accounted for eight of the first ten. Three articles focused on nanotubes, two on nanowires, two on nanocrystallites/ quantum dots, and the remainder on surface-dominated applications (molecular sieves, self-assembled monolayers, and solar cells). The articles as a unit focused on demonstration of growth, fabrication, synthesis, and some small-scale device integration. Two authors were from industry, and the remainder from universities.

The top tier of the most cited journals contained Phys Rev B and Appl Phys Letters. On average, the most cited journals appear more fundamental than the most prolific journals, a trend that has been observed in other text mining studies as well. The distribution of journal disciplines is about the same in both the most prolific and most cited journals, focusing on Physics, Chemistry, and Materials, in that order. Eleven of the journals are in common between the two lists. There are no Chinese journals on either list, implying that many Chinese authors are publishing in the more recognized international journals, where they are more likely to receive higher citations.

Computational Linguistics

Two taxonomies (technology categorizations) of the SCI nanotechnology literature were generated: a hierarchical taxonomy for displaying the high level literature structure, and a flat taxonomy for displaying the detailed thrusts in each category. The flat taxonomy of the SCI nanotechnology literature contains the following categories: Polymers/ Nanocomposites; Particles/ Nanoparticles; Nanowires, Powders, and Catalysts; Materials; Thin Films; Self-Assembled Monolayers and Gold Electrodes; Surface Layer Modification; Optics/ Spectroscopy; Quantum Dots; Magnetics; Solid State Electronic Structure/ Properties; Nanotubes; Nano-Bio-Technology. A hierarchical taxonomy of the EC nanotechnology literature was generated. The first level of the hierarchical EC taxonomy bears similarity to the second level of the hierarchical SCI taxonomy. In both cases, Carbon Nanotubes form a separate major category, and are about ten percent of the other nanostructure records. At the fourth taxonomy level, the categories are quite similar. The EC has moderately more emphasis on fabrication, while the SCI has more emphasis of the fundamental areas such as excited emissions, band absorption, energy states, self-assembly, and DNA proteins.

For the SCI taxonomy, relative to the other categories, Nano-Bio-Technology appears to be under-represented. This may be a real effect, or it may result from use of a query terminology different from that used by the biology research authors. This observation is supported by the absence of any biology journals in the top twenty most cited journals or top twenty journals containing the most nanotechnology papers.

Based on the SCI nanotechnology literature taxonomy, the focal point of the total database is research and development to develop products using technology at the nanometer scale. This is essentially a technology production database, focused on the nanotechnology front end. There is almost no research on health effects (animal or human), environmental/ climate impacts, security issues, vulnerability, synergistic effects from coupling with other new technologies, etc. Of the 64 elemental document clusters examined, none had themes or even critical phrases that addressed these important issues.

For the EC taxonomy, the comments on the SCI taxonomy above apply here as well, especially as pertaining to the focus of the database. In both cases, more research on the back-end of nanotechnology production would add balance to the overall science and technology effort.

Finally, none of the published nanotechnology research literature surveys offer the background, infrastructure and technology structure of the nanotechnology literature, as described in the present paper. This additional information to the traditional literature survey/ review offers a perspective on nanotechnology beyond what any individual or team of individuals can offer. Future literature surveys should contain both the traditional approach and the text mining approach. ***Additionally, future nanotechnology text mining studies should include: 1) Expanded databases (e.g., Medline, DTIC Technical Reports, RADIUS, and Federal agency award databases); 2) Expanded queries (more phrases, broader phrases, other fields); 3) Discovery analyses (literature-based discovery, literature-assisted discovery); 4) Expanded time frames for detailed trend analyses; 5) Larger numbers of clusters for finer resolution; and 6) Citation mining for identifying and tracking the myriad impacts and applications of nanotechnology research.***

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APPENDIX 1 – REFERENCE BOOKS

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APPENDIX 2 – EC AND SCI FACTOR ANALYSIS

Factor analysis of a text database aims to reduce the number of words/ phrases (variables) in a system, and to detect structure in the relationships among words/ phrases. Word/ phrase correlations are computed, and highly correlated groups (factors) are identified. The relationships of these words/ phrases to the resultant factors are displayed clearly in the factor matrix, whose rows are words/ phrases and columns are factors. In the factor matrix, the matrix elements M_{ij} are the factor loadings, or the contribution of word/ phrase i (in row i) to the theme of factor j (in column j). The theme of each factor is determined by those words/ phrases that have the largest values of factor loading. Each factor has a positive value tail and negative value tail. For each factor, one of the tails dominates in terms of absolute value magnitude. This dominant tail is used to determine the central theme of each factor.

Factor analyses were performed on the EC and SCI retrievals. Factor matrices ranging from two to 32 factors were generated, the main themes identified, and the themes were manually categorized into a hierarchical taxonomy. The SCI taxonomy is presented first, followed by the EC taxonomy.

SCI Taxonomy

Level 1
Instruments (XRD-TEM-SEM)
Phenomena/ Properties (Crystal Structure)

Level 2
Instruments (XRD-TEM-SEM; Differential Calorimetry)
Phenomena/ Properties (Crystal Structure; Surface Adsorption [SAM/ Film Deposition])

Level 3
Instruments (XRD-TEM-SEM; Differential Calorimetry; AFM)
Phenomena/ Properties (Crystal Structure; Surface Adsorption [SAM/ Film Deposition]; Photoluminescence [Quantum Dots]; Catalysis

EC Taxonomy

For a two factor analysis, the main thrusts are:
1) Films
2) Nanocomposites-Clay/ Differential Calorimetry.

For a four factor analysis, the main thrusts are:
1) Films (hardness, mechanical properties)
2) Nanocomposites-Clay/ Differential Calorimetry
3) Nanoparticle formation/ reaction/ catalysis
4) Microstructure (Ni/ Zr/ C/ B)

For an eight factor analysis, the main thrusts are:
1) Differential Calorimetry/ Nanocomposites-Clay
2) Films (temperature/ thickness/ deposition)
3) XRD/ TEM (size, catalysis)
4) Ni/ Cu (alloys, Fe, Co)
5) Hardness/ Mechanical Properties
6) CNT
7) SAMs
8) Crystal Structure

These results contrast the differences between the SCI and EC databases from the factor matrix perspective, as well as the differences between document clustering-based taxonomies and factor matrix-based taxonomies. The document clustering taxonomies are categorized essentially by structures (e.g., nanowires, nanotubes, nanoparticles, films) and phenomena (optics, magnetics), the SCI factor matrix taxonomies are characterized by instruments (XRD, TEM, SEM, AFM, differential calorimetry) and the quantities they measure (crystal structure, surface adsorption, photoluminescence), and the EC factor matrix taxonomies are characterized by structures (films, nanocomposites, nanoparticles, microstructures).

At the first level of the factor matrix taxonomies, the science focus of the SCI, which concentrates on instrumentation and basic scientific phenomena (crystal structure), is clearly seen. The technology focus of the EC, which concentrates on structures and materials (films, nano-composites-clay) is also evident.

At the second level, the science focus of the SCI remains the same, with additional instrumentation and measured phenomena shown. The EC focus continues on particles and microstructure. At the third level, the focus of the EC on structures and materials continues (CNT, SAMs, alloys, mechanical properties), but some of the applied research aspects begin to emerge (XRD/TEM, crystal structure).

APPENDIX 3 – ELEMENTAL SCI CLUSTER DESCRIPTIONS

The details of each of the 64 elemental clusters are presented. The first metric shown (Cluster xx) is the cluster number in the computer output, where xx ranges from 0 to 63. The second metric (Size) is the number of records in the cluster. The third and fourth metrics are measures of cohesiveness, and the clusters are ordered according to the numerical difference of each metric pair. These metrics are followed by the ‘features’ in each cluster. The first set of features (Descriptive) identifies the phrases in each cluster’s records that contribute strongly to the central theme of the cluster, and presents the numerical weighting of each phrase’s relative contribution to the theme. The second set of features (Discriminating) identifies the phrases in each cluster’s records that contribute strongly to the uniqueness of the cluster relative to the other clusters, and presents the numerical weighting of each phrase’s relative contribution to the uniqueness.

Cluster 0, Size: 105, ISim: 0.099, ESim: 0.007 Descriptive: mwnt 49.3%, nanotub.mwnt 5.6%, nanotub 5.4%, carbon.nanotub.mwnt 5.0%, carbon.nanotub 3.0%, carbon 2.9%, multi.wall 1.8%, multi.wall.carbon 1.7%, multi 1.3%, multiwal 1.1%, multiwal.carbon.nanotub 1.1%, multiwal.carbon 1.1%, wall.carbon 1.0%, wall 1.0%, wall.carbon.nanotub 1.0%, electrod 0.3%, catalyst 0.2%, gce 0.2%, mwnt.electrod 0.2%, mwnt.grown 0.2%, mwnt.film 0.1%, growth 0.1%, current 0.1%, electron 0.1%, chemic.vapor.deposit 0.1%, chemic.vapor 0.1%, deposit 0.1%, align 0.1%, vapor.deposit 0.1%, chemic 0.1% Discriminating: mwnt 32.8%, nanotub.mwnt 3.7%, carbon.nanotub.mwnt 3.4%, film 1.4%, nanotub 1.4%, multi.wall 1.1%, multi.wall.carbon 1.1%, carbon.nanotub 1.1%, multi 0.7%, multiwal 0.7%, multiwal.carbon.nanotub 0.6%, multiwal.carbon 0.6%, surfac 0.6%, layer 0.6%, magnet 0.6%, particl 0.6%, carbon 0.5%, size 0.5%, structur 0.5%, nanoparticl 0.5%, wall.carbon 0.4%, wall.carbon.nanotub 0.4%, phase 0.4%, temperatur 0.4%, quantum 0.3%, crystal 0.3%, energi 0.3%, dot 0.3%, wall 0.3%, thick 0.3% - focuses on multi-wall nanotubes, especially carbon, especially vertically-aligned catalyzed chemical vapor deposition grown films, including use as glassy-coated film electrode.

Cluster 1, Size: 226, ISim: 0.095, ESim: 0.006 Descriptive: swnt 56.1%, nanotub.swnt 4.2%, nanotub 3.8%, carbon.nanotub.swnt 3.8%, singl.wall 3.1%, singl.wall.carbon 2.9%, wall 2.7%, wall.carbon 2.6%, wall.carbon.nanotub 2.6%, carbon 1.8%, carbon.nanotub 1.8%, singl 0.9%, tube 0.4%, bundl 0.4%, raman 0.3%, metal 0.1%, diamet 0.1%, adsorpt 0.1%, function 0.1%, rope 0.1%, molecul 0.1%, sampl 0.1%, electron 0.1%, dwnt 0.1%, swnt.bundl 0.1%, semiconduct 0.1%, function.swnt 0.1%, insid 0.1%, align 0.1%, purifi 0.1% Discriminating: swnt 37.5%, nanotub.swnt 2.8%, carbon.nanotub.swnt 2.5%, singl.wall 1.8%, singl.wall.carbon 1.7%, wall.carbon 1.4%, wall.carbon.nanotub 1.4%, film 1.4%, wall 1.2%, nanotub 0.8%, surfac 0.7%, particl 0.6%, layer 0.6%, nanoparticl 0.6%, carbon.nanotub 0.5%, magnet 0.5%, size 0.5%, structur 0.4%, temperatur 0.4%, phase 0.4%, quantum 0.4%, crystal 0.4%, deposit 0.4%, dot 0.3%, oxid 0.3%, electron 0.3%, ion 0.3%, optic 0.3%, thick 0.3%, energi 0.3% - focuses on single wall nanotubes, especially carbon, including growth of bundles and ropes, and determination of composition using Raman Scattering, as well as adsorption properties.

Cluster 2, Size: 251, ISim: 0.086, ESim: 0.007 Descriptive: cnt 63.7%, nanotub 3.9%, carbon.nanotub.cnt 3.4%, nanotub.cnt 3.4%, carbon 2.9%, carbon.nanotub 2.5%, align 0.5%, emiss 0.5%, field 0.5%, growth 0.5%, catalyst 0.4%, plasma 0.4%, field.emiss 0.4%, chemic 0.2%, deposit 0.2%, chemic.vapor.deposit 0.2%, chemic.vapor 0.2%, vapor.deposit 0.2%, grown 0.2%, tip 0.2%, vapor 0.2%, wall 0.2%, electr 0.2%, align.cnt 0.1%, cnt.grown 0.1%, plasma.chemic 0.1%, densiti 0.1%, electrod 0.1%, electron 0.1%, diamet 0.1% Discriminating: cnt 44.0%, nanotub.cnt 2.4%, carbon.nanotub.cnt 2.4%, film 1.4%, carbon.nanotub 0.9%, nanotub 0.9%, magnet 0.6%, surfac 0.6%, carbon 0.5%, layer 0.5%, nanoparticl 0.5%, size 0.5%, particl 0.5%, temperatur 0.4%, crystal 0.4%, phase 0.4%, quantum 0.4%, structur 0.4%, optic 0.3%, dot 0.3%, laser 0.3%, energi 0.3%, oxid 0.3%, ion 0.3%, measur 0.3%, two 0.3%, sampl 0.3%, electron 0.2%, state 0.2%, thick 0.2% - focuses on carbon nanotubes, especially vertically aligned catalytically activated plasma-assisted chemically vapor deposited grown CNT, and examines their applications to field emission devices and field-effect transistors.

Cluster 3, Size: 108, ISim: 0.083, ESim: 0.006 Descriptive: mill 48.0%, ball 4.9%, ball.mill 4.8%, powder 3.0%, alloi 2.6%, mill.time 1.9%, phase 1.7%, high.energi 0.7%, mechan.alloi 0.7%, energi.ball 0.7%, high.energi.ball 0.7%, energi.ball.mill 0.6%, mechan.mill 0.6%, nanocrystallin 0.6%, mechan 0.6%, amorph 0.6%, mg2ni 0.5%, magnet 0.4%, mixtur 0.3%, time 0.3%, sampl 0.3%, anneal 0.3%, size 0.3%, mill.powder 0.3%, composit 0.3%, high 0.2%, hydrogen 0.2%, crystallit 0.2%, planetari 0.2%, energi 0.2% Discriminating: mill 31.6%, ball.mill 3.1%, ball 3.1%, film 1.7%, mill.time 1.3%, powder 1.1%, alloi 0.9%, surfac 0.8%, layer 0.7%, nanotub 0.6%, nanoparticl 0.5%, energi.ball 0.5%, high.energi.ball 0.5%, deposit 0.4%, mechan.alloi 0.4%, high.energi 0.4%, energi.ball.mill 0.4%, mechan.mill 0.4%, quantum 0.4%, electron 0.4%, optic 0.4%, carbon 0.4%, substrat 0.4%, field 0.3%, structur 0.3%, dot 0.3%, mg2ni 0.3%, laser 0.3%, polym 0.3%, oxid 0.3% - focuses on use of high-energy ball milling to produce alloy powders, including effects on particle structureand phase of mill time, material composition, and annealling temperature.

Cluster 4, Size: 189, ISim: 0.078, ESim: 0.005 Descriptive: dna 68.5%, strand 1.7%, oligonucleotid 1.2%, dna.molecul 0.8%, molecul 0.6%, hybrid 0.6%, detect 0.6%, strand.dna 0.6%, gold 0.5%, target 0.5%, bind 0.5%, probe 0.4%, nanoparticl 0.4%, complex 0.4%, surfac 0.4%, gene 0.4%, protein 0.4%, assembl 0.4%, doubl.strand 0.4%, base 0.3%, immobil 0.3%, sequenc 0.3%, label 0.2%, singl.strand 0.2%, doubl.strand.dna 0.2%, assai 0.2%, electrod 0.2%, dna.complex 0.2%, singl 0.2%, doubl 0.2% Discriminating: dna 44.1%, film 1.3%, strand 1.0%, oligonucleotid 0.8%, temperatur 0.6%, nanotub 0.6%, magnet 0.5%, layer 0.5%, dna.molecul 0.5%, electron 0.4%, carbon 0.4%, phase 0.4%, structur 0.4%, particl 0.4%, deposit 0.4%, crystal 0.4%, quantum 0.4%, strand.dna 0.4%, energi 0.3%, field 0.3%, dot 0.3%, laser 0.3%, size 0.3%, optic 0.3%, state 0.3%, materi 0.3%, oxid 0.3%, emiss 0.3%, high 0.3%, ion 0.3% - focuses on DNA, emphasizing oligonucleotides used in hybridization studies in order to detect and study specific nucleic acid fragments, such as single or double-strand DNA.

Cluster 5, Size: 202, ISim: 0.073, ESim: 0.006 Descriptive: qd 52.4%, quantum.dot.qd 4.3%, dot.qd 4.3%, dot 3.7%, quantum.dot 2.6%, quantum 2.4%, ina 1.9%, gaa 1.0%, photoluminesc 0.7%, ina.qd 0.5%, carrier 0.4%, layer 0.4%, emiss 0.4%, qd.grown 0.4%, cdse 0.4%, energi 0.4%, grown 0.3%, growth 0.3%, ingaa 0.3%, self 0.3%, state 0.3%, temperatur 0.2%, strain 0.2%, ina.gaa 0.2%, self.assembl 0.2%, assembl 0.2%, excit 0.2%, qd.embed 0.2%, znse 0.2%, intens 0.2% Discriminating: qd 37.0%, quantum.dot.qd 3.0%, dot.qd 3.0%, film 1.7%, dot 1.1%, ina 1.0%, quantum.dot 1.0%, particl 0.7%, nanoparticl 0.7%, nanotub 0.6%, surfac 0.6%, carbon 0.6%, quantum 0.5%, magnet 0.5%, phase 0.4%, oxid 0.4%, gaa 0.4%, structur 0.4%, crystal 0.4%, ina.qd 0.4%, polym 0.3%, ion 0.3%, metal 0.3%, electron 0.3%, deposit 0.3%, materi 0.3%, qd.grown 0.3%, thick 0.3%, laser 0.3%, rai 0.2% - focuses on quantum dots, especially InAs, GaAs, CdSe QDs, emphasizing growth techniques, self-assembled layers, and photoluminescent properties.

Cluster 6, Size: 233, ISim: 0.064, ESim: 0.006 Descriptive: sam 44.5%, monolay 5.2%, monolay.sam 3.7%, assembl.monolay.sam 3.6%, assembl.monolay 3.4%, self.assembl.monolay 3.4%, self.assembl 2.1%, assembl 2.0%, self 1.5%, alkanethiol 1.3%, surfac 1.0%, gold 1.0%, termin 0.9%, group 0.6%, chain 0.5%, ch2 0.4%, molecul 0.3%, ch3 0.3%, adsorpt 0.3%, thiol 0.3%, contact 0.3%, electrod 0.3%, contact.angl 0.3%, solut 0.2%, angl 0.2%, spectroscopi 0.2%, friction 0.2%, termin.sam 0.2%, pattern 0.2%, acid 0.2% Discriminating: sam 31.7%, monolay 2.8%, monolay.sam 2.6%, assembl.monolay.sam 2.6%, assembl.monolay 2.3%, self.assembl.monolay 2.2%, film 1.1%, self.assembl 0.9%, alkanethiol 0.9%, magnet 0.7%, assembl 0.7%, particl 0.7%, nanotub 0.6%, temperatur 0.6%, nanoparticl 0.5%, size 0.5%, layer 0.5%, carbon 0.5%, termin 0.5%, self 0.4%, electron 0.4%, quantum 0.4%, phase 0.4%, field 0.4%, crystal 0.4%, dot 0.4%, optic 0.4%, structur 0.3%, laser 0.3%, materi 0.3% - focuses on self-assembly, emphasizing thiols because of their capability to form self assembled monolayers (SAM) on noble and semi-noble metals, and examining the adsorption properties of thiols with various terminal groups.

Cluster 7, Size: 233, ISim: 0.059, ESim: 0.006 Descriptive: nanowir 63.0%, nanowir.arrai 1.3%, growth 1.2%, diamet 1.0%, arrai 1.0%, zno.nanowir 0.5%, length 0.5%, silicon 0.5%, electron.microscopi 0.5%, zno 0.4%, microscopi 0.4%, vapor 0.3%, templat 0.3%, oxid 0.3%, wire 0.3%, synthes 0.3%, nanowir.synthes 0.3%, electron 0.3%, nanowir.diamet 0.3%, singl.crystallin 0.3%, anod 0.3%, crystallin 0.3%, transmiss.electron 0.3%, gan.nanowir 0.3%, gan 0.3%, transmiss.electron.microscopi 0.3%, silicon.nanowir 0.2%, transmiss 0.2%, liquid.solid 0.2%, singl 0.2% Discriminating: nanowir 42.3%, film 1.6%, nanowir.arrai 0.9%, particl 0.7%, surfac 0.6%, nanoparticl 0.6%, layer 0.5%, nanotub 0.5%, carbon 0.5%, size 0.4%, quantum 0.4%, zno.nanowir 0.4%, dot 0.4%, arrai 0.3%, state 0.3%, optic 0.3%, laser 0.3%, ion 0.3%, phase 0.3%, temperatur 0.3%, polym 0.3%, field 0.3%, magnet 0.3%, energi 0.3%, thick 0.2%, measur 0.2%, system 0.2%, thin 0.2%, structur 0.2%, two 0.2% - focuses on nanowires, especially the fabrication and synthesis of nanowire arrays, and on evaluation of the geometric, structural, and electronic properties of these nanowires as a function of fabrication technique and parameters.

Cluster 8, Size: 340, ISim: 0.054, ESim: 0.005 Descriptive: clai 22.2%, nanocomposit 15.3%, intercal 7.0%, mmt 6.0%, montmorillonit 4.0%, silic 3.3%, organoclai 2.0%, exfoli 1.9%, layer.silic 1.2%, clai.nanocomposit 1.1%, polym 0.9%, layer 0.8%, melt 0.7%, rai.diffract 0.4%, dispers 0.4%, rai 0.4%, polymer 0.4%, cure 0.4%, properti 0.4%, content 0.4%, diffract 0.4%, nylon 0.4%, montmorillonit.mmt 0.3%, organ 0.3%, modulu 0.3%, thermal 0.3%, epoxi 0.3%, silic.layer 0.3%, matrix 0.3%, mmt.nanocomposit 0.3% Discriminating: clai 15.0%, nanocomposit 9.0%, intercal 4.5%, mmt 4.1%, montmorillonit 2.7%, silic 2.0%, film 1.5%, organoclai 1.4%, exfoli 1.3%, layer.silic 0.8%, clai.nanocomposit 0.7%, magnet 0.7%, surfac 0.6%, nanotub 0.6%, nanoparticl 0.5%, deposit 0.5%, carbon 0.5%, size 0.4%, particl 0.4%, quantum 0.4%, field 0.4%, dot 0.3%, substrat 0.3%, laser 0.3%, structur 0.3%, energi 0.3%, metal 0.3%, optic 0.3%, temperatur 0.3%, electron 0.3% - focuses on clays, emphasizing production of polymer-layered silicate nanocomposites from organoclays and montmorillonite-derived clays using melt intercalation.

Cluster 9, Size: 162, ISim: 0.051, ESim: 0.006 Descriptive: spin 50.1%, orbit 1.8%, state 1.4%, polar 1.3%, spin.polar 1.3%, spin.orbit 1.3%, electron 1.1%, quantum 1.0%, dot 0.9%, coupl 0.9%, magnet 0.8%, electron.spin 0.6%, current 0.6%, interact 0.6%, orbit.coupl 0.6%, ferromagnet 0.6%, spin.orbit.coupl 0.5%, nuclear.spin 0.5%, spin.relax 0.4%, field 0.4%, relax 0.4%, nuclear 0.4%, quantum.dot 0.4%, spin.state 0.4%, magnet.field 0.3%, depend 0.3%, two 0.3%, spin.depend 0.3%, precess 0.3%, theori 0.3% Discriminating: spin 33.7%, film 1.7%, orbit 1.1%, spin.orbit 0.9%, spin.polar 0.9%, surfac 0.7%, nanotub 0.6%, nanoparticl 0.6%, particl 0.6%, layer 0.5%, carbon 0.5%, oxid 0.5%, structur 0.5%, deposit 0.5%, polar 0.5%, size 0.4%, orbit.coupl 0.4%, electron.spin 0.4%, temperatur 0.4%, phase 0.4%, nuclear.spin 0.4%, spin.orbit.coupl 0.4%, crystal 0.4%, substrat 0.3%, polym 0.3%, ion 0.3%, optic 0.3%, spin.relax 0.3%, emiss 0.3%, materi 0.3% - focuses on spin, including spin-dependent electron scattering, spin-orbit interactions, spin channels, quantum dot spin states, quantum dot spin polarization, and electron spin resonance.

Cluster 10, Size: 149, ISim: 0.051, ESim: 0.006 Descriptive: silver 46.3%, silver.nanoparticl 6.6%, nanoparticl 4.7%, sln 3.8%, colloid 1.8%, shell 1.4%, core 0.7%, core.shell 0.7%, silver.ion 0.6%, particl 0.5%, reduct 0.5%, size 0.4%, ion 0.4%, silver.particl 0.4%, metal 0.4%, solut 0.4%, stabil 0.3%, silver.nitrat 0.3%, pvp 0.2%, dispers 0.2%, tem 0.2%, absorpt 0.2%, silver.nanowir 0.2%, solid.lipid 0.2%, reduct.silver 0.2%, lipid 0.2%, growth 0.2%, vi 0.2%, agno3 0.2%, format 0.2% Discriminating: silver 32.4%, silver.nanoparticl 4.8%, sln 2.8%, film 1.5%, nanoparticl 1.1%, colloid 0.9%, shell 0.7%, magnet 0.7%, nanotub 0.6%, layer 0.6%, temperatur 0.6%, carbon 0.5%, surfac 0.5%, structur 0.5%, core.shell 0.4%, silver.ion 0.4%, field 0.4%, deposit 0.4%, quantum 0.4%, dot 0.3%, energi 0.3%, oxid 0.3%, electron 0.3%, state 0.3%, materi 0.3%, measur 0.3%, silver.particl 0.3%, high 0.3%, substrat 0.3%, emiss 0.3% - focuses on silver, especially nanoparticles (especially with core-shell nanostructures), colloids, particles, and determination of their structural, chemical, and electrical properties.

Cluster 11, Size: 129, ISim: 0.049, ESim: 0.006 Descriptive: gan 23.4%, led 3.9%, algan 2.8%, mqw 2.5%, ingan 2.3%, diod 2.2%, layer 1.8%, light 1.7%, light.emit 1.6%, current 1.5%, light.emit.diod 1.5%, emit.diod 1.5%, emit 1.4%, grown 1.0%, aln 0.9%, emiss 0.9%, wavelength 0.8%, ingan.gan 0.8%, devic 0.8%, sapphir 0.7%, emit.diod.led 0.6%, diod.led 0.6%, quantum 0.6%, peak 0.5%, forward 0.5%, output.power 0.4%, fabric 0.4%, effici 0.4%, output 0.4%, power 0.4% Discriminating: gan 16.1%, led 2.6%, algan 2.1%, mqw

1.9%, ingan 1.7%, diod 1.4%, film 1.3%, light.emit 1.1%, light.emit.diod 1.0%, emit.diod 1.0%, particl 0.8%, surfac 0.7%, emit 0.7%, magnet 0.7%, nanoparticl 0.7%, nanotub 0.6%, aln 0.6%, size 0.6%, ingan.gan 0.6%, carbon 0.6%, light 0.5%, emit.diod.led 0.5%, diod.led 0.5%, sapphir 0.4%, electron 0.4%, current 0.4%, oxid 0.4%, crystal 0.4%, polym 0.3%, phase 0.3% - focuses on GaN for light emitting diodes, and also includes AlGaN, InGaN, and AlN.

Cluster 12, Size: 236, ISim: 0.048, ESim: 0.006 Descriptive: tio2 43.4%, photocatalyt 7.0%, anatas 4.3%, rutil 2.0%, titania 1.9%, photocatalyt.activ 1.5%, particl 1.3%, powder 1.2%, activ 1.1%, degrad 1.0%, photocatalyst 0.9%, titanium 0.6%, tio2.powder 0.6%, calcin 0.5%, tio2.particl 0.5%, size 0.5%, reaction 0.4%, surfac.area 0.4%, tio2.nanoparticl 0.4%, sol 0.4%, surfac 0.3%, dope 0.3%, oxid 0.3%, area 0.3%, light 0.3%, gel 0.3%, anatas.rutil 0.3%, phase 0.3%, irradi 0.3%, nanoparticl 0.2% Discriminating: tio2 30.5%, photocatalyt 5.2%, anatas 3.1%, rutil 1.4%, titania 1.3%, film 1.2%, photocatalyt.activ 1.1%, magnet 0.7%, photocatalyst 0.7%, degrad 0.5%, layer 0.5%, tio2.powder 0.4%, nanotub 0.4%, field 0.4%, carbon 0.4%, dot 0.4%, tio2.particl 0.4%, quantum 0.3%, deposit 0.3%, laser 0.3%, optic 0.3%, titanium 0.3%, temperatur 0.3%, electron 0.3%, energi 0.3%, measur 0.3%, tio2.nanoparticl 0.3%, emiss 0.3%, structur 0.3%, calcin 0.3% - focuses on TiO2 (including titania colloids), especially for its photocatalytic activity, and examines electronic and metallurgical properties resulting from different fabrication techniques, including conversion of the anatase phase into rutile phase as a function of annealing temperature.

Cluster 13, Size: 128, ISim: 0.047, ESim: 0.005 Descriptive: membran 40.3%, vesicl 10.7%, lipid 4.5%, liposom 2.2%, bilay 1.4%, protein 1.2%, pore 0.8%, fusion 0.7%, cell 0.7%, nafion 0.5%, permeabl 0.5%, lipid.bilay 0.4%, domain 0.3%, select 0.3%, drug 0.3%, permeat 0.3%, membran.surfac 0.3%, plasma.membran 0.3%, fluoresc 0.3%, complex 0.2%, fusion.pore 0.2%, phospholipid 0.2%, proton 0.2%, dppc 0.2%, surfac 0.2%, ion 0.2%, ga 0.2%, water 0.2%, unilamellar 0.2%, form 0.2% Discriminating: membran 27.4%, vesicl 7.6%, lipid 3.1%, film 1.6%, liposom 1.5%, bilay 0.8%, magnet 0.7%, particl 0.6%, temperatur 0.6%, nanoparticl 0.5%, electron 0.5%, protein 0.5%, fusion 0.5%, field 0.4%, carbon 0.4%, nanotub 0.4%, layer 0.4%, quantum 0.4%, oxid 0.4%, dot 0.3%, deposit 0.3%, laser 0.3%, nafion 0.3%, crystal 0.3%, surfac 0.3%, energi 0.3%, size 0.3%, optic 0.3%, emiss 0.3%, permeabl 0.3% - focuses on artificial and biological membranes, including their structure determination, and formation of the artificial membranes as well. Some emphasis was placed on nanoscopic structures using hydrated single lipids and lipid mixtures, where.the nanostructures formed by these extruded vesicles/ liposomes ranged from isolated unilamellar vesicles to flat sheet membranes.

Cluster 14, Size: 187, ISim: 0.047, ESim: 0.006 Descriptive: devic 7.9%, emit 6.2%, light.emit 4.0%, light 3.8%, electroluminesc 3.8%, effici 3.1%, alq 3.0%, emiss 2.3%, ito 2.1%, diod 1.7%, light.emit.diod 1.4%, emit.diod 1.4%, lumin 1.3%, ol 1.2%, ppv 1.2%, organ 1.1%, layer 1.0%, blue 1.0%, quantum.effici 0.9%, bright 0.8%, organ.light 0.8%, hole 0.7%, copolym 0.7%, organ.light.emit 0.7%, polym 0.7%, maximum 0.7%, transport 0.6%, red 0.6%, bi 0.6%, tpd 0.5% Discriminating: devic 4.0%, emit 4.0%, light.emit 2.8%, electroluminesc 2.6%, alq 2.2%, light 1.7%, effici 1.5%, ito 1.3%, film 1.0%, diod 1.0%, light.emit.diod 1.0%, emit.diod 0.9%, lumin 0.9%, ol 0.8%, surfac 0.8%, ppv 0.8%, particl

0.7%, magnet 0.7%, nanoparticl 0.6%, nanotub 0.6%, emiss 0.6%, quantum.effici 0.6%, organ.light 0.5%, size 0.5%, temperatur 0.5%, organ.light.emit 0.5%, carbon 0.5%, bright 0.5%, blue 0.5%, phase 0.5% **-** focuses on electroluminescent emitters and fabrication of light-emitting devices/ diodes, with strong emphasis on determining and increasing efficiency.

Cluster 15, Size: 179, ISim: 0.045, ESim: 0.007 Descriptive: ina 21.6%, gaa 9.8%, dot 3.7%, quantum 3.4%, quantum.dot 1.8%, layer 1.6%, ina.quantum 1.4%, growth 1.3%, grown 1.2%, island 1.1%, ina.gaa 1.1%, strain 1.1%, beam.epitaxi 1.1%, qwr 1.1%, epitaxi 1.0%, ina.quantum.dot 1.0%, photoluminesc 1.0%, molecular.beam.epitaxi 1.0%, molecular.beam 0.9%, inp 0.8%, ingaa 0.7%, qd 0.5%, wire 0.5%, beam 0.5%, temperatur 0.5%, self 0.5%, stack 0.4%, assembl.ina 0.4%, self.assembl.ina 0.4%, gaa.quantum 0.4% Discriminating: ina 16.6%, gaa 6.8%, film 2.0%, dot 1.3%, ina.quantum 1.1%, quantum 1.0%, particl 0.8%, ina.gaa 0.8%, qwr 0.8%, nanoparticl 0.8%, ina.quantum.dot 0.8%, beam.epitaxi 0.7%, magnet 0.7%, nanotub 0.7%, quantum.dot 0.7%, molecular.beam.epitaxi 0.7%, molecular.beam 0.6%, carbon 0.6%, oxid 0.5%, inp 0.5%, surfac 0.5%, island 0.5%, epitaxi 0.5%, phase 0.5%, ingaa 0.5%, grown 0.4%, strain 0.4%, crystal 0.4%, ion 0.4%, photoluminesc 0.4% **-** focuses on InAs and GaAs, especially InAs quantum dots grown by molecular beam epitaxy.on GaAs substrates.

Cluster 16, Size: 265, ISim: 0.042, ESim: 0.005 Descriptive: space.group 7.9%, crystal 6.9%, degre 5.2%, space 4.2%, group 3.9%, beta 3.8%, compound 3.1%, structur 1.6%, complex 1.6%, monoclin 1.5%, crystal.structur 1.5%, angstrom 1.5%, h2o 1.4%, system.space 1.1%, system.space.group 1.1%, atom 1.1%, singl.crystal 1.0%, unit 1.0%, 000 0.9%, coordin 0.8%, rai 0.7%, diffract 0.6%, degre.gamma 0.6%, degre.beta 0.6%, two 0.6%, gamma 0.6%, crystal.rai 0.6%, belong 0.6%, singl.crystal.rai 0.6%, ligand 0.5% Discriminating: space.group 5.5%, degre 3.2%, crystal 2.6%, space 2.4%, beta 2.2%, group 1.8%, film 1.8%, compound 1.6%, monoclin 1.0%, crystal.structur 0.9%, surfac 0.8%, h2o 0.8%, angstrom 0.8%, system.space 0.8%, system.space.group 0.8%, particl 0.7%, nanoparticl 0.7%, nanotub 0.6%, 000 0.5%, size 0.5%, electron 0.5%, singl.crystal 0.5%, unit 0.5%, complex 0.5%, carbon 0.5%, layer 0.5%, deposit 0.5%, coordin 0.4%, temperatur 0.4%, degre.gamma 0.4% **-** focuses on structure of crystals, emphasizing space group parameters.

Cluster 17, Size: 251, ISim: 0.041, ESim: 0.005 Descriptive: laser 8.2%, power 5.9%, harmon 5.4%, pump 5.2%, output 4.4%, second.harmon 2.7%, gener 2.0%, second 1.9%, output.power 1.8%, harmon.gener 1.7%, crystal 1.7%, effici 1.5%, wavelength 1.5%, optic 1.4%, puls 1.4%, caviti 1.3%, frequenc 1.3%, diod 1.1%, second.harmon.gener 1.0%, wave 0.9%, convers 0.8%, mode 0.7%, shg 0.7%, nonlinear 0.7%, frequenc.doubl 0.6%, oper 0.6%, vcsel 0.6%, yag 0.6%, phase.match 0.6%, continu.wave 0.6% Discriminating: harmon 3.7%, laser 3.6%, power 3.4%, pump 3.3%, output 3.0%, second.harmon 1.9%, film 1.6%, output.power 1.3%, harmon.gener 1.2%, second 1.0%, gener 0.8%, particl 0.8%, caviti 0.7%, second.harmon.gener 0.7%, nanoparticl 0.7%, magnet 0.6%, nanotub 0.6%, diod 0.6%, surfac 0.6%, effici 0.6%, carbon 0.6%, layer 0.6%, electron 0.6%, wavelength 0.5%, size 0.5%, puls 0.5%, shg 0.5%, frequenc 0.5%, structur 0.5%, frequenc.doubl 0.5% **-** focuses on laser power and output, especially second harmonic generation from diode and optically pumped lasers.

Cluster 18, Size: 158, ISim: 0.040, ESim: 0.006 Descriptive: tunnel 13.0%, kondo 6.0%, coulomb 4.6%, junction 4.3%, blockad 3.0%, coulomb.blockad 2.4%, tmr 2.0%, current 1.9%, voltag 1.5%, bia 1.1%, singl.electron 1.1%, magnetoresist 1.1%, transport 1.0%, electron 1.0%, barrier 0.9%, spin 0.9%, josephson 0.8%, quantum 0.8%, conduct 0.7%, tunnel.junction 0.7%, tunnel.magnetoresist 0.7%, regim 0.7%, charg 0.7%, nois 0.7%, coupl 0.7%, dot 0.6%, singl 0.6%, temperatur 0.5%, state 0.5%, two 0.5% Discriminating: tunnel 8.5%, kondo 4.4%, coulomb 3.2%, junction 2.8%, blockad 2.2%, film 1.8%, coulomb.blockad 1.7%, tmr 1.5%, surfac 0.9%, singl.electron 0.8%, particl 0.7%, magnetoresist 0.7%, current 0.6%, nanoparticl 0.6%, josephson 0.6%, nanotub 0.6%, bia 0.6%, tunnel.magnetoresist 0.6%, carbon 0.5%, voltag 0.5%, tunnel.junction 0.5%, layer 0.5%, size 0.5%, deposit 0.5%, crystal 0.4%, structur 0.4%, barrier 0.4%, nois 0.4%, optic 0.4%, transport 0.4% - focuses on tunneling, in tunneling junctions, especially magnetic tunnel junctions in magnetoresistance devices, with emphasis on Kondo states and Coulomb blockades.

Cluster 19, Size: 272, ISim: 0.040, ESim: 0.006 Descriptive: alloi 54.6%, phase 1.9%, nanocrystallin 1.8%, amorph 1.5%, magnet 1.5%, mechan.alloi 1.0%, amorph.alloi 0.7%, anneal 0.6%, precipit 0.5%, mechan 0.5%, melt 0.5%, microstructur 0.5%, magnet.properti 0.4%, powder 0.4%, crystal 0.4%, structur 0.4%, temperatur 0.4%, grain 0.3%, properti 0.3%, composit 0.3%, content 0.3%, nanocrystallin.alloi 0.3%, glass 0.3%, alpha 0.2%, materialia 0.2%, scienc 0.2%, acta 0.2%, diffract 0.2%, glassi 0.2%, heat 0.2% Discriminating: alloi 40.7%, film 1.8%, nanocrystallin 0.8%, mechan.alloi 0.8%, nanotub 0.6%, surfac 0.6%, nanoparticl 0.6%, amorph 0.6%, amorph.alloi 0.5%, layer 0.5%, particl 0.5%, quantum 0.4%, carbon 0.4%, dot 0.4%, optic 0.4%, polym 0.4%, substrat 0.4%, deposit 0.3%, emiss 0.3%, phase 0.3%, energi 0.3%, ion 0.3%, nanowir 0.3%, laser 0.3%, electron 0.2%, molecul 0.2%, field 0.2%, nanocrystallin.alloi 0.2%, thick 0.2%, oxid 0.2% - focuses on alloys, especially relation of phase composition to magnetic properties of nanocrystalline alloys and amorphous alloys, and the tailoring of these properties by annealing.

Cluster 20, Size: 227, ISim: 0.040, ESim: 0.006 Descriptive: exciton 26.1%, quantum 10.3%, dot 5.1%, quantum.dot 3.1%, hole 2.1%, phonon 2.1%, state 2.0%, confin 1.3%, energi 1.2%, electron.hole 1.0%, photoluminesc 0.8%, exciton.state 0.8%, excit 0.7%, optic 0.7%, polar 0.7%, biexciton 0.6%, carrier 0.5%, ground 0.4%, cdse 0.4%, electron 0.4%, field 0.4%, radi 0.4%, well 0.4%, ground.state 0.4%, transit 0.4%, gaa 0.4%, local 0.4%, time 0.4%, recombin 0.4%, semiconductor 0.3% Discriminating: exciton 19.9%, quantum 5.1%, dot 2.1%, film 1.9%, quantum.dot 1.4%, phonon 1.3%, hole 1.2%, surfac 0.9%, electron.hole 0.7%, nanotub 0.7%, nanoparticl 0.7%, confin 0.6%, carbon 0.6%, exciton.state 0.6%, oxid 0.5%, layer 0.5%, deposit 0.5%, state 0.5%, magnet 0.5%, biexciton 0.5%, phase 0.5%, particl 0.5%, metal 0.4%, crystal 0.4%, substrat 0.4%, polym 0.4%, ion 0.3%, temperatur 0.3%, structur 0.3%, materi 0.3% - focuses on exciton (electron-hole pair) states, especially in quantum dots.

Cluster 21, Size: 233, ISim: 0.038, ESim: 0.006 Descriptive: copolym 24.2%, block 11.2%, micel 4.1%, block.copolym 3.6%, poli 3.4%, peg 1.8%, peo 1.6%, chain 1.1%, ethylen 1.1%, diblock 1.0%, polym 0.8%, diblock.copolym 0.8%, poli.ethylen 0.7%, polymer 0.6%, methacryl 0.6%, pla 0.5%, acryl 0.5%, weight 0.5%, ethylen.oxid 0.5%, polystyren 0.4%, molecular.weight 0.4%, triblock 0.4%, amphiphil 0.4%, core 0.4%, vesicl 0.4%, assembl 0.3%, molecular 0.3%, acid 0.3%, water 0.3%, aggreg 0.3% Discriminating: copolym 18.1%, block 8.0%, micel 2.9%, block.copolym 2.7%, poli 1.8%, peg 1.3%, film 1.1%, peo 1.1%, diblock 0.7%, magnet 0.7%, nanotub 0.7%, ethylen 0.6%, particl 0.6%, diblock.copolym 0.6%, layer 0.5%, carbon 0.5%, electron 0.5%, deposit 0.5%, poli.ethylen 0.5%, temperatur 0.4%, quantum 0.4%, field 0.4%, chain 0.4%, surfac 0.4%, pla 0.4%, dot 0.4%, energi 0.4%, methacryl 0.4%, acryl 0.3%, laser 0.3% - focuses on addition of block copolymers, or polymeric micelles, to promote self-assembly and improve material properties and structures.

Cluster 22, Size: 401, ISim: 0.037, ESim: 0.006 Descriptive: grain 41.2%, grain.size 8.2%, boundari 5.7%, grain.boundari 4.9%, size 2.7%, nanocrystallin 1.2%, sinter 0.9%, deform 0.7%, microstructur 0.7%, grain.growth 0.6%, powder 0.6%, disloc 0.5%, phase 0.4%, temperatur 0.4%, alloi 0.4%, anneal 0.3%, growth 0.3%, averag.grain 0.3%, materialia 0.3%, materi 0.3%, acta 0.3%, ceram 0.3%, diffus 0.2%, averag.grain.size 0.2%, magnet 0.2%, mechan 0.2%, mill 0.2%, strain 0.2%, sampl 0.2%, decreas 0.2% Discriminating: grain 31.0%, grain.size 6.2%, boundari 4.2%, grain.boundari 3.8%, film 1.2%, nanoparticl 0.7%, nanotub 0.7%, surfac 0.6%, size 0.5%, sinter 0.5%, nanocrystallin 0.5%, grain.growth 0.5%, layer 0.5%, carbon 0.5%, quantum 0.4%, optic 0.4%, dot 0.4%, laser 0.4%, polym 0.4%, deform 0.4%, particl 0.4%, deposit 0.3%, substrat 0.3%, emiss 0.3%, electron 0.3%, structur 0.3%, field 0.3%, microstructur 0.3%, nanowir 0.3%, state 0.3% - focuses on grains, especially their size and boundaries, and how bulk crystalline properties depend on grain size, especially at nanometer levels.

Cluster 23, Size: 237, ISim: 0.036, ESim: 0.005 Descriptive: waveguid 13.1%, grate 12.5%, fiber 11.2%, wavelength 4.1%, optic 2.7%, filter 2.2%, mode 1.8%, tune 1.3%, devic 1.2%, laser 0.9%, bragg.grate 0.8%, bragg 0.8%, loss 0.8%, multiplex 0.7%, bandwidth 0.7%, spectral 0.7%, fabric 0.7%, index 0.6%, 1550 0.6%, america 0.5%, dispers 0.5%, mum 0.5%, coupl 0.4%, beam 0.4%, power 0.4%, channel 0.4%, output 0.4%, singl.mode 0.4%, polar 0.4%, photon 0.3% Discriminating: waveguid 9.4%, grate 9.1%, fiber 7.3%, wavelength 2.1%, filter 1.5%, film 1.5%, tune 0.8%, mode 0.7%, nanoparticl 0.7%, particl 0.7%, surfac 0.7%, optic 0.7%, bragg.grate 0.6%, nanotub 0.6%, magnet 0.6%, carbon 0.6%, bragg 0.6%, electron 0.6%, multiplex 0.5%, temperatur 0.5%, size 0.5%, oxid 0.5%, structur 0.5%, bandwidth 0.5%, layer 0.4%, deposit 0.4%, 1550 0.4%, dot 0.4%, loss 0.4%, energi 0.4% - focuses on optical waveguides, including their gratings and optical fibers.

Cluster 24, Size: 333, ISim: 0.037, ESim: 0.006 Descriptive: gate 20.9%, transistor 4.3%, channel 4.2%, devic 4.0%, mosfet 3.4%, drain 2.4%, oxid 2.3%, current 2.2%, voltag 1.8%, soi 1.4%, silicon 1.0%, oxid.semiconductor 0.9%, metal.oxid.semiconductor 0.8%, fabric 0.8%, metal.oxid 0.8%, gate.oxid 0.8%, field.transistor 0.8%, sourc.drain 0.7%, thick 0.7%, gate.length 0.7%, trap 0.7%, leakag 0.7%, characterist 0.6%, charg 0.6%, mobil 0.6%, semiconductor 0.6%, leakag.current 0.5%, mo 0.5%, simul 0.5%, memori 0.5% Discriminating: gate 15.6%, transistor 3.1%, channel 2.7%, mosfet 2.6%, devic 1.9%, drain 1.8%, film 1.5%, soi 1.1%, particl 0.8%, voltag 0.8%, current 0.8%, magnet 0.8%, surfac 0.7%, nanoparticl 0.7%, nanotub 0.7%, oxid.semiconductor 0.6%, metal.oxid.semiconductor

0.6%, gate.oxid 0.6%, carbon 0.6%, sourc.drain 0.6%, field.transistor 0.5%, gate.length 0.5%, metal.oxid 0.5%, size 0.5%, phase 0.5%, oxid 0.5%, leakag 0.4%, crystal 0.4%, temperatur 0.4%, mo 0.4% - focuses on gates for transistors and other electronic devices.

Cluster 25, Size: 647, ISim: 0.036, ESim: 0.006 Descriptive: dot 36.4%, quantum 16.2%, quantum.dot 15.8%, state 0.8%, electron 0.8%, coupl 0.5%, energi 0.5%, gaa 0.4%, confin 0.4%, ina 0.3%, phonon 0.3%, system 0.3%, two 0.3%, singl 0.3%, tunnel 0.3%, field 0.2%, interact 0.2%, photon 0.2%, level 0.2%, excit 0.2%, spin 0.2%, layer 0.2%, carrier 0.2%, conduct 0.2%, self 0.2%, charg 0.2%, ground 0.2%, current 0.2%, peak 0.2%, optic 0.2% Discriminating: dot 26.3%, quantum.dot 11.4%, quantum 10.0%, film 2.0%, surfac 0.8%, nanotub 0.7%, nanoparticl 0.7%, particl 0.7%, carbon 0.6%, deposit 0.4%, magnet 0.4%, crystal 0.4%, oxid 0.4%, metal 0.4%, polym 0.4%, structur 0.3%, ion 0.3%, temperatur 0.3%, phase 0.3%, layer 0.3%, materi 0.3%, thin 0.3%, substrat 0.3%, high 0.3%, nanowir 0.3%, size 0.3%, rai 0.3%, thick 0.2%, grain 0.2%, solut 0.2% - focuses on quantum dots, emphasizing electronic states and energy levels, and growth mechanisms.

Cluster 26, Size: 470, ISim: 0.037, ESim: 0.006 Descriptive: nanotub 20.2%, tube 7.7%, wall 6.5%, carbon 6.3%, carbon.nanotub 5.9%, singl.wall 4.8%, wall.carbon 4.5%, wall.carbon.nanotub 4.1%, singl.wall.carbon 3.5%, swcnt 2.1%, singl 1.7%, bundl 1.0%, calcul 0.5%, armchair 0.4%, electron 0.4%, diamet 0.4%, zigzag 0.4%, atom 0.4%, function 0.4%, energi 0.3%, semiconduct 0.3%, densiti 0.3%, raman 0.3%, doubl.wall 0.3%, metal 0.3%, chiral 0.3%, phonon 0.3%, bind 0.3%, structur 0.2%, bond 0.2% Discriminating: nanotub 11.9%, tube 5.8%, wall 4.3%, singl.wall 3.6%, carbon.nanotub 3.5%, wall.carbon 3.3%, wall.carbon.nanotub 3.0%, singl.wall.carbon 2.6%, carbon 2.5%, film 2.0%, swcnt 1.7%, surfac 0.8%, nanoparticl 0.7%, particl 0.7%, bundl 0.7%, layer 0.6%, size 0.6%, magnet 0.5%, temperatur 0.5%, crystal 0.5%, deposit 0.4%, singl 0.4%, oxid 0.4%, substrat 0.4%, dot 0.4%, armchair 0.3%, phase 0.3%, thick 0.3%, ion 0.3%, optic 0.3% - focuses on nanotubes, especially single-wall carbon nanotubes, and addresses properties of bundles, emphasizing zigzag and armchair nanotubes.

Cluster 27, Size: 298, ISim: 0.036, ESim: 0.006 Descriptive: catalyst 35.7%, support 6.0%, catalyt 4.0%, activ 3.9%, oxid 2.2%, reaction 1.8%, carbon 1.5%, hydrogen 1.3%, metal 1.1%, particl 1.0%, catalyt.activ 0.9%, surfac 0.8%, reduct 0.7%, al2o3 0.7%, zeolit 0.6%, surfac.area 0.6%, impregn 0.5%, methan 0.5%, speci 0.4%, area 0.4%, select 0.4%, nanofib 0.3%, nanoparticl 0.3%, temperatur 0.3%, dispers 0.3%, load 0.3%, activ.catalyst 0.3%, adsorpt 0.3%, size 0.3%, carbon.nanofib 0.3% Discriminating: catalyst 27.4%, support 4.2%, catalyt 2.8%, film 2.0%, activ 1.9%, magnet 0.7%, catalyt.activ 0.7%, layer 0.6%, reaction 0.6%, electron 0.5%, field 0.5%, quantum 0.5%, nanotub 0.5%, optic 0.4%, hydrogen 0.4%, dot 0.4%, impregn 0.4%, oxid 0.4%, crystal 0.4%, substrat 0.4%, laser 0.4%, energi 0.4%, zeolit 0.4%, structur 0.4%, thick 0.3%, methan 0.3%, al2o3 0.3%, emiss 0.3%, surfac.area 0.3%, singl 0.3% - focuses on catalysts using very small particles, especially their deposition on carbon supports, and the nature of reactions at these small particle sizes.

Cluster 28, Size: 211, ISim: 0.035, ESim: 0.005 Descriptive: cell 40.7%, dye 4.0%, solar 1.9%, adhes 1.9%, tio2 1.6%, peg 1.6%, solar.cell 1.3%, sensit 1.1%, cultur 0.9%, effici 0.8%, surfac 0.7%, dye.sensit 0.6%, protein 0.5%, tissu 0.5%, transfect 0.5%, membran

0.4%, receptor 0.4%, cell.adhes 0.3%, express 0.3%, convers 0.3%, complex 0.3%, human 0.3%, cellular 0.3%, gene 0.3%, electrolyt 0.3%, cell.wall 0.3%, convers.effici 0.3%, deliveri 0.3%, nanocrystallin.tio2 0.2%, vivo 0.2% Discriminating: cell 28.7%, dye 2.6%, film 1.4%, solar 1.3%, adhes 1.2%, peg 1.1%, solar.cell 0.9%, nanotub 0.7%, temperatur 0.7%, cultur 0.7%, magnet 0.6%, tio2 0.5%, structur 0.5%, carbon 0.5%, sensit 0.5%, phase 0.5%, dye.sensit 0.5%, crystal 0.4%, size 0.4%, layer 0.4%, deposit 0.4%, dot 0.4%, field 0.4%, quantum 0.4%, particl 0.4%, optic 0.3%, transfect 0.3%, tissu 0.3%, electron 0.3%, sampl 0.3% - focuses on animal and solar cells, emphasizing the use of indicator dyes to enhance the photosensitivity of these cells, and both increase the efficiency of solar cells and use the luminescence as detectors for animal cells.

Cluster 29, Size: 271, ISim: 0.036, ESim: 0.007 Descriptive: ion 20.0%, implant 14.7%, irradi 4.2%, kev 2.5%, dose 1.9%, depth 1.9%, fluenc 1.6%, ion.beam 1.6%, beam 1.4%, ion.implant 1.3%, sputter 1.1%, surfac 1.1%, anneal 1.0%, layer 1.0%, energi 0.8%, damag 0.7%, defect 0.6%, film 0.6%, mev 0.6%, bombard 0.5%, profil 0.5%, sampl 0.5%, sio2 0.5%, silicon 0.5%, track 0.5%, sim 0.5%, atom 0.4%, ion.irradi 0.4%, -
Cluster 0.4%, incid 0.4% Discriminating: ion 13.7%, implant 12.3%, irradi 2.6%, kev 2.1%, dose 1.5%, depth 1.4%, fluenc 1.3%, ion.beam 1.3%, ion.implant 1.1%, nanotub 0.8%, particl 0.7%, magnet 0.7%, sputter 0.6%, beam 0.6%, film 0.6%, nanoparticl 0.6%, damag 0.5%, quantum 0.5%, dot 0.5%, field 0.4%, carbon 0.4%, bombard 0.4%, phase 0.4%, size 0.4%, mev 0.4%, sim 0.4%, ion.irradi 0.4%, electron 0.3%, polym 0.3%, track 0.3% - focuses on ion bombardment, irradiation, and implantation of surfaces, examines the effects as a function of energy levels, dose, depth of penetration, fluence, and annealing.

Cluster 30, Size: 225, ISim: 0.034, ESim: 0.005 Descriptive: indent 11.2%, deform 10.6%, plastic 6.2%, nanoindent 2.9%, disloc 2.6%, plastic.deform 2.5%, load 2.4%, hard 2.0%, stress 1.7%, materi 1.7%, elast 1.6%, crack 1.5%, mechan 1.4%, strain 1.2%, fractur 1.1%, test 1.0%, modulu 0.9%, sever.plastic 0.7%, shear 0.7%, scale 0.6%, sever.plastic.deform 0.6%, tensil 0.6%, alloi 0.6%, ductil 0.6%, sever 0.5%, depth 0.5%, mechan.properti 0.5%, strength 0.5%, acta 0.4%, materialia 0.4% Discriminating: indent 8.5%, deform 7.7%, plastic 4.6%, nanoindent 2.1%, plastic.deform 1.9%, disloc 1.7%, film 1.5%, load 1.5%, hard 1.1%, crack 1.0%, elast 1.0%, stress 0.9%, fractur 0.7%, magnet 0.7%, particl 0.7%, nanoparticl 0.7%, nanotub 0.7%, test 0.6%, modulu 0.6%, sever.plastic 0.5%, carbon 0.5%, deposit 0.5%, sever.plastic.deform 0.5%, strain 0.5%, quantum 0.5%, oxid 0.4%, layer 0.4%, ductil 0.4%, sever 0.4%, shear 0.4% - focuses on use of indentation, especially nanoindentation, and plastic deformation to measure mechanical properties of nanostructures, including stress-strain relationships, tensile strength, shear, ductility, and fracture.

Cluster 31, Size: 244, ISim: 0.036, ESim: 0.007 Descriptive: magnet 27.0%, magnet.properti 3.6%, anneal 3.6%, coerciv 3.1%, phase 2.3%, ribbon 2.2%, soft 1.4%, temperatur 1.4%, amorph 1.2%, fept 1.2%, sampl 1.2%, alpha 1.2%, anisotropi 1.1%, properti 0.9%, grain 0.9%, soft.magnet 0.9%, exchang 0.7%, nanocrystallin 0.7%, spun 0.6%, alloi 0.6%, koe 0.5%, exchang.coupl 0.5%, curi 0.5%, structur 0.4%, anneal.temperatur 0.4%, field 0.4%, curi.temperatur 0.4%, ferrit 0.4%, melt.spun 0.4%, decreas 0.4% Discriminating: magnet 16.9%, magnet.properti 2.8%, coerciv 2.3%, ribbon 1.8%, anneal 1.7%, film 1.2%, soft 1.0%, fept 1.0%, nanotub 0.8%, surfac 0.8%, soft.magnet 0.7%, anisotropi 0.7%, alpha 0.6%, carbon 0.5%, spun 0.5%, phase 0.5%, quantum 0.5%, optic 0.5%, oxid 0.4%, amorph 0.4%, dot 0.4%, layer 0.4%, deposit 0.4%, koe 0.4%, laser 0.4%, exchang.coupl 0.4%, electron 0.4%, polym 0.4%, emiss 0.4%, curi 0.4% - focuses on magnetic properties of nanomaterials and nanostructures, and the variation of these properties with growth and treatment parameters, such as annealing.

Cluster 32, Size: 162, ISim: 0.034, ESim: 0.006 Descriptive: zno 11.9%, nanobelt 11.0%, nanorod 8.1%, growth 2.1%, electron.microscopi 1.8%, electron 1.3%, microscopi 1.2%, transmiss.electron 1.2%, transmiss 1.1%, transmiss.electron.microscopi 1.0%, diffract 0.8%, rai 0.7%, synthes 0.6%, gan 0.6%, powder 0.6%, nanostructur 0.6%, length 0.5%, singl.crystallin 0.5%, tem 0.5%, whisker 0.5%, crystal 0.5%, sno2 0.4%, oxid 0.4%, vapor 0.4%, zinc 0.4%, crystallin 0.4%, singl 0.4%, nanosheet 0.4%, boron 0.4%, hexagon 0.4% Discriminating: nanobelt 9.3%, zno 8.5%, nanorod 6.1%, film 2.0%, magnet 0.8%, particl 0.7%, electron.microscopi 0.7%, surfac 0.7%, nanoparticl 0.6%, growth 0.6%, layer 0.5%, quantum 0.4%, transmiss.electron 0.4%, dot 0.4%, state 0.4%, polym 0.4%, singl.crystallin 0.4%, transmiss.electron.microscopi 0.4%, nanotub 0.4%, whisker 0.4%, size 0.4%, field 0.3%, transmiss 0.3%, deposit 0.3%, ion 0.3%, nanosheet 0.3%, optic 0.3%, zno.nanostructur 0.3%, properti 0.3%, zno.nanorod 0.3% - focuses on growth and fabrication of ZnO nanomaterials and nanostructures, especially nanobelts and nanorods, emphasizing structural determination with transmission electron microscopy.

Cluster 33, Size: 572, ISim: 0.034, ESim: 0.006 Descriptive: nanotub 45.0%, carbon 13.0%, carbon.nanotub 10.7%, multiwal 0.6%, field 0.6%, align 0.6%, mwcnt 0.5%, multiwal.carbon 0.5%, multiwal.carbon.nanotub 0.5%, field.emiss 0.4%, emiss 0.4%, wall 0.4%, electron 0.3%, graphit 0.3%, diamet 0.3%, catalyst 0.3%, growth 0.3%, conduct 0.2%, tip 0.2%, multi.wall 0.2%, current 0.2%, multi 0.2%, electrod 0.2%, vapor 0.2%, chemic 0.2%, structur 0.2%, nanowir 0.2%, deposit 0.2%, devic 0.2%, electr 0.2% Discriminating: nanotub 33.2%, carbon.nanotub 7.7%, carbon 7.5%, film 1.7%, surfac 0.6%, particl 0.6%, magnet 0.6%, nanoparticl 0.6%, layer 0.6%, size 0.6%, multiwal 0.5%, phase 0.5%, mwcnt 0.4%, crystal 0.4%, dot 0.4%, multiwal.carbon 0.4%, quantum 0.4%, multiwal.carbon.nanotub 0.4%, temperatur 0.4%, optic 0.4%, oxid 0.3%, ion 0.3%, laser 0.3%, sampl 0.3%, structur 0.3%, align 0.3%, state 0.3%, rai 0.3%, thick 0.2%, two 0.2% - focuses on nanotubes, mainly carbon but including carbon nanotube composites and other nanotube materials as well. Emphasizes multi-wall nanotubes, their alignment, and their use as field emission devices.

Cluster 34, Size: 165, ISim: 0.032, ESim: 0.006 Descriptive: coat 10.9%, sinter 4.6%, sic 4.3%, al2o3 3.3%, powder 2.8%, ceram 2.3%, composit 1.9%, sprai 1.8%, microstructur 1.7%, hard 1.7%, fractur 1.5%, alumina 1.4%, wear 1.2%, gpa 1.1%, nano 0.9%, tough 0.9%, strength 0.8%, nanocrystallin 0.8%, si3n4 0.8%, nanocomposit 0.7%, zirconia 0.7%, steel 0.6%, nitrid 0.6%, mpa 0.5%, tzp 0.5%, mechan 0.5%, mechan.properti 0.5%, test 0.5%, materi 0.5%, tin 0.5% Discriminating: coat 6.6%, sinter 3.3%, sic 2.9%, al2o3 2.1%, film 1.8%, ceram 1.6%, sprai 1.3%, powder 1.2%, fractur 1.1%, hard 1.0%, microstructur 0.9%, wear 0.9%, alumina 0.8%, gpa 0.8%, nanotub 0.7%, nanoparticl 0.7%, surfac 0.7%, magnet 0.7%, tough 0.7%, si3n4 0.5%, composit 0.5%, quantum 0.5%, zirconia 0.4%, tzp 0.4%, carbon 0.4%, dot 0.4%, electron 0.4%, field 0.4%, steel 0.4%, structur 0.4% - focuses on coatings, and the effect of sintering on their properties, especially for Al2O3 and SiC powders and other structures, and Al2O3-SiC composites.

Cluster 35, Size: 515, ISim: 0.030, ESim: 0.006 Descriptive: magnet 38.6%, field 8.5%, magnet.field 6.0%, spin 2.3%, ferromagnet 2.1%, domain 1.0%, anisotropi 1.0%, exchang 0.9%, vortex 0.5%, coupl 0.5%, temperatur 0.5%, moment 0.5%, depend 0.5%, superconduct 0.4%, state 0.4%, layer 0.4%, magnetoresist 0.3%, switch 0.3%, wire 0.3%, interact 0.3%, domain.wall 0.3%, model 0.3%, loop 0.3%, thick 0.3%, measur 0.3%, plane 0.3%, quantum 0.3%, magnet.moment 0.2%, extern 0.2%, sampl 0.2% Discriminating: magnet 26.8%, magnet.field 4.7%, field 4.5%, ferromagnet 1.5%, film 1.2%, spin 1.1%, surfac 0.8%, nanotub 0.8%, carbon 0.6%, anisotropi 0.6%, particl 0.5%, deposit 0.5%, domain 0.5%, oxid 0.5%, vortex 0.5%, exchang 0.5%, size 0.4%, polym 0.4%, nanoparticl 0.4%, laser 0.4%, crystal 0.4%, moment 0.3%, emiss 0.3%, ion 0.3%, substrat 0.3%, structur 0.3%, metal 0.3%, electron 0.3%, composit 0.3%, growth 0.3% - focuses on behavior of magnetic nanostructures in magnetic fields, including effect on spin, domain structures, and optical, magnetic, and mechanical anisotropies.

Cluster 36, Size: 380, ISim: 0.030, ESim: 0.006 Descriptive: laser 39.7%, puls 7.7%, laser.puls 2.0%, ablat 2.0%, irradi 1.5%, optic 1.3%, beam 0.9%, wavelength 0.8%, femtosecond 0.7%, pump 0.7%, threshold 0.6%, laser.induc 0.6%, induc 0.5%, plasma 0.5%, power 0.5%, intens 0.5%, target 0.4%, emiss 0.4%, fluenc 0.4%, radiat 0.4%, laser.irradi 0.4%, laser.beam 0.4%, femtosecond.laser 0.3%, yag 0.3%, mum 0.3%, light 0.3%, energi 0.3%, surfac 0.3%, ion 0.3%, materi 0.3% Discriminating: laser 29.9%, puls 5.4%, laser.puls 1.7%, ablat 1.6%, film 1.2%, nanotub 0.8%, magnet 0.8%, carbon 0.6%, particl 0.6%, irradi 0.6%, femtosecond 0.6%, nanoparticl 0.5%, temperatur 0.5%, oxid 0.5%, layer 0.5%, laser.induc 0.4%, structur 0.4%, size 0.4%, phase 0.4%, pump 0.4%, electron 0.4%, deposit 0.4%, dot 0.3%, threshold 0.3%, surfac 0.3%, beam 0.3%, laser.beam 0.3%, laser.irradi 0.3%, femtosecond.laser 0.3%, growth 0.3% - focuses on pulsed lasers, emphasizing beam properties, and their use in characterizing optical properties of materials, nanofabrication of materials, and on materials for solid-state lasers.

Cluster 37, Size: 456, ISim: 0.028, ESim: 0.006 Descriptive: pore 18.4%, silica 14.0%, mesopor 9.8%, templat 2.3%, mcm 2.2%, pore.size 2.0%, materi 1.3%, sba 1.1%, carbon 1.1%, size 1.0%, mesopor.silica 1.0%, surfac.area 0.9%, adsorpt 0.8%, membran 0.8%, alumina 0.7%, porou 0.6%, area 0.6%, surfact 0.6%, surfac 0.6%, aerogel 0.6%, gel 0.6%, structur 0.5%, nanopor 0.5%, particl 0.4%, diamet 0.4%, pore.diamet 0.4%, order 0.3%, synthesi 0.3%, poros 0.3%, pore.size.distribut 0.3% Discriminating: pore 15.1%, silica 10.8%, mesopor 8.4%, film 1.9%, mcm 1.9%, pore.size 1.7%, templat 1.5%, sba 1.0%, mesopor.silica 0.8%, layer 0.7%, magnet 0.6%, nanotub 0.6%, surfac.area 0.6%, quantum 0.5%, aerogel 0.5%, dot 0.5%, electron 0.4%, field 0.4%, laser 0.4%, deposit 0.4%, energi 0.4%, substrat 0.4%, alumina 0.4%, temperatur 0.4%, optic 0.4%, emiss 0.3%, membran 0.3%, state 0.3%, pore.diamet 0.3%, atom 0.3% - focuses on porous materials, especially mesoporous silica structures generated with nanomaterial templates, and emphasizes pore size distribution of activated meso-carbon-microbeads.

Cluster 38, Size: 288, ISim: 0.027, ESim: 0.006 Descriptive: monolay 20.9%, assembl 8.8%, self.assembl 7.2%, self 5.8%, surfac 2.2%, assembl.monolay 2.1%, self.assembl.monolay 2.0%, chain 1.6%, molecul 1.6%, alkyl 1.1%, gold 0.8%, molecular 0.8%, group 0.8%, water 0.7%, alkyl.chain 0.5%, forc 0.5%, bond 0.4%, orient 0.4%, thiol 0.4%, interfac 0.4%, substrat 0.4%, form 0.4%, structur 0.4%, film 0.4%, bilay 0.3%, acid 0.3%, contact 0.3%, interact 0.3%, alkanethiol 0.3%, termin 0.3% Discriminating: monolay 17.2%, assembl 6.1%, self.assembl 5.3%, self 3.7%, assembl.monolay 1.7%, self.assembl.monolay 1.6%, film 1.0%, alkyl 0.9%, chain 0.8%, magnet 0.8%, nanotub 0.7%, temperatur 0.6%, particl 0.6%, molecul 0.6%, quantum 0.5%, carbon 0.5%, nanoparticl 0.5%, field 0.5%, alkyl.chain 0.5%, electron 0.5%, size 0.5%, dot 0.5%, optic 0.4%, laser 0.4%, oxid 0.4%, emiss 0.4%, sampl 0.4%, deposit 0.3%, thiol 0.3%, materi 0.3% **-** focuses on monolayers, especially self-assembled surface monolayers, with some emphasis on alkyl monolayers, gold monolayers or gold substrates, and molecular chains in ordered and disordered monolayers.

Cluster 39, Size: 325, ISim: 0.026, ESim: 0.006 Descriptive: electrod 17.2%, gold 13.3%, electrochem 2.6%, gold.nanoparticl 2.2%, surfac 2.1%, assembl 1.6%, immobil 1.4%, nanoparticl 1.4%, potenti 1.3%, monolay 1.3%, enzym 1.1%, gold.electrod 1.0%, electrod.surfac 1.0%, sensor 1.0%, detect 1.0%, solut 0.8%, glucos 0.7%, thiol 0.6%, oxid 0.6%, redox 0.6%, voltammetri 0.6%, self.assembl 0.6%, film 0.5%, cyclic 0.5%, antibodi 0.5%, self 0.5%, reduct 0.5%, activ 0.5%, respons 0.5%, transfer 0.4% Discriminating: electrod 13.3%, gold 9.9%, gold.nanoparticl 1.8%, electrochem 1.7%, immobil 1.1%, electrod.surfac 0.9%, enzym 0.9%, gold.electrod 0.9%, magnet 0.8%, temperatur 0.8%, nanotub 0.8%, film 0.7%, glucos 0.6%, sensor 0.6%, assembl 0.6%, structur 0.6%, particl 0.6%, monolay 0.5%, quantum 0.5%, size 0.5%, potenti 0.5%, thiol 0.5%, energi 0.5%, phase 0.4%, dot 0.4%, voltammetri 0.4%, field 0.4%, redox 0.4%, antibodi 0.4%, detect 0.4% **-** focuses on the use of gold electrodes in electrochemical systems, typically coated with self-assembled monolayers for enhanced electrochemical performance, as well as deposition of gold nanoparticle films on surfaces for detection/ sensing purposes.

Cluster 40, Size: 511, ISim: 0.026, ESim: 0.007 Descriptive: film 22.3%, thin.film 17.7%, thin 14.6%, pzt 1.8%, tio2 1.2%, thick 0.8%, sol 0.7%, substrat 0.7%, deposit 0.7%, optic 0.6%, gel 0.6%, sol.gel 0.6%, ferroelectr 0.5%, coat 0.5%, layer 0.4%, properti 0.3%, anneal 0.3%, temperatur 0.3%, structur 0.3%, tio2.thin.film 0.3%, tio2.thin 0.3%, sensor 0.3%, polar 0.3%, dielectr 0.3%, pzt.film 0.2%, measur 0.2%, grain 0.2%, 100 0.2%, fabric 0.2%, crystal 0.2% Discriminating: thin.film 16.4%, thin 12.3%, film 11.8%, pzt 1.9%, nanotub 1.0%, particl 0.9%, nanoparticl 0.8%, carbon 0.7%, quantum 0.6%, surfac 0.6%, dot 0.5%, magnet 0.5%, tio2 0.5%, ferroelectr 0.5%, electron 0.5%, sol 0.4%, sol.gel 0.4%, size 0.4%, state 0.3%, tio2.thin 0.3%, tio2.thin.film 0.3%, energi 0.3%, carbon.nanotub 0.3%, pzt.film 0.3%, gel 0.3%, two 0.3%, emiss 0.3%, quantum.dot 0.2%, singl 0.2%, temperatur 0.2% **-** focuses on thin films, emphasizing PZT films for application to high-density ferroelectric random access memory, and TiO2 films for application to high efficiency solar cells, and further emphasizing films created by the sol-gel process..

Cluster 41, Size: 587, ISim: 0.025, ESim: 0.007 Descriptive: particl 44.3%, particl.size 5.3%, size 4.9%, nanoparticl 2.1%, magnet 1.6%, distribut 0.6%, diamet 0.6%, size.distribut 0.5%, aerosol 0.4%, temperatur 0.4%, concentr 0.4%, surfac 0.4%, phase 0.4%, soot 0.3%, agglomer 0.3%, mean 0.3%, solut 0.3%, particl.size.distribut 0.3%, oxid 0.3%, iron 0.3%, model 0.2%, dispers 0.2%, composit 0.2%, particl.diamet 0.2%, primari.particl 0.2%, aggreg 0.2%, precipit 0.2%, rang 0.2%, primari 0.2%, nano 0.2% Discriminating: particl 37.7%, particl.size 4.7%, film 2.3%, size 2.1%, nanotub 0.9%, layer 0.7%, carbon 0.6%, dot 0.5%, quantum 0.5%, deposit 0.4%, aerosol 0.4%, thick 0.4%, structur 0.4%, size.distribut 0.4%, optic 0.3%, soot 0.3%, thin 0.3%, nanowir 0.3%, crystal 0.3%, state 0.3%, nanoparticl 0.3%, electron 0.3%, emiss 0.3%, substrat 0.3%, agglomer 0.3%, surfac 0.3%, carbon.nanotub 0.3%, energi 0.3%, particl.size.distribut 0.3%, thin.film 0.3% - focuses on particles, especially nanoparticles, their size distribution, and properties of particle aggregates, especially magnetic.

Cluster 42, Size: 936, ISim: 0.025, ESim: 0.007 Descriptive: film 25.9%, deposit 11.3%, substrat 2.4%, film.deposit 2.3%, thin.film 1.5%, thin 1.4%, anneal 1.2%, sputter 1.1%, temperatur 0.8%, degreesc 0.7%, amorph 0.6%, substrat.temperatur 0.6%, optic 0.5%, plasma 0.5%, deposit.film 0.5%, zno 0.5%, thick 0.5%, puls 0.5%, diamond 0.4%, silicon 0.4%, growth 0.4%, rai 0.4%, laser 0.4%, oxid 0.4%, properti 0.4%, rate 0.4%, layer 0.4%, grown 0.3%, oxygen 0.3%, high 0.3% Discriminating: film 17.9%, deposit 9.3%, film.deposit 2.6%, substrat 1.1%, nanotub 1.1%, sputter 1.0%, particl 0.9%, magnet 0.9%, nanoparticl 0.8%, thin.film 0.8%, quantum 0.7%, substrat.temperatur 0.6%, dot 0.6%, deposit.film 0.5%, field 0.5%, thin 0.5%, polym 0.5%, surfac 0.5%, state 0.4%, anneal 0.4%, size 0.4%, nanowir 0.4%, electron 0.3%, interact 0.3%, molecul 0.3%, carbon.nanotub 0.3%, model 0.3%, laser.deposit 0.3%, magnetron 0.3%, diamond 0.3% - focuses on films, especially thin films and their deposition on substrates, and parameters that affect their properties such as annealing.

Cluster 43, Size: 385, ISim: 0.024, ESim: 0.007 Descriptive: island 17.2%, growth 6.4%, surfac 3.6%, layer 2.4%, substrat 2.4%, epitaxi 1.6%, Cluster 1.6%, gan 1.4%, deposit 1.3%, atom 1.3%, grown 1.2%, 111 1.1%, film 0.9%, step 0.9%, temperatur 0.8%, nucleat 0.7%, microscopi 0.7%, coverag 0.6%, strain 0.6%, 001 0.6%, terrac 0.6%, structur 0.5%, buffer 0.5%, interfac 0.5%, scan.tunnel 0.5%, buffer.layer 0.5%, stm 0.4%, form 0.4%, disloc 0.4%, format 0.4% Discriminating: island 17.7%, growth 4.3%, epitaxi 1.3%, gan 1.0%, nanotub 0.9%, particl 0.9%, nanoparticl 0.9%, 111 0.8%, substrat 0.8%, magnet 0.8%, surfac 0.7%, Cluster 0.7%, grown 0.6%, terrac 0.6%, quantum 0.5%, coverag 0.5%, field 0.5%, laser 0.5%, polym 0.5%, film 0.5%, nucleat 0.4%, optic 0.4%, step 0.4%, 001 0.4%, buffer.layer 0.4%, buffer 0.4%, state 0.4%, dot 0.4%, emiss 0.4%, carbon 0.4% - focuses on growth of surface layers on substrates, including GaN layers, emphasizing epitaxial deposition, and the formation of islands and their parameter-dependent clustering.

Cluster 44, Size: 481, ISim: 0.023, ESim: 0.006 Descriptive: emiss 18.2%, excit 6.8%, luminesc 3.8%, fluoresc 3.2%, intens 2.1%, band 1.8%, ion 1.6%, spectra 1.5%, absorpt 1.5%, peak 1.2%, er3 1.2%, dope 1.1%, photoluminesc 1.0%, crystal 1.0%, eu3 0.8%, decai 0.8%, energi 0.8%, lifetim 0.7%, nanocryst 0.7%, state 0.7%, spectrum 0.7%, blue 0.7%, transit 0.6%, temperatur 0.6%, center 0.6%, level 0.6%, optic 0.6%, laser 0.6%, emiss.spectra 0.5%, exciton 0.5% Discriminating: emiss 13.5%, excit 4.9%, luminesc 3.0%, fluoresc 2.3%, film 1.5%, intens 1.1%, er3 1.1%, layer 0.8%, surfac 0.8%, magnet 0.8%, nanotub 0.8%, carbon 0.7%, band 0.7%, eu3 0.7%, particl 0.7%, nanoparticl 0.6%, spectra 0.6%, decai

0.5%, structur 0.5%, photoluminesc 0.5%, absorpt 0.5%, lifetim 0.5%, deposit 0.5%, size 0.5%, emiss.spectra 0.5%, dot 0.4%, phase 0.4%, oxid 0.4%, upconvers 0.4%, phosphor 0.4% - focuses on luminescent and fluorescent emissions from excited energy states, emphasizing intensity, emission and absorption spectra, emission peaks, and photoluminescence.

Cluster 45, Size: 278, ISim: 0.022, ESim: 0.005 Descriptive: protein 16.6%, bind 5.6%, peptid 4.6%, inhibitor 1.6%, acid 1.6%, activ 1.2%, receptor 1.2%, inhibit 1.0%, residu 1.0%, detect 1.0%, human 0.8%, sequenc 0.8%, calcium 0.8%, enzym 0.7%, affin 0.7%, site 0.7%, fold 0.6%, interact 0.6%, mug 0.6%, concentr 0.5%, domain 0.5%, complex 0.5%, mutant 0.5%, beta 0.5%, fluoresc 0.5%, capillari 0.5%, cell 0.4%, ion 0.4%, amino 0.4%, amino.acid 0.4% Discriminating: protein 12.2%, bind 3.7%, peptid 3.5%, film 2.0%, inhibitor 1.3%, receptor 0.9%, inhibit 0.7%, nanotub 0.7%, magnet 0.7%, temperatur 0.7%, particl 0.7%, layer 0.6%, residu 0.6%, electron 0.6%, human 0.6%, acid 0.6%, calcium 0.5%, sequenc 0.5%, affin 0.5%, deposit 0.5%, carbon 0.5%, surfac 0.5%, size 0.5%, enzym 0.5%, field 0.5%, quantum 0.5%, mug 0.4%, dot 0.4%, fold 0.4%, mutant 0.4% - focuses on detection of proteins and inhibitors, emphasizing their active binding sites.

Cluster 46, Size: 690, ISim: 0.023, ESim: 0.006 Descriptive: nanoparticl 52.3%, particl 1.4%, gold 1.3%, magnet 1.2%, size 1.2%, gold.nanoparticl 0.9%, shell 0.7%, core 0.7%, surfac 0.4%, diamet 0.4%, zno 0.4%, solut 0.4%, metal 0.4%, dispers 0.4%, drug 0.3%, synthes 0.3%, coat 0.3%, silica 0.3%, polym 0.3%, electron 0.3%, tem 0.3%, metal.nanoparticl 0.3%, rai 0.3%, electron.microscopi 0.3%, composit 0.2%, reduct 0.2%, absorpt 0.2%, stabil 0.2%, structur 0.2%, microscopi 0.2% Discriminating: nanoparticl 45.2%, film 1.9%, nanotub 0.8%, gold.nanoparticl 0.7%, layer 0.6%, gold 0.6%, dot 0.5%, carbon 0.5%, quantum 0.5%, deposit 0.4%, substrat 0.4%, shell 0.4%, field 0.4%, temperatur 0.3%, thick 0.3%, core 0.3%, crystal 0.3%, thin 0.3%, structur 0.3%, current 0.3%, surfac 0.3%, carbon.nanotub 0.3%, nanowir 0.3%, laser 0.3%, grain 0.3%, emiss 0.2%, silicon 0.2%, drug 0.2%, energi 0.2%, two 0.2% - focuses on nanoparticles, with primary emphasis divided between gold/ noble metal nanoparticle mixtures and magnetic nanoparticles in magnetic fluids, and secondary emphasis on ZnO nanoparticles. Also addresses production of nanoparticles or nanobubbles by core-shell separation.

Cluster 47, Size: 326, ISim: 0.022, ESim: 0.006 Descriptive: nanorod 6.4%, nanocryst 4.3%, product 3.4%, reaction 2.2%, synthes 2.0%, tem 1.8%, rai 1.7%, xrd 1.5%, diffract 1.5%, crystal 1.4%, electron.microscopi 1.4%, transmiss.electron 1.4%, hydrotherm 1.4%, transmiss 1.3%, transmiss.electron.microscopi 1.3%, morpholog 1.2%, zn 1.0%, cd 1.0%, microscopi 1.0%, synthesi 0.9%, diffract.xrd 0.8%, electron 0.8%, powder 0.8%, surfact 0.8%, electron.microscopi.tem 0.7%, microscopi.tem 0.7%, nanowir 0.7%, rout 0.7%, rai.diffract 0.6%, size 0.6% Discriminating: nanorod 5.5%, nanocryst 2.7%, film 2.3%, product 2.3%, hydrotherm 1.1%, tem 1.0%, synthes 0.9%, reaction 0.9%, xrd 0.9%, layer 0.8%, zn 0.8%, surfac 0.7%, cd 0.7%, magnet 0.7%, transmiss.electron 0.7%, deposit 0.6%, transmiss.electron.microscopi 0.6%, diffract.xrd 0.6%, electron.microscopi 0.5%, diffract 0.5%, rai 0.5%, solvotherm 0.5%, electron.microscopi.tem 0.5%, microscopi.tem 0.5%, dot 0.5%, transmiss 0.5%, morpholog 0.5%, substrat 0.5%, rout 0.5%, sulfid 0.5% - focuses on nanorod and nanocrystal production through chemical reaction synthesis routes, and determination of the structural properties by transmission electron microscopy and x-ray diffraction.

Cluster 48, Size: 287, ISim: 0.022, ESim: 0.006 Descriptive: particl 10.0%, colloid 4.4%, shell 3.2%, surfact 3.1%, emuls 2.4%, core 2.3%, water 1.9%, size 1.9%, polymer 1.7%, droplet 1.5%, dispers 1.1%, concentr 1.0%, sphere 1.0%, polym 1.0%, core.shell 1.0%, scatter 0.9%, stabil 0.8%, poli 0.8%, silica 0.7%, oil 0.7%, drug 0.7%, microemuls 0.6%, solut 0.6%, monom 0.6%, nanocryst 0.6%, composit 0.5%, latex 0.5%, particl.size 0.5%, magnet 0.5%, suspens 0.5% Discriminating: particl 5.0%, colloid 3.7%, shell 2.6%, emuls 2.4%, surfact 2.4%, film 2.0%, core 1.6%, droplet 1.4%, polymer 1.1%, water 1.0%, nanotub 0.9%, core.shell 0.9%, sphere 0.8%, oil 0.6%, microemuls 0.6%, drug 0.5%, quantum 0.5%, layer 0.5%, deposit 0.5%, dot 0.5%, latex 0.5%, carbon 0.5%, monom 0.5%, dispers 0.5%, surfac 0.4%, temperatur 0.4%, electron 0.4%, substrat 0.4%, state 0.4%, energi 0.4% - focuses on particles in fluids, especially colloids, typically a particle core with surfactant shell, and use of emulsions and microemulsions polymerization to generate these particles.

Cluster 49, Size: 299, ISim: 0.021, ESim: 0.006 Descriptive: nanocomposit 17.5%, polym 3.6%, composit 2.6%, fiber 2.4%, ldh 1.9%, blend 1.8%, filler 1.7%, hybrid 1.6%, matrix 1.5%, silica 1.2%, conduct 1.1%, poli 0.9%, resin 0.9%, properti 0.8%, content 0.8%, materi 0.7%, peo 0.7%, epoxi 0.7%, inorgan 0.7%, dispers 0.6%, electrolyt 0.6%, strength 0.6%, melt 0.5%, particl 0.5%, mechan 0.5%, organ 0.4%, crystal 0.4%, rubber 0.4%, poss 0.4%, thermal 0.4% Discriminating: nanocomposit 13.9%, ldh 1.7%, film 1.7%, fiber 1.6%, polym 1.5%, filler 1.5%, blend 1.4%, hybrid 1.1%, composit 1.0%, nanotub 0.7%, resin 0.7%, matrix 0.7%, surfac 0.7%, deposit 0.6%, epoxi 0.6%, peo 0.6%, quantum 0.5%, substrat 0.5%, dot 0.5%, magnet 0.5%, field 0.5%, laser 0.4%, inorgan 0.4%, silica 0.4%, layer 0.4%, electron 0.4%, electrolyt 0.4%, rubber 0.4%, poss 0.4%, energi 0.4% - focuses on nanocomposites, mainly polymer, including fiber composites as well as nanoparticles embedded in matrices.

Cluster 50, Size: 348, ISim: 0.021, ESim: 0.006 Descriptive: adsorpt 13.0%, surfac 8.5%, adsorb 7.2%, protein 6.0%, molecul 3.8%, stm 1.0%, site 0.9%, monolay 0.8%, coverag 0.8%, solut 0.7%, interact 0.7%, atom 0.7%, forc 0.6%, water 0.6%, substrat 0.6%, afm 0.5%, layer 0.5%, desorpt 0.5%, 111 0.5%, potenti 0.4%, gold 0.4%, charg 0.4%, bind 0.4%, hydrophob 0.4%, molecular 0.4%, hydrogen 0.4%, function 0.4%, model 0.4%, scan.tunnel.microscopi 0.3%, tunnel.microscopi 0.3% Discriminating: adsorpt 11.7%, adsorb 6.5%, protein 5.2%, surfac 3.6%, molecul 2.3%, film 1.7%, magnet 0.9%, nanotub 0.9%, stm 0.8%, coverag 0.6%, particl 0.6%, electron 0.6%, temperatur 0.6%, quantum 0.5%, dot 0.5%, size 0.5%, optic 0.5%, carbon 0.5%, site 0.5%, field 0.5%, emiss 0.4%, crystal 0.4%, materi 0.4%, properti 0.4%, desorpt 0.4%, laser 0.3%, nanowir 0.3%, nanoparticl 0.3%, thin 0.3%, anneal 0.3% - focuses on surface adsorption, emphasizing proteins, monolayers, and molecules, and the use of scanning tunneling microscopy to characterize the adsorption process..

Cluster 51, Size: 272, ISim: 0.021, ESim: 0.006 Descriptive: tip 13.5%, cantilev 2.5%, lithographi 2.3%, mask 1.9%, fabric 1.6%, probe 1.5%, beam 1.3%, microscop 1.2%, resolut 1.2%, field 1.2%, pattern 1.2%, scan 1.2%, forc 1.1%, imag 1.0%, devic 1.0%, stm 0.9%, electron.beam 0.8%, resist 0.7%, american 0.7%, surfac 0.7%, local 0.6%, etch 0.6%, simul 0.6%, voltag 0.5%, atom 0.5%, silicon 0.5%, system 0.5%, tunnel 0.5%, electron 0.5%, optic 0.5% Discriminating: tip 11.9%, cantilev 2.3%, film 2.0%, lithographi 2.0%, mask 1.6%, particl 0.9%, probe 0.9%, nanotub 0.9%, nanoparticl 0.8%, temperatur 0.7%, stm 0.7%, microscop 0.7%, fabric 0.7%, electron.beam 0.6%, magnet 0.6%, resolut 0.6%, carbon 0.6%, beam 0.6%, layer 0.5%, phase 0.5%, pattern 0.5%, forc 0.4%, scan 0.4%, quantum 0.4%, imag 0.4%, crystal 0.4%, polym 0.4%, deposit 0.3%, size 0.3%, structur 0.3% **-** focuses on proximal probe tip properties and dynamics, including cantilever dynamics and fabrication complexities, and the use of electron beam lithography for mask fabrication.

Cluster 52, Size: 328, ISim: 0.020, ESim: 0.006 Descriptive: optic 11.7%, photon 7.2%, wavelength 2.9%, nonlinear 2.9%, photon.crystal 2.3%, refract 2.2%, light 2.2%, index 1.6%, crystal 1.5%, reflect 1.4%, refract.index 1.2%, mirror 0.9%, beam 0.9%, field 0.9%, measur 0.7%, america 0.7%, polar 0.6%, absorpt 0.5%, caviti 0.5%, two 0.4%, wave 0.4%, intens 0.4%, coeffici 0.4%, laser 0.4%, signal 0.4%, fibr 0.4%, imag 0.4%, microcav 0.4%, detector 0.4%, incid 0.4% Discriminating: optic 7.6%, photon 5.9%, nonlinear 2.3%, photon.crystal 2.2%, refract 1.9%, wavelength 1.8%, film 1.7%, index 1.2%, light 1.1%, refract.index 1.0%, nanotub 0.8%, mirror 0.8%, reflect 0.8%, particl 0.8%, magnet 0.8%, nanoparticl 0.7%, carbon 0.7%, electron 0.6%, temperatur 0.6%, america 0.6%, surfac 0.5%, deposit 0.5%, dot 0.5%, size 0.4%, oxid 0.4%, quantum 0.4%, ion 0.4%, beam 0.3%, photon.band 0.3%, fibr 0.3% **-** focuses on optics, especially nonlinear optical materials, and material refractive indices, especially for photonic crystals.

Cluster 53, Size: 292, ISim: 0.020, ESim: 0.006 Descriptive: state 5.9%, excit 5.3%, energi 5.0%, Cluster 3.5%, calcul 1.9%, dissoci 1.7%, spectra 1.6%, electron 1.5%, excit.state 1.3%, absorpt 1.2%, molecul 1.0%, transfer 1.0%, vibrat 0.8%, transit 0.8%, sigma 0.7%, photon 0.7%, photodissoci 0.7%, bond 0.7%, two 0.7%, atom 0.7%, radic 0.6%, band 0.6%, time 0.5%, ground 0.5%, initio 0.5%, fragment 0.5%, distribut 0.5%, experiment 0.5%, porphyrin 0.5%, molecular 0.4% Discriminating: excit 3.8%, state 3.3%, film 2.5%, energi 2.4%, Cluster 2.0%, dissoci 1.5%, calcul 1.2%, excit.state 1.1%, layer 1.0%, particl 1.0%, magnet 0.9%, nanoparticl 0.8%, nanotub 0.8%, photodissoci 0.7%, temperatur 0.7%, spectra 0.6%, deposit 0.6%, sigma 0.6%, carbon 0.6%, vibrat 0.6%, size 0.5%, dot 0.5%, transfer 0.5%, radic 0.5%, phase 0.5%, thick 0.5%, substrat 0.5%, initio 0.4%, oxid 0.4%, fragment 0.4% **-** focuses on molecular dynamics, emphasizing calculations of excited state energies, dissociation spectra, molecular energy transfer, electron vibrational energy and transitions, photon energy absorbtion, and molecular bonds.

Cluster 54, Size: 420, ISim: 0.020, ESim: 0.006 Descriptive: wire 17.1%, quantum 3.2%, quantum.wire 2.3%, state 2.1%, electron 1.8%, energi 1.7%, calcul 1.6%, conduct 1.6%, dimension 1.5%, system 1.2%, function 1.2%, potenti 1.0%, densiti 0.9%, transport 0.9%, on 0.9%, theori 0.9%, interact 0.9%, field 0.8%, model 0.8%, on.dimension 0.8%, two 0.8%, nanowir 0.6%, molecular 0.6%, current 0.6%, impur 0.5%, strain 0.5%, charg 0.5%, local 0.5%, oscil 0.4%, structur 0.4% Discriminating: wire 15.9%, film 2.5%, quantum.wire 2.2%, quantum 1.2%, calcul 0.9%, nanoparticl 0.8%, surfac 0.8%, dimension 0.8%, layer 0.8%, nanotub 0.7%, deposit 0.7%, state 0.7%, on.dimension 0.6%, carbon 0.6%, oxid 0.6%, particl 0.6%, conduct 0.6%, crystal 0.5%, theori 0.5%, laser 0.5%, transport 0.4%, ion 0.4%, molecular.wire 0.4%, optic 0.4%, polym 0.4%, substrat 0.4%, magnet 0.4%, sampl 0.4%, emiss 0.4%, rai 0.4% - focuses on quantum wires, emphasizing energy states, and electrical conductivity and transport in one dimensional systems.

Cluster 55, Size: 393, ISim: 0.020, ESim: 0.006 Descriptive: etch 15.8%, surfac 4.4%, pattern 3.4%, forc 2.2%, silicon 1.9%, rough 1.8%, afm 1.5%, resist 1.5%, deposit 1.5%, plasma 1.3%, mask 1.2%, atom.forc 1.1%, atom 1.1%, film 0.9%, tip 0.9%, substrat 0.9%, forc.microscopi 0.8%, layer 0.8%, contact 0.7%, microscopi 0.7%, fabric 0.6%, atom.forc.microscopi 0.6%, wafer 0.6%, lithographi 0.6%, chemic 0.6%, diamond 0.6%, surfac.rough 0.5%, etch.rate 0.5%, beam 0.4%, imprint 0.4% Discriminating: etch 16.2%, pattern 2.4%, rough 1.5%, forc 1.4%, surfac 1.1%, mask 1.1%, afm 1.1%, nanotub 1.0%, particl 0.9%, nanoparticl 0.9%, magnet 0.8%, silicon 0.8%, atom.forc 0.8%, plasma 0.8%, resist 0.8%, quantum 0.6%, forc.microscopi 0.5%, etch.rate 0.5%, surfac.rough 0.5%, tip 0.5%, temperatur 0.5%, state 0.5%, film 0.5%, lithographi 0.5%, dot 0.4%, wafer 0.4%, crystal 0.4%, imprint 0.4%, field 0.4%, atom.forc.microscopi 0.4% - focuses on etching of surface patterns, especially silicon-based films or crystals/ wafers, and the relationship, and control, of surface roughness to increase etching resolution. Also focuses on AFM for both measuring surface roughness and wear, as well as performing the etching process.

Cluster 56, Size: 753, ISim: 0.020, ESim: 0.007 Descriptive: film 41.9%, thick 5.3%, film.thick 3.6%, substrat 1.3%, layer 1.1%, thin 1.0%, magnet 0.7%, surfac 0.6%, thin.film 0.6%, thick.film 0.5%, measur 0.5%, deposit 0.4%, multilay 0.4%, dielectr 0.4%, structur 0.4%, temperatur 0.4%, properti 0.4%, conduct 0.4%, multilay.film 0.3%, orient 0.3%, polym 0.3%, ultrathin 0.3%, optic 0.3%, order 0.3%, growth 0.2%, domain 0.2%, solut 0.2%, decreas 0.2%, coerciv 0.2%, rang 0.2% Discriminating: film 35.3%, film.thick 4.1%, thick 4.0%, nanotub 1.1%, particl 0.8%, carbon 0.8%, nanoparticl 0.8%, quantum 0.7%, dot 0.7%, thick.film 0.6%, electron 0.5%, size 0.4%, energi 0.4%, ion 0.4%, multilay.film 0.4%, emiss 0.4%, state 0.4%, nanowir 0.3%, carbon.nanotub 0.3%, laser 0.3%, quantum.dot 0.3%, substrat 0.3%, oxid 0.3%, thin 0.3%, powder 0.3%, crystal 0.2%, sampl 0.2%, ultrathin 0.2%, field 0.2%, two 0.2% - focuses on films, both thick and thin, and the variation of properties with fim thickness, especially magnetic and dielectric properties.

Cluster 57, Size: 499, ISim: 0.018, ESim: 0.006 Descriptive: powder 13.8%, particl 2.3%, precursor 2.2%, gel 2.0%, materi 1.7%, size 1.7%, calcin 1.5%, reaction 1.3%, sol 1.1%, degreesc 1.1%, phase 1.1%, particl.size 1.0%, oxid 1.0%, synthes 1.0%, xrd 1.0%, temperatur 1.0%, surfac.area 0.9%, rai 0.9%, diffract 0.8%, synthesi 0.8%, area 0.7%, sol.gel 0.7%, rai.diffract 0.6%, nitrat 0.6%, capac 0.6%, solut 0.6%, sampl 0.6%, nano 0.5%, product 0.5%, solid 0.5% Discriminating: powder 12.2%, film 2.7%, precursor 1.6%, gel 1.5%, calcin 1.3%, layer 0.9%, sol 0.8%, nanotub 0.8%, surfac.area 0.7%, deposit 0.6%, particl.size 0.6%, field 0.6%, quantum 0.6%, magnet 0.6%, dot 0.6%, xrd 0.6%, substrat 0.6%, nitrat 0.5%, optic 0.5%, sol.gel 0.5%, thick 0.5%, materi 0.5%, laser 0.5%, reaction 0.5%, capac 0.4%, synthesi 0.4%, thin 0.4%, surfac 0.4%, nanowir 0.4%, nanoparticl 0.4% p focuses on powders, emphasizing sol-gel synthesis processes with different precursors for optimal growth, and parameterizing the effect of temperature on growth during the calcination process.

Cluster 58, Size: 473, ISim: 0.019, ESim: 0.007 Descriptive: layer 15.3%, oxid 6.7%, sio2 4.0%, thick 3.4%, coat 2.8%, deposit 2.4%, silicon 2.4%, interfac 1.6%, multilay 1.4%, anneal 1.4%, layer.thick 0.9%, diffus 0.9%, substrat 0.9%, oxid.layer 0.8%, tin 0.7%, surfac 0.7%, plasma 0.7%, degreesc 0.7%, structur 0.6%, film 0.6%, oxygen 0.6%, sampl 0.5%, temperatur 0.5%, thin 0.4%, spectroscopi 0.4%, rai 0.4%, sputter 0.4%, hfo2 0.4%, thermal 0.4%, high 0.4% Discriminating: layer 11.6%, oxid 4.5%, sio2 3.5%, thick 1.9%, coat 1.9%, silicon 1.4%, nanotub 1.1%, multilay 1.1%, interfac 1.0%, nanoparticl 1.0%, layer.thick 0.9%, oxid.layer 0.9%, film 0.9%, particl 0.8%, deposit 0.8%, magnet 0.7%, quantum 0.6%, dot 0.6%, size 0.6%, tin 0.6%, anneal 0.5%, field 0.5%, carbon 0.5%, diffus 0.5%, hfo2 0.5%, crystal 0.4%, phase 0.4%, polym 0.4%, nanowir 0.4%, emiss 0.4% - focuses on layers, especially multi-layer oxides/ SiO2 on silicon-based substrates, emphasizing thick layers/ coatings, factors affecting their deposition, and characterization of their interface properties.

Cluster 59, Size: 383, ISim: 0.018, ESim: 0.006 Descriptive: band 8.2%, absorpt 4.2%, raman 3.0%, spectra 2.9%, optic 2.7%, gap 1.9%, phonon 1.9%, excit 1.6%, plasmon 1.6%, reson 1.5%, scatter 1.5%, mode 1.5%, peak 1.4%, spectral 1.2%, shift 1.2%, band.gap 1.0%, frequenc 0.9%, energi 0.9%, wavelength 0.8%, surfac 0.7%, field 0.7%, surfac.plasmon 0.7%, light 0.6%, intens 0.6%, region 0.5%, transit 0.5%, vibrat 0.5%, depend 0.5%, local 0.5%, electron 0.4% Discriminating: band 7.0%, absorpt 3.0%, raman 2.4%, spectra 1.9%, phonon 1.7%, film 1.6%, plasmon 1.6%, gap 1.5%, optic 1.1%, nanotub 1.0%, magnet 1.0%, reson 1.0%, spectral 0.9%, band.gap 0.9%, excit 0.9%, scatter 0.9%, mode 0.9%, shift 0.7%, surfac.plasmon 0.6%, carbon 0.6%, layer 0.6%, peak 0.6%, deposit 0.6%, dot 0.6%, particl 0.5%, frequenc 0.4%, oxid 0.4%, polariton 0.4%, structur 0.4%, growth 0.4% - focuses on radiation interaction with nanomaterials, emphasizing spectral bands, absorption bands, band gaps, especially at Raman and optical frequencies.

Cluster 60, Size: 456, ISim: 0.016, ESim: 0.005 Descriptive: complex 12.4%, ligand 6.3%, bond 3.6%, compound 2.9%, group 2.4%, Cluster 1.9%, hydrogen 1.4%, hydrogen.bond 1.3%, metal 1.0%, coordin 1.0%, bi 0.9%, iii 0.9%, structur 0.9%, molecul 0.8%, reaction 0.8%, ion 0.7%, nmr 0.6%, two 0.6%, form 0.6%, atom 0.5%, bpy 0.5%, h2o 0.5%, acid 0.5%, interact 0.5%, bridg 0.4%, speci 0.4%, angstrom 0.4%, site 0.4%, cation 0.4%, molecular 0.4% Discriminating: complex 9.6%, ligand 5.4%, bond 2.3%, compound 1.9%, film 1.9%, group 1.3%, hydrogen.bond 1.1%, particl 0.9%, nanotub 0.8%, Cluster 0.8%, coordin 0.7%, magnet 0.7%, bi 0.7%, deposit 0.6%, nanoparticl 0.6%, iii 0.6%, hydrogen 0.6%, layer 0.6%, surfac 0.5%, field 0.5%, carbon 0.5%, temperatur 0.5%, dot 0.5%, size 0.5%, quantum 0.5%, nmr 0.4%, thick 0.4%, bpy 0.4%, measur 0.3%, sampl 0.3% - focuses on the bonds and ligands among groups in complexes and compounds, with some emphasis on hydrogen bonds.

Cluster 61, Size: 431, ISim: 0.017, ESim: 0.006 Descriptive: phase 8.6%, anneal 3.4%, temperatur 2.7%, degreesc 2.4%, crystal 2.3%, sampl 1.9%, implant 1.8%, amorph 1.7%, nanocryst 1.5%, glass 1.4%, precipit 1.1%, Cluster 1.1%, diffract 1.1%, rai 1.1%, size 0.9%, pressur 0.9%, heat 0.9%, structur 0.8%, transit 0.7%, powder 0.7%, transform 0.7%, crystallit 0.6%, high 0.6%, defect 0.6%, tetragon 0.6%, electron 0.6%, rai.diffract 0.6%, sic 0.6%, electron.microscopi 0.6%, lattic 0.5% Discriminating: phase 6.2%, film 2.6%, anneal 2.4%, implant 1.7%, degreesc 1.5%, amorph 1.1%, nanotub 1.1%, precipit 0.9%, nanocryst 0.9%, glass 0.9%, surfac 0.9%, magnet 0.8%, crystal 0.8%, nanoparticl 0.7%, quantum 0.7%, particl 0.7%, sampl 0.6%, dot 0.6%, layer 0.6%, temperatur 0.6%, tetragon 0.6%, deposit 0.5%, polym 0.5%, crystallit 0.5%, substrat 0.5%, phase.transit 0.5%, pressur 0.4%, diffract 0.4%, nanowir 0.4%, field 0.4% - focuses on nanomaterial structures with emphasis on implants, emphasizing phases of crystals and amorphous materials, and especially their variation with thermal factors, such as annealing, growth, implantation, and synthesis temperatures.

Cluster 62, Size: 534, ISim: 0.016, ESim: 0.006 Descriptive: polym 20.4%, chain 2.9%, poli 2.6%, polymer 1.6%, water 1.4%, molecular 1.4%, aggreg 1.3%, weight 1.0%, group 1.0%, molecular.weight 0.9%, acid 0.9%, solut 0.8%, monom 0.7%, solvent 0.7%, organ 0.7%, graft 0.6%, surfac 0.6%, self 0.6%, film 0.5%, molecul 0.5%, form 0.5%, structur 0.4%, concentr 0.4%, side 0.4%, liquid 0.4%, interact 0.4%, phase 0.4%, layer 0.4%, assembl 0.3%, system 0.3% Discriminating: polym 19.6%, chain 2.4%, poli 2.0%, polymer 1.2%, aggreg 1.0%, magnet 1.0%, nanotub 1.0%, weight 0.9%, film 0.9%, molecular.weight 0.9%, particl 0.8%, electron 0.7%, water 0.7%, monom 0.7%, carbon 0.6%, molecular 0.6%, dot 0.6%, deposit 0.6%, quantum 0.6%, graft 0.6%, nanoparticl 0.5%, field 0.5%, size 0.5%, oxid 0.4%, group 0.4%, solvent 0.4%, energi 0.4%, temperatur 0.4%, acid 0.3%, side 0.3% - focuses on polymers, especially on the molecular chain structures, and the structures and molcular weights of polymer aggregates in solution, especially water-based.

Cluster 63, Size: 449, ISim: 0.016, ESim: 0.006 Descriptive: current 4.9%, field 4.2%, voltag 4.1%, electr 3.2%, emiss 2.3%, devic 2.1%, conduct 1.7%, electr.field 1.5%, charg 1.5%, electron 1.4%, nanowir 1.3%, junction 1.1%, transport 1.0%, field.emiss 0.9%, bia 0.8%, molecul 0.7%, metal 0.7%, layer 0.7%, characterist 0.7%, silicon 0.6%, contact 0.6%, densiti 0.6%, model 0.6%, trap 0.6%, current.voltag 0.5%, tunnel 0.5%, carrier 0.5%, film 0.5%, state 0.5%, molecular 0.5% Discriminating: current 4.1%, voltag 3.8%, electr 2.7%, field 2.4%, electr.field 1.6%, devic 1.2%, film 1.1%, magnet 1.1%, nanotub 1.1%, nanoparticl 1.1%, emiss 1.1%, junction 1.1%, particl 1.0%, field.emiss 0.9%, conduct 0.8%, charg 0.8%, bia 0.7%, transport 0.6%, size 0.6%, dot 0.6%, current.voltag 0.6%, phase 0.6%, carbon 0.5%, surfac 0.5%, crystal 0.5%, nanowir 0.5%, trap 0.5%, rai 0.4%, optic 0.4%, capacit 0.4% - focuses on electrical properties and characteristics of nanomaterial structures, including voltage-current plots, electric fields, field emission, electrical conductivity, and electronic devices.