South Korea Plans to Stand among World's Top 3 States in Nanotechnology

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Statnano - South Korea is one of the fastest-growing developed countries in the 2000s and the main goal of South Korea Nanotechnology Initiative is to stand among the top 3 countries in nanotechnology by the end of 2015. The current study is attempting to collect information and compare scientific and technological data related to nanotechnology in South Korea.

Introduction

South Korea is an East Asian territory that is bordered by China to the Northwest and Russia to the Northeast. It has a market economy which ranks 15th in the world by nominal GDP and 12th by purchasing power parity (PPP), turning it into a G-20 major economy. It is a high-income developed country with a developed market and is a member of OECD. South Korea is one of the Asian Tigers, and is the only developed country so far to have been included in the group of the Next Eleven countries. It had one of the world's fastest growing economies from the early 1960s to the late 1990s, and South Korea is still one of the fastest-growing developed countries in the 2000s, along with Hong Kong, Singapore, and Taiwan, the other three members of the Asian Tigers. Having almost no natural resources and always suffering from overpopulation in its small territory, which deterred continued population growth and the formation of a large internal consumer market, South Korea adapted an export-oriented economic strategy to fuel its economy, and in 2010, it was the seventh largest exporter and tenth largest importer in the world. Bank of Korea and Korea Development Institute periodically release major economic indicators and economic trends of South Korea.[1]

National Nanotechnology Plan of South Korea

The Korea National Nanotechnology (NT) Initiative started in December 2000 by the National Science and Technology Council (NSTC).Nanotechnology Development Plan was approved by the NSTC on July 18 2001.The NT Development Promotion Act was passed in

November 2002 at the National Assembly.In December 2006, NSTC reviewed the outcomes of the NT Development Plan for the first 5 years of the Phase-1 Plan and approved the newly-revised Phase-2 Plan for nanotechnology development for the next 10years.

Figure 1 shows milestones in Korea Nanotechnology Policy between 2000 and 2012.Korea National Nanotechnology Initiative and Nanotechnology Industrialization Support Center were established in 2001. Then Korea focused on infrastructure improving so that some research center and research societies such as Korea Nanotechnology Research Society (KoNTRS) and Nano Particles Application Center were established.Korea Nanotechnology initiative program was revised in 2005 and 2011and its supplement was released in late 2005.Korea nanotechnology roadmap was provided in 2008.

Figure 1: Milestones in Korea Nanotechnology Policy between 2000 and 2012

Table 1 gives results of the 1st and 2ndphases on Korea nanotechnology initiative program (2001-2005). The table shows the results for 2007 and two years after the 2nd phase's implementation. Korea nanotechnology investments in 2005 were 277.2 billion won in 2005 which is roughly 1.6 times more than that of 2001. At the same time, growth rate of nano-projects was 3.8% so that it increased from 1,015 to 3900. Number of nano-companies reached to 214 with 1.7 growth rate. Maximum growth rate belonged to "number of departments" where it raised from 3 to 37; it means the indicator grew 11 times in 4 years. Korean scientists published 407 nano-articles in 2001 so Korea's rank was 8 in the indicator. The number of nano-articles reached 1,431 in 2005and Korea ranked 5th in nano-publication generation in the world. However 5.9% of the nano-articles were international collaboration. Two years after the 2nd phase's implementation, the rate of investigations increased 2.7 times and reached 281 billion won.Number of nano-companies had grown 3.5 times and reached to 274.The number of nano-departments also reached to 56.

Korea kept its position (5th) in 2007 by publishing 2,236 nano-articles. Korea published 979 nanotechnology patents in 2005, ranked 5th in the world and in 2007, it ranked 4th with 1769 nanotechnology patents.

Table1: Results of the 1st and 2nd phases of Korea nanotechnology initiative program [2]

	2001	2005	2007

Investments	105.2 billion won	277.2 billion won	281 billion won
Number of NT researchers	1,015	3,900	No info available
Number of NT companies	78	214	274
Number of NT departments	3	38	56
Number of NT papers	408	1,421	2,236
Number of NT patents	-	979	1,769

M.C.Roco et. All [3] compared governmental funding of the 1st phase in Korea with that of the US, Japan and EU between 2001 and 2005. Figure 2 shows the results.

Figure2: Comparing the governmental funding in Korea with the US, Japan and EU

Governmental nano-investments in Korea are significantly less than that of US, Japan and EU. The main goal of Korea Nanotechnology Initiative is to stand amongst the top 3 countries in nanotechnology by the end of 2015. The following research centers help Korea in this way:

KPEC (Korea Printed Electronics Center), u-ITC (Ubiquitous IT Cluster), NCNE (National Center of Nanoprocess&Equipments), NNFC (National Nano Fab Center), KANC (Korea Advanced Nano Fab Center), NCNT (National Center for Nanomaterials Technology), NNIC (National Nanotechnology Integration Center), GNIC (Gwangju Nanotechnology Integration Center). Figure 3 represents location of the centers.

Figure 3: Distribution of nano-research centers in Korea

Three major organizations are active in securing national competitive edge by facilitating the creation of new industries and industrialization through the development of the fundamental technology in the area of nanotechnology and gradual/systematical construction of the cooperation system among academy, research institute and government. Table 2 introduces the organizations.

Table2: Three main nanotech-related organizations

Organizations	**Abbr.**	**Homepages**
Nanotechnology Information Center,	KISTI	http://www.nanonet.info
Korea Nanotechnology Research Society	KoNTRS	http://www.kontrs.or.kr

Budgets and Plans

The organizations have their own plans for nanotechnology. In overall, 0.5 to 1 million US dollars are dedicated annually to develop nanotechnology by the organizations. They should invest the budget on nanomaterial production during 5 to 7 years. The organizations must dedicate 20 million dollars, over 9 years, to nano related projects which overcome the current challenges in industries. In Nanotechnology Development Plan, special budget is dedicated to commercialization. The budget is not constant for each year and it varies year by year. 15 million dollars per year is dedicated to energy. Energy-related projects are managed by science and technology ministry.In Nanotechnology Development Plan, 45.5 million dollars per year is dedicated to the development and commercialization of energy-related projects.

The budget of nanotechnology applications in ecosystem and environment is 12 million dollars per year from which 2.7 million dollars is dedicated to innovations in ecosystem, 8.2 million dollars for environment and 1.2 million dollars for nanomaterials safety evaluations.

In 2011,Nano Safety Management Master Plan was introduced by Korea Nanotechnology Initiative and launched since 2012. The plan will finish in 2016. The overall objective of this plan is to define methods/processes for the identification and management/minimization of the inherent safety risks associated with nanoproducts. In fact, the plan considers safety aspects in product commercialization.

Korea Nanotechnology Development Plan aims to improve Korea's global situation in the field of nanotechnology to generate wealth and improve the quality of life in the country. Evaluation results of the executive activities show the first and second phases had good effects on Korean industries and products. But there is a long way to reach the set target and desirable situation.

Figure 4: Nanotechnology dedicated budget in Korea between 2001 and 2013

Figure 4 shows nanotechnology dedicated budget in Korea between 2001 and 2013[4]. South Korea invested 2,834 trillion won (US $ 2.6 billion) in nanotechnology last year;it will

be increased to 2,929 in 2013.

There are additional activities and programs in Korea, including national projects in nanotechnology. Table 3 introduces three research centers associated with national projects. The centers implement "21C Frontier R&D Program".

Table 3: Three research centers associated with national projects

Research center	website
Center for Tera-level Nanodevices	http://www.nanotech.re.kr
Center for Nanostructured Materials,	http://cnmt.kist.re.kr
Center for Nanoscale Mechatronics,	http://www.nanomecca.re.kr

Publications and Patents

Figure 5 represents number of nano-articles published by Korea between 2000 and 2012. There is continuous growth in the last 12 years. In 2000, Korea, with 513 nano-articles, stood 9thin the world in the field of nanotechnology. Korea reached 8th and 6th in 2003 and 2004 respectively. In 2008, Korea improved its position in world ranking so that it reached 5th with 4,213 nano-articles.However Korea kept the rank for 3 years, in 2012 it published 6,880 nano-articles and stood 4th in the world.

Figure 5: Number of nano-articles published by Korea between 2000 and 2012

Citation indicators are used extensively to evaluate the impact of the research of individual scientists, institutes and university departments, and sometimes even countries. The outcomes of such analyses can have a profound influence on the careers of scientists or, for example, the future funding of research institutes. Number of citations and h-index are two frequently-used parameters to evaluate the quality and quantity of nano-articles.

Figure 6 represents Korea's rank in "number of citations per nano-article" between 2001 and 2012.

Figure 6: World rank of Korea in "number of citations per nano-article" from 2001 to 2012

Figure 7: H-index of nano-articles published by Korea (2001–2012)

Figure 8: World rank of Korea in H-index (2001-2012)

The H-index,a small number with a big impact, is a relatively simple way to calculate and measure the impact of a scientist. The h-index is the numbers of items which is in the h rank of the mentioned ranking and have at least "h" citations. For example, an h-index of 20 means there are 20 items that have 20 citations or more. This metric is useful because it discounts the disproportionate weight of highly cited papers or papers that have not yet been cited. The H-index can only increase if someone keeps publishing papers and they are cited. But the higher H-index you get, the harder it is to increase it.

Figure 7 shows H-index of nano-articles published by Korea. However there is a steady increase between 2001 and 2005, H-index decreases after 2006. Figure 8 represents rank of Korea in the world in H-index between 2001 and 2012. Korea stood 7th and 6th before 2007, but after 2008 it reached 5th in the world in H-index. It is seen that H-index of Korea nano-articles had a highly positive trend during the last four years.It proves that Korea is improving itself both in quantity and quality since h-index reflects peer review, and peer review reflects research quality.

Number of patents (published or granted) used frequently as a tool to assess a technology. Figure 9 gives the number of nanotechnology patents published (but not yet granted) in USPTO. There is steadily growth in the indicator over the period 2009-2013. Based on Statnano [5],share of Korea nanotechnology patent publications in USPTO increased from 2009 (372 patents) to 2013 (562 patents).

Figure 9: Number of nano-patents published (but not yet granted) in USPTO

Based on Korea nanotechnology annual report published in 2007, there were 78 nanotechnology-related companies in 2001 (including 33 venture companies). The number of companies increased to 274 (including 145 venture companies)in 2007. Table 4 represents the number of nanotechnology companies in Korea between 2001 and 2007.

Year	2001	2004	2005	2006	2007

Large	45	18	32	32	37
Small&Medium		28	56	79	92
Venture	33	78	128	125	145
total	78	124	241	238	274

Figure 10 shows distribution of nanotechnology companies by field in 2007. 44% of companies are active in material science and 16% in process/Metrology. There is no enough information about the companies. Nanowerk [6]maintains a number of unique and extensive databases for nano-related companies. There are only 25 nano-companies for Korea in the database.

Based on Korea nanotechnology annual report in 2007, numbers of commercialized products since 2004 are 274 (119 in 2004, 81 in 2005 and 74 in 2006). 74 cases of the companies in 2006 sorted by technological fields are as follows:

- Nano Devices: 24 (32%)
- Nano Materials: 15 (19%)
- Nano Fundamentals: 11 (14%) (Nano Measurement, Tools,Processing)
- Environmental & Energy: 10 (13%)
- Nano Medicals & Health: 9 (12%)
- Nano Bio: 8 (10%)

Figure 10: Distribution of Korean nanotechnology companies by field (2007)

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