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Description	一般論文

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Nanotechnology Fusion with Science Fields

— an empirical analysis

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Abstract

In the early stages of nanotechnology development and diffusion, many expected benefits have not yet been fully accomplished but researchers of many countries in the science fields aggressively involved the relevant research to boost nanotech competitiveness through academic research, and corporations directed their R&D activities towards the exploration of nanotech opportunities. The paper compares science fields' diversification into nanotechnology related research in a global perspective. The main objective is to understand to what extent nanotech research fused with basic scientific research. The research is based on Quantitative method, combining bibliometrics and tech mining, using SCI-EXPANDED database in a 5-years time frame (2000-2004), based on 163 specialist nano* keywords or fullerene. The research offers useful insights for science & technology policy makers and researchers for traditional science fields in a global Community, revealing fusion of the emerging nanotechnological research, existing country-level competencies and differences between traditional disciplines.

1. Introduction

Nanotechnology, manipulating atoms and molecules at the nanometer level (nano means one-billionth of a meter), is an emerging technology, introducing new dimensions to science and technology by the convergence of traditional disciplines such as materials science, chemistry, physics, biology, computational science and engineering (Islam, Miyazaki 2006). The emergence of nanotech was enabled by the development of specialist instruments such as scanning tunneling microscope, which in turn facilitated the observation of nanostructures and manipulation of the matter at the atomic or molecular scale (Islam, Miyazaki and Klincewicz 2006). This article compares scientific fields' diversification into nanotechnology related research in a global perspective. It attempts to answer a question about the relevance of nanotech academic research focusing on nanotech fusion with traditional science disciplines such as chemistry, physics, material sciences and biology, using tech mining/bibliometrics research method. While science & technology policies of governments in countries worldwide attach particular importance to promoting nanotech basic research within academia, public research institutes and consequently in private companies, the present research asks a more fundamental question: How scientific fields are diversifying their research into nanotechnology and what extent? The paper characterizes the involvement of different science fields, identifying the leading regional players conducting nano-scientific research.

2. Research Method

This research applies Quantitative method (tech mining), proposed by Porter and Cunningham (2005), combining bibliometrics based on article set extracted from SCI database, most representative collections of peer-reviewed scientific and technical articles, to compare them with parallel results of nano-scientific activities by cross-country analysis. Previous studies include Meyer's (2001) analysis based on SCI database, focusing on the period of the 1990s, revealing S-T linkage between patents and publications; Hullmann and Meyer's study (2003) with SCI papers from 1981 to 1998, delineating nanotechnology from the so-called nano-science. Data for the present study was collected by querying SCI, using 163 specialist nano* keywords[1] or fullerene[2], derived from the Nano Science and Technology Institute publications. The top rated and most popular 25 journals of each scientific discipline such as chemistry, physics, material science and biology, have been selected for the basis of analysis. Database queries were formatted for the desired 5-years time frame (2000-2004) – the reason for this relatively short period of analysis are dramatic increasing of the global nanotech research in recent years, especially after the announcement of the National Nanotechnology Initiatives (NNI) by the United States government in 2001. Similar studies were conducted on robotics (Kumaresan, Miyazaki 1999), on software (Klincewicz, Miyazaki 2005).

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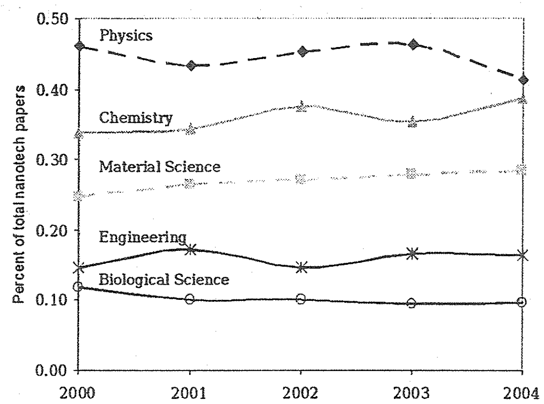
1 [The keywords included among others: nanomaterial, nanoparticle, nanocrystal, nanocomposite, carcon nanotubes, nanoscale, nanotubes, nanostructures, nanofiber, nanocomposites, nanocoating, nanofilms, nanostructures thin films, nanorobotics, nanowire, nanosensor etc]

2 [*Fullerenes* called carbon 60, a new class of carbon material, are spherical molecules about 1 nm in diameter, comprising 60 carbon atoms arranged as 20 hexagons and 12 pentagons: the configuration of a football]

3. Diversification of Science Fields' Research into Nanotechnology – Cross-country Comparisons

Nanotechnology is highly prioritized on the global scientific agenda. Many Asian and Western countries regard it as an interesting area of future exploitation, setting up national initiatives in order to prepare for the technological challenge. Volumes of scientific publications are a commonly accepted indicator of scientific performance in specific technological domains, help illustrate the existing status and forecast future developments of a technology.

Figure 1: Nanotech appearance in scientific research over time



The following presentation of research findings start with a general analysis of all nano-scientific articles, based on keyword searching, into Science disciplines over time. We then move towards the analyses of specific fields' involvements as well as the relative importance of emerging nanotechnologies for researchers in the Asian and Western countries. The Figure 1 presents the total volumes of identified nanotech-related article and compares their relative distribution with each scientific fields over time. They clearly indicate that the nanotech-related research plays a significant role in every analyzed discipline, accounting for above 40% of all nanotech academic articles in physics, as well as around 40% in chemistry, around 30% in material science and around 10% in biological science. The fields vary in the relative importance of the nanotech research for academic activities, with physics, chemistry and material science positioning nanotech as a key research area (over 1/3 of all nanotech articles) and biological science lagging behind which seems as an emerging field.

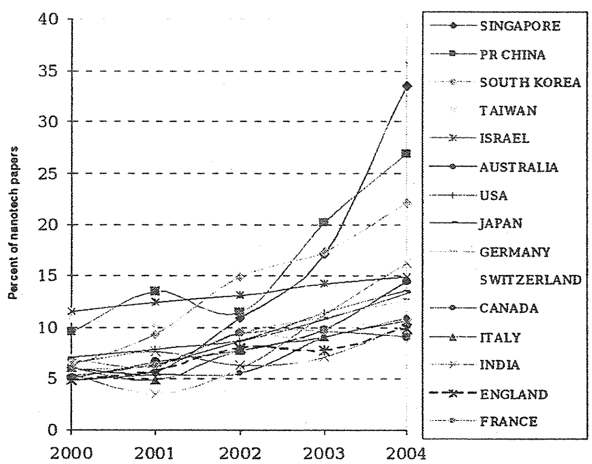
3.1 Extent of Nanotech Fusion with Chemistry Field

Table 1 demonstrates the overall shares of nanotech articles in the chemistry field authored in the respective countries and subsequently compares them with the most active countries' share indexed by SCI for the same period (2000-2004) and countries. When compared with other countries, the volumes of nanotech-related articles in Asian countries (such as Singapore, China, South Korea, Taiwan, Israel and Japan) appear to the substantial. Nanotech article volumes have been rapidly increasing in every country, as Figure 2 demonstrates. This growth corresponds to the extent of nanotechnology research fusion and its growing importance for chemistry discipline. Since the percentage share of nanotech articles of China, South Korea and Singapore indicates their significance value of basic chemistry research, the R^2 value of those countries are relatively less than Japan (0.99) and the United States (0.96) as illustrated in Figure 2. It should however be noted that the position on the science pole of the techno-economic network (Bell, Callon 1994) cannot merely be measured by the number of publications, but also their importance for researchers and practitioners – citations and commercial impacts – and additionally by aggregate national R&D expenditures on an emerging technology.

Table 1: Percent share in Chemistry field over time

Country	2000	2002	2004
SINGAPORE	6.09	10.83	33.52
PR CHINA	9.48	11.43	26.94
SOUTH KOREA	6.25	14.94	22.12
TAIWAN	5.37	5.98	16.20
ISRAEL	11.53	13.15	14.92
AUSTRALIA	5.03	7.71	14.42
USA	7.05	8.76	13.58
JAPAN	5.27	8.61	13.28
GERMANY	6.84	9.43	12.66
SWITZERLAND	10.75	9.62	12.32
CANADA	4.87	5.46	10.83
ITALY	6.06	7.71	10.60
INDIA	6.44	6.32	10.28
ENGLAND	4.82	7.93	9.84
FRANCE	5.90	9.35	9.08

Figure 2: Trend of nanotech fusion by regional players



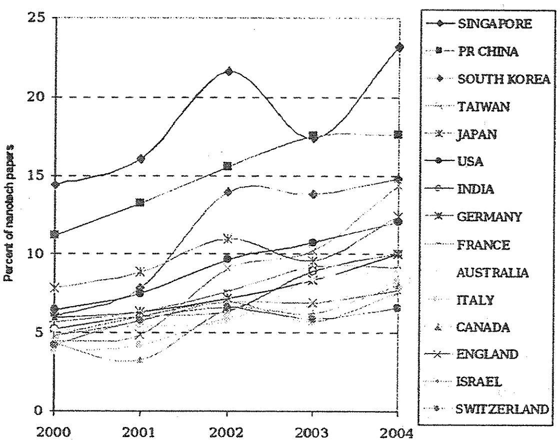
3.2 Extent of Nanotech Fusion with Physics Field

Table 2 demonstrates the overall shares of nanotech articles in the physics field authored in the respective countries and subsequently compares them with the most active countries' share indexed by SCI for the same period (2000-2004) and countries. When compared with other countries, the volumes of nanotech-related articles in Asian countries (such as Singapore, China, South Korea, Taiwan and Japan) appear to the substantial. Nanotech article volumes have been rapidly increasing with physics in every country, as illustrated in Figure 3. This growth corresponds to the fusion of nanotechnology research and its growing importance for physics discipline. Since the percentage share of nanotech articles of Singapore and China indicates their position relatively higher in basic physics research, the R^2 value of those countries are relatively less than the United States (0.97), demonstrated in Figure 3.

Table 2: Percent share in Physics field over time

Country	2000	2002	2004
SINGAPORE	14.38	21.58	23.18
PR CHINA	11.19	15.53	17.59
SOUTH KOREA	6.04	13.92	14.84
TAIWAN	4.46	9.11	14.36
JAPAN	7.82	10.94	12.39
USA	6.44	9.64	12.07
INDIA	5.19	6.37	10.06
GERMANY	5.97	7.21	10.02
FRANCE	5.66	7.63	9.16
AUSTRALIA	5.16	5.75	8.91
ITALY	3.74	5.95	8.30
CANADA	4.27	6.48	8.09
ENGLAND	4.77	6.95	7.70
ISRAEL	4.77	6.95	7.60
SWITZERLAND	4.24	6.59	6.62

Figure 3: Trend of nanotech fusion by regional players



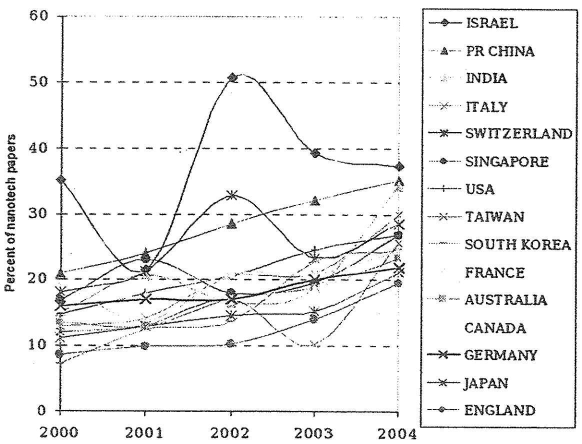
3.3 Extent of Nanotech Fusion with Material Science Field

Table 3 demonstrates the overall shares of nanotech articles in the material science field authored in the respective countries and subsequently compares them with the most active countries' share indexed by SCI for the same period (2000-2004) and countries. When compared with other countries, the volumes of nanotech-related articles in Israel and China appear to the substantial. Nanotech article volumes were relatively increasing higher than other Science fields of each country, as illustrated in Figure 4. This growth corresponds to the relatively higher extent of nanotech research fusion with material science field. Since the percentage share of nanotech articles of Israel, China, India and Singapore indicates Asian position relatively higher in material science research, the R^2 value of those countries are relatively less (except China with 0.98) than the United States (0.98), demonstrated in Figure 4, while Japan's nanotech research strength is comparable which lies in a significance level (0.92).

Table 3: Percent share in Mat. Sci. field over time

Country	2000	2002	2004
ISRAEL	35.10	50.70	37.28
PR CHINA	21.01	28.56	35.05
INDIA	15.12	16.54	34.14
ITALY	12.88	20.35	29.97
SWITZERLAND	18.09	32.72	28.47
SINGAPORE	16.91	17.85	26.81
USA	14.768	20.60	26.80
TAIWAN	12.02	16.99	25.62
SOUTH KOREA	7.11	13.56	24.55
FRANCE	19.42	20.82	24.42
AUSTRALIA	13.49	17.02	23.24
CANADA	15.52	16.74	22.33
GERMANY	15.88	16.93	21.92
JAPAN	11.17	14.58	21.10
ENGLAND	8.64	10.15	19.49

Figure 4: Trend of nanotech fusion by regional players



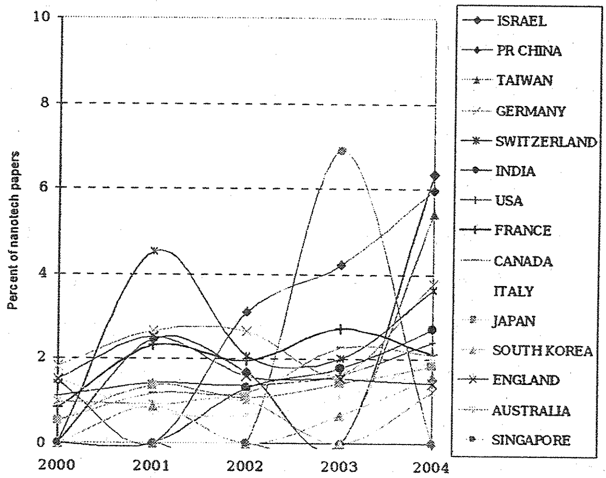
3.4 Extent of Nanotech Fusion with Biology Field

Table 4 demonstrates the overall shares of nanotech articles in the biology field authored in the respective countries and subsequently compares them with the most active countries' share indexed by SCI for the same period (2000-2004) and countries. When compared with other countries, the volumes of nanotech-related articles in Asian countries such as China and Israel, and in European countries such as Germany and Switzerland appear to the substantial. Nanotech article volumes of biology field were slowly increasing relative to other science fields of each country, as illustrated in Figure 5. This slow growth is instructive in that biological sciences are still emerging field for nanotech research. The percentage share of nanotech articles of this field is too small to compare with other disciplines, revealing its weak strength right now but likely to be promising in near future, demonstrated in Figure 5.

Table 4: Percent share in Bio. Sci. field over time

Country	2000	2002	2004
ISRAEL	0	1.66	6.32
PR CHINA	1.47	3.10	5.96
TAIWAN	0	0	5.40
GERMANY	1.82	2.64	3.77
SWITZERLAND	0	2.07	3.62
INDIA	0	1.31	2.70
USA	1.11	1.36	2.41
FRANCE	0.83	1.95	2.13
CANADA	0.52	1.21	2.09
ITALY	1.50	0.67	1.99
JAPAN	0.52	1.09	1.85
SOUTH KOREA	0	0	1.58
ENGLAND	1.51	1.59	1.43
AUSTRALIA	0.97	0.99	1.22
SINGAPORE	0	0	0

Figure 5: Trend of nanotech fusion by regional players



4. Discussion

In the present research, we tried to explore the extent of nanotech basic research fused with science fields such as in chemistry, physics, material science and biology. The analysis addressed that Asian countries play an important role in the rapid fusion of nanotechnology research, accounts for relatively higher share and significant growth in comparison with Western countries. It demonstrated the dominant position and significant growth of China, South Korea, Israel and Singapore in nanotech research fusion. On the other hand, Japan and the US are posing their potential research strength in similar trend. An average diversification of material science research into nanotechnology is relatively higher, followed by chemistry, physics and relatively less in the case of biological science which is instructive of the emerging field of nanotech fusion.

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