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Mapping Nanotechnology Research and Innovation in India

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ABSTRACT

Nanotechnology has generated a great deal of excitement world-wide and is being cited as the key technology of the 21st century. Nanotechnology provides a window of opportunities for countries like India that tends to address developmental problems and forge economic growth through technological intervention. Emerging technology such as nanotechnology provides a level playing field as even advanced OECD economies are developing competency in this technology. From 2001 onwards, Government of India has given special attention to this area. The present study examines, through bibliometric and other innovation indicators (standards, products/processes developed), the present state of development of nanotechnology research and innovation in India. These findings are discussed in the context of China's activity in this field.

Keywords: Nanotechnology, bibliometric analysis, india, linkage analysis, product-processes

1. INTRODUCTION

Nanotechnology has generated a great deal of excitement world-wide and is being cited as the key technology of the 21st century. Nanotechnology is not a discreet technology or an industry sector. It simply refers to a range of technologies that operates at the nano-scale (roughly 1-100 nanometers, one nanometer is 10^{-9} m). Novel properties manifest at the nano scale which make this technology so exiting. Nanotechnology is already addressing key economic sectors, namely, materials and manufacturing (coatings and composites for products like automobiles and buildings), information and communication technology (ICT) and electronics (displays, chips, photonics, batteries), health and fitness, food and beverages, and life sciences (pharmaceutical applications).

Nano-applications can provide solutions in areas that are of pressing concerns in developing and improvised economies, i.e., environment, water purification, agriculture, energy, and in a host of other products and services. Nanotechnology provides a window of opportunities for countries like India that tends to address developmental problems and forge economic growth through technological intervention. Emerging technology such as nanotechnology provides a level playing field as even leaders are also developing their competency.

From 2001 onwards, Government of India has given special attention to this area. Nanotechnology was launched as a mission mode programme in the Xth Five Year Plan (2002-2007); programme termed as NSTI (Nanoscience and Technology Initiative) with an allocation of Rs 60 crore. In 2007, this programme was upgraded with another major initiative known as 'Nano Mission' with a budgetary allocation of Rs. 1000 crore for 5 years. These programmes intend to create necessary innovation climate for nanotechnology in India[1]. At this juncture when the mission mode programme is to complete its period soon, it is important to evaluate as to what extent governments stimulation has led to creation of capacity and capability, and development of applications. The present study attempts to evaluate the development of this field in India using bibliometric (publication and patents) and other innovation indicators (standards, products/processes developed). In this paper, it is argued that multiple applications of indicators can show the contemporary status of nanotechnology development in India.

Developing innovation capability/competency is an immense challenge in nanotechnology as it is an emergent science-based area having idiosyncratic characteristics and complexity, requiring development of competitive R&D infrastructure, significant R&D investment, skilled manpower having inter-disciplinary competence, access/development of sophisticated instruments, entrepreneurship, and requiring synergy among divergent set of stakeholders. There have been an increasing number of studies to uncover the developing scenario of this field using bibliometric methods. Four major strands of research have occurred in nanotechnology-based bibliometric studies, namely, who is winning the nanotechnology race?; examining to what extent the field is interdisciplinary? to what nanotechnology is becoming path-dependent; and whether nanoscience and nanotechnology are closely interlinked[2]?. Among the influential contributions in this area have been the works of Kostoff[3], *et al*.; Meyer[4,5], *et al*.; Glanel[6], *et al*. and Leydesdorff[7]. Another important line of research has been to 'properly' delineate the research field, to reduce noise and capture the research papers and patents that define the field. This is a challenging area of work as nanotechnology is interdisciplinary in nature, evolving rapidly and the contours of the field are changing very fast. Key contributions in this area are by Noyons[8], *et al*.; Porter[9], *et al*.; Kostoff[10], *et al*.; and Mogoutov[11], *et al*.

A drawback of the majority of bibliometric studies has been the reluctance to capture indications from other key indicators that can provide a more complete picture of the contemporary status of this field. The present study attempts to fill this gap by applying bibliometric and other innovation indicators to capture the dynamics and development of nanotechnology in a more informed manner.

2. METHODOLOGY

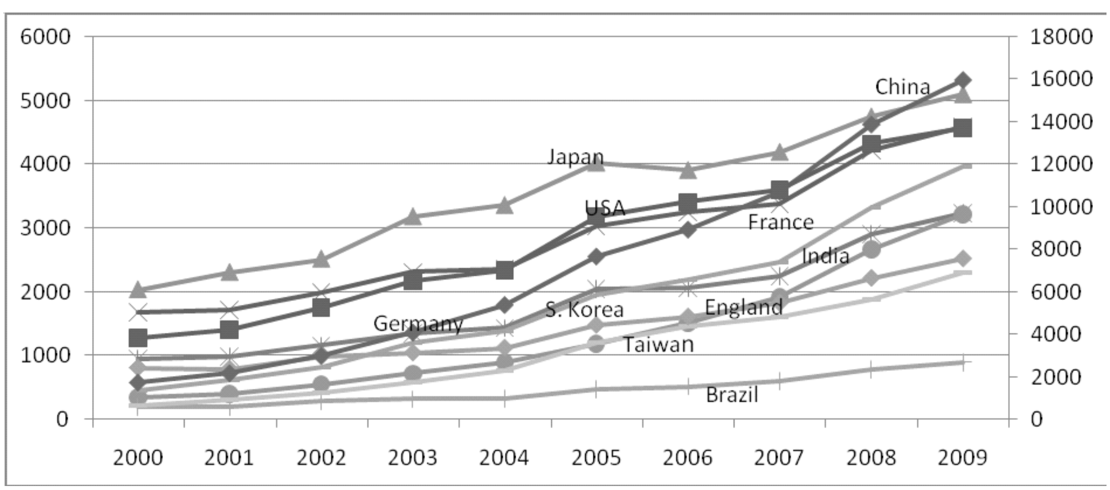
The present study is based on capturing data from varied secondary sources. *Web of Sciences*' *Science Citation Index-Expanded (SCI-E*) and data of US Patent Office accessed from Delphion Patent Database was used for capturing publication and patent data. Indian domestic patents were captured from *India.bigpatents.com.* Publication activity provides good indication of innovative capability in knowledge-intensive areas as evolution is contingent on strong interaction with scientific research. Not all products are patented and not all patents yield products. However, patenting activity demonstrates the inventive ability of a firm or a country and a possible indication of creating future novel products particularly applicable to knowledge-intense areas such as nanotechnology. In addition, involvement of various actors and linkages among them can be revealed through bibliometric indicators.

For an emerging technology, the standard setting is a key strategy as it can shape future market for domestic firms if the technical standards created by a country are adopted internationally. For a country with a large domestic market, the technical standards created by it in a particular product class can also become a useful strategy for dominating internal market and can influence the future adoption of that standard internationally. Standards being developed were delineated from metrology activity of BIS, NPL, etc. Products/processes developed provide the final indication of a countries)/ firm(s) ability to assert in a particular technology. Indian Business Insight Database (newspaper clipping service), annual reports, etc. were used to capture the application development.

3. FINDINGS

3.1 Publication Analysis

From 2000-2009, India published 13,366 papers out of which 24 per cent of the publication emerged in 2009. Figure 1 exhibits publication activity of advanced OECD and major emerging economies. One can note that China



Source: Constructed from Web of Science

Figure 1. Publication activity of key advanced OECD and emerging economies (Right axis: China, USA; Left axis: Japan, France, India, England, Taiwan, Brazil, Germany, S. Korea).

has emerged as the leading country in the publishing race. India is much behind the leaders, but is among the top 10 countries publishing in this field. Figure 2 shows some of the emerging Asian economies which are developing the scientific capacity.

Figure 2 highlights the strong progress of Iran and Singapore. Nanotechnology is frontier, highly science-intensive area and thus publications provide a good indication of emerging economies presence which was earlier hegemony of only advanced OECD countries.

Nanotechnology, being an interdisciplinary area of research, it is important to know which of the research fields within nanotechnology, India is most active in terms of publishing. Comparison with India's overall publications makes a more informed assessment as it helps indicate to what extent India's strength in a subject field finds reflection in activity within nanotechnology.

Strong mismatch with overall publication profile would show that India is not properly strategising its scientific strength in addressing an emerging frontier research area. Figures 3 and 4 highlight two aspects: India'sprolific areas of research and research areas within nanotechnology where Indian researchers exhibit maximum activity.

Material science, physics, and chemistry are the three dominant areas of India's research. It is observed that within nanotechnology, these three areas also have strong focus. Computer science, agriculture, and pharmacology (pharmacy) are also areas where publication activity is increasing. These areas are also important within nanotechnology. However, It is found that these are not major areas of research activity within nanotechnology field. Journals also provide an indication of cross-fertilisation of researchers from different research fields. India's dominant publishing activity, as reflected through journal-type, shows major concentration in applied physics, material science, chemistry and polymer science. Table 1 also shows some of the publications are in high impact factor (IF) journals. Among high IF journals, Indian researchers have published 232 papers in the journal *Nanotechnology* (IF-10.03), 249 papers in *Journal of Physical Chemistry C* (IF-4.22), 243 papers in *Physics Review B* (IF-3.47) during the period 2000-09. Table 2 highlights activity of institutions that exhibit prolific activities in overall period 2000-09.

Institutions of prolific activity are reputed academic institutions and research laboratories (mainly laboratories of CSIR). Indian Institute of Science with 1004 publications during 2000-09 exhibits maximum activity followed by IIT Khargapur (830 papers), CSIR-National Chemical Laboratory (734 papers), and Indian Association of Cultivation of Science (734 papers). National Physical Laboratory, CSIR and National Chemical Laboratory, CSIR exhibited high degree of collaboration intensity of 12.78 and 10.48. Among the prolific institutions, Indian Association for the Cultivation of Science and National Chemical Laboratory, CSIR showed highest growth, relative growth rate of 3.62 and 2.86. Figure 5 highlights linkages among prolific institutions in 2009. Institutional linkages are developing from sparse network (2001) towards a more connected network in 2009. Cluster formation has strong bearing on geographical location. This formation may be due to sharing of sophisticated capital-intensive instruments that are prerequisite for nanotechnology research.

Table 1. Journals in which Indian researchers are actively publishing in Nanotechnology (2000-2009)

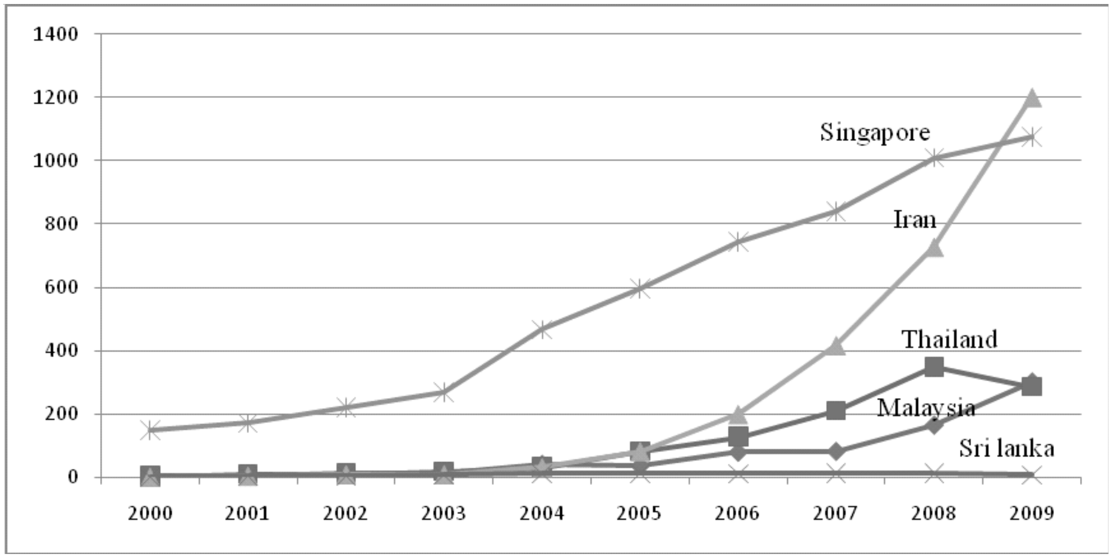
Journal	Publication count	Impact factor (IF)
Journal of Nananoscience and Nanotechnology	482	1.44
Journal of Applied Physics	353	2.07
Applied Physics Letters	278	3.55
Material Letters	256	1.94
Journal of Physical Chemistry C	249	4.22
Physical Review B	243	3.47
Nanotechnology	232	10.03
Applied Surface Sciences	182	1.61
Material Chemistry and Physics	181	1.80
Journal of Applied Polymer Science	179	1.19

Source: Constructed from Science Citation Index

Table 2. Activity of prolific Indian institutes in nanotechnology

Institute	No. of papers	Collaborative papers (Intensity)	Growth (RGR)*
Indian Institute of Science, Bengaluru	1004	170 (5.9)	3.54
Indian Institute of Technology, Kharagpur	830	136 (6.10)	1.35
National Chemical Laboratory	734	70 (10.48)	2.86
Indian Association of Cultivation of Science	734	112 (6.55)	3.62
Bhabha Atomic Research Centre	660	172 (3.83)	2.23
Indian Institute of Technology, Madras	483	76 (6.35)	1.14
Indian Institute of Technology, Delhi	415	85 (4.88)	1.66
National Physical Laboratory	409	32 (12.78)	2.04

**RGR (Relative Growth Rate)= [(Ln(Y)-Ln(X))/(Y-X)]*100 (2000 to 2009 change)*



Source: Constructed from SCI-E

Figure 2. Emerging Asian countries making progress in nanotechnology.

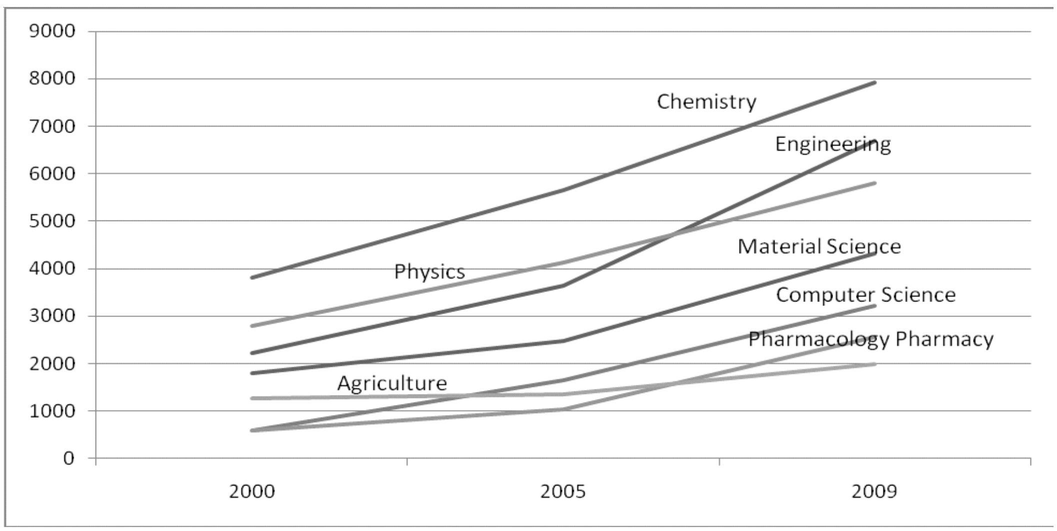


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Figure 3. Areas in which Indian researchers are most prolific.

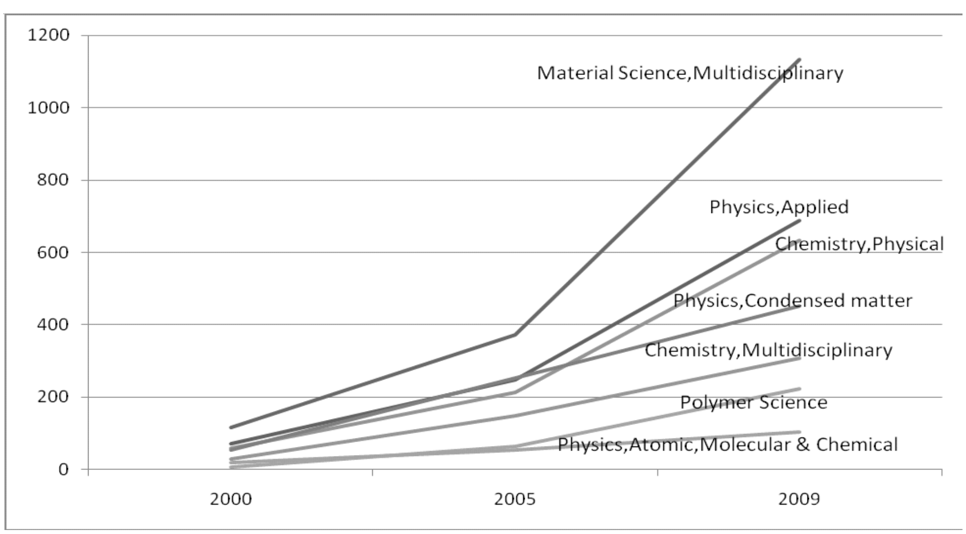

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Figure 4. Areas within nanotechnology in which Indian researchers are actively publishing.

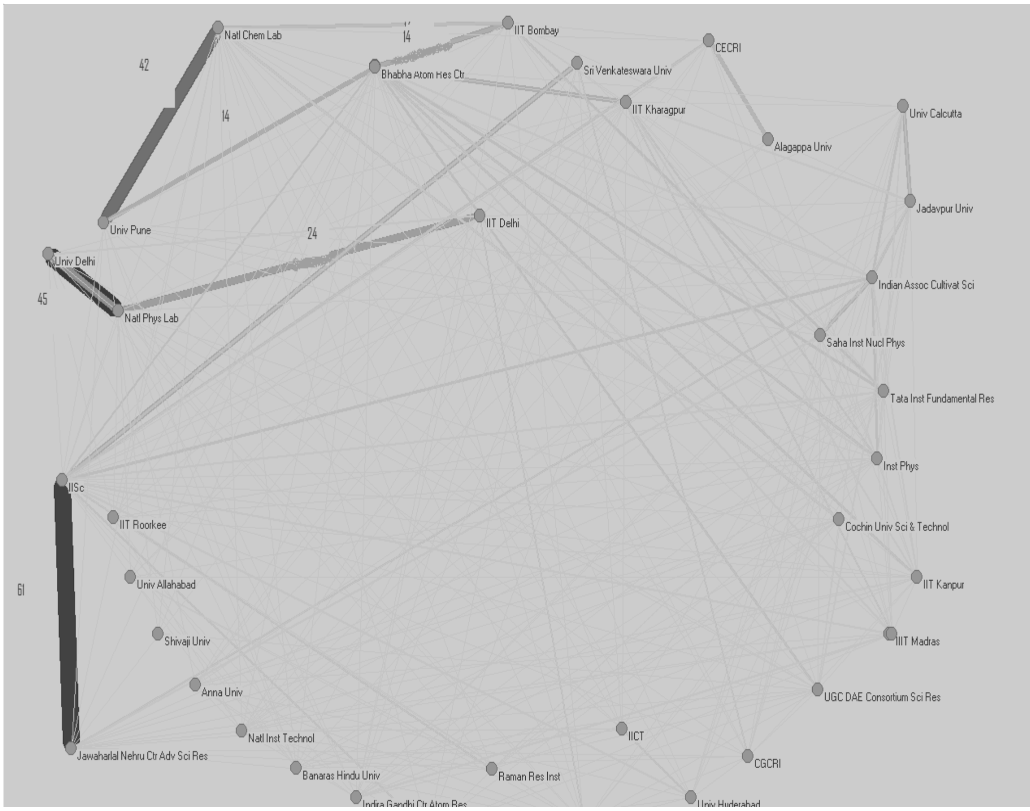

Figure 5. Linkages among prolific institutions (2009).

3.2 Keywords Analysis

Keywords delineate each research article and provide signal to others of the key aspects that form the core of the said article[12]. In patents, classifications provide insight of the technology class in which the patent belongs. This is useful, but for emerging technology where field of evolution is fast, keywords extracted from patent title and/or abstract can provide a more current delineation. In the present exercise, we have extracted conceptual words from patent topics. Table 3 highlights the prominent keywords visible in publications and patents. Key patent terms are metrology, i.e., measurement aspect (nm), and nanoparticles. Nanostructured materials of different types are gaining prominence in scientific research papers.

Figure 6 further highlights the linkages among keywords in scientific papers published by India in 2009. Keywords linkage analysis provides insight to the sophistication of research in this field. In 2000, keywords indicated only basic level of research activity. Material characterisation (mainly in electrical/optical properties) was the main area of activity. Nanoparticle of titanium oxide and formation of new particles were visible. In 2005, use of more sophisticated instruments like AFM

Table 3. Comparative profile of key terms in nanotechnology (patents and publications) (2000-2009)

Keywords	Patent (US-granted)		No. of publications *(SCI-E)*	
	World	India	World	India
Nanometer*	29899	18	24646	1766
Nanoparticle*	2630	13	>100000	957
Nanostructure*	2246	0	55286	331
Nanotub*	2114	2	61928	283
Nanocrystal*	1915	3	57337	591
Nanotechnology*	1386	0	10999	43
Nanocomposite*	1069	1	34263	320
Nanowire*	950	0	29836	143
Nanomaterial*	346	0	9514	83
Nanofiber*	330	0	9317	49
Nanosphere*	314	3	5313	36
Nanocluster*	258	0	7480	55
Nanorod*	219	0	13655	132

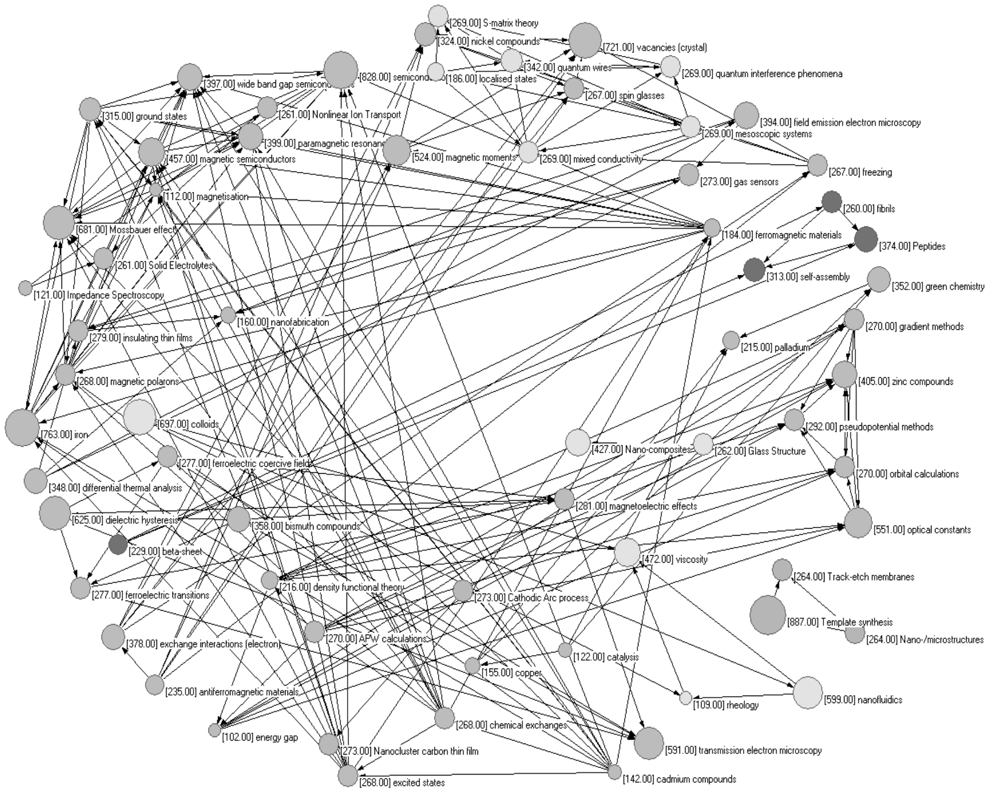

Figure 6. Linkage among active keywords (2009).

Table 4. Top 1 per cent cited papers in different time periods

	2000				2005				2009		
Country	**Output**	**No of papers that were in top 1% cited**	**Ratio of paper wrt output**	**Country**	**Output**	**No of papers that were in top 1% cited**	**Ratio of papers wrt output**	**Country**	**Output**	**No of papers that were in top 1% cited**	**Ratio of papers wrt output**
USA	3344	68	0.42	USA	10453	155	1.48	USA	13553	257	1.90
Germany	1388	9	0.65	Germany	2845	35	1.23	China	14329	132	0.92
Japan	1661	7	0.42	China	6512	30	0.46	Germany	4298	103	2.40
Switzerland	266	5	1.88	Japan	3740	19	0.51	England	2327	53	2.28
England	561	4	0.71	France	1975	18	0.91	France	2977	51	1.71
China	1314	3	0.23	England	1283	15	1.17	South Korea	3787	48	1.27
France	834	3	0.36	Italy	1031	15	1.46	Japan	4743	44	0.93
Netherlands	182	3	1.69	Switzerland	508	9	1.77	Australia	1191	36	3.02
Italy	334	2	0.60	South Korea	1894	8	0.42	Singa-pore	1062	35	3.30
Israel	175	2	1.14	Canada	792	8	1.01	Switzer land	929	31	3.34
South korea	320	2	0.63	Australia	542	8	1.48	Spain	1854	30	1.62
Canada	238	1	0.42	Singapore	598	7	1.17	Netherlands	755	27	3.58
Russia	629	1	0.16	Netherlands	472	7	1.48	India	3086	26	0.84

(atomic force microscope), FTIR (Fourier transform infrared spectroscopy) were observed. Some applications were also visible in drug delivery applications, and alternate energy applications. To what extent Indian researchers papers are attracting visibility is examined through top 1 per cent cited papers in this filed (Table 4).

Only 3 papers were among the top 1 per cent cited papers in 2003, and 6 papers in 2005. In 2009, India made its presence more visible with 26 of its papers among the top 1 per cent cited papers in nanotechnology (Table 5). However, wrt total output, number of Indian researchers papers in top 1 per cent cited papers is low in comparison to ratio of majority of active countries.

Figure 7 illustrates the top 1 per cent cited papers that were outcome of collaborations. Among the 26 papers, 65 per cent of papers (17) were collaborative papers. Thus, collaboration is playing an important role in papers getting high degree of visibility. It is observed that foreign organisations were also involved in collaborative linkages.

Table 5 highlights the no. of citations that Indian researchers papers have received. The above data shows that there is an absolute increase in papers as well as citations over the years. Citation reception is to an extent a function of time, i.e., dates of publication. So keeping this in contention, Indian researchers papers in later years seem to capture attention more quickly, i.e., receiving citation (on an average) in a short period after publication. More detailed analysis will however clarify this picture further.

3.3 Pattern of Authorship

Science is no longer a matter of individuals. Most of the big projects are completed in groups. Thus, it is necessary to study collaborative intensity of authors (Table 6).Table 6 shows that multi-authorship is the dominant feature of Indian publication activity. As nanotechnology research is a laboratory-intensive activity, so it is natural to find multi-authorship pattern. This pattern is significantly increasing from 2000 possibly implying more experimental then theoretical research.

Table 5. Citation analysis of nanotechnology papers by Indian researchers

Year	Total publications	Total citations	Citations per paper
2000	246	8748	35.56
2001	401	10512	26.21
2002	472	10627	22.51
2003	624	14004	22.44
2004	922	17024	18.46
2005	1104	16214	14.69
2006	1501	17888	11.92
2007	1757	16556	9.42
2008	3193	20707	6.49
2009	3450	13354	3.87

Table 6. Collaboration intensity

	Share of publications		
Year	Single Author	Two Authors	Multi-authors
2000	13 (5.28)	60 (24.39)	173 (70.33)
2001	18 (4.49)	92 (22.94)	291 (72.57)
2002	27 (5.72)	103 (21.82)	342 (72.46)
2003	32 (5.13)	141 (22.60)	451 (72.28)
2004	38 (4.11)	203 (21.95)	684 (73.95)
2005	51 (4.55)	225 (20.05)	846 (75.40)
2006	54 (3.43)	338 (21.47)	1182 (75.10)
2007	61 (2.79)	462 (21.15)	1661 (76.05)
2008	92 (3.22)	620 (21.70)	2145 (75.08)
2009	103(2.98)	718 (20.78)	2634 (76.24)

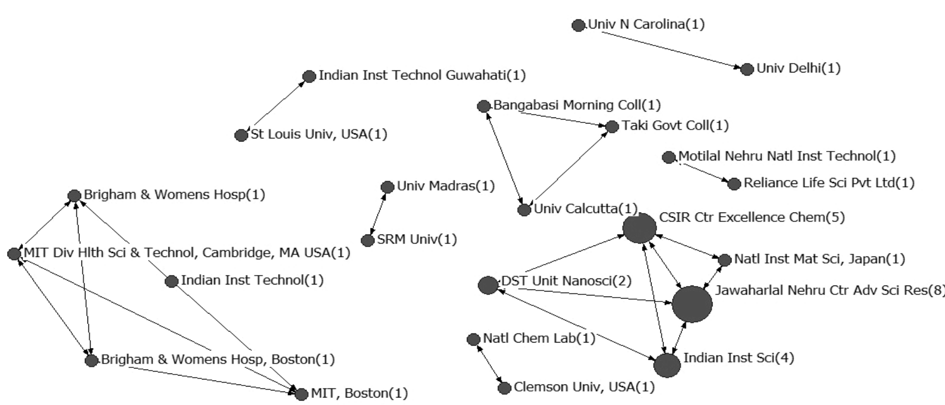

Figure 7. Network of linkages among institutions in highly cited papers (2009).

4. PATENTING ACTIVITY

India has shown limited patenting activity in comparison to its publications. Thirty-five patents in the US Patent Office and 45 domestic patents have been granted till early half of 2010. Till 2000, patenting activities in India was in a very nascent stage. However, patenting activity rose from the middle half of 2005 which is particularly visible in the applications filed. There are 1356 patent applications in nanotechnology filed till the early half of 2010 in the Indian Patent Office. One hundred and eighteen patents have been granted till then. Indian institutions have been granted 56 patents with CSIR, IIT, and Agarkar Research Institute accounting for 22, 8, and 6 patents, respectively. In application filed in the IPO, 289 patents have been filed by Indian institutions. CSIR and IIIT are the two prolific institutions, filing 83 and 50 patents, respectively. Countries primarily filing patent in India are: USA (42), Germany (6), and Australia (5). In all, patent filing has come from 16 countries with 118 institutions being involved.The CSIR is the key player in IPO as well as in the USPTO. Academia is again dominating this activity; however, unlike US PTO, firms are actively involved in the IPO. Linkages are almost non-existent, only one linkage visible between IIT and ICI in application filed as well as in granted.Basic chemicals and pharmaceuticals were the main areas in which patents were granted, each accounting for 14 patents each during the period 1998-2009. The main areas of focus within technology classes were: Nanopolymers, nanopharama, and nanoelectronics.

4.1 Standards and Products

Technical Committee 229 (TC229), International Organisation for Standardisation is responsible for developing international guidelines for nanotechnology. In 2010, Nanotechnologies Sectional Committee, Bureau of Indian Standards (BIS) formed four National Mirror Working Groups adopting from ISO TC229. Presently, two standards are at the initial testing stage: (1) National standard on use of AFM for characterisation and evaluation of nanomaterials, and (2) electron microscopic characterisation of multi-wall carbon nanotubes. The remaining two standards proposed are: Luminescent nanomaterials and magnetic nanoparticles, and toxicity of zinc oxide nanomaterials.

Table 7. Technology classes in which India is active in US Patent Office

Field	Code	Description	Total patent count	CSIR-patent count	Biocon
Basic chemical (14)	C01B	Non-metallic elements; Compounds thereof	5	4	
	C01G	Compounds containing metals not covered by subclasses C01D Or C01F	2	2	
	C07C	Acyclic or carbocyclic compounds	1	1	
	B01J	Chemical or physical processes, eg catalysis, colloid chemistry; Their relevant apparatus	6	5	
Pharmaceuticals (14)	C12P	Fermentation or enzyme-using processes to synthesise a desired chemical compound or composition or to separate optical isomers from a racemic mixture	1	1	
	C12Q	Measuring or testing processes involving enzymes or micro-organisms; Compositions or test papers therefor; Processes of preparing such compositions; Condition-responsive control in microbiological or enzymological processes	1	1	
	A61K	Preparations for medical, dental, or toilet purposes	12	1	6
Non-metallic mineral products (2)	C03B	Manufacture or shaping of glass, or of mineral or slag wool; Supplementary processes in the manufacture or shaping of glass, or of mineral or slag wool	1	1	
	B32B	Layered products, ie products built-up of strata of flat or non-flat, eg cellular or honeycomb, form	1		
Measuring instruments (2)	G01F	Measuring volume, volume flow, mass flow, or liquid level; Metering by volume	2		
Paper (1)	B41M	Printing, duplicating, marking, or copying processes; Colour printing	1	1	
Special purpose machinery (1)	B05D	Processes for applying liquids or other fluent materials to surfaces, in general	1	1	

4.2 Product–Processes Developed

Table 8 highlights some of the applications that have been developed or are being developed in these sectors. It shows that firms have developed nanotechnology-based products in areas like textiles, medicines, computers, energy, sports, biotechnology, and various consumer products. Majority of the products are in pharmaceuticals and information technology. Foreign firms have also introduced nanotechnology- based products in the Indian market. For example, Samsung has launched silver nanotechnology for home appliances in India. The technology is expected to prevent bacteria from growing inside appliances.

4. DISCUSSIONS AND CONCLUSIONS

Strong government stimulation from 2000 onwards towards capacity creation and liberal funding has been instrumental in nanotechnology emerging as an active area of research in India. Significant upward trends are on account of increasing activity of institutions, increase in number of institutions involved in publishing, wider set of journals used for publication and increasing collaborations. Research is exhibiting more interdisciplinary characteristics (reflection through journals) and activity within different subfields of nanotechnology. Keyword analysis provides an indication that sophisticated instruments is now more accessible to researchers. India's papers are also attracting attention but still are much below world standards. India's patenting activity is still in a nascent stage. It, however, has been found that there is increase in patent filing both through PCT (international filing) and Indian Patent Office. But linkages are almost non-existent. Standardisation is very important as it defines and regulates product/process quality. India, has only taken initial first steps in addressing standardisation issue. India is focusing on few key areas for nanotechnology-based intervention. Nano-biotechnology is one of the important areas now getting attention. India has developed nanotechnology-based products mainly in textiles, medicines, computers, energy, sports, biotechnology, and various consumer products. Thus overall India has created a reasonable scientific capacity as visible through its research publications output. In other aspects, it has started making tangible progress.

Table 8. Applications created in different sectors in nanotechnology*

Broad areas	Indian Firms/Institutions involved	Applications developed/being developed
Pharmaceuticals	Prakruthik Healthcare	En-Tube capsules as an over the counter drug for intracorporeal detoxification
	Shasun Pharmaceuticals and Nanoparticle Biochem	Developed NBI 129 for prostate cancer
	Bilcare	Nanotechnology-based anti-counterfeit technology
	NATCO Pharma	Nanotechnology drug albupax
	Richmond Chemical Corporation	Nanotech-based drug for cancer treatment
	Vascular Concepts	Combination drug eluting stent (targets different cells at the same time)
Information technology	Velbionanotech	Bionanochip
	Nano Development Corporation of Houston and Institute of Advanced Research	DNA optimising and protein sequencing chip system, helpful in developing new drugs to prevent genetic diseases
Energy	Industrial Nanotech	Nansulate speciality coatings and energy saving technology that contains nanotechnology-based material
	United Nanotechnology and NEI Corp.	Nanotechnology-based lithium ion battery electrode materials
Biotechnology	National Research Development Corporation	Calcium phosphate nanotechnology for non-viral gene delivery
	Biomix Network	Nanotechnology-based biotechnology tools
Textiles	Bodal Chemicals	Dyes for textile industries (nanotechnology- based)
	Arvind Brands	Unstainable collection of shirts for men (based on nanotechnology)
Consumer products	Titan Industries	Body-wearable healthcare products based on microelectromechanical systems (MEMS) technology
Water purification	CSIR, IIT, and TATA	Nanotechnology-based water filter
Sports	Amer Sports	Tennis and badminton rackets and golf accessories offering higher strength, stability and power (nanotech-based)

*Selected sample

Nanotechnology, as a priority area of research was articulated more or less at the same time when other countries started their programmes influenced by US National Nanotechnology Initiative. Comparison of India's progress with other countries brings to focus the major gaps that need to be addressed. China's nanotechnology development provides a useful benchmark for other emerging countries to follow[13]. China is already leading the nanotechnology publishing race. This is a strong assertion of capability when the field is science-intensive. China's patenting activity was negligible earlier but has shown strong progress. This can be seen for applications filed in the USPTO. During 2005-09, it filed 289 patents, emerging as the sixth most active patent filing country in the USPTO. Among the most visible changes is the emergence of Chinese universities in the patenting activity and also joint industry partnerships. For example, during 2005-09, Tshinghua University emerged as the third most prolific patent filing entity in the USPTO and had filed 256 patents with Hon-Hai Precision, which has a nanotechnology centre in Tsinghu University campus.

China, in 2005, became the first country to issue national standards for nanotechnology. It has so far created 27 nano-dimensional material and characterisation standards on terminology and nomenclature and 12 nanomaterials/product standards of which 21 have been implemented. China's active involvement in standard creation and adoption is its over-reaching strategy for future technology domination in this critical field. This can be seen from its standard developed for textile industry. The adoption of this standard in nanotechnology-embedded textile makes the textile more acceptable to consumers and also gives a brand value in the global market. China's nanotechnology products are visible in international markets. For example Woodrow Wilson database of nanotechnology product inventory globally (www.nanotechproject.org) lists over 1000 consumer products in eight different application areas. After USA, Korea, and Germany, China has the maximum number of products in this inventory, i.e., 63 products. None of the Indian firms has any product in this inventory. Thus, China providing learning lesson, i.e., with strong strategic focus, it is possible to emerge as a leading country in a frontier area of research. India needs to become more aggressive like China to make its presence more strongly felt in the international stage.

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