# Current situation and industrialization of Taiwan nanotechnology

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Perspectives
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## Abstract

Nanotechnology is projected to be a very promising field, and the impact of nanotechnology on society is increasingly significant as the research funding and manufactured goods increase exponentially. A clearer picture of Taiwan's current and future nanotechnology industry is an essential component for future planning. Therefore, this investigation studies the progress of industrializing nanotechnology in Taiwan by surveying 150 companies. Along with understanding Taiwan's current nanotechnology industrialization, this paper also suggests ways to promote Taiwan's nanotechnology. The survey results are summarized and serve as the basis for planning a nanotechnology industrialization strategy.

## Keywords

Nanotechnology Industrialization Industry R&D planning National survey Science policy International comparison

## Introduction

### Emerging nanotechnology

Nanotechnology is the development and utilization of devices and structures with a size range from 1 nm to 100 nm. In comparison to bulk and molecular scale structures, new physical and chemical properties occur with this scale. Interdisciplinary nanotechnology has been growing explosively in the past few years because nanotechnology can possibly occur in every conventional field if it is purposefully engineered. Figure 1 shows that growing attention and development in nanotechnology are exploratory. Year 2001 is estimated to be near the beginning sector of the classical 'S' development curve of nanotechnology, and 2006 is the first rising sector of the curve (Roco 2001).

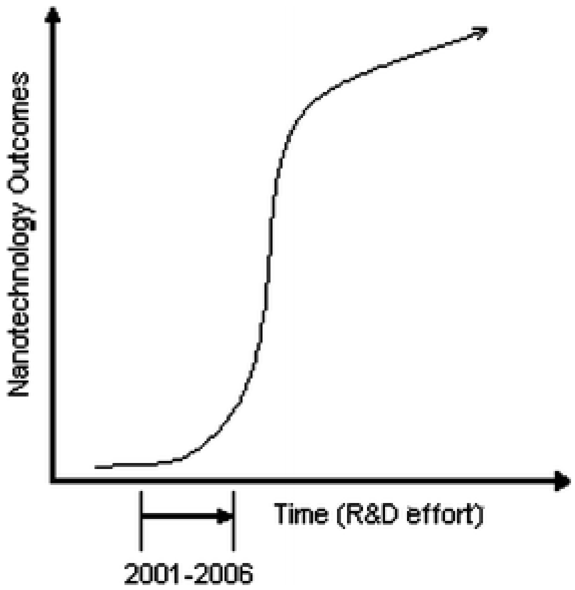


Fig. 1

Nanotechnology R&D 'S' development curve (Roco 2001)

As predicted in Fig. 2 by Lux Research, nanotechnology is approaching a phase change that will see it spread exponentially across manufactured goods within 10 years. The $13 billion worth of products incorporating emerging nanotechnology in 2004 accounted for less than onetenth of 1% of global manufacturing output. In 2014, this will rise to $2.6 trillion, 15% of manufacturing output (Lux 2006).

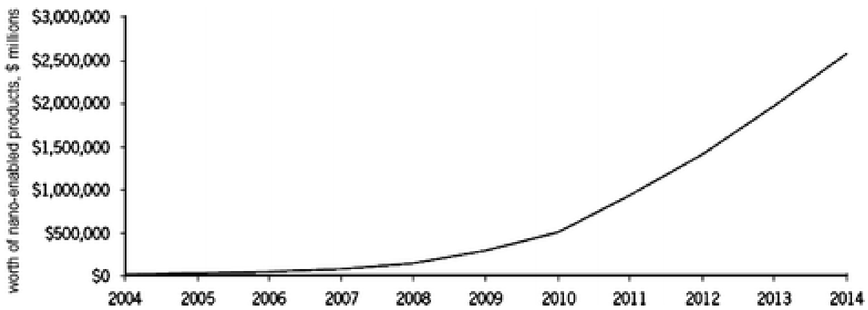


Fig. 2

Projection of revenues from products incorporating nanotechnology (Lux 2006)

The increasing government nanotechnology funding all over the world, as shown in Table 1, indicates the awareness of the importance of nanotechnology. Global government funding in 2004, about $3,660 million, is more than eight times the $432 million in 1997. In 2004 West Europe, Japan, and USA are the three major areas with the highest government funding, and these are each comparable to the total government funding from other countries. These leading countries in fields of traditional science will always be present in the revolution of emerging nanotechnology. High government funding plus well-developed science and industry infrastructure allow these countries to have significant nanotechnology patents (Huang et al. 2004; Scheu et al. 2006; Marinova and McAleer 2003) and publication outputs (Miranda Santo et al. 2006; Tegart 2002).

**Table 1**

Government nanotechnology funding continues to increase, where the data for Taiwan were added (unit: US$ million/year) (Roco 2005)

| Country | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| West Europe | 126 | 151 | 179 | 200 | ~225 | ~400 | ~650 | ~900 |
| Japan | 120 | 135 | 157 | 245 | ~465 | ~720 | ~800 | ~900 |
| USA[a] | 116 | 190 | 255 | 270 | 465 | 697 | 862 | 960 |
| Other[b] | 70 | 83 | 96 | 110 | ~380 | ~550 | ~800 | ~900 |
| Taiwan | N/A | N/A | N/A | N/A | N/A | N/A | 78 | 91 |
| Total | 432 | 559 | 687 | 825 | 1535 | 2367 | 3112 | 3660 |
| (% of 1997) | (100%) | (129%) | (159%) | (191%) | (355%) | (547%) | (720%) | (847%) |

[a] Excluding non-federal spending, e.g., California

[b] 'Others' includes Australia, Canada, China, Eastern Europe, the Former Soviet Union, Singapore, Taiwan and other countries with nanotechnology R&D

## Taiwan's strategy

In order to develop Taiwan's competitiveness and to be part of this nanotechnology revolution, the Taiwan government started a six-year national program to develop nanotechnology. Accordingly, the National Science and Technology Program for Nanoscience and Nanotechnology was approved in June 2002 at the 5th Science and Technology Congress of the National Science Council (National Science Council 2005). The program office was established in Oct. 2002. A steering Committee was set up to oversee the execution of the overall program. Members of the Committee include representatives from the NSC, other government officials, and industry leaders. The program office consists of eight working groups including four execution groups and four R&D programs. The four R&D programs are (1) Academic Excellence Research Program, (2) Nanotechnology Industrialization Program, (3) Core Facilities Program, and (4) Education Program. Figure 3 shows the funding ratios of the four R&D programs in 2005 (Nanoscience and Technology Program Office 2007). Industrialization funding is 64% of the total funding, and indicates Taiwan's National Science Program for Nanoscience and Nanotechnology is an industrialization driven program. There are many organizations playing different roles in Taiwan's nanotechnology industrialization process. A lot of interactions have been established among industry, government and academia. However, Industrial Technology Research Institute (ITRI) is one of the most important organizations that is directly in touch with industry and serves as a key technical center for industry.

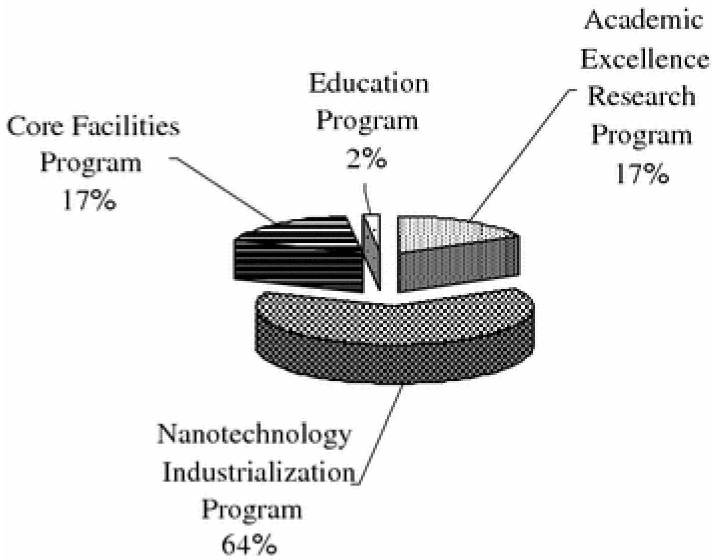


Fig. 3

Funding ratios of four R&D programs in National Science and Technology Program for Nanoscience and Nanotechnology in 2005 (overall funding: US$ 98 million)

In accordance with the industrial ecology of the small and medium enterprises dominating Taiwan, Taiwan's industrialization funding is divided into three parts according to a "20–60–20" strategic policy. Twenty percent is for promoting nanotechnology products that can be easily and quickly commercialized (mainly focus on traditional industry). Sixty percent is for promoting nanotechnology with strategic influence upon future Taiwan industry on the basis of a properly developed five-year roadmap. The final 20% is for long-term (over 10 years) exploratory investigation with academic and international collaboration to improve future R&D competitiveness (Wu 2002).

## Organizations promoting Taiwan nanotechnology

The ITRI, a non-profit R&D organization engaging in applied research and technical service, was founded in 1973 by the Ministry of Economic Affairs (MOEA), and dominates the area providing 64% of the overall funding of National Science Program for Nanoscience and Nanotechnology for industrializing nanotechnology in Taiwan. ITRI has played a vital role in the transformation of the Taiwan economy from an agriculture-based model to an industrial one, and serves as the technical center for industry. For the coming of nanotechnology revolution, ITRI is still the most important organization for industrializing nanotechnology by developing key technologies, disseminating research results, and fostering technology development (Industrial Technology Research Institute 2007).

In addition to the industrialization driven by ITRIs core competence, several associations were founded in Taiwan for integrating innovative developments and promoting nanotechnology industrialization. Taiwan Nanotechnology Industrialization Development Association (TANIDA) was established in 2004 with the support of the Industrial Development Bureau, Ministry of Economic Affairs (MOEA) (Lin and Jang 2004), Other associations include Nanotechnology and Micro System Association (Nanotechnology and Micro System Association 2007), Taiwan Photocatalyst Industry Association (Taiwan Photocatalyst Industry Association 2007), Industries Nanotechnology Application Promotion Association, Carbon Nano Capsule Research Alliance (CNCRA), Nano Electronic Common Laboratory User's Club (Nano Electronic Common Laboratory User"s Club 2007), and Nano Common Facility Club; are also established to consolidate the infrastructure of Taiwan nanotechnology industry; and provide good platforms for information interchange and strategic cooperation.

### Initiation of nanomark certificate

Nanomark was first initiated in Taiwan in 2004 to standardize nano products. The Center for Measurement Standards (CMS) within ITRI is responsible for the Nanoproduct Certificate System. The main purpose of granting nanomark certificate to all the claimed products is to serve as a control measure for both industry and the public in order to avoid counterfeit or low quality nano related products (Schulte 2004). This innovative idea is also aimed at installing a new accreditation board within Taiwan, which is scheduled to be materialized in the very near future by TNIDA to promote the creation of laboratories of international standards (Schulte 2004).

Five nano product test methods were established and announced in 2005, such as wear-resistant PU synthetic leathers, self-cleaning ceramic tiles, anti-smudge paints, anti-smudge toilet, and air-cleaning lamp (Nano Mark Technical Committee 2005). Six companies successfully obtained nanomark certificates in 2005 (ITRI nanomark 2007), e.g., photocatalyst anti-bacteria lamp of TAIWAN FLUORESCENT LAMP CO., LTD was certified in December 2005, which indicates their nano products are reliable in terms of nano characteristics, functionality, and safety. Corporate image and product competitiveness are therefore improved because of their nanomark certificates. It is to be expected that 20 more nano product test methods will be established and a 100 more companies will apply for nanomark certificate before the end of 2007 (Industrial Technology Research Institute 2007).

## Survey

Even though Taiwan has put significant effort on increasing government funding, nanotechnology alliances, nanomark, infrastructure, and technique transferring mechanisms, the current situation is not clear. Some existing industrialization problems have been discussed, such as nanomaterial suppliers cannot assure the success of downstream users, downstream users cannot obtain large quantities of the nanomaterial, small enterprises find it difficult to be in this field without integrating knowledge cross different disciplines, etc (Su 2006). In addition, Yuan et al.'s research used fuzzy multi-criteria decision making to evaluate the strategy for Taiwan's nanotechnology development (Yuan et al. 2004).

Therefore, there is a need to have a fundamental and quantitative approach to nanotechnology industrialization's status as a basis for refining the strategic plans of Taiwan's nanotechnology industry, both on technology development and policy. Even though our office undertook a Taiwan Nanotechnology Industrialization survey in 2002 (Luo et al. 2002), in 2006 the current nanotechnology industry again must be investigated in order to compare the difference of nanotechnology industrialization before and after National Science and Technology Program for Nanoscience and Nanotechnology started in 2003. The survey results are analyzed in five dimension, (1) company profile, (2) reasons and benefit, (3) industrialization and manpower, (4) funding and profit, and (5) difficulties and perspectives. In addition, the features of current nanotechnology industry together with comparison between survey results of 2002 and 2006 are also summarized.

# Survey results

## Company profile

One hundred and fifty survey participants are collected from nanotechnology related companies in Taiwan. The 150 survey participants are mainly from chemical material (18.7%); chemical products (17.3%); and electrical, electronic machinery, and supplies (13.3%). The industrial classification used in Fig. 4 is based on the 7th version of Standard Industrial Classification of the Republic of China (Director-General of Budget, Accounting and Statics, Executive Yuan, R.O.C 2007). However, 20.7% of the companies, e.g., the photoelectronics industry and the ceramic industry, are difficult to categorize by this classification.

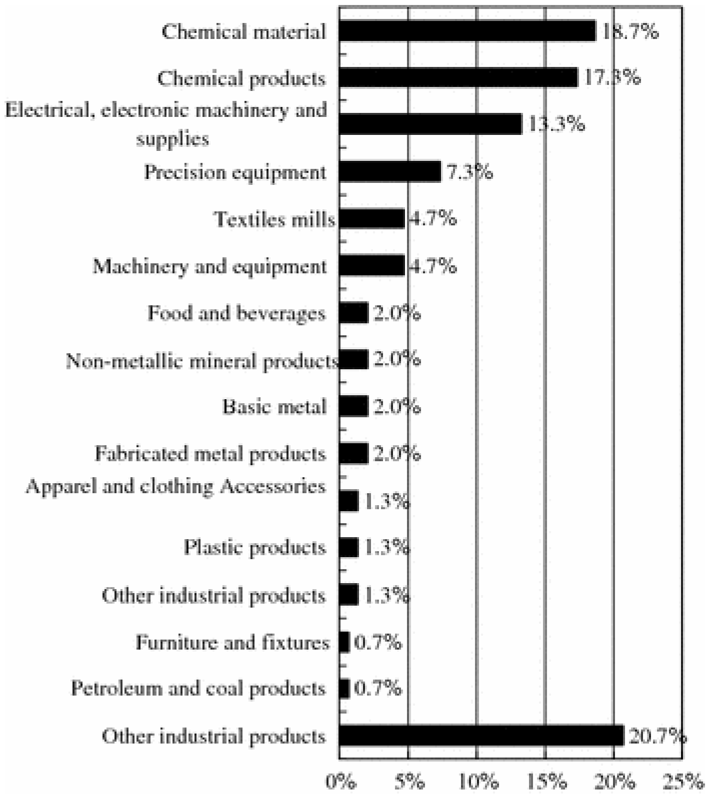


Fig. 4

Technical fields of the surveyed nanotechnology companies

Most participants (44.7%) are companies with paid-in capital below 3 million US$, reflecting the traditional structure of Taiwan's industry which is small and medium-sized enterprises oriented. Two percent of participants refused to provide company paid-in capital information (Fig. 5).

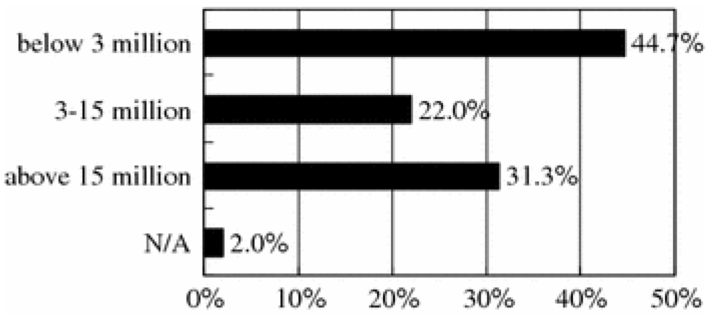


Fig. 5

Investment capital of the surveyed companies (unit: US$, convert NT$ to US$)

The number of companies with employees less than 100 persons (40.0%) is almost eight times that of companies with 500–1,000 employees and almost three times larger than the largest companies (Fig. 6).

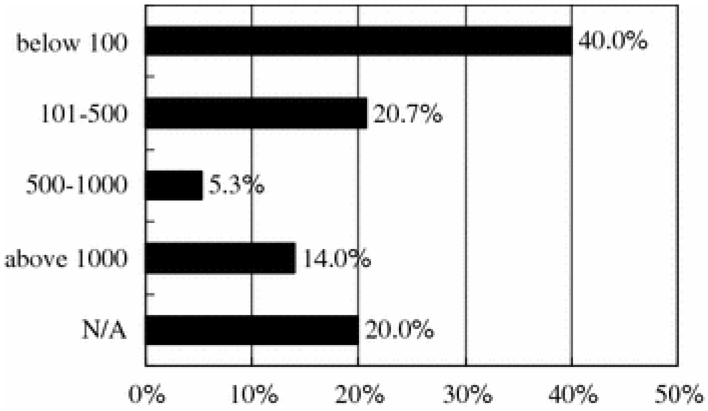


Fig. 6

Number of employees of the surveyed companies

## Reasons and benefits of using nanotechnology

Three main reasons why companies are involved in nanotechnology are company innovation strategy (49.6%), increase company profit (48.0%) and early market occupation (37.8%). Most companies believe nanotechnology will lead to high profit in the near future so it is necessary to catch up with newly innovative nanotechnology in order to occupy early market, first mover position (Fig. 7).

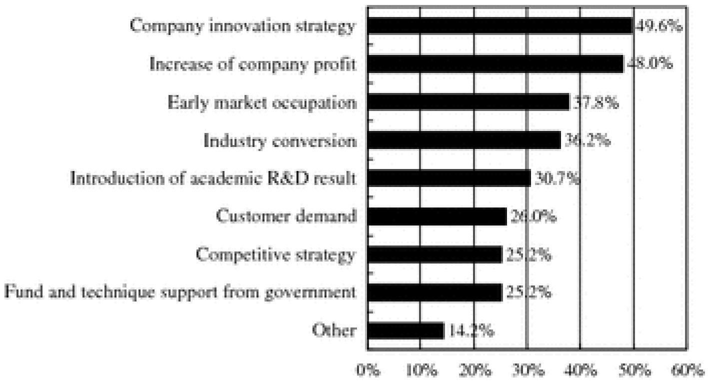


Fig. 7

Reason for the surveyed companies to introduce nanotechnology (multiple choice)

A total of 84.7% companies believe the benefit of introducing nanotechnology is product function innovation. Brand value increase is considered by 76.7% companies as the second popular answer regarding the source of benefit. Therefore, it is to be expected that Nanomark (Schulte 2004; ITRI Nanomark 2004) initiated in 2004 will continue to play a very important role for increasing brand value in Taiwan (Fig. 8).

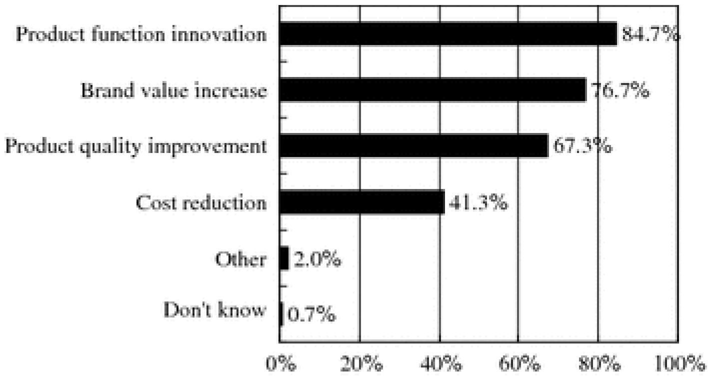


Fig. 8

Benefit for the surveyed companies to introduce nanotechnology (multiple choice)

## Industrialization and manpower

### Industrialization

According to an additional set of in-depth interviews, most of current nano related products are simply applying nanomaterials to existing products. Therefore, nanomaterial is in most demand among the other nano fields. The suggestion from in-depth interviews is confirmed by the survey result shown in Fig. 9. The number of companies doing R&D on nanomaterial (53.3%) is significantly larger than that of other fields.

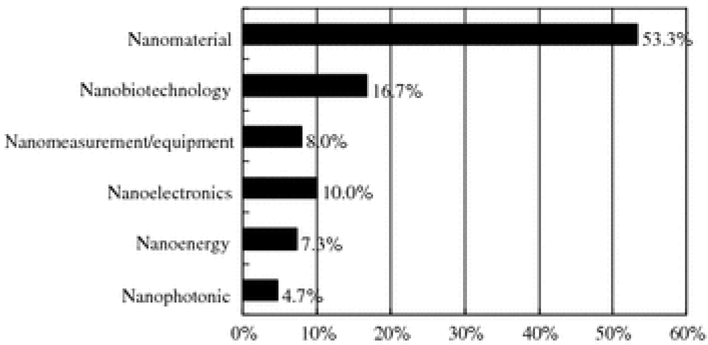


Fig. 9

Current or future fields of nanotechnology R&D and manufacturing of the surveyed companies

The whole commercialization process is categorized into four different steps: (1) R&D, (2) prototype testing, (3) mass production, and (4) product application. Most companies are doing technique development (R&D) (96.2%), prototype testing (82.4%), and mass production (66%). For those companies with technique development, 52% of them belong to nanomaterial, 16% companies belong to nanobiotechnology, 10% companies belong to nanomeasurement/equipment, 9% companies belong to nanoelectronics. For those companies with product application, 40% of overall companies, most of them (65%) also belong to nanomaterial field. These subsets are similar to overall findings (Fig. 10).

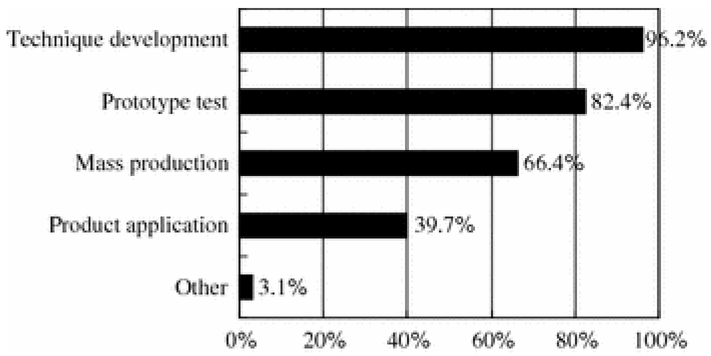


Fig. 10

Steps of commercialization of the surveyed companies (multiple choice)

The number of companies introducing nanotechnology to products greatly increased in 2003 and 2004 due to the facts that the Taiwan government started the National Science Program for Nanoscience and Nanotechnology in 2003 and that industrialization funding from that program is 64% of the total funding. Therefore, a rapid increase of number of companies with nano related techniques can be observed both in 2003 and 2004 as shown in Fig. 11.

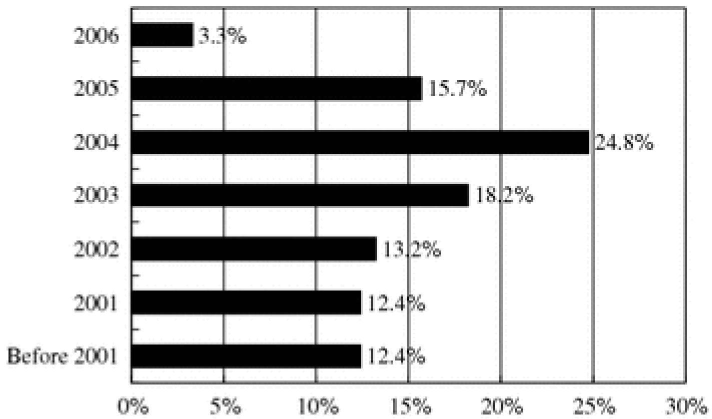


Fig. 11

Time for the surveyed companies to introduce nanotechnology to product

For the four steps of commercializing process above, R&D or technique development is the most time consuming, and the other three steps take similar length of time (Fig. 12).

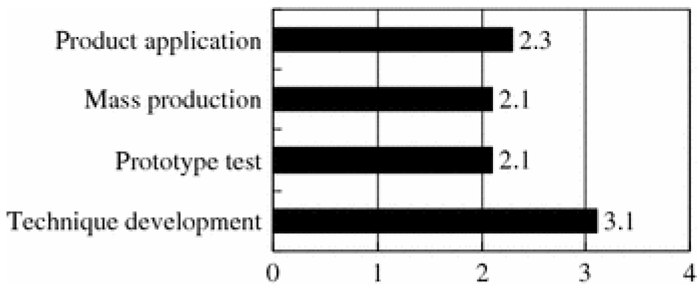


Fig. 12

Average length of time for the surveyed companies to spend on each step of commercialization process (unit: year)

The sources of nanotechnology are mainly research institutes and in-house research. As Fig. 3 shows 64% funding of National Science and Technology Program for Nanoscience and Nanotechnique is for nanotechnology industrialization. Therefore, nanotechnology transfers from research institutes to almost half of companies should be expected, and are demonstrated below (44.7%) (Fig. 13).

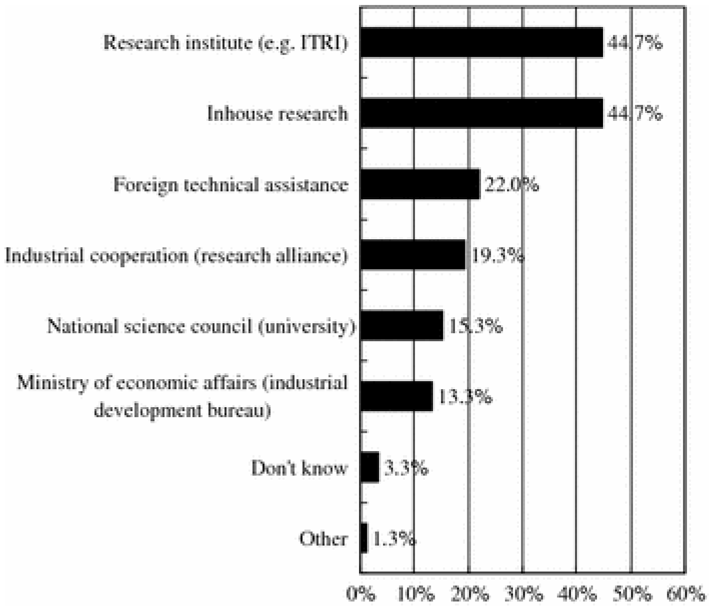


Fig. 13

Nanotechnology sources of the surveyed companies (multiple choice)

## Manpower

As shown in Fig. 6, 40% of companies have less than 100 employees in the medium and small enterprises that dominated Taiwan. Therefore, it is not surprising that 44.7% of companies have less than five employees working on nanotechnology related jobs. However, half of all companies, as shown in Fig. 9, are doing nanomaterial R&D. Hence, it can be speculated that most of current nano products are simply obtained by introducing nano materials into existing manufacturing processes. This does not really require much manpower since the manufacturing processes may not be modified too much in many cases. The product innovation, shown in Fig. 8, expected by 84.7% companies probably is currently based on minor product modification (Fig. 14).

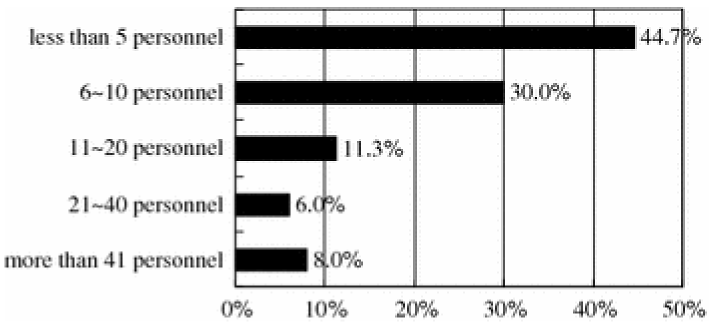


Fig. 14

Number of employees in charge of nanotechnology job in the surveyed companies

The overwhelmingly most favored manpower field is nanomaterial (52.7% of companies), while nanobiotechnology (14% of companies) and nanomeasurement/equipment (12.7% of companies) are next in importance. Figure 9 shows companies doing research and development on these three areas are 53.3%, 16.7%, and 8.0%, respectively. The similarity between preferred manpower specialty and the research and development field indicates that manpower introduced into industry is mainly for research and development. This is consistent with the fact that nanotechnology is a newly focused field which requires introduction of more manpower doing research and development (96.2% in Fig. 10) to innovate product function (84.7% in Fig. 8) for company innovation (49.6% in Fig. 7) and increasing company profit (48.8% in Fig. 7) (Fig. 15).

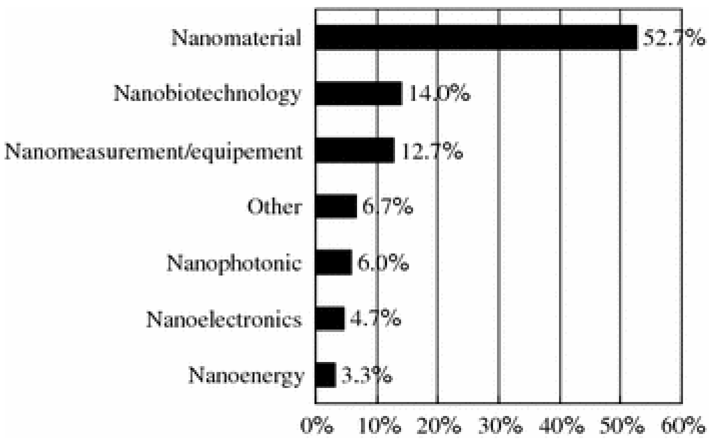


Fig. 15

Preferred fields of manpower of the surveyed companies

Figure 16 shows the desired nanotechnology personnel of companies. Personnel for doing research and development are needed by 64.7% of the companies, and 35.3% need marketing personnel. This is consistent with the observation, mentioned above, that research and development are crucial for this emerging field. Marketing personnel are also required since products with innovative modifications are easily released to market in order both to occupy market niches early and to increase company profit. Furthermore, the in-depth interviews suggest that Taiwan’s nano market is small and local so companies are in urgent need of international marketing manpower when globalization is considered.

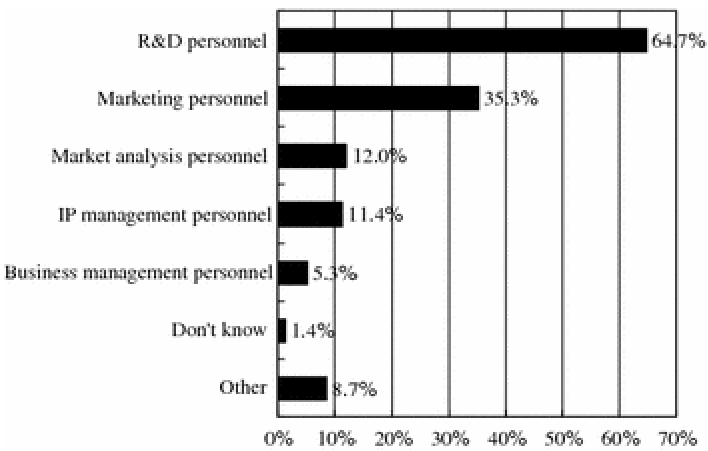


Fig. 16

Personnel required by the surveyed companies (multiple choice)

Nanotechnology sourcing of human resources for different companies does not differ too much from company to company (32.0–41.3%), but internal training (41.3%) is the most usual way to obtain nanotechnology manpower (Fig. 17).

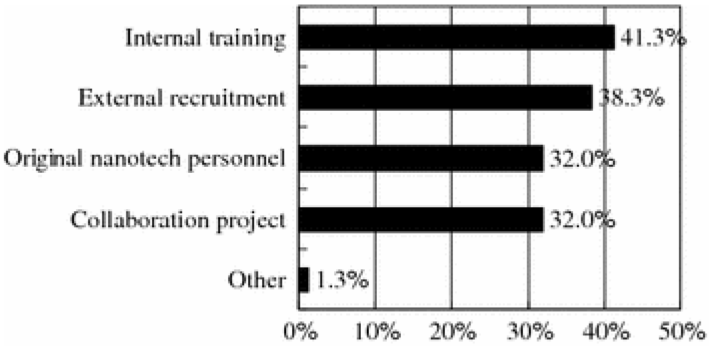


Fig. 17

Nanotechnology human resource of the surveyed companies (multiple choice). “Collaboration project” means hiring people educated or trained by an industry-academy collaboration project

## Funding and profit

### Funding

Most companies (30.7%) have nanotechnology R&D expenditure less than 5% of overall funding, while 14% of companies invest more than 50% of funding for nanotechnology R&D (Fig. 18).

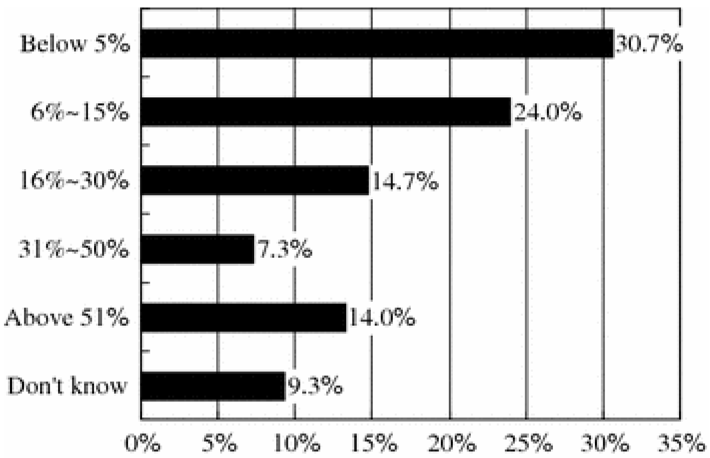


Fig. 18

Percentage of nanotechnology funding of the surveyed companies

Corporate funding is the major nanotechnology funding which is significantly larger than other funding sources, with 87% of companies making their own investment while only 4% of companies obtained funding from venture capital (Fig. 19).

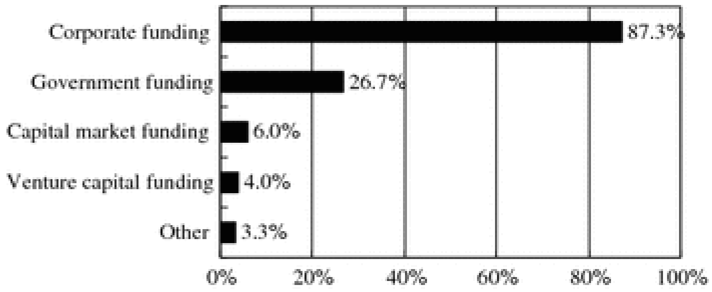


Fig. 19

Funding sources of the surveyed companies (multiple choice)

## Profit

Figure 10 shows that 39.7% companies have already commercialized products (product application) while 39.3% companies have started making profits. This suggests that almost all companies with commercialized nano product are making profit.

For those companies (Fig. 20, 56.7% of all companies) which are not yet making profit, most are still doing research and development (36.9%). Of these companies, 32% are expecting to make profit within 1–2 years. Another 32% believe it is hard to estimate when the company will make a profit, and 11% believe no profit will develop in the near-term. This indicates conservative expectations for profitable nano products. Of the companies, 11.9% provide other reasons such as still being in the middle of introducing techniques, the company is a new start-up, there is low-market acceptance, etc (Fig. 21).

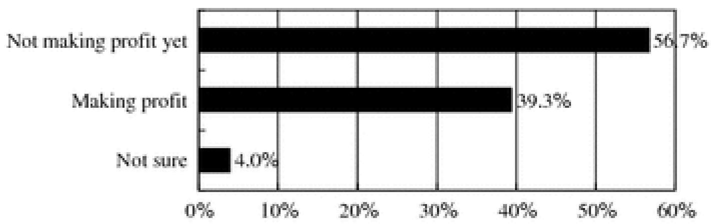


Fig. 20

Current profit status of the surveyed companies

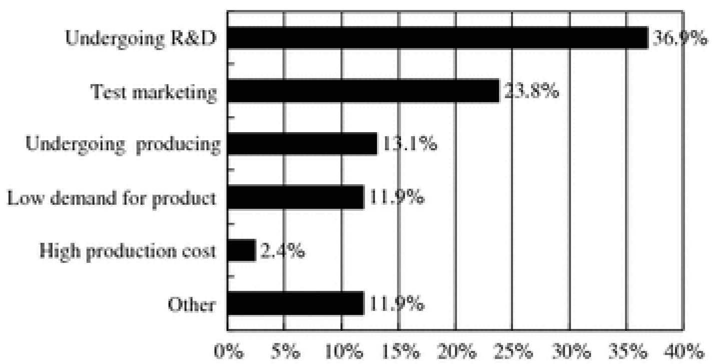


Fig. 21

Progress of commercializing nano product of the surveyed companies

## Difficulties and perspectives

### Difficulties

The top seven difficulties in current nanotechnology industry are (1) nanotechnique manpower, (2) consumer recognition, (3) high product cost, (4) technique (Intellectual property), (5) marketing channels, (6) product standards and certificate, and (7) cross field integration. The two important difficulties in 2002, market information and funding, no longer belong to the top seven in 2006. However, consumer recognition, high product cost and marketing channel, which directly relate to markets, are three new issues in the top seven difficulties in 2006 (Fig. 22).

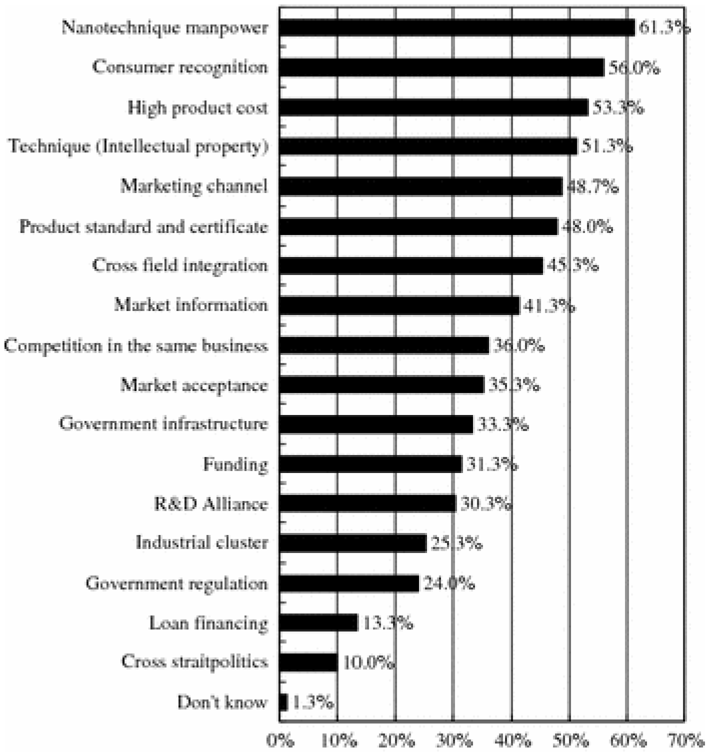


Fig. 22

Difficulties of nanotechnology industrialization of the surveyed companies (multiple choice)

Nanotechnology personnel training, building information platform for academic R&D result diffusion, and increase industrial applicability of academic R&D results are the top three issues with which the government should be concerned in order to support the nanotechnology industry (Fig. 23).

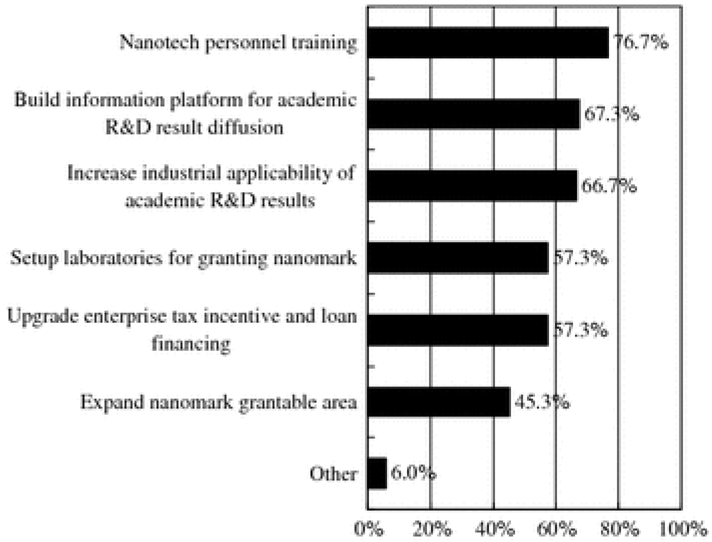


Fig. 23

Expected support from government of the surveyed companies (multiple choice)

## Perspectives

Nanotechnology R&D and manufacturing within the next 2 years, as shown in Fig. 9, are not very different from the current status. Nanomaterial will still be the focus of nanotechnology before 2009 (Fig. 24).

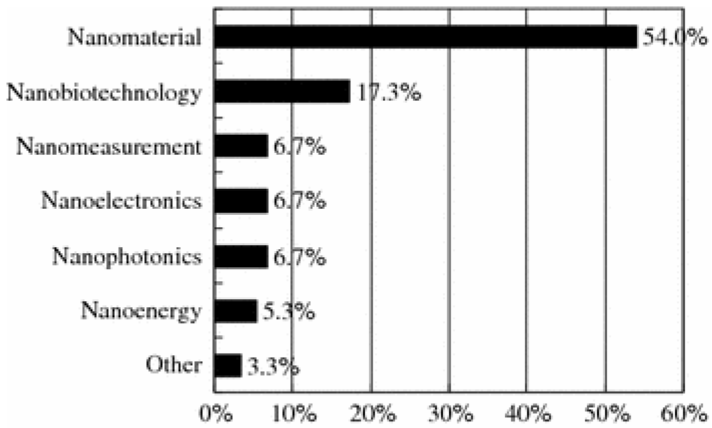


Fig. 24

Fields of nanotechnology of the surveyed companies before 2009

A total of 32.0% companies will introduce nanotechnology funding of less than 0.15 million before 2009 and only 8% of companies are willing to invest more than 1.5 million. Because Taiwan is a small and medium-sized enterprise oriented country, the total funding to be introduced into nanotechnology is not very significant. Those companies which are willing to invest more than US$ 3 million comprises three nanomaterial companies, two nanoenergy companies, and four companies from the other four nano fields (Fig. 25).

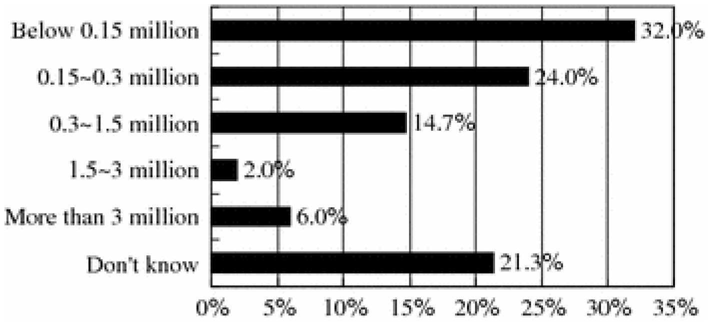


Fig. 25

Funding to be introduced before 2009 (unit: US$, convert NT$ to US$)

Companies opinions about the prospect of Taiwan nanotechnology industry in their specific fields show 84.7% of the companies believe Taiwan nanotechnology industry is either promising or very promising. Only 13.4% of companies are negative about Taiwan's nanotechnology future (Fig. 26).

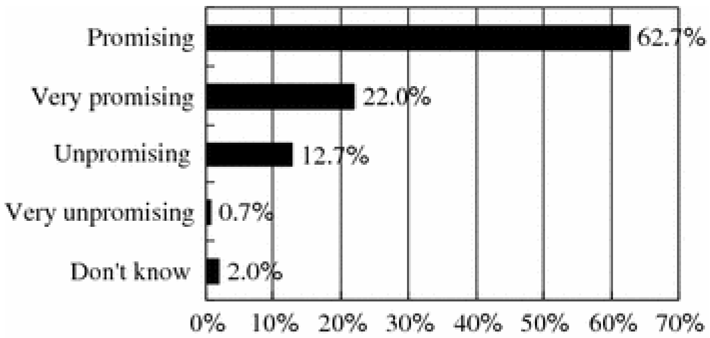


Fig. 26

Perspective of nanotechnology in Taiwan

# Discussion

Since small and medium-sized enterprises have been the backbone of Taiwan's economic development, most of the survey participants have paid-in capital of less than US$ 3 million (44.7%, Fig. 5) and less than 100 employees (40%, Fig. 6). 47% of companies in 2002 and 44% of companies in 2006 are chemistry related and the major filed of nanotechnology in Taiwan is nanomaterial (53.3%, Fig. 9). The main reasons for introducing nanotechnology are company innovation (49.6%, Fig. 7) and increase of profit (48.0%, Fig. 7) through both product function innovation (84.7%, Fig. 8) and brand value increase (76.7%, Fig. 8).

Nanomaterial has dominated Taiwan nanotechnology since 2002 (51.6% in 2002 and 53.3% in 2006) because of Taiwan's conventional industry. Most nano products are manufactured by introducing nanomaterial to existing products. From 2002 to 2006, nanophotonic has decreased from 16.1% to 4.7%, nanoelectronics has increased from 3.2% to 10%, and nanobiotechnology from 9.7% to 16.7%. The time when a company introduces nanotechnology to a product has obviously increased in 2003 and reached a maximum in 2004. This has something to do with nanotechnology promotion by the National Program started in 2003 (National Science Council 2005).

Since interdisciplinary collaboration increases efficiency for nanotechnology and next generation technology development, promoting nanotechnology in every field is necessary so that a complete nanotechnology environment with balanced development in every field can be expected in order to maximize further the possibility of future interdisciplinary collaboration.

Investigated results of 2002 show only two companies had more than 50 employees working on nano products, but in 2006 (Fig. 14), 8% of companies have more than 41 employees and 6% of companies have 21–40 employees. This remarkable manpower increase is consistent with the explosive growth of nanotechnology all over the world. There is no doubt that enterprises will keep increase nanotechnology manpower in the foreseeable future. However, as shown in Fig. 16, the most desirable nanotechnology manpower is R&D personnel who are most likely trained in-house (41.3%, Fig. 17), because companies (61.3%, Fig. 22) believe a shortage of nanotechnology manpower is the most difficult problem.

As shown in Fig. 2, the forecasted revenues from products incorporating nanotechnology has exponentially increased. Figures 22 and 23 and the result of 2002 indicate the two important problems to be solved in 2006 are manpower and technique.

## Conclusions

This investigation shows that nanomaterial (both R&D and manufacturing) is the main focus and will continue to be the key point of Taiwan's nanotechnology industrialization. Even though the prospect of Taiwan nanotechnology industry is believed to be positive, solving nanotechnology related problems such as nanotechnology manpower, consumer recognition, high product cost, limited technique, market channel, product standard and certificate, and cross field integration is essential.

Therefore, the Taiwan government should help develop nanotechnology, cultivate a large number of nanotechnology talents, and then introduce them into industry to satisfy the basic requirement. More nanomark certifying mechanisms for different products have to be developed continuously in order to ensure the quality of more types of nano products. The nanotechnology manpower developed by the national nanotechnology program initiated in 2003 will be much more apparent after completion of national program in 2008. In addition, it is necessary for government to plan and integrate diversified nanotechnology resources in order to promote Taiwan's nanotechnology industrialization.

## Notes

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## References

Director-General of Budget, Accounting and Statics, Executive Yuan, ROC (2007) Standard Industrial Classification of the Republic of China, http://eng.stat.gov.tw/ct.asp?xItem=5008ctNode=1528
(http://eng.stat.gov.tw/ct.asp?xItem=5008ctNode=1528)

Huang ZH, Chen H, Chen ZK, Roco MC (2004) International Nanotechnology Development in 2003: Country, institution, and technology field analysis based on USPTO Patent Database. J Nanoparticle Res 6(4):325–54
CrossRef (https://doi.org/10.1007/s11051-004-4117-6)
Google Scholar (http://scholar.google.com/scholar_lookup?title=International%20Nanotechnology%20Development%20in%202003%3A%20Country%2C%20institution%2C%20and%20technology%20field%20analysis%20based%20on%20USPTO%20Patent%20Database&author=ZH.%20Huang&author=H.%20Chen&author=ZK.%20Chen&author=MC.%20Roco&journal=J%20Nanoparticle%20Res&volume=6&issue=4&pages=325-54&publication_year=2004)

Industrial Technology Research Institute (2007) http://www.itri.org.tw/eng/index.jsp
(http://www.itri.org.tw/eng/index.jsp)

ITRI Nanomark (2007) http://www.nanomark.itri.org.tw/Eng/
(http://www.nanomark.itri.org.tw/Eng/)

Lin JL, Jang GW (2004) Opportunities for Taiwan's industry. Mater Today 7(12):36–41
CrossRef (https://doi.org/10.1016/S1369-7021(04)00629-7)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Opportunities%20for%20Taiwan%E2%80%99s%20industry&author=JL.%20Lin&author=GW.%20Jang&journal=Mater%20Today&volume=7&issue=12&pages=36-41&publication_year=2004)

Luo YL, Wu DS, Chien KM, Kuo KH, Shiao YP, Wang YM (2002) Final report of pre-planning and promotion of the nanotechnology industrialization program. Industrial Development Bureau, Ministry of Economic Affairs (in Chinese)
Google Scholar (https://scholar.google.com/scholar?q=Luo%20YL%2C%20Wu%20DS%2C%20Chien%20KM%2C%20Kuo%20KH%2C%20Shiao%20YP%2C%20Wang%20YM%20%282002%29%20Final%20report%20of%20pre-planning%20and%20promotion%20of%20the%20nanotechnology%20industrialization%20program.%20Industrial%20Development%20Bureau%2C%20Ministry%20of%20Economic%20Affairs%20%28in%20Chinese%29)

Lux (2006) The nanotech report, 4th, Vol 1. Lux research
Google Scholar (https://scholar.google.com/scholar?q=Lux%20%282006%29%20The%20nanotech%20report%2C%204th%2C%20Vol%201.%20Lux%20research)

Marinova D, McAleer M (2003) Nanotechnology strength indicators: international rankings based on US Patents. Nanotechnology 14:R1–R7
CrossRef (https://doi.org/10.1088/0957-4484/14/1/201)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Nanotechnology%20strength%20indicators%3A%20international%20rankings%

20based%20on%20US%20Patents&author=D.%20Marinova&author=M.%20McAleer &journal=Nanotechnology&volume=14&pages=R1-R7&publication_year=2003)

Miranda Santo M, Massari Coelhno G, dos Santos DM, Fellows Filho L (2006) Text mining as a valuable tool in foresight exercises: a study on nanotechnology. TechnolForecast Social Change 73:1013–1027
CrossRef (https://doi.org/10.1016/j.techfore.2006.05.020)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Text%20mining%20as%20a%20valuable%20tool%20in%20foresight%20exercises%3A%20a%20study%20on%20nanotechnology&author=M.%20Miranda%20Santo&author=G.%20Massari%20Coelhno&author=DM.%20dos%20Santos&author=L.%20Fellows%20Filho&journal=TechnolForecast%20Social%20Change&volume=73&pages=1013-1027&publication_year=2006)

Nano Electronic Common Laboratory User's Club (2007) About This Club, http://www.nanoelab.itri.org.tw/about.html (http://www.nanoelab.itri.org.tw/about.html)

Nano Mark Technical Committee (2005) Current operation of nanoproduct certification system. Taiwan Nano Newslett 3:78–78 (In Chinese)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Current%20operation%20of%20nanoproduct%20certification%20system&journal=Taiwan%20Nano%20Newslett&volume=3&pages=78-78&publication_year=2005)

Nanoscience and Technology Program Office (2007) http://nano-taiwan.sinica.edu.tw (http://nano-taiwan.sinica.edu.tw)

Nanotechnology and Micro System Association (2007) http://www.nma.org.tw (http://www.nma.org.tw)

National Science Council (2005) Yearbook of Science and Technology, Taiwan, ROC, 2005 (In Chinese)
Google Scholar (https://scholar.google.com/scholar?q=National%20Science%20Council%20%282005%29%20Yearbook%20of%20Science%20and%20Technology%2C%20Taiwan%2C%20ROC%2C%202005%20%28In%20Chinese%29)

Roco MC (2001) International strategy for nanotechnology research and development. J Nanoparticle Res 3:353–360
CrossRef (https://doi.org/10.1023/A%3A1013248621015)
Google Scholar (http://scholar.google.com/scholar_lookup?title=International%20strategy%20for%20nanotechnology%20research%20and%20development&author=MC.%20Roco&journal=J%20Nanoparticle%20Res&volume=3&pages=353-360&publication_year=2001)

Roco MC (2005) International perspective on Government nanotechnology funding in 2005. J Nanoparticle Res 7(6):707–712
CrossRef (https://doi.org/10.1007/s11051-005-3141-5)
Google Scholar (http://scholar.google.com/scholar_lookup?title=International%20perspective%20on%20Government%20nanotechnology%20funding%20in%202005&author=MC.%20Roco&journal=J%20Nanoparticle%20Res&volume=7&issue=6&pages=707-712&publication_year=2005)

Scheu M, Veefkind V, Verbandt Y,Molina Galan E, Absalom R, Förster W (2006) Mapping nanotechnology patents: the EPO approach. World Patent Inform 28(3):204–211
Google Scholar (http://scholar.google.com/scholar_lookup?title=Mapping%20nanotechnology%20patents%3A%20the%20EPO%20approach&author=M.%20Scheu&author=V.%20Veefkind&author=Y.%20Verbandt&author=E.%20

Molina%20Galan&author=R.%20Absalom&author=W.%20F%C3%B6rster&journal=World%20Patent%20Inform&volume=28&issue=3&pages=204-211&publication_year=2006)

Schulte J (ed) (2004) Nanomark lable on Taiwanese Nanoproducts. Asian Pacif Nanotechnol Forum News J 3(4):38–45
Google Scholar (https://scholar.google.com/scholar?q=Schulte%20J%20%28ed%29%20%282004%29%20Nanomark%20lable%20on%20Taiwanese%20Nanoproducts.%20Asian%20Pacif%20Nanotechnol%20Forum%20News%20J%203%284%29%3A38%E2%80%9345)

Su TT (2006) Commercialization of nanotechnology—Taiwan experiences, Emerging Technologies: IEEE Conference on Nanoelectronics, pp 25–28
Google Scholar (https://scholar.google.com/scholar?q=Su%20TT%20%282006%29%20Commercialization%20of%20nanotechnology%E2%80%94Taiwan%20experiences%2C%20Emerging%20Technologies%3A%20IEEE%20Conference%20on%20Nanoelectronics%2C%20pp%2025%E2%80%9328)

Taiwan Photocatalyst Industry Association (2007) http://www.t-pia.org.tw (http://www.t-pia.org.tw)

Tegart G (2002) Nanotechnology: the technology for the 21st Century, Vol. II, The Full Report, APEC Center for Technology Foresight, Bangkok, 88
Google Scholar (https://scholar.google.com/scholar?q=Tegart%20G%20%282002%29%20Nanotechnology%3A%20the%20technology%20for%20the%2021st%20Century%2C%20Vol.%20II%2C%20The%20Full%20Report%2C%20APEC%20Center%20for%20Technology%20Foresight%2C%20Bangkok%2C%2088)

Wu MK (2002) Nanotechnology Industry, 2002. In: Conference on Strategy for Industrial Development, Taipei, Taiwan (In Chinese)
Google Scholar (https://scholar.google.com/scholar?q=Wu%20MK%20%282002%29%20Nanotechnology%20Industry%2C%202002.%20In%3A%20Conference%20on%20Strategy%20for%20Industrial%20Development%2C%20Taipei%2C%20Taiwan%20%28In%20Chinese%29)

Yuan JC, Wang CP, Tzeng GH (2004) Fuzzy multi-criteria decision making for evaluating the performance Nanotechnology strategies of Taiwan. J Technol Manag 9:125–162
Google Scholar (http://scholar.google.com/scholar_lookup?title=Fuzzy%20multi-criteria%20decision%20making%20for%20evaluating%20the%20performance%20Nanotechnology%20strategies%20of%20Taiwan&author=JC.%20Yuan&author=CP.%20Wang&author=GH.%20Tzeng&journal=J%20Technol%20Manag&volume=9&pages=125-162&publication_year=2004)

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