The Chemical Industry of South Korea: Progress and Challenges

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South Korea's chemical industry is entering a position of leadership in the world market. However, new investments in energy resources, a shift to higher-value-added products, and development of core environmentally friendly technologies are needed for South Korea to better compete with the most advanced chemical economies.

The manufacturing industry in South Korea has played a key role in the country's economic development. Among all manufacturing sectors, the chemical industry has been a critical driving force in rebuilding the nation's economy after the Korean War ended in 1953.

The dramatic emergence of South Korea on the world stage after the devastation of the Korean War has been referred to as the "Miracle on the Han River." Export-fueled economic growth — marked by rapid industrialization, technological advancement, urbanization, democratization, and globalization — transformed the country from a near-zero- to a trillion-dollar economy.

Since 1960, the South Korean chemical industry has made remarkable contributions to the country's economic prosperity. South Korea is now ranked as the most competitive of Asia's 35 nations, according to a 2011 report by Boao Forum for Asia *(1)*. Based on ethylene capacity, in 2010, South Korea's petrochemical industry was the world's fifth largest (Figure 1).

Today, South Korea's chemical industry is in the process of transforming from a large-scale commodity industry to one that produces innovative, high-value-added products. This article describes the chemical industry's current position and some of its efforts to address global and domestic challenges.

The creation of a chemical industry

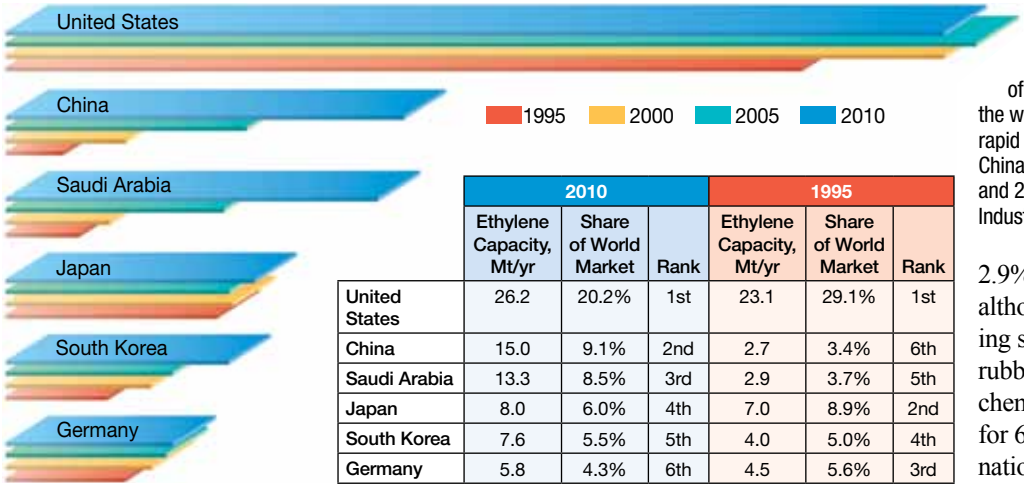
The history of South Korea's chemical industry since 1960 comprises five phases (Table 1). The first three phases, between the 1960s and 1990s, were government-led nationwide economic-development plans. Since the late 1990s, change has been driven by the private sector.

Today, exports play a key role in strengthening the economy, since South Korea imports most of its raw materials. Indeed, the trade balance index is a significant barometer for South Korea's economic progress. As shown in Table 1, the trade balance has been shifting from one dominated by domestic demand to domination by exports since the early 1990s.

Petrochemicals in South Korea's chemical industry ...

In 2009, shipments by South Korea's chemical and petrochemical industries were valued at 99.4 and 63.7 trillion Korean won (W) (U.S.$87.7 billion and $56.2 billion*),

* U.S. dollar amounts are based on a Nov. 17, 2011, exchange rate conversion of 1,133 Korean won per U.S. dollar.



	2010			1995		
	Ethylene Capacity, Mt/yr	Share of World Market	Rank	Ethylene Capacity, Mt/yr	Share of World Market	Rank
United States	26.2	20.2%	1st	23.1	29.1%	1st
China	15.0	9.1%	2nd	2.7	3.4%	6th
Saudi Arabia	13.3	8.5%	3rd	2.9	3.7%	5th
Japan	8.0	6.0%	4th	7.0	8.9%	2nd
South Korea	7.6	5.5%	5th	4.0	5.0%	4th
Germany	5.8	4.3%	6th	4.5	5.6%	3rd

◀ **Figure 1.** In 2010, South Korea's ethylene capacity of 7.6 million ton/yr (Mt/yr) (5.5% of the global market) ranked fifth in the world. This diagram also shows the rapid growth, and change in position, of China and Saudi Arabia between 1995 and 2010. Source: Korea Petrochemical Industry Association.

respectively. These sectors accounted for 8.9% and 5.7% of South Korea's total manufacturing shipments. The chemical industry's exports were slightly more than its imports (W39.8 vs. W34.3 billion), while petrochemical exports were nearly triple petrochemical imports (W27.5 vs. W9.5 billion).

In the wake of the recent global economic crisis, the value of South Korean petrochemicals shipments decreased 2.9% between 2008 and 2009, although petrochemicals (including synthetic resins and synthetic rubbers, and other basic organic chemicals) still accounted for 64.1% of the value of the nation's chemical shipments (Table 2). Overall, the expansion of production capacity and higher product prices due to rising oil prices resulted in an average annual growth rate of 9.9% for petrochemical production between 2005 and 2009.

South Korea exported $35.7 billion worth of petrochemicals in 2010 (Table 3), which represented 7.7% of the country's total exports. Imports totaled $13.3 billion, accounting for 3.1% of all imports. This translates to a $22.4 billion trade surplus.

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Table 1. History of the South Korean chemical industry, 1966–2010.

	Government Sector Led			Private Sector Led	
	1966–1978 Development	1979–1988 Growth	1989–1997 Take-off	1998–2003 Restructuring	2004–2010 Second Take-off
Major Players and Key Industry Characteristics	Government-led nurturing of industries, launch of Ulsan Complex	Petrochemical industry foundation laid, launch of Yeosu Complex	Large-scale expansion, launch of Daesan Complex	Restructuring of industries Proactive mergers and acquisitions	Expansion of economic scale and foreign investment
Ethylene Capacity	115 kton/yr 1 company	5,055 kton/yr 2 companies	4,330 kton/yr 8 companies	5,760 kton/yr 7 companies	7,770 kton/yr 6 companies
Trade Balance	Net import	Net import to balanced	Net import to net export	Net export	Net export
Major Growth-Leading Industries	Light industry	Light industry transitioned to heavy industry and chemical industry	Heavy industry and chemical industry Markets in Asian developing countries	Parts and materials industries Markets in China	Biotech, Nanotech, Information technology, and Environmental technology; Markets in BRIC countries
Global Environment	Companies in developed countries led industry, globalization Stable earnings; demand growth in Western Europe, North America, and Japan	Oil majors expanded beyond oil; developed petrochemicals industry after oil crisis Majors diversified business due to falling profits	The end of the Cold War; economic globalization Economic depression in Europe and Japan; growth of Asian economic power	Accellerated mergers and acquisitions: BP+Amoco (1998); Exxon+Mobil (1999); Chevron+Philips (2000); Dow+UCC (2001); SABIC+DSM (2002)	High competitiveness of Middle East petrochemicals Projects in China for self-sufficiency High cost pressure; record oil prices

Source: Korea Petrochemical Industry Association.

Table 2. Shipments of chemicals and petrochemicals, 2005–2009.							
Products	Year					Growth Rate 2008–2009	AAGR, 2005–2009
	2005	2006	2007	2008	2009		
Chemicals	$60.8	$62.8	$70.2	$87.5	$87.8	0.3%	9.6%
Petrochemicals	$38.6	$37.7	$44.7	$56.2	$56.2	–2.9%	9.9%
Basic organic petrochemicals	$14.2	$13.2	$16.1	$22.6	$17.6	–22.1%	5.6%
Other organic chemicals	$9.8	$9.4	$10.9	$13.3	$14.2	7.1%	9.7%
Synthetic rubbers	$1.3	$1.4	$1.8	$2.1	$1.8	–12.6%	8.9%
Synthetic resins	$13.2	$13.6	$16.0	$19.9	$22.5	13.2%	14.3%

Notes: Based on companies with more than ten employees (excluding medical supplies). AAGR = Average annual growth rate. Shipments are in U.S.$ billions, based on a Nov. 17, 2011, exchange rate conversion of W1,133 /U.S. dollar. Source: Statistics Korea.

... and in the world market

South Korea's current commodity petrochemical industry finds itself sandwiched between the massive production of developing countries like China and the rapid progress of Middle East countries such as the United Arab Emirates (UAE) and Saudi Arabia, placing it in intense competition. These developed nations have been producing petrochemical products as well as high-value-added fine chemicals, dominating world markets, while the South Korean fine chemicals industry remains far behind.

A 2008 report *(2)* by the Korea Institute for Industrial Economics and Trade advises that the South Korean petrochemical industry, in order to become more responsive to changes in demand and to compete with neighboring countries, must participate in global trade of high-value-added fine-chemical products. To do so, it will need to strengthen its entire value chain — from basic and applied technologies, to development, to manufacturing and marketing.

Furthermore, in order to secure advanced technologies for the future, as well as to respond effectively to the upcoming wave of green technology, South Korea must develop collaborative technology and investment partnerships with organizations in developed and developing countries *(2)*. Recent examples of such partnerships include Rhodia (France) investing in a 48,000-ton/yr polyamide 66 (nylon 66) plant in South Korea's Ulsan complex, and the investment by Evonik (Germany) in SKC Chemical for a propylene oxide process. Foreign investment in the country's value-added products businesses is also needed to restructure the petrochemical industry. For example, Germany's Solvay Fluor GmbH recently invested 50 million Euro in the Onsan complex for the production of fluorine, iodine pentafluoride (IF_5), sulfur hexafluoride (SF_6), and Nocolok (a fluxing agent).

To ensure its competitiveness, the development of advanced core technologies has become a main objective of the South Korean petrochemical industry. The national government has recommended a plan *(3)* to increase R&D investment from 3.23% of gross domestic product (GDP) in 2006 to 5% of GDP in 2012 to support the development of key technologies, such as catalysts and their related process technologies, as well as advanced composite materials and new organic materials, such as plastic optical fiber, fluorine resins, and silicone resins.

Table 3. Petrochemicals trade, 2006–2010.						
Products		Year			Growth Rate 2009–2010	AAGR, 2006–2010
		2006	2009	2010		
Basic Petrochemicals	Export	$3,069	$3,470	$4,403	26.9%	9.4%
	Import	$2,184	$1,715	$2,585	50.7%	4.3%
Intermediates	Export	$2,945	$2,621	$3,434	31.0%	3.9%
	Import	$1,880	$2,230	$2,660	19.3%	9.1%
Synthetic Resins	Export	$11,177	$13,260	$17,051	28.6%	11.1%
	Import	$2,597	$2,424	$3,371	39.1%	6.7%
Synthetic Fiber Raw Materials	Export	$3,072	$3,495	$4,213	20.5%	8.2%
	Import	$729	$442	$707	60.0%	–0.8%
Synthetic Rubbers	Export	$979	$1,560	$2,427	55.6%	25.5%
	Import	$361	$386	$556	44.0%	11.4%
Others	Export	$2,856	$3,062	$4,186	36.7%	10.0%
	Import	$2,637	$2,338	$3,420	46.3%	6.7%
Total Petrochemicals	Export	$24,099	$27,466	$35,714	30.0%	10.3%
	Import	$10,388	$9,535	$13,299	39.5%	6.4%
	Balance	$13,711	$17,932	$22,415	25.0%	13.1%

Notes: AAGR = Average annual growth rate. Shipments are in U.S.$ millions.
Source: Korea International Trade Association.

Petrochemical Trade by Region in 2010

In 2010, 78.2% of petrochemical exports originated from Asia, with 47.8% of those exports coming from China. Most imports came from developed countries, with Japan, North America, and Europe together accounting for 65.3% of petrochemical imports.

Exports				Imports		
	AAGR 2006–2010	Share of World Total, 2010	Region/Country		AAGR 2006–2010	Share of World Total, 2010
$27,942	14.9%	78.2%	**Asia**	$7,720	8.8%	58.0%
$17,074	14.7%	47.8%	China	$1,189	11.5%	8.9%
$1,465	1.1%	4.1%	Hong Kong	$4	-23.7%	0.0%
$1,347	2.9%	3.8%	Japan	$4,628	6.2%	34.8%
$2,084	4.2%	5.8%	Taiwan	$625	26.7%	4.7%
$791	16.1%	2.2%	Thailand	$324	27.9%	2.4%
$1,680	65.9%	4.7%	India	$141	10.7%	1.1%
$3,501	26.8%	9.8%	Others	$809	4.6%	6.1%
$1,750	25.0%	4.9%	**Middle East**	$1,260	14.1%	9.5%
$2,360	10.3%	6.6%	**Europe**	$1,500	13.4%	11.3%
$1,492	9.0%	4.2%	**North America**	$2,550	4.2%	19.2%
$1,225	5.6%	3.4%	**Latin America**	$137	–16.2%	1.0%
$656	5.5%	1.8%	**Africa**	$7	5.3%	0.1%
$288	–0.7%	0.8%	**Oceania**	$128	79.9%	1.0%
$1	0%	0%	**Others**	–$3	—	0.0%
$35,714	**14.0%**	**100.0%**	**Total**	**$13,299**	**8.6%**	**100.0%**

Notes: AAGR = Average annual growth rate. Exports and imports are in U.S.$ millions.
Source: Korea International Trade Association.

This diversity of target products will help the petrochemical industry to maximize its impact on high-demand industry sectors, such as electronics, airplanes, automobiles, machinery, and healthcare, and will also promote the development of specialty commodity goods such as composite materials, medical polymers, and eco-friendly products.

Recently, impressive achievements in high-value-added technology applications have been reported in the fields of catalysts and related process technologies. For example, SK Energy successfully developed and licensed three new catalytic process technologies: an advanced transalkylation (ATA) process that converts mixtures of toluene and heavy aromatic byproducts into xylene and benzene, and which has been licensed to Formosa Plastic Group in the Republic of China; a selective catalytic reduction (SCR) technology that reduces the nitrogen oxides emitted from power plants, incinerators, boilers, chemical plants and other stationary sources, which has been exported to Huatuo, an environmental engineering subsidiary of the Huadian Group, one of the five largest state-run Chinese power companies; and an advanced catalytic olefin (ACO) process, a lower-temperature catalytic naphtha-cracking technology that saves energy and reduces CO_2 emissions. The ACO process, also licensed to Huatuo, is regarded as a role model for government-initiated collaboration with industry, academia, and research institutes. SK Energy has also developed a new catalyst for removing NOx from process gas exhaust via selective catalytic reduction to replace a catalyst that was previously imported.

Fine and specialty chemicals

The groundwork for South Korea's fine and specialty chemicals industry was laid by the adoption of technology from developed countries in the 1970s. The fine chemicals sector — including pharmaceuticals, agricultural chemicals, dyes, pigments, paints, perfumes, surfactants, and catalysts — grew out of the fertilizer industry in the late 1970s.

Over the past 30 years, the fine chemicals industry has grown, replacing imports with domestic production of pharmaceuticals, dyes, and paints to fulfill domestic demands — rather than focusing on developing raw materials and intermediates for high-value-added products that would require long-term and risky investments.

Between the 1960s and 1990s, the South Korean chemical industry grew at an average annual rate of 7–8%; from 2000 to 2010, the growth rate accelerated to an annual rate of 12.5% due to increased production of value-added products. In particular, the production of dyes, paints, pigments, and surfactants increased, and these products are now competitive in the world market. And, with South Korean biopharmaceuticals, cosmetics, and surfactants expected to grow at an annual rate of 14–15%, the country will soon claim a 3% share of the world market for fine chemicals.

One recent success is silicon polymers, an important raw material for the development of solar cells. The company OCI (founded as Oriental Chemical Industries) produces high-purity polysilicon, and is now ranked as the

▲ **Figure 2.** Key chemical industry complexes were established during South Korea's government-led economic development plans, from 1966 to 1997.

world's fourth-largest producer of polysilicon. OCI plans to invest W1.8 trillion ($1.6 billion) to build an additional polysilicon plant with a capacity of 24,000 m.t./yr. OCI will then have a total manufacturing capacity of 86,000 m.t./yr, making it the largest polysilicon supplier in the world *(4)*.

Multinational companies that focus on high-value-added products have long dominated the world's fine and specialty chemicals markets. South Korea remains far behind in terms of the innovative front-end technologies required to develop new materials and formulation techniques to compete in these markets on the global level.

However, South Korea is the world's leader in semiconductor manufacturing technology. Nanotechnology-related fields also have high potential for success in South Korea; currently, microelectromechanical system (MEMS) technology is under active development.

In the pharmaceuticals arena — which requires huge R&D investment and has high risk, but which also yields high-value products — South Korea is still in a formative stage. Most pharmaceutical companies are small or medium-sized, which limits their global competitiveness, although the industry has made progress.

The electronic chemicals industry has not yet developed its own core technologies, so the country's electronic device manufacturers must rely on technology transfer from, or collaboration with, foreign companies.

Although South Korea's technology competitiveness has reached a global level in commodity chemicals and a few specialty materials, a set of core technologies needed to produce new materials is still an unfulfilled need. Since 1990, the specialty chemicals industry and the South Korean government have made enormous efforts to develop and secure such front-end technologies.

Furthermore, recent global changes — such as competition from developers of innovative chemical technology, more aggressive efforts to protect intellectual property (*i.e.*, patents on advanced technologies), and increasing environmental regulations — might place South Korea under additional pressure.

Yet, there are also positive signs in South Korea: steady growth in manufacturing to meet increasing consumer demand for manufactured goods; high potential for technology convergence of the specialty chemicals industry into information technology, biotechnology, nanotechnology, and environmental technology; and expanding investment opportunities resulting from the restructuring of the domestic chemical industry. As an example, Honam Petrochemical is expanding its business to include new eco-friendly materials, while also securing core technologies for composite resins and new engineering plastics. Honam has been supplying Hyundai and Kia with long-fiber thermoplastics as a replacement for metals in cars, and is developing eco-friendly expanded polystyrene.

Technology convergence in the chemical industry

In the 21st century, a new wave of technology convergence has brought changes to the global marketplace, and the worldwide chemical industry is expected to play a significant role in such fields as energy and the environment (among others). While the South Korean chemical industry can compete internationally in the area of commodity chemical exports, the nation's chemical industry overall is not as advanced as those in many developed countries. South Korea needs an impetus for new growth, in accordance with the opening of markets through U.S. and European free trade agreements and the chemical industry's shift to environment-friendly policies *(2)*.

In 2010, the South Korean government launched a nationwide project to address worldwide initiatives in green chemistry and clean energy, establishing an investment plan called "Material and Component Technology 2012" *(5)*. The objective of this plan is to develop 100 core technologies for new materials and components in areas such as light-emitting diodes (LEDs), solar power, green

cars, and new or renewable energy. The plan involves:

• investment in promising composite materials for driving "green growth" business during 2009 to 2012

• investment during 2010 to 2018 in the development of 10 new materials (*e.g.*, plastics for flexible displays and multifunctional polymers), with the goal of claiming 30% of world market share *(6, 7)*

• development of 20 core basic materials (*e.g.*, coatings for electronic-paper technology used in electronic reading devices, and epoxy resin for high-end epoxy molding compounds), the demand for which is expected to sharply increase in the world market *(7)*.

Private sector progress

Complementing these government-led R&D investments are many private sector projects. For example:

• In 2011, Japan's Institute of Information reported that South Korea's Samsung SDI and LG Chem (Lucky GoldStar Chemical, Korea's largest chemical company), have built lithium-ion battery production plants of 780 and 586 million batteries per year, respectively — the largest and third-largest capacities in the world. Also, South Korea is ranked as the leader in worldwide production of rechargeable batteries, with a world market share of 38.5%.

• LG Chem is developing new high-performance materials for solar batteries, LED technology, a battery for storing electric power in smart grid systems, and new processes to improve energy efficiency and to reduce greenhouse gas emissions.

• Hanwha Chemicals is expanding its business into new areas, including solar power, materials for lithium-ion batteries, biochemistry, and nanotechnology. Recently, Hanwha acquired Solarfun Power Holdings, China's fourth-largest solar power company, to increase its capacity of solar power from 900 MW to 1.5 GW. Hanwha also plans to construct a lithium-iron-phosphate battery plant.

• Honam Petrochemical is focusing on large-capacity secondary batteries for smart grid networks, and technologies for CO_2 recovery and reuse.

• Samsung Total has developed advanced environment-friendly materials such as super-gloss anti-scratch polypropylene as a replacement for existing acrylonitrile butadiene styrene (ABS) and polystyrene in electronic devices, as well as a lightweight biaxial concrete building material that replaces existing concrete slab. It has also developed a nanocomposite polypropylene used in cars.

• Cheil Industries has developed a new technology for making polyethylene terephthalate (PET) reusable, as well as environment-friendly reusable metallic ABS resin.

Closing thoughts

The future of South Korea's chemical industry depends on new, environment-friendly composite materials of higher functionality. Extensive, efficient, and proactive R&D investment in chemical industry technology convergence will help South Korea to continue to gain its share of the new global market. CEP

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