Trends in nanotechnology patents

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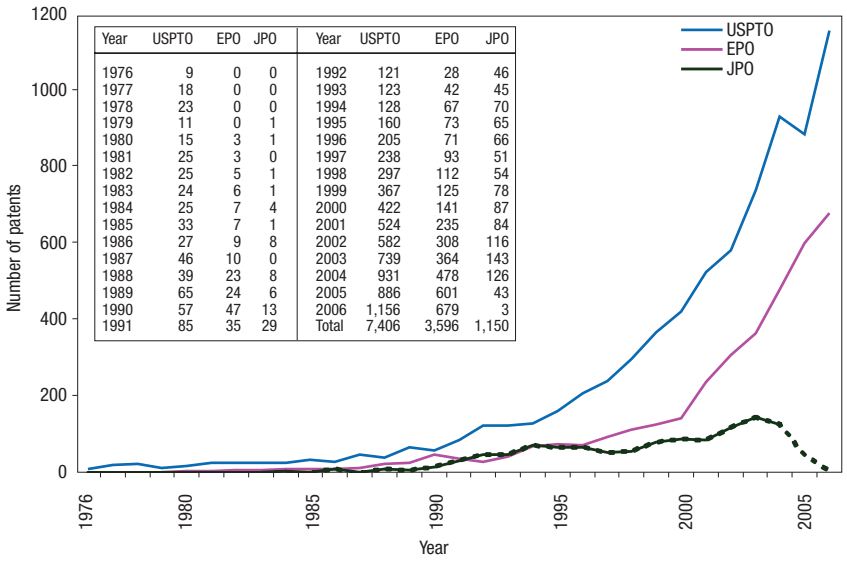
An analysis of 30 years of data on patent publications from the US Patent and Trademark Office, the European Patent Office and the Japan Patent Office confirms the dominance of companies and selected academic institutions from the US, Europe and Japan in the commercialization of nanotechnology.

The papers that reported the invention of the scanning tunnelling microscope in 1981 and the atomic force microscope in 1986 have been credited in part with 'opening the doors to the nanoworld'[1], and the fact that these papers have been cited thousands of times by other researchers is a testament to the impact that these two instruments have had in the field of nanoscale science and technology. There were also significant advances in other areas such as molecular self-assembly and nanomechanics around the same time, and these fragmented areas were brought together by the increased availability of techniques to control and restructure matter at the nanoscale at the end of 1990s[2]. Today, more than 60 countries have national programmes in nanotechnology[3] and hundreds of nanotechnology-based products are commercially available[4]. In addition to scientific papers and commercial products, however, there is another way to gauge the rate of progress in nanotechnology over the past few decades — patents.

Various authors have made significant efforts to identify[5] and analyse[6] nanotechnology patents, but this can be difficult because applicants tend to file patents with their national patent office rather than with foreign patent offices[7], and because different patent offices have different policies and examination procedures[8,9]. To gain a global perspective on trends in nanotechnology patents we have analysed those granted by the United States Patent and Trademark Office (USPTO), the European Patent Office (EPO) and the Japan Patent Office (JPO). These three patent offices cover most of the world's patents in nanotechnology[10,11].



Year	USPTO	EPO	JPO	Year	USPTO	EPO	JPO
1976	9	0	0	1992	121	28	46
1977	18	0	0	1993	123	42	45
1978	23	0	0	1994	128	67	70
1979	11	0	1	1995	160	73	65
1980	15	3	1	1996	205	71	66
1981	25	3	0	1997	238	93	51
1982	25	5	1	1998	297	112	54
1983	24	6	1	1999	367	125	78
1984	25	7	4	2000	422	141	87
1985	33	7	1	2001	524	235	84
1986	27	9	8	2002	582	308	116
1987	46	10	0	2003	739	364	143
1988	39	23	8	2004	931	478	126
1989	65	24	6	2005	886	601	43
1990	57	47	13	2006	1,156	679	3
1991	85	35	29	Total	7,406	3,596	1,150

Figure 1 Number of nanotechnology patents published by the USPTO, EPO and JPO according to publication date. The drop in the number of USPTO patents in 2005 is due to the USPTO enforcing a stricter definition of nanotechnology. The decline in the number of JPO patents for 2005 and 2006 is due to the delay between the publication and granting of patents at the JPO.

Data for this study were collected by searching for a list of nanotechnology keywords in the titles and abstracts of patents published by the USPTO, EPO and JPO between 1976 and 2006. These keywords, which were provided by domain experts[10,11], include atomic force microscope (and variations thereon), molecular electronics, nano*, quantum dot, and self assembly. We removed some noise from the data, and included only patents that had been granted in our analysis. (See Table S1 in Supplementary Information for a full list of keywords and details of the analysis).

PATENTS BY COUNTRY

We found that the USPTO had granted 7,406 nanotechnology patents during this period, which was about two times the number granted by the EPO

Table 1 Summary of nanotechnology patent publications for the USPTO (1976–2006), EPO (1978–2006) and JPO (1976–2006).

	USPTO	EPO	JPO
No. of Patents	7,406	3,596	1,150
No. of Countries	46	50	N/A
No. of Institutions	2,196	1,733	404
No. of Inventors	12,885	8,305	2,087

(3,596) and over six times the number granted by the JPO (1,150; see Table 1). Not surprisingly, most of the patents granted by the USPTO came from the US (4,772 patents; Fig. S2). However, with 1,410 patents, the US was also the most successful nation at the EPO, and seven other nations — Japan, Germany, France, South Korea, Switzerland, the UK and the Netherlands — also featured in the top ten for both the USPTO and the EPO. (This patent assignee country information is not available for the JPO.)

We also studied how the number of nanotechnology patents has evolved with time. The number of nanotechnology patents granted by the USPTO grew faster than the numbers for the EPO and JPO (Fig. 1). Over the past 30 years, the annual number of nanotechnology patents granted by the USPTO and EPO grew quasi-exponentially, whereas the number granted by the JPO increased relatively slower, especially between 1994 and 2001.

We also studied three distinct phases in the history of nanotechnology (Fig. S2). From 1976 to 1989, nanotechnology research was just beginning around the world and most countries did not have many patents (although researchers were applying to the USPTO for nano patents as long ago as 1976). From 1990 to 1999, publication grew rapidly in the US, Japan and some European countries. For USTPO patents, Japan was second to the US in terms of numbers, followed by France, Germany and Canada. In the EPO, where the US was granted the most patents, Japan, Germany and France were all granted a similar number of patents, followed by Switzerland, the UK and the Netherlands. Although the potential of nanotechnology has been recognized in more and more countries since 2000[3], the US has continued to dominate according to number of patents. Asian countries have, however, shown good growth. At the USPTO, for example, South Korea and Taiwan have published 209 patents and 161 patents respectively since 2000, moving into the top ten for this period, while South Korea jumped to fifth place at the EPO.

Although the US dominates nanotechnology patent publications in terms of quantity, patents from some other countries may have a similar or even higher average impact on the field of nanotechnology. At the USPTO, for example, nanotechnology patents from the US were cited by other nanotechnology patents an average of 2.49 times, compared with 2.44 for Swiss patents and 2.20 for Japanese patents. However, a different picture emerges for EPO patents, which have fewer citations than USPTO patents[8]. On average, each EPO patent from the US was cited 0.10 times by other EPO nanotechnology patents, which was significantly less than the average for patents from Japan (average of 0.19 times), Belgium (0.15), and France (0.14), and similar to South Korea and Switzerland (both 0.10).

Table 2 The institutions that published the most patents in nanotechnology with the USPTO (1976–2006), EPO (1978–2006) and JPO (1976–2006) ranked according to number of patents. All the institutions in the USPTO list are from the US, and all those in the JPO list are from Japan. Only four of the institutions in the EPO list are from Europe.

Rank	Institution	No. of patents
	US Patent and Trademark Office	
1	IBM	209
2	University of California	184
3	US Navy	99
4	Eastman Kodak	90
5	Massachusetts Institute of Technology	76
6	Micron Technology	75
7	Hewlett-Packard	67
8	Xerox Corporation	62
9	3M Company	59
10	Rice University	51
	European Patent Office	
1	Japan Science and Technology Agency (Japan)	78
2	L'Oreal (France)	60
3	IBM (US)	50
4	Rohm & Haas (US)	47
5	Samsung (South Korea)	45
6	Eastman Kodak (US)	40
7	CEA (France)	39
8	CNRS (France)	37
9	Matsushita Electric Industrial (Japan)	32
10	BASF(Germany)	31
	Japan Patent Office	
1	Nippon Electric	109
2	Japan Science and Technology Agency	70
3	National Institute for Materials Science	52
4	National Institute of Advanced Industrial Science and Technology	48
5	Matsushita Electric Industrial	45
6	The Agency of Industrial Science and Technology	43
7	Tokyo Shibaura Electric	43
8	Sony	32
9	Canon	31
10	Seiko Instruments	27

PATENTS BY INSTITUTION AND RESEARCH AREA

Over the last 30 years, the USPTO, EPO and JPO assigned nanotechnology patents to 2,196, 1,733, and 404 institutions, respectively (Table 1). There is, however, very little overlap between the top ten institutions identified in each office, although IBM and Eastman Kodak both feature in the USPTO and EPO top tens, and the Japan Science and Technology Agency and Matsushita Electric Industrial are both in the EPO and JPO lists (Table 2). Overall, institutions from the US and Japan dominate these three lists, emphasizing their strength in nanotechnology. Commercial companies, especially electrical and electronics companies, also dominate the three lists, accounting for six of the top ten positions in both the USPTO and JPO lists, and seven in the EPO. Within the academic sector, US universities and Japanese national

laboratories also contributed a large number of nanotechnology patents.

Further analysis shows that most institutions started publishing nanotechnology patents in the 1990s, but IBM has been filing nanotechnology patents with the USPTO since the 1970s (as has the US Navy and Eastman Kodak), and with the EPO since the 1980s. Other organizations — notably the University of California and the Japan Science and Technology Agency — have shown significant growth in numbers of nanotechnology patents since the start of this decade.

Nanotechnology is a multidisciplinary research field[12] and the products of nanotechnology research can have applications in fields that range from scientific research to medical products, so we classified patents according to the different sections in the International Patent Classification scheme (Fig. S3). Most nanotechnology patents were published in sections B (performing operations; transporting), C (chemistry; metallurgy), G (physics) and H (electricity). The USPTO contains significantly more patents than the EPO and JPO in most sections, although the EPO had a similar number of patents to the USPTO in section C. All three patent offices showed rapid growth in most sections over the time period covered by our study, although the JPO published fewer patents in sections G and H between 2000 and 2006 than it did in the period 1990–1999.

CONCLUSIONS

Our analysis of patents from the USPTO, EPO and JPO confirms the fast growth of nanotechnology over the past three decades, which is consistent with previous research on individual data sources[13]. Although further efforts to identify nanotechnology patents[5] may provide a more detailed picture, it is clear that competition among countries and companies is increasing, and we can expect this trend to continue for the foreseeable future.

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Acknowledgements

This research is supported by the US National Science Foundation (IIS-0311652, CMMI-0533749 and CMMI-0654232). M.C.R. was partially supported by the Directorate for Engineering, NSF. The authors thank the USPTO, EPO and JPO for making their databases available for research.

Supplementary Information accompanies this paper on www.nature.com/naturenanotechnology.